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2013 Micro+Nano Materials, Devices, and Applications

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Conference
8–11 December 2013

Location
RMIT University,
Emily McPherson Building
Melbourne, Victoria, Australia

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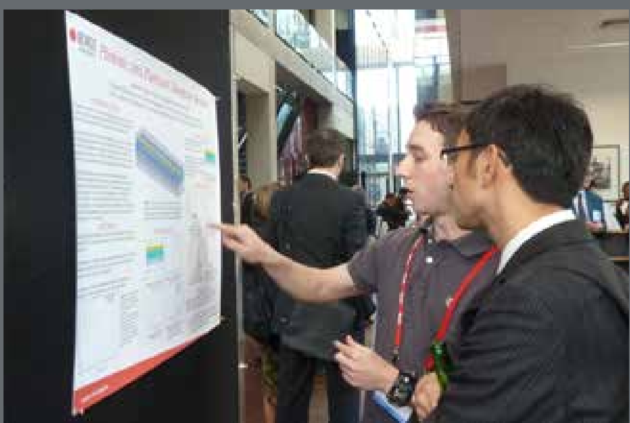

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SPIE would like to express its deepest appreciation to the symposium chairs, conference chairs, Programme committees, and session chairs who have so generously given of their time and advice to make this symposium possible. The symposium, like our other conferences and activities, would not be possible without the dedicated contribution of our participants and members.

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Conference 8923: SPIE Micro+Nano Materials, Devices, and Systems

SPIE Smart Nano+Micro Materials and Devices

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8923-1, Session 1

Black-Si as a platform for sensing

Pierrette Michaux, Gediminas Gervinskas, Gediminas Seniutinas, Jennifer S. Hartley, Paul R. Stoddart, Dru Morrish, Narges F. Fahim, Md. Sohrab Hossain, Saulius Juodkazis, Swinburne Univ. of Technology (Australia)

The nano-textured surface of black silicon can be used as a surface-enhanced Raman scattering (SERS) substrate [1]. Sputtered gold films showed increasing SERS sensitivity for thicknesses from 10 nm up to 300 nm, with sensitivity growing nonlinearly from around 50 nm until saturation sets in at 500 nm. At 50 nm, a cross over occurs from a discontinuous to a fully percolated film [2], as revealed by morphological and electrical characterization of the surfaces. The roughness of the Au coating increases due to formation of nanocrystallites of gold. Chemically synthesized Au-nanoparticles were added to black-Si to boost SERS sensitivity.

Plasma dry etching procedures are described for nano-texturing the Si surface via a controlled flow of SF_6:O_2 mixture, with voltages of the bias and inductively-coupled plasma that influence the anisotropy of surface etching together with chamber pressure. The formation of nano-pillars of aspect ratio 2-2.5:1 takes 10-15 min of plasma etching, with full area coverage of 3- and 4-inch wafers. Au-colloidal nanoparticles prepared by laser ablation in water without surfactant [3] can be used for chemical functionalization and applied on the black-Si platform.

[1] G. Gervinskas, et al. Annalen der Physik (2013) in press.

[2] A. Zukauskas, et al., Opt. Express 21, 6901 (2013).

[3] R. Kubiliute, et al., Int. J. Nanomedicine (2013) in press.

8923-4, Session 1

Development of silicon optics for an integrated micro-optical system-on-a-chip

David C. Ng, National ICT Australia (Australia); Sasikaran Kandasamy, Melbourne Ctr. for Nanofabrication (Australia); Efstratios S. Skafidas, The Univ. of Melbourne (Australia)

Development of silicon-based passive optical components such as reflectors, waveguides, and beam splitters coupled with active elements such as light emitters and detectors enable miniaturisation of a low-cost system-on-a-chip sensing device. In this work, we investigate methods to fabricate passive silicon elements on a chip. We use a combination of wet and dry etching techniques to realise angled and vertical walls normal to the surface of a silicon wafer, respectively. For wet etching, we used Triton-X, a surfactant, added to TMAH as the etchant. This allows perfect 45° inclined walls to be fabricated. Dry etching using DRIE was performed on the reverse-side of the same wafer to realise through-hole vias with straight vertical walls. A final Au metallisation step completes the device fabrication process. Photolithography masks used in the wet and dry etch processes were designed and fabricated. By careful alignment of these masks using a mask aligner, we can fabricate a combination of inclined and vertical walls to build optical reflectors and beam splitters with complex geometries. When integrated with active Si-optical devices, a fully integrated micro-optical system-on-a-chip can be realised.

8923-5, Session 2

Enhanced photovoltaic performance of dye-sensitized solar cell using composite photoanode on 3D electrode

Chiew Keat Lim, Nanyang Technological Univ. (Singapore); Hui Huang, A*STAR Singapore Institute of Manufacturing Technology (Singapore); Man Siu Tse, Ooi Kiang Tan, Nanyang Technological Univ. (Singapore)

For dye-sensitized solar cell (DSSC), an efficient transport of electron from the dye sensitizer through the mesoporous oxide layer and collected at the electrode is crucial for high photovoltaic conversion efficiency. In this work, two novel approaches were developed in DSSC fabrication to improve the overall photovoltaic performance. The concurrent improvement in the charge transport property and light harvesting efficiency was achieved by incorporating N-doped TiO_2 in the mesoporous TiO_2 layer of the photoanode. These N-doped TiO_2 (TiN_xO_y) was formed by using the single step thermal oxidation of Titanium Nitride (TiN) nanomaterials. At the same time, 3D electrode with SnO_2 nanorods grown on the FTO glass using plasma enhanced chemical vapor deposition (PECVD) system was used to enhance the charge collection efficiency. By combining these two approaches, the DSSC with composite TiN_xO_y-TiO_2 photoanode on SnO_2 nanorods 3D electrode was successfully fabricated and characterized. As compared to the standard DSSC, an overall improvement of 28 % in the conversion efficiency was achieved as compared to the standard DSSC. Higher incident photon-current conversion efficiency (IPCE) values were also obtained, specifically for the region 400 – 500 nm due to the co-sensitization effect of N-doped TiO_2. Efficient transfer of electron due to the decrease in charge transfer resistance at the mesoporous oxide/dye/electrolyte interface was observed from electrochemical impedance spectroscopy (EIS) measurement. With the use of SnO_2 nanorods, the adhesion between the mesoporous TiO_2/FTO was enhanced and the transit time of the photogenerated electrons through the mesoporous layer before being collected at the FTO electrode was significantly reduced by 50%.

8923-6, Session 2

Mixed metal oxides for dye-sensitized solar cell using zinc titanium layered double hydroxide as precursor

Jianqiang Liu, Yaowei Qin, Liangji Zhang, Hongdi Xiao, Jianye Song, Dehe Liu, Mingzhe Leng, wanguo hou, Na Du, Shandong Univ. (China)

Layered double hydroxides (LDH) are layered materials whose sheets are constituted by octahedra occupied by two or more different metals. Mixed metal oxides (MMO) can be obtained from LDH by simple thermal decomposition. In this work, a zinc titanium layered double hydroxide (ZnTi-LDH) with the zinc titanium molar ratio of 4.25 was prepared by urea method. The XRD pattern and SEM for ZnTi-LDH showed it has a typical LDH structure. A series of MMO was obtained by calcining ZnTi-LDH at proper temperatures. The XRD results indicated that, when ZnTi-LDH was cacinated at 500°C for 1h, the layered structure of the precursor had been destroyed and the calcined products was composed of ZnO and TiO_2. The TiO_2 disppeared and another band gap semiconductor Zn_2TiO_4 phase appeard at 600 °C and became sharper as the calcination temperature increasing to 700 °C. The UV-vis diffuses reflectance spectrum of the MMO by calcining ZnTi-LDH at 500, 600 and 700°C showed that they exhibited similar band gap to pure ZnO. The MMO was used as electrode for dye sensitized solar cells (DSSC). SEM images showed the prepared electrodes based on MMO obtained at 600°C have crack-free surface and thickness of 10?m. The cells constructed by films of prepared composite materials using a N719 as dye were prepared. The efficiency values of these cells are 0.691%, 0.572% and 0.302% with MMO prepared at 500, 600 and 700°C, respectively. The decrease of efficiency values may caused by the appearance of Zn_2TiO_4 which shows lower electronic mobility than TiO_2.

8923-7, Session 2

Heat transfer simulation of vacuum-packaged micro solar thermal collector

Yusnira Husaini, Arnan Mitchell, Gary Rosengarten, Vijay Prasad Sivan, RMIT Univ. (Australia)

Heat harnessed from the sun using solar-thermal collectors has many applications such as heating, drying and even air-conditioning in both

residential and industrial environments. Recently, researchers have shown that by implementing vacuum packaging, small scale solar collectors can be made more efficient and compact. Solar-thermal collection can also be used with miniaturised fuel cells, thermoelectric and thermophotovoltaic devices for alternative energy sources. Generally, such devices employ active heating to achieve the elevated temperatures required to convert methanol or butane into hydrogen for example. Several micro-scale devices employing solar-thermal collection have been reported [1-2]. In this paper, we report on the design of a high temperature micro solar thermal collection device employing suspended microchannels and vacuum packaging.

Our design uses 2D and 3D computational fluid dynamics including diffusive and convective heat transfer, conduction in support structures within the package, and radiation heat transfer. Our investigation compares the relative importance of these various forms of heat loss in the context of the operating temperature, and presents design strategies to optimally balance these heat loss mechanisms with the conflicting requirements for maximal solar collection.

8923-8, Session 2

Direct transfer of solar radiation to high temperature applications

Maryam Rahou, John Andrews, Gary Rosengarten, RMIT Univ. (Australia)

This paper reviews the different methods of transferring solar radiation from concentrated solar collectors to high temperature thermal absorbers, at temperatures ranging from 100 to 400°C. These methods are divided into four main categories associated with the radiation transfer medium and include optical fibers, photonic crystal fibers, metal wave-guides and light guides. The reviewed methods are novel compared to most rooftop solar concentrators that have the receiver and thermal storage unit. Bundled optical fibers have the capability of transferring concentrated solar energy across the full wavelength spectrum with the maximum optical efficiency for thermal processing. Results of the experiments are carried out by employing two different types of optical bundle, hard polymer cladding silica (HPCS) and air-cladding silica which offer a broad spectrum transmission range from 400 to 1800 nm, low levels of losses through attenuation and the best resistance to heating. The main parameters that determine the overall efficiency of the system are the concentration ratio, the acceptance angle of the fibers, and the matching of the diameter of the focus spot of the concentrator and the internal diameter of the fiber. In order to maximize the coupling efficiency of the system, higher levels of concentration are required which can be achieved through lenses or other non-imaging concentrators. However, these additional components add to the cost and complexity of the system. To avoid this problem we use tapered bundles of optical fibers that enhance the coupling efficiency by increasing the acceptance angle and consequently the coupling efficiency of the system.

8923-9, Session 3

Fluorescent single defects in different silicon carbide polytypes

Stefania Castelletto, RMIT Univ. (Australia); Brett C. Johnson, The Univ. of Melbourne (Australia); Alberto Boretti, RMIT Univ. (Australia)

Silicon carbide (SiC) offers a unique opportunity to realize advanced quantum based devices and sensors. We will discuss here the role of paramagnetic defects in this material to achieve optical and spin quantum coherence control. Specifically, we will show the engineering of single photon emission in bulk and nanoparticles in SiC.

The characteristics and properties of this emission in the visible will be discussed. The combination of nanostructures and in-built paramagnetic defects in SiC could pave the way for future single particle and single defects quantum devices and related biomedical sensors.

8923-11, Session 3

Density functional theory calculations of phenol-modified monolayer silicon nanosheets

Michelle J. Spencer, RMIT Univ. (Australia); Tetsuya Morishita, National Institute of Advanced Industrial Science and Technology (Japan); Michael R. Bassett, La Trobe Univ. (Australia)

Silicon nanosheets are one of most exciting recent discoveries, being a two-dimensional form of silicon that is only nanometers in thickness, with large lateral dimensions. A single layer silicon nanosheet is known as silicene and can be grown with different surface terminations. We have previously shown that organo- modified silicene can be grown with phenyl groups covalently bonded to both sides of the nanosheet at separations of >6.6Å, with hydrogen atoms terminating the under-coordinated silicon atoms. In this work, we use density functional theory calculations and ab initio molecular dynamics simulations to determine the effect of hydroxyl group substitutions on the phenyl-modified silicene. Different positions of the OH groups on the phenyl rings were modelled including ortho-, meta- and para-substituted positions. Overall, the ortho-substituted position was favoured, however, the electronic properties of the sheet could be altered depending on the location of the hydroxyl group substitution, leading to a widening or reduction of the band gap. Our ab initio MD simulations showed that the phenyl groups will freely rotate on the nanosheet, aligning so as to form hydrogen bonds between adjacent phenol groups. The unique properties of this material could be useful for future electronic device applications.

8923-12, Session 3

Tamm plasmon polariton enhancement of the photoluminescence signal from silicon nanocrystals

Sergey A. Dyakov, KTH Royal Institute of Technology (Sweden)

Ensembles of silicon nanocrystals (SiNCs) in silica matrix have been intensively studied in last decades due to their ability to emit light at room temperature, to be compatible with standard silicon technology and to have potential in optoelectronics applications. Irrespective the origin of the photoluminescence (PL) of SiNCs, the emitted light can be out-coupled from the sample, reabsorbed by SiNCs or coupled to the waveguiding modes. The resulted PL intensity of the sample strongly depends on the spatial distribution of the refractive index and can be sufficiently suppressed or enhanced by its appropriate choice.

In this work we consider the one-dimensional multilayered structure with where the thin layer of silica with silicon nanocrystals is located at the interface between a metal and a dielectric Bragg mirror. This structure supports the existence of Tamm plasmon polaritons. The interaction of the emitted light with the interface modes leads to the sufficient narrowing and increase of the PL spectrum of the sample with SiNCs.

8923-13, Session 4

Challenges in specificity and collection efficiency for integrated optical biosensors

(Invited Paper)

Andrea M. Armani, Simin Mehrabani, Ashley J. Maker, Cecilia Lopez, Mark C. Harrison, The Univ. of Southern California (United States)

Innovation in technology routinely leads the way for discovery in chemistry and biology. Most notably, x-ray diffraction data was instrumental in the elucidation of the structure of DNA. To explore the inherent complexity present in biological systems, existing technologies are being pushed to their limits. Once again, scientists are looking to engineers to create innovative solutions to enable their exploration and discovery. While many of the new methods currently

being developed focus on increasing the sensitivity of the detection technique, the balance between sensitivity, specificity and collection efficiency are critical. For example, although high Q optical resonant cavities are inherently sensitive, specificity and collection efficiency are often over-looked. By combining new devices with improved specificity of the device from engineered synthetic targeting moieties and increasing the sample collection efficiency of the sensing element, even further advancements are possible. I will discuss many of the recent advances in the optimization of these two parameters, including finite element method simulations of mass transport to the device and surface functionalization methods for immobilization of biomolecules. The combination of these two achievements has enabled several biophysics experiments and significantly improved the sensing limits of the devices.

8923-14, Session 4

Laser nanostructured surface for biomedical sensing using surface-enhanced Raman spectroscopic mapping

Ricardas Buividas, Swinburne Univ. of Technology (Australia); Nerijus Dzingelevicius, Vilnius Univ. (Lithuania) and Swinburne Univ. of Technology (Australia); Reda Kubiliute, Kaunas Univ. of Technology (Lithuania) and Swinburne Univ. of Technology (Australia); Paul R. Stoddart, Vi K. Truong, Elena P. Ivanova, Saulius Juodkazis, Swinburne Univ. of Technology (Australia)

Surface-enhanced Raman scattering (SERS) is a promising technique for biosensing, as it can provide label-free identification of complex biomolecules at trace levels [1]. We demonstrate that laser nano-textured ripple surfaces on sapphire [2], that previously showed good performance as a SERS substrate [3] can be used for low concentration detection of amyloid A?-40 oligomers, which are known as one of the biomarkers for early stage Alzheimer's disease [4]. We show a fast (< 5min), label-free, functionalization-free, yet high fidelity method of detection. Statistically reliable data, based on more than 1000 spectra, showed 300 times higher spectral intensity using ripples compared to a flat surface coated by the same gold thickness. The SERS spectral intensity correlates with A?-40 concentration, which is prospective for a quantitative concentration measurement.

We describe the laser fabrication and mechanism of surface nano-texturing using femtosecond laser irradiation. The quasi-periodic sub-wavelength ripple pattern with random texture of features down to 20-30 nm in cross section makes a unique sensing platform. Ripple substrates perform up to 10 times better in terms of SERS intensity than current commercial counterparts. A comparative study of different sensors for liquid environments will be presented, together with results showing the possibility of detecting gaseous analytes.

[1] W. Smith et al. Chem. Soc. Rev. 37(5), 955–964 (2008).

[2] R. Buividas et al. Nanotechnology 22(5), 055304 (2011).

[3] R. Buividas et al. Annalen der Physik 524(11), L5–L10 (2012).

[4] J. Hardy et al. Science 297(5580), 353–356 (2002).

8923-15, Session 4

Nanostructured diamond microelectrodes for medical applications

Kumaravelu Ganesan, David J. Garrett, The Univ. of Melbourne (Australia) and Bionic Vision Australia (Australia); Kate Fox, The Univ. of Melbourne (Australia); Hamish Meffin, National ICT Australia (Australia) and The Univ. of Melbourne (Australia) and Bionic Vision Australia (Australia); Steven Prawer, The Univ. of Melbourne (Australia)

Microelectrodes are used in diagnostic or therapeutic systems in medicine. Advances in both lab-on-a-chip diagnostic systems and implantable therapeutic biomedical microdevices have the potential to advance new therapies and solutions to improve our well-being. However there are significant limitations on device architectures, efficacy, safety and uptake due to the restrictions imposed by current electrode technology. An implantable electrode needs to be biocompatible, chemically inert and mechanically robust. Further the electrode needs to be hermetic if it encloses electronics or hazardous materials.

We fabricated a monolithic diamond microelectrode array with all the above mentioned characteristics. Electrical feedthroughs were made on electrically insulating polycrystalline diamond (PCD) substrate using pulsed laser milling and electrically conducting nitrogen incorporated ultrananocrystalline diamond (N-UNCD) was grown on top of it using microwave enhance chemical vapour deposition technique. Finally, the N-UNCD electrodes were electrically isolated by pulsed laser milling followed by oxygen plasma cleaning and metal brazing in vacuum was performed to fill the electrical feedthrough. In order to test the stimulation efficacy, diamond electrodes were tested using acute in vivo preclinical models. Electrodes of size 120µm X 120µm was used for the stimulation experiment. The hermeticity of the array was tested using a helium leak tester and the helium leak rate was found lower than the detection limit of the helium mass spectrometer (10-11 mbar L s-1).

8923-16, Session 4

Nanosensors for next generation drug screening

Sridhar Kannam, Matthew T. Downton, Natalie Gunn, Sung Cheol Kim, Priscilla Rogers, Christine Schieber, John Wagner, IBM Research Collaboratory for Life Sciences-Melbourne (Australia); Daniel Scott, Ross Bathgate, Efstratios S. Skafidas, The Univ. of Melbourne (Australia); Stefan Harrer, IBM Research Collaboratory for Life Sciences-Melbourne (Australia)

One promising path for future drug screening technologies is to examine the binding of ligands to target proteins at the single molecule level by passing them through nanometer sized pores and measuring the change in pore current during translocation. With the aim of evaluating such technologies we perform virtual experiments on the translocation of proteins through silicon nitride nanopores. These simulations consist of large scale, fully atomistic models of the translocation process that involve steering the protein through the pore on a timescale of tens of nanoseconds. We make a comparison between theoretically expected and simulated values of the current drop that is seen when a protein occupies the pore. Details of the stability of the protein and the preservation of its function as measured by its secondary and tertiary structure will be presented to validate both the simulation results and the fundamental design of the proposed device. Finally, the results will be placed in the context of experimental work that combines nanofabrication and microfluidics to create a high throughput, low cost, drug screening device.

8923-18, Session 5

Trapping and mapping: what optical tweezers can tell us about semiconductor nanowires and nanoparticles *(Invited Paper)*

Peter J. Reece, The Univ. of New South Wales (Australia)

Optical tweezers is emerging as an important tool for characterising the physical, optical and optoelectronics properties of individual nanoparticles and nanowires. Moreover optically trapped objects can be used as a nanoscale probe for sensing, interrogating and manipulating the local environment in the vicinity of the trap. In this presentation I will describe a number of novel techniques we have developed for combining dynamic optical tweezers with spectroscopic modalities to provide important information about optically trapped nanoscale objects. These include: (i) the use of synchronous beam steering and position sensing to provide absolute position calibration of particle motion; (ii) the incorporation of dark field imaging / spectroscopy with optical tweezers to visualise metallic nanoparticles and measure their plasmonic properties; and (iii) the use of intrinsic luminescence and nonlinear optical properties of trapped objects to characterise their properties and dynamics.

8923-19, Session 5

Third-order optical nonlinearity in BDN dye encapsulated polymer matrix induced by nanosecond laser pulses

Devendra Mohan, Purnima Arya, Guru Jambheshwar Univ. of Science and Technology (India); Anil Kumar, Instruments Research & Development Establishment (India)

The present work focuses on the study of nonlinear optical properties of bis(4-dimethylaminodithiobenzyl)-nickel (BDN) dye encapsulated in poly-methylmethacrylate (PMMA) matrix. The Z-scan measurements are carried out using nanosecond laser pulses of Nd: YAG laser at 532nm wavelength with maximum energy of 200mJ per pulse as excitation source. The nonlinearity in terms of excited state absorption (ESA) has been discussed. A switching from saturation absorption (SA) to reverse saturation absorption (RSA) is reported from absorptive study in samples of different thickness. The nonlinear parameters viz. nonlinear absorption coefficient ( ), nonlinear index of refraction ( ) and third order nonlinear susceptibility ( ) are calculated. The thermal diffusivity that provides the rate at which a temperature disturbance travels within the medium is used to estimate thermal conductivity of solid-state polymeric samples. The nonlinear refractive index gradient is determined in terms of thermo-optic coefficient ( ).The observed nonlinearity is attributed to laser induced acoustic motion with rise time of thermal lens of nanosecond order that agrees well with literature reported earlier. The study shows that BDN dye encapsulated polymers are excellent material for stable optical limiting and pulse shaping applications.

Keywords: Z-scan, Saturation absorption, Nonlinear refractive index, Thermo-optic coefficient.

8923-20, Session 5

Multi-photon absorption and third-order nonlinearity in silicon at mid-infrared wavelengths

Ting Wang, Dawn Tan, Singapore Univ. of Technology & Design (Singapore)

Silicon based nonlinear photonics has been extensively researched at telecom wavelength in recent years. But the studies of Kerr nonlinearity in silicon at mid-infrared (mid-IR) wavelengths still remain limited. Here, we report the wavelength dependency of third-order nonlinearity in the spectral range from 1.6 µm to 6 µm in silicon, as well as multi-photon absorption coefficients in the same range. The third-order nonlinear coefficient n2 was measured with a peak value of 1.65?10-13 cm2/W at a wavelength of 2.1 µm followed by the decaying of nonlinear refractive index n2 upto 2.6 µm. Our latest measurements extend the wavelength towards 6 µm, which show a sharp decrement of n2 beyond 2.1 µm and steadily retains above 3 µm. In addition, the analysis of three-photon absorption (3PA) and four-photon absorption (4PA) processes are simultaneously performed over the wavelength range from 2.3 µm to 4.4 µm by ultra-fast femto-second laser. Furthermore, the effect of multi-photon absorption on nonlinear figure of merit (FOM) in silicon has been discussed in details.

The multi-photon absorption place a fundamental limitation on the usefulness of any high ?(3) material in all-optical switching schemes based on an intensity-dependent refractive index, especially strong two-photon absorption (TPA) in silicon. At telecom wavelength, relatively high peak intensity is normally required to trigger the third-order Kerr nonlinearity, but also leads to a strong TPA. Therefore, it shows the great potential of combining the high Kerr nonlinearity at mid-IR wavelengths with a relatively weaker MPA beyond the presence of strong TPA.

8923-21, Session 5

Translation interference pattern in nano-scale precision by phase control based on spatial light modulator

Jie Ma, Yongchun Zhong, Zhe Chen, Jinan Univ. (China); Kam Sing Wong, Hong Kong Univ. of Science and Technology (China)

Holographic lithography (HL) have under gong a rapidly development over last 10 years, this technique had fabricated a variety of functional micro-structures. The range of its work includes from one-dimension Bragg grating to three-dimension photonic crystals and even some meta-material structures. But, for fabricating some kinds of photonic crystals (PCs) with compound structure and introducing intrinsic defects in the manufacturing operation, precisely, a pattern shift approach is required. Recently we have developed a general technique using phase control method to translate multi-beam interference pattern. The pith of this technique is a matrix algorithm. For a specific pattern which beam configuration is already known, by using the algorithm, we can obtain a variation of phase correspond to the desired translation. In theory, this approach should apply to any kind of multi-beam interference pattern, and with no limited in translation direction and accuracy. However, in the experiment, a Liquid Crystal-Spatial Light Modulator (LC-SLM) was used to control the phases of the interference beams. Subject to the limit of this modulator driver precision, the resolution of the phase adjustment is about 1/128 of 2pi . So, the shift resolution is about 1/100 of the pattern's period. That means for a pattern used in fabricating a visible range PhCs, the shift resolution is about 1/100 of lattice parameters, or 5nm as well. In additional, the phase adjustment driver was controlled by a computer, so this system also has a real-time capability. By taking advantage of this capability, the pattern can move dynamically, that will be very useful in fabricating complex micro-structures by using HL.

8923-22, Session 5

Constructing microstructures using the optical trapping map of dielectric spheres

Murat S. Muradoglu, Tuch W. Ng, Monash Univ. (Australia)

Many applications use a focused Gaussian laser beam to manipulate spherical dielectric particles. The axial trapping efficiency of this process is a function of (i) the particle radius r, (ii) the ratio of the refractive index of particle over the medium, and (iii) the numerical aperture of the delivered light beam. During what we believe is the first comprehensive simulation of its kind, we uncovered optical trapping regions in the three-dimensional (3D) parameter space forming an iso-surface landscape with ridge-like contours. Using specific points in the parameter space, we drew attention to difficulties in using the trapping efficiency and stiffness metrics in defining how well particles are drawn into and held in the trap. We have proposed an alternative calculation based on the maximum forward and restoration values of the trapping efficiency in the axial sense, called the trapping quality. We also discuss the manner in which the map may be harnessed for effective particle sorting and constructing microstructures.

8923-23, Session 6

Hydride Vapor Phase Epitaxy: the unexpected process for the fast growth of GaAs and GaN nanowires with record aspect ratio and polytypism-free crystalline structure *(Invited Paper)*

Evelyne Gil, Universite Blaise Pascal - CNRS (France)

Hydride Vapor Phase Epitaxy makes use of chloride III-Cl and hydride V-H3 gaseous growth precursors. It is known as near-equilibrium process, providing the widest range of growth rate from 1 to more than 100 ?m/h. When it comes to metal catalyst-assisted VLS (vapor-liquid-solid) growth, the physics of HVPE growth is maintained: high dechlorination frequency, high axial growth rate of nanowires (NWs) up to 170 ?m/h. The remarkable features of NWs grown by HVPE are the constant diameter untapered morphology and the stacking fault-free crystalline phase. Record pure zinc blende cubic phase in 20 ?m long GaAs NWs with a radius of 5 nm is shown. The absence of wurtzite phase in GaAs NWs grown by HVPE whatever the diameter is discussed with respect to surface energetic grounds and kinetics. Au assisted, Ni-Au assisted and catalyst-free HVPE growth of wurtzite GaN NWs is also addressed. Micro-photoluminescence spectroscopy analysis revealed GaN nanowires of great optical quality, with a FWHM of 1 meV at 10 K for the neutral donor bound exciton transition.

8923-24, Session 6

In situ monitoring of resistivity and carrier concentration during molecular beam epitaxy of topological insulator Bi2Se3

Jack Hellerstedt, Monash Univ. (Australia) and Univ. of Maryland, College Park (United States); Jianhao Chen, Dohun Kim, William Cullen, Univ. of Maryland, College Park (United States); ChangXi Zhang, Monash Univ. (Australia); Michael S. Fuhrer, Univ. of Maryland, College Park (United States) and Monash Univ. (Australia)

Bismuth selenide (Bi_2Se_3) is a three-dimensional strong topological insulator of particular interest due to its relatively large bulk band gap (300 meV), single set of topologically non-trivial surface states, and layered van der Waals structure. Theoretical work on the topological classification of states of matter in the last decade has led to exciting predictions, subsequently realized experimentally, of systems with edge and surface conduction states with electron momentum locked at right angle to spin. These states have immediate application to spin electronics, and also more exotic physics phenomena, such as condensed matter analogues to magnetic monopoles, and systems obeying Majorana Fermion (non- Abelian) statistics. However, there are outstanding problems in isolating the surface states of interest from bulk (trivial) conduction: this problem is frequently attributed to doping from selenium vacancies, and atmospheric exposure. To address these questions, we have constructed a system capable of growing thin film bismuth selenide by van der Waals epitaxy with the additional capability to do real time, in situ transport measurements, specifically resistivity and Hall carrier density. Post growth cooling to 15K, and controlled exposure to atmospheric dopants is possible without breaking vacuum. We have demonstrated growth of Bi_2Se_3 films with charge carrier mobilities up to 1650 cm^2/Vs and carrier densities of 1x10^13 cm^-2, and have successfully demonstrated in situ transport measurements during growth as well as post-growth without breaking vacuum The latest results exploring the dependence of mobility on growth conditions, and post-growth exposure to atmospheric dopants, will be reported.

8923-25, Session 6

Effect of compositional gradient on mechanical properties in aluminum/ duralumin multi-layered clad structures

Hideaki Tsukamoto, Nagoya Institute of Technology (Japan)

This study aims to investigate the effect of compositional gradient on nano-, micro- and macro-mechanical properties in aluminum (A1050)/ duralumin (A2017) multi-layered clad structures fabricated by hot rolling. Such multi-layered clad structures are possibly adopted to a new type of automobile crash boxes to effectively absorb the impact forces generated when automobiles having collisions. 2- and 6-layered clad structures with asymmetric lay-ups from one side of aluminum to another side of duralumin have been fabricated, which have been suffering three different heat-treatments such as (1) as-rolled (no heat-treatment), (2) annealed at 400oC and (3) homogenized at 500oC followed by water quenching and aging (T4 heat treatment). For nano- and micro-scale mechanical properties proved by nanoindentation, higher hardness and elastic modulus correspond to higher Cu content at the interface in annealed and aged samples. For macro-scale mechanical properties, internal friction of 2-layered clad structures is higher than that of 6-layered clad structures in any heat-treatment samples. Deep drawing formability of annealed samples is considerably high compared to as-rolled and aged ones. Impact compressive behavior of deep-drawn cups with such aluminum/ duralumin clad structures has been investigated in terms of energy absorption, maximum force and maximum displacement. Deep-drawn cups consisting of 6-layerd clad structures exhibit superior properties in impact compressive tests.

8923-26, Session 6

Electron spin resonance spectroscopy of high purity crystals at millikelvin temperatures

Warrick G. Farr, Daniel L. Creedon, Maxim Goryachev, The Univ. of Western Australia (Australia); Karim Benmessai, The Univ. of Western Australia (Australia) and Ctr. de Développement des Téchnologies Avancées (Algeria); Michael E. Tobar, The Univ. of Western Australia (Australia)

It is well known that the highest purity single-crystal sapphire resonators (Al2O3) contain paramagnetic impurity ions at a concentration of parts per billion to parts per million. The inclusion of such ions has been particularly useful in a number of precision microwave experiments, allowing Cryogenic Sapphire Oscillator technology to operate at its highest stability, and more recently facilitating the discovery of a number of nonlinear effects with application to quantum measurement and control.

In this work, we cool large cylindrical sapphire resonators close to 30 millikelvin and with a new technique, use extremely high Q-factor Whispering Gallery modes as a sensitive probe of Electron Spin Resonance frequencies of ion impurities, under the influence of an external DC magnetic field. We describe the interaction of the inhomogeneously broadened ESR with a number of paramagnetic spin species in the crystal, such as Fe3+, Cr3+ and the hyperfine split Co4+. We determine the Lande g-factor for these species to high precision. This high precision reveals anisotropic behavior of the Zeeman splitting. In our sapphire crystals, we observe a different g-factor for the two Zeeman components of the |+3/2> to |+1/2> transition in the Fe3+ ion. We also observe the Zeeman components intersect at a non zero magnetic field which leads to splitting at zero magnetic field. We observe the classically forbidden quadrupole transition of Fe3+ in sapphire. By measuring the temperature dependence of the AC magnetic susceptibility of Fe3+ we observe weak spin spin interactions leading to a spin glass phase.

8923-27, Session 6

Composite anode LSM impregnated with cobalt oxide for steam electrolysis

Shisong Li, Jigui Cheng, Kui Xie, Yucheng Wu, Hefei Univ. of Technology (China)

Oxygen-ion conducting solid oxide electrolyzer (SOE) has attracted a great deal of interest because it converts electrical energy into chemical energy directly. The oxygen evolution reaction (OER) is occurred at the anode of solid oxide electrolyzer as the O2- being oxidized and form O2 gas, which is considered as one of the major cause of overpotentials in steam electrolyzers. This paper investigates the electrolysis of steam based on cobalt oxide impregnated La0.8Sr0.2MnO3 (LSM) composite anode in an oxide-ion-conducting solid oxide electrolyzer. The conductivity of LSM is studied versus temperature and oxygen partial pressure and correlated to the electrochemical properties of the composite electrodes in symmetric cells at 800 ºC. Different contents of C°3O4 (wt.1%, 2%, 4%, 6%, 8%, 10%) were impregnated into LSM electrode and it was found that the polarization resistance (Rp) of symmetric cells gradually improved from 1.16 Ω•cm2 (LSM) to 0.24 Ω•cm2 (10%Co3O4-LSM). Steam electrolysis based on LSM and 6%C°3O4-LSM anode electrolyzers are tested at 800°C and the AC impedance spectroscopy results indicated that the Rp of high frequency process significantly decreased from1.1 Ω•cm2 (LSM) to 0.5 Ω•cm2 (6%C°3O4-LSM) under 1.8V electrolysis voltage and the Rp of low frequency process decreased from 14.9 Ω•cm2 to 5.7 Ω•cm2. Electrochemical catalyst C°3O4 can efficiently improve the electrode and enhance the performance of high temperature solid oxide electrolyzer.

8923-29, Session 7

Small volume particulate and non-particulate sample collection for fluidic systems

Brandon H. Cheong, Tuck W. Ng, Monash Univ. (Australia); Oi Wah Liew, National Univ. of Singapore (Singapore)

In fluidic systems, it is often desired to collect samples in the hydrated state at one location. Most methods devised to do this are often complex. In this work, we present a method that uses a simple squeeze flow. We demonstrate its use in the collection of cells (algal cells), particulates (microbeads and fluorescent nanobeads) and non-particulates (EGFP). This fluidic system is amenable for high content microscopy. An assumption often made is that objects being observed are fixed spatially and are sufficiently populated. Without the ability to collect, this can lead to the need for searching through multiple field of views. We report that the generation of a squeeze flow by the circular coverslip onto a liquid sample allows for objects to be acquired at the rim regions of the circular coverslip. By using a coverslip of 13mm diameter and sample volumes between 2?L and 4?L, the coverslip was completely filled without any excess flow beyond its outer rim. Furthermore, sample compression speeds between 100?m/s and 1000?m/s did not change the effect of the object collection outcome. A comparison was made between manually placing the coverslip on the liquid sample by hand and using a motorised translator to generate the squeeze flow and in both cases, similar outcomes were obtained. Quantitative measurements and image analysis confirmed that all the objects investigated had been displaced and relocated at the rim regions of the coverslip at a very high degree and ready to be collected.

8923-30, Session 7

Characterization of magnetic force driven microflow

Karolina Petkovic-Duran, Anthony Swallow, Yuan Gao, Timothy J. Davis, Judy Scoble, Greg Coia, Yonggang Zhu, Commonwealth Scientific and Industrial Research Organisation (Australia)

Functionalized magnetic nano-beads coated with biomolecules can be used for a large number of biological applications and have attracted a great attention during the last decade because of their unique properties. The transport of magnetic beads in lab-on-a-chip devices can be controlled by using a suitable tailored magnetic field. The generation of a strong and localized magnetic field gradient is a prerequisite for the satisfactory operation of a magnetic beads based microfludic device. In this study we have used super-paramagnetic particles, whose magnetization curve is hysteresis-free and form a supraparticle structures (SPS) when exposed to an external magnetic field. We have observed a dipole-dipole interaction and formations of chain-like structures under the influence of a homogenous magnetic field. By changing the magnetic field direction and intensity we could change the magnetic beads chains orientations. Viscous interaction between the super-paramagnetic beads chains and the surrounding fluid leads to advective motion in micro structures, which can enhance the otherwise diffusion limited mixing. Advection is induced by the relative motion of the beads with respect to the liquid. This phenomenon, which results from inertia and magnetic forces, has been studied and the fluid flow velocity has been measured using micro particles image velocimetry techniques (μPIV).

8923-31, Session 7

Acoustowetting: film spreading, fingering instabilities and soliton-like wave propagation

Amgad Rezk, Ofer Manor, James Friend, Leslie Y. Yeo, RMIT Univ. (Australia)

Surface acoustic waves (SAWs) are nanometer order mechanical vibrations with high velocity of order 1 m/s and tremendous acceleration of few Mm/s2 that can be generated on piezoelectric surfaces such as lithium niobate (LN) via microelectrodes called inter-digital transducers (IDTs) by converting an AC electrical input into 10 – 1000 MHz order mechanical vibrations. SAWs have been used to drive a wide spectrum of Lab-on-a-Chip (LOC) microfluidic applications including fast droplet translation along the waves propagation direction. Here we show, quite curiously, how SAWs can be used drive thin film spreading opposite to the SAW propagation direction. The film's interface subsequently exhibits an instability triggered by the Fresnel diffraction of SAWs in the underlying substrate to form fingering patterns above which 'soliton-like' wave pulses grow and translate along the waves propagation direction. In addition to deriving a dynamic spreading model, we show how the relative dominance of Eckart and Rayleigh streaming is responsible for the drop motion along the SAWs propagation direction, for the former and the thin film propagation counter to the SAWs propagation direction, for the latter.

8923-32, Session 7

Mapping the effect of pulsed surface acoustic waves on a sessile drop

Sean A. Collignon, Leslie Y. Yeo, James Friend, RMIT Univ. (Australia)

For its capacity to drive high acceleration from piezoelectric sources integrated directly within a microfluidic device, surface acoustic waves (SAW) have become a preferred method for droplet manipulation. To generate a surface acoustic wave, a piezoelectric transducer converts an AC voltage at a resonant frequency into a vibrational elastic wave which travels through the undulations of a substrate until reacting with its target or attenuating. Previous studies observed a variety of propulsion phenomena occurring when these continuous elastic waves interacted with a sessile drop dependent on the input power, frequency, wavelength, and size of the drop. Continuous wave input however, is limited by the fragility of the piezoelectric substrate; high vibrations cause fractures in the material. Pulsed surface acoustic waves have only been mildly investigated yet conceal broader SAW potential as a pulsed high power will dissipate, permitting the application of a larger power spectrum without substrate fracturing. While maintaining a constant input power, this study examines and maps the effect of pulsed SAW on water droplets correlating the droplet diameter to the width of the pulse.

8923-213, Session 7

Spreading of liquids at small scales on structured and patterned surfaces *(Invited Paper)*

Craig Priest, Pontus S.H. Forsberg, Zhantao Wang, Ciro Semprebon, Martin Brinkmann, Rossen Sedev, John Ralston, Univ. of South Australia (Australia)

Thin liquid films at micro- and nano-scales are often responsible for interesting macroscopic behaviour of liquids at interfaces. These films can be induced or prevented using smart surface structuring or patterning of surfaces. However, understanding the interplay between macroscopic wetting, surface design, and film formation is not straight-forward. Spontaneous structure-induced spreading of thin liquid films, or 'wicking', is a visually impressive phenomenon at the macroscale during which a liquid may quickly wet into the topography of the surface to form a thin liquid film. A necessary condition to observe the film formation is obtained by balancing the global energy minimum in the wet and dry cases, often referred to as the thermodynamic criterion. Here we will consider an array of microscale pillars and show that this is not always the case due to local pinning of the liquid front that depends on the specific geometry of the structure. We will show that in the region where film formation is thermodynamically allowed, several 'pinned' liquid morphologies can exist. As a consequence, the onset of wicking is shifted away from the thermodynamic criterion, with a high sensitivity to the wettability of the material itself. A second thin film of interest, the precursor film, will also be discussed in the context of macroscopic spreading. The influence of nanoscale heterogeneity on precursor film formation has not been studied previously. Here, it will be demonstrated that the connectivity of nanoscale surface patches is a critical factor in arresting or propagating a precursor film of a non-volatile liquid, which, in turn,

affects macroscopic spreading. In essence, where a pathway for the growth of a nanoscale precursor film does not exist, macroscopic spreading is arrested.

8923-33, Session 8

Metamaterials: an ideal platform to manipulate electromagnetic waves *(Invited Paper)*

Lei Zhou, Fudan Univ (China)

The arbitrary control of electromagnetic (EM) waves is a key aim of photonic research. Conventional optical materials have limited abilities to manipulate EM waves due to their limited variation ranges of material parameters. Metamaterials (MTM), artificial composites made by EM microstructures in deep-subwavelength scales, can possess arbitrary values of permittivity ? and permeability ? and thus offer much expanded freedoms to manipulate EM waves. In this talk, I will briefly review our recent efforts, both theoretically and experimentally, in employing MTMs to control EM waves in various aspects. Examples include how to manipulate polarizations of EM waves, how to make high-conducting transparent metals, and how to bridge propagating EM waves and surface EM waves by gradient mea-surfaces and manipulate the surface wave properties of a plasmonic metal. In particular, I will introduce our recent efforts in establishing an effective model, derived from a rigorous physical ground and free of adjustable parameters, to accurately describe the coupling behaviors between two general plasmonic resonators.

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8923-34, Session 8

Simulation of the gap plasmon coupling with a quantum dot

Chamanei Perera, Kristy C. Vernon, Queensland Univ. of Technology (Australia)

Active control of plasmon propagation via coupling to Quantum Dots (QDs) is a hot topic in nano-photonic research.1, 2,3 When a QD is excited it acts as a dipole emitter. If this excited QD is placed near a metallic waveguide structure, it can decay either radiatively into bulk electromagnetic radiation, non-radiatively into heating of the metal or, of interest to this project, into a plasmon mode (γpl).1 By altering the position of the QD it is possible to optimise the decay into the plasmon mode.

In this paper we present a system with a QD placed within the vicinity of a single mode Gap Plasmon Waveguide (GPW). First, we constructed a 2D finite element modelling simulation to find γ0pl using COMSOL MULTIPHYSICS for symmetric GPW structures with varying width (w) of the gap and distance of the QD to the waveguide surface (d). The height was chosen to be 50 nm, and the metal was gold, dielectric material was air.

We then constructed a 3D model to calculate total rate of spontaneous emission of a QD (?tot) hence calculate spontaneous emission ? factor where ? factor represents the all possible decay channels. It is shown that the decrease in width of the gap results in much larger ? factor. As the gap width decreases, fraction of modal power in the metal increases slowing down the plasmon mode resulting enhancement in coupling efficiency. The estimated optimized spontaneous emission beta factor for a square metallic slot waveguide is estimated up to 80%.

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8923-35, Session 8

Angular alignment of gold nanorods by photothermal depletion

Adam B. Taylor, Timothy T. Y. Chow, James W. M. Chon, Swinburne Univ. of Technology (Australia)

Thin gold nanorod films are conventionally produced using the spin-coating process, producing sub-2μm thin films of gold nanorods embedded into poly-vinyl alcohol. While this produces high quality nanorod films, the hydrodynamic forces involved in the spin-coating process leaves the nanorods within the film having a random angular alignment in the sample plane.

However, in order to use this film as a polarisation sensitive device, the angular distribution of the rods must be made non-uniform. Here we demonstrate the use of photothermal heating and subsequent melting, to 'deplete' out an angular range of the nanorods within the film. The energy absorbed by a gold nanorod, due to excitation of its Surface Plasmon Resonance, will show a cos2 dependence on the angle between the rods long axis and the laser polarisation. Rods most closely aligned to the laser polarisation will experience the fastest rates of heating and thus melting, relaxing into a spherical shape, when exposed to a high fluence laser pulse. The extent of the angular range around the polarisation angle within which nanorods are melted will increase with laser fluence. The extreme case of angular control is using when photothermal absorption of the laser by the nanorods causes all but those aligned near-orthogonally to the laser polarisation to melt, allowing use to impose alignment on the nanorods, to within a 20degree range, by means of depleting out any not fitting our alignment criteria.

8923-36, Session 8

Localized surface plasmon resonance study of a plasmonic structure using spectroscopic ellipsometry

Mohammad T. Yaseen, Academia Sinica (Taiwan)

Spectroscopic ellipsometry was used to study localized surface plasmon resonance (LSPR) response of a plasmonic structure that consists of gold nanoislands partially embedded in a glass substrate. Partially embedded gold nanoislands in a glass substrate were prepared by the thermal annealing process to produce a simple, stable, and low-cost plasmonic structure. For this plasmonic structure, an initial gold thin layer was evaporated on a glass substrate using E-gun evaporator then thermally annealed near the melting temperature of the glass substrate. Several samples at different initial thickness of gold films were prepared and used to study the thickness effect on their optical properties. For optical characterization, a UV-Vis spectrophotometer was used to study absorption spectra of the plasmonic structure. The UV-Vis spectrophotometer results showed that a thick initial gold film produces a wide and red shift absorption spectrum compared to a thin initial gold film. Also, the spectroscopic ellipsometry was used to study the sensitivity based LSPR of this plasmonic structure. Therefore, this plasmonic structure could be a good candidate as a low cost sensor for biosensing applications.

8923-37, Session 8

Polarization effect and emission control in asymmetric cross-shaped slot antennas surrounded with periodic corrugations

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(Australia); Timothy J. Davis, Commonwealth Scientific and Industrial Research Organisation (Australia) and Melbourne Ctr. for Nanofabrication (Australia); Ann Roberts, The Univ. of Melbourne (Australia)

The ability to control the state of polarisation and the radiation pattern as well as to increase the amount of radiation by quantum emitters is highly desirable for next generation telecommunications and quantum computing. Nanometric apertures perforated in metallic films exhibit localized surface plasmon resonances which depend on the shape and size of the aperture and the dielectric environment of the film. We have previously shown computationally and experimentally that a high degree of circular polarization is achievable by detuning the two orthogonal LSP modes in an array of asymmetric cross-cavities. The utilization of surface plasmon polaritons and their coupling to the LSP modes in an elliptical bull's eye structure was also shown to produce the same effect. Apertures in metallic films surrounded by surface corrugations have also been shown to control the directionality of the emission from dipoles in apertures. We discuss progress in the development of asymmetric cross-shaped plasmonic antennas based on resonant nanoscale apertures surrounded by surface corrugations. By tailoring the aperture and the surrounding surface, we show transmission and radiation enhancement as well as directionality and polarisation control.

8923-38, Session 9

Graphene-based functional soft materials

(Invited Paper)

Dan Li, Monash University (Australia)

From a chemistry point of view, graphene is a giant conductive macromolecule. As with other polymers, its chemistry, molecular configuration and assembly structure all affect its properties. It is thus of great importance to engineer graphene-based materials at different length scales ranging from atomic, individual sheet-level to three-dimensional bulk assembly. Our group has been developing cost-effective colloidal strategies to engineer graphene since 2006. We have been particularly keen to study the unique physical and chemical properties of solvated graphene in the past years. We discovered that solvation of chemically converted graphene not only enables its solution processability, but more importantly, offers new unique avenues to tailor its structure and functionalities. In particular, solvation can activate various colloidal forces, allowing graphene sheets to interface with each other and other functional nanomaterials in ways that are impossible for dried materials. This has enabled us to successfully develop a series of functional soft materials based on solvated graphene to address long-standing challenges in energy storage, nanofluidics, nanoplasmonics and catalysis.

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8923-39, Session 9

Examination of Au nanopore formation mechanism on nano-membrane using FESEM electron beam irradiation

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We have examined the metallic nanopore fabrication using high energy electron beam irradiation. It is generally known that the nanopore becomes shrinking under irradiation of the FESEM electron beam. In this report, adiabatic formation of Au nanopore was examined using slowscan mode and fastscan mode.

8923-40, Session 9

Aspect ratio dependent photothermal reshaping of single gold nanorods

Adam B Taylor, James W. M. Chon, Swinburne Univ. of Technology (Australia)

The use of gold nanorods has become widespread across many areas of science and technology, yet no systematic study of the dependence of the melting point on aspect ratio (AR) has been reported.

To investigate this, we used transmission electron microscopy (TEM) to image a set of gold nanorods with varying AR and randomly dispersed in a thin polymer film, before and after irradiation by a femtosecond laser pulse. The TEM images, provide dimensions and orientation of the nanorods, which are then used to calculate absorbed laser energy and temperature during irradiation from their numerically calculated absorption cross sections. Linearly polarized laser pulses were scanned over the area of interest with speed to allow the area to be irradiated with only single pulses, and then the TEM image was taken, allowing the change in dimension of each rod due to laser absorption to be tracked.

Nanorods most resonant with the laser exhibit the greatest reshaping as expected. However nanorods with aspect ratios longer than the range resonant with the laser wavelength also show significant reshaping, despite absorbing far less laser energy. These results are divided up into 18 'bins', based on their initial AR, to study the variance in reshaping with aspect ratio. Misalignment between the randomly oriented nanorods and the laser polarization create a distribution in absorbed energy within each bin.

We attribute the below melting-point thermal reshaping to the effects of surface diffusion, and thus use a theoretical model to fit the reshaping data in each bin. This enables extraction of the temperature dependent diffusion coefficients for each aspect ratio, and the absorbed energy required to completely reshape nanorods of different aspect ratios. Evidently, the activation energy for surface diffusion decreases rapidly with increasing aspect ratio, and increasing surface-to-volume ratios, indicating strongly reduced thermal stability in increasing aspect ratio.

In this paper we will present full details of this experiment, including simulation of the nanorod reshaping process, together with further investigations showing critical importance of understanding the effect of aspect ratio on the nanorod melting temperature.

8923-41, Session 9

MUA and MPA capped CdSeZnS quantum dot fluorescent sensors

Adrian Trinchi, Commonwealth Scientific and Industrial Research Organisation (Australia)

Fluorescent semiconductor quantum dots are 0-dimensionional that possess size dependent optical and electronic properties. Such materials have been shown to be applicable to a variety of sensing applications. Here we report the fluorescence response of water dispersible CdSe/ZnS core-shell quantum dots with different capping agents, namely mercaptopropionic acid (MPA) and

mercaptoundecanoic acid, (MUA) towards different concentrations of various metal cations. The QDs were synthesized via a colloidal approach, in which the cadmium selenide cores were first formed, followed by successive shelling with zinc sulphide, thus yielding the core/shell QDs. Shelling the QDs with the ZnS improves their quantum yield. The surface functionalities were then changed via ligand exchanges with either the mercaptopropionic acid and mercaptoundecanoic acid, thus rendering the water insoluble QDs water soluble. It was found that when exposed to various metal cations, the greatest quenching was achieved in the presence of copper, and the amount of quenching showed dependence on the capping agent. The resultant quantum dots were subsequently characterised by UV-Vis spectroscopy, photo-luminescent spectroscopy, Raman Spectroscopy and X-ray diffraction. The quantitative detection of Cu^{2+} and Ag^{+} ions was based on the fluorescence quenching of QDs, with the recorded fluorescence intensity being proportional to the concentration of the ion species.

8923-42, Session 9

Development and utilization of nanophosphors in medical, security and energy devices

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Working at the nano-scale, scientists are able to create new products, new tools, and advanced technologies to address some of the world's biggest challenges viz.: clean, secure, affordable energy; stronger, lighter, durable materials; medical devices; drugs to treat deadly diseases; high efficient lighting; and sensors to detect and identify harmful chemical and biological agents. Specialty Phosphors Inc. (SPI) is focused on fulfilling these challenges. SPI is a startup venture whose demonstrated expertise and success extends to product development and manufacturing of advanced multifunctional nanophosphors with unique properties for medical, security, lighting, and military applications.

Currently, SPI is investigating the feasibility of X-Ray luminescence imaging using a dual-modality imaging with a team of oncology experts at Stanford University. This modality utilizes X-Ray activated nanophosphors. Some of the results with oxysulphides nanophosphors are presented here. In reflection geometry, X-Ray luminescence has nearly a 430-fold greater contrast to background than X-Ray fluoroscopy. Some of the designs and results of our novel high-resolution digital mammography approach for early detection of breast cancer will be presented.

We are able to design a cell with phosphor coatings by printing the nanophosphors with suitable binders on to Si based solar cell by ink jet process and testing their performance in required temperature and humidity. We are focusing in a simple solution with unique materials of exceptional signatures in NIR as authentication markers for security and military applications. The benefit of these phosphor-pigment combinations will be to help the military to visualize enemy targets, equipment, and personnel movement.

8923-43, Session 10

Surface acoustic wave (SAW) atomization of therapeutic antibodies for pulmonary delivery *(Invited Paper)*

Christina Cortez-Jugo, Monash Univ. (Australia); Aisha Qi, RMIT Univ. (Australia); Anushi Rajapaksa, Monash Univ. (Australia); James Friend, Leslie Y. Yeo, RMIT Univ. (Australia)

The lung presents an attractive target for both systemic and local therapeutic delivery. Small drugs have routinely been delivered by inhalation to the lung with high bioavailability and rapid action. The pulmonary delivery of large macromolecules, including therapeutic nucleic acids, peptides and proteins, is gaining interest stemming from encouraging results with human growth hormone and insulin in previous decades. Research into devices that can deliver macromolecules to the lungs effectively without loss of activity and function is increasingly important.

A technology being developed for the generation and delivery of aerosolized drugs—the Respire® system—is based on surface acoustic wave (SAW) atomization. The waves, which travel along the surface of an elastic material, are excited when power is supplied in the form of an electrical signal via interdigital transducer (IDT) electrodes, patterned using photolithography techniques, on a piezoelectric substrate. The excited waves interact with liquid placed as a drop on the substrate, inducing capillary waves on the free surface of the liquid. At high enough power, the interface rapidly destabilizes, leading to the atomization of the liquid drop into a fine mist.

The SAW atomization of antibodies will be presented. The antibodies are targeted against the epidermal growth factor receptor (EGFR), which is over-expressed in lung cancer. The stability, immunoactivity and function of the atomized antibody were characterized using gel electrophoresis, confocal microscopy and flow cytometry. The results indicate that the Respire® system provides a feasible means of delivering active antibodies as a fine inhalable mist to the lung.

8923-44, Session 10

Water-soluble bis(arylidene)cycloalkanone dyes for two-photon excited photodynamic therapy

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A series of polyethylene glycol-functionalized bis(arylidene) cycloalkanone dyes with gradient lipid-water partition coefficients were synthesized in high yields by a simple process. Detailed characterization and systematic studies of these compounds, including their linear and nonlinear photophysical properties, reactive oxygen yields, in vitro photodynamic therapy (PDT) and two-photon excited (2PE) PDT activities, were conducted and compared with a clinical drug PDS007. Most of these dyes exhibited appropriate lipid-water partition coefficients (which is sufficient to clinical venous injection), high reactive oxygen yields, large two-photon absorption and low dark toxicity under therapy dosages. Among them, four dyes could be absorbed efficiently by liver hepatocellular HepG2 cells, presented strong PDT and 2PE-PDT activity by in vitro cell experiments. Furthermore, in vivo tumor experiments were carried out on BALB/c mouse models. The results showed that the tumor growth could be suppressed effectively by such dyes under 2PE-PDT. This work demonstrated the feasibility of using a simple molecular structure to construct high efficient photosensitizers for 2PE-PDT.

8923-45, Session 10

Effects of laser-exposed gold nanorods on biochemical pathways of neuronal cells

Chiara Paviolo, Swinburne Univ. of Technology (Australia); John W. Haycock, The University of Sheffield (United Kingdom); Paul R. Stoddart, Sally L. McArthur, Swinburne Univ. of Technology (Australia)

Gold nanoparticles have attracted considerable interest for biological applications such as labeling, drug/gene delivery, heating, sensing and imaging [1]. A recent application of Au NRs with citrate termination, poly(4-styrenesulfonic acid) coating and SiO_2 coating showed a stimulatory effect on the neurite length of NG108-15 neuronal cells [2]. Here we investigate two different biochemical mechanisms involved in the process: i) the activation of the nuclear factor kappa-b (NF-kB) and ii) the recording of intracellular calcium transients (Ca^{2+}).

Importantly, internalized Au NRs assessed by live/dead staining and MTS cell viability showed no significant toxicity. Indeed, neuronal cells cultured with Au NRs for one hour showed a significant increase in reactive oxygen species (ROS) production together with activation of the NF-kB pathway. After five hours incubation, both the ROS production and the NF-kB activation decreased. Subsequent laser exposure did not produce any permanent cell damage or ROS elevation.

Neuronal cells cultured with NRs for three days and irradiated with different pulse lengths and powers showed evidence of photo-generated transient calcium releases. The highest Ca2+ peaks were observed at radiant exposures of 0.33 J/cm2. This effect may be linked to nanoparticle induced heating that could serve to (a) generate transient changes in membrane capacitance and activate temperature sensitive ion channels in the cell membrane [3] or (b) deplete the intracellular calcium storage organelles [4]. Some initial efforts to quantify the temperature increase due to NR excitation will be described.

This work suggests new opportunities for peripheral nerve regeneration treatments and for infrared nerve stimulation.

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8923-46, Session 10

Influence of surface acoustic wave induced acoustic streaming on the kinetics of electrochemical reactions

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The kinetics of electrochemical reactions is controlled by diffusion processes of charge carriers across a boundary layer between the electrode and the electrolyte, which result in a shielding of the electric field inside the electrolyte and a concentration gradient across this boundary layer. In accumulators the diffusion rate determines the rather long time needed for charging, which is a major drawback for electric mobility. This diffusion boundary can be removed by acoustic streaming in the electrolyte induced by surface acoustic waves propagating of the electrode, which results in an increase of the charging current and thus in a reduction of the time needed for charging.

For a quantitative study of the influence of acoustic streaming on the charge transport an electropolishing cell with vertically oriented copper electrodes and diluted H3PO4-Propanol electrolytes were used. Lamb waves with various excitation frequencies were exited on the anode with different piezoelectric transducers, which induced acoustic streaming in the overlaying electrolytic liquid. An increase of the polishing current of up to approximately 100 % has been obtained with such a set-up.

8923-47, Session 10

Laser measurements of bacterial endospore destruction from shock waves

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During periods of environmental stress such as lack of nutrition, some bacteria form cells called endospores, which are dormant and highly resistant to harsh environmental conditions. Endospores can survive high pressures and temperatures, however little is known about their ability to survive the extreme yet ephemeral conditions typically found in blast waves. This paper presents an experimental procedure for quantifying endospore breakdown in shock-heated gases having similar temperature and pressure traces to blast waves. The procedure can be used to determine the conditions needed to inactivate endospores that are hazardous to humans.

Here we report optical diagnostics to monitor, in real time, the interaction of shock waves of various strengths with aerosols containing bacterial endospores in a shock tube. These experiments used a new laboratory procedure, performed on the Stanford Aerosol Shock Tube (SAST). The procedure entails nebulizing an aqueous suspension of Bacillus atrophaeus (BA) endospores and loading the resulting bioaerosol into the SAST before being shock-heated. The incident shock waves and the shock waves reflected by the end wall of the SAST successively compress, heat and accelerate the bioaerosol in the order of 2 to 3 milliseconds. The structural integrity of the shock-heated endospores is monitored with time-resolved laser extinction measurements at two wavelengths, 665 nm and 266 nm. The visible light at 665 nm is scattered by the endospores, intact or otherwise. The UV light at 266 nm is not only scattered by the endospores but is also attenuated by UV-absorbing endospore biochemicals. Thus, the transmitted intensity of the 665nm light provides a time history for the destruction of the endospore structure, while the transmitted UV light intensity at 266 nm monitors the release of biochemicals otherwise residing in the endospore. BA endospores were found to break down when shock-heated above 750 K. Complete disintegration of the endospores occurred for shocks above 950 K.

8923-48, Session 11

Mechanically reconfigurable metamaterials: bendable, stretchable and inflatable platforms at GHz, THz and optical frequencies *(Invited Paper)*

Arnan Mitchell, RMIT Univ. (Australia)

No Abstract Available

8923-50, Session 11

The application of carbon nanotubes in mode locked fiber laser

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The optically absorption of carbon nanotubes decreases with intensity or energy of the incident light. This nonlinear optical behavior makes them promising for applications in ultrafast photonics. For passively mode locked lasers, the CNTs are indeed good saturable absorbers because of their broad absorption bandwidth, ultrafast recovery time (~1ps), high optical damage threshold and easy fabrication. We demonstrate a highly stable mode locked fiber laser based on single wall carbon nanotubes. A short segment of a microfiber was embedded in the carbon nanotubes and polyvinyl alcohol composite acting as a saturable absorber. The pulse width was 96fs. The center of the wavelength is 1555nm with 27nm spectral width. The time-bandwidth product is 0.322 which is near to the transform-limited pulse (0.315).The repetition rate is 110MHz.The output pulses are monitored for 100h to find that there is no significant degradation of the spectral width.

8923-51, Session 11

Comparison of Al2O3 nano-overlays deposited with atomic layer deposition and magnetron sputtering on optical fibers for sensing purposes

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There is a wide selection of thin film deposition methods. The most repeatable and advanced ones are based on physical (PVD) or chemical vapor deposition (CVD), and thus they have already been applied in semiconductor industry. These deposition methods allow

for good control over properties of the films. In this work we compare effects of thin (<300 nm) aluminium oxide (Al2O3) deposition using advanced chemical (Atomic Layer Deposition – ALD) and physical (Magnetron Sputtering - MS) vapor deposition methods on optical fibers. We investigate influence of the process parameters on optical properties of the nano-films deposited with each of the methods. In order to investigate the properties of the films directly on the fibers, we induced long-period fiber grating (LPG) in the fiber prior the deposition. Thanks to LPG sensitivity to thickness and optical properties of the overlays deposited on the fiber, we are able to monitor Al2O3 nano-overlay properties. Moreover, we investigate influence of the overlays deposited with both the methods on LPG-based refractive index (RI) sensing. We show and discuss tuning of the RI sensitivity be proper selection of both thickness and optical properties of the Al2O3 nano-overlays. The sensing platform based on LPGs coated with Al2O3 may find applications in label-free biosensing.

8923-52, Session 11

Evaluation of optical fibres for surface-enhanced Raman scattering probes

Jennifer S. Hartley, Saulius Juodkazis, Paul R. Stoddart, Swinburne Univ. of Technology (Australia)

A range of optical fibres have been evaluated for use as surface-enhanced Raman scattering (SERS) probes. Optical fibres, when coupled with SERS, can be utilised as micro-scale sensing devices [1]. The SERS effect originates from plasmons created when a nano-rough metal film is excited by a coherent light source [2]. The tip of the optical fibre is coated with a nano-roughened film, on which the target analyte must be adsorbed [3].

Optical fibres when coupled with a spectrometer form a complex optical element which needs to be fully optimised in order to create an efficient remote probe [4]. The relationship between SERS intensity and different fibre parameters has been investigated to determine the suitability of each fibre as a remote probe. The fibres chosen for the study were both single mode and multi-mode and varied in core size and numerical aperture.

It has been determined that the numerical aperture, core size, mode structure and core material have a major effect on the probe performance. Each factor contributes to the intensity in background signal from the fibre core and the intensity of signal from the molecule under investigation. The numerical aperture of the excitation/collection microscope objective also contributes to the ratio of sample signal to optical fibre core signal (signal to background ratio). The results suggest that an ideal fibre for SERS sensing should be single mode at the excitation wavelength and have a low-background core material. The microscope objective should be chosen carefully for optimal probe performance.

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8923-53, Session 12

III-V compound semiconductor quantum dot solar cells *(Invited Paper)*

Lan Fu, Haofeng Lu, Australian National University (Australia); Greg Jolley, University of Western Australia (Australia); Samuel Turner, Sudha Mokkapati, Hoe Tan, Chennupati Jagadish, Australian National University (Australia)

In recent years, enormous research efforts have been invested on exploring new concepts and approaches to achieve high efficiency solar cells. The fast emerging nanotechnology has opened up great opportunities to produce solar cells with lower cost and/or improved performance by employing the unique properties of nanostructures, such as self-assembled quantum dots (QDs). By incorporating multiple layers of self-assembled QDs into the intrinsic region of a standard p-i-n solar cell structure during the epitaxial growth, the low energy photons (lower than the energy gap of the host material) in the solar spectrum can be absorbed by the QD layers, leading to an extended photoresponse to longer wavelengths and thus larger photocurrent (compared with the GaAs reference cell). Quantum dot solar cells (QDSCs) have also shown promise in further improving the performance of the most efficient multi-junction solar cell devices due to the flexibility in bandgap engineering which provides better current-matching and hence the increased output current of the entire device. In this talk, we will review the basic physical processes dominating the operation of quantum dot solar cells that are based on self-assembled InGaAs/GaAs quantum dots grown by metalorganic chemical vapour deposition (MOCVD) technique. We will propose and demonstrate various approaches to enhance the quantum dot solar cell performance and also provide further discussion on their limitations and prospects for high efficiency applications.

8923-55, Session 12

Heterogeneous nano-particle array for the realization of the hot carrier solar cell

Yu Feng, Shu Lin, The Univ. of New South Wales (Australia); Xiaoming Wen, Pengfei Zhang, Univ of New South Wales (Australia); Shujuan Huang, Santosh Shrestha, Gavin Conibeer, The Univ. of New South Wales (Australia)

The hot carrier solar cell is a novel concept for converting solar energy to electricity with efficiency higher than the Shockley-Quesiier limit. This high performance is achieved by maintaining a hot population of the photo-generated carriers that is extracted before being thermalized to the band edge. Previous effort mainly focused on enlarging the energy gap between optical phonons and acoustic branches of absorber materials. In this work a different approach has been proposed, by localizing phonons within the absorber. Such localization can be achieved by fabricating a nano-particle array with large acoustic impedance. This yields lattice waves with reduced group velocities, hence resulting in smaller lattice heat conductivity. In this work the reduction of lattice heat conductivity has been computed quantitatively for a nano-particle array consisting of two different types of material. On the other hand, their electronic band gaps can be controlled by adjusting the respective particle sizes. In an optimal case, the band gaps of the component particles shall be close so that the carrier transport is not largely limited. Its effect has also been analyzed based on tight-binding calculations. Finally several material candidates for the nano-particle array have been introduced and discussed. Their respective potentials on realizing the hot carrier solar cell have been evaluated in terms of their electronic, phononic and photonic properties.

8923-56, Session 12

Solution processing of next-generation nanocrystal solar cells

Jacek J. Jasieniak, Joel van Embden, Anthony Chesman, Enrico Della Gaspera, Noel Duffy, Commonwealth Scientific and Industrial Research Organisation (Australia)

Next-generation solar cells will be fabricated from low-cost and earth abundant elements using streamlined processes that depart from conventional batch processing. This talk will delve into the opportunity of utilizing compositionally and structurally controlled colloidal nanocrystals as building blocks of such devices. Our recent efforts in developing kesterite Cu2ZnSnS4 (CZTS) nanocrystals, one of the most promising materials to emerge in this area, enable the deposition of CZTS thin-films using a variety of solution-processed methods. Such nanocrystalline thin films possess poor electronic properties, which obviates their use in solar cell devices. To overcome this, chemical and thermal treatment steps are applied to induce large scale crystallite growth. Each of these processing steps will be discussed in detail; thus, highlighting the significant challenges that need to be overcome in order to fabricate working CZTS thin film solar cells.

8923-57, Session 12

Optical properties and electron dynamics in carbon nanodots

Xiaoming Wen, Shujuan Huang, Gavin Conibeer, Santosh Shrestha, The Univ. of New South Wales (Australia); Pyng Yu, Yon-Rui Toh, Jau Tang, Academia Sinica (Taiwan)

Carbon is one of the most abundant elements on earth. During the last few years, colloidal carbon nanodots (CNDs) have emerged as fascinating materials with unique optical properties, wide availability, environment friendly (non-toxic), thus offering great potential applications in photovoltaics and photocatalysis.1,2 On the other hand, the synthesis techniques are making significant advance for low cost, high quantum yields (QY. ~80%),3 high photostability, tunable optical properties, as well as the possibility to functionalize for the required properties for the device fabrication. CNDs basically consist of sp2 carbon nano domains (aromatic structures) embedded in sp3 carbon matrix. 4,5 The isolated carbon nano domains possess suitable band gaps and thus can emit UV, visible or near infrared fluorescence by electron-hole radiative recombination.1,4-8 The abundant oxygenous functional groups not only passivate the surface of the CNDs but also lead to fluorescence due to various fluorophores. CNDs have been shown to exhibit fluorescent behavior quite similar to that observed in few-layered graphene quantum dots (GQDs). Controlling the layers of graphene can realize the transition from GQDs (few of layers) to CNDs.

It is interesting to note that CNDs have also been demonstrated to be good electron donors, as well as electron acceptors. Moreover, it was demonstrated the relaxation of hot electrons is slowed down due to quantum confinement.9-11 Therefore, CNDs offer great potential for a broad range of applications in photovoltaics. Herein we present the investigation of optical properties of carbon nanodots using steady state and time-resolved techniques, with time scale from sub-picosecond up to millisecond. The luminescent mechanism was studied for the better physical understanding in this novel material. We demonstrated the synthesized CNDs exhibit quantum confinement and the relaxation rate induced by phonon scattering is significantly slower than the other carbon materials, which suggests CND can be a candidate for hot carrier solar cells. The electron transfer was confirmed in the CNDs-graphene oxide system, which further support that CNDs are prospective photovoltaic material.

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8923-58, Session 13

Nano-architecture: creating complex surface structures using supramolecular self-assembly of tripeptides *(Invited Paper)*

Adam Mechler, Rania Seoudi, La Trobe Univ. (Australia); Mark P. Del Borgo, Mibel Aguilar, Patrick Perlmutter, Monash Univ. (Australia)

Supramolecular self-assembly offers a powerful strategy for the design of new functional nanomaterials. The specificity and selectivity offered by supramolecular recognition minimizes defects, while the geometrically optimized physical bonding networks introduce high strength. Here we report on using small unnatural helical beta peptides to implement supramolecular recognition, via a unique 3-point H-bonding motif, that leads to unprecedented head-to-tail self-assembly, thus continuing the intramolecular helix into a fibrous superstructure. These helices have a perfect pitch, requiring exactly three amino acids per turn, and thus the residues are aligned along the helix. The smallest peptide still capable of self-assembly had a sequence of only three beta amino acids. By appropriate choice of the peptide sequence we have control over lateral coupling between the fibres, and thus a hierarchical self-assembly process, which can be designed to form macroscopic silk-like threads as well as complex nanometer scale surface structures. We have achieved dendritic as well as parallel surface coverage. The free residues of the peptides that do not participate in the lateral and/or surface binding might be used to attach a payload, such as a drug or a fluorescent compound. Both the synthesis and the derivatization of the fibres is relatively straigthforward, making this platform technology ideally suited for the highly exacting requirements of materials science.

8923-59, Session 13

A novel transfer process for high temperature oxides stretchable electronics

Philipp Gutruf, Charan M. Shah, Sumeet Walia, Hussein Nili Ahmadabadi, Ahmad S. Zoolfakar, RMIT Univ. (Australia); Christian Karnutsch, Fachhochschule Karlsruhe Technik und Wirtschaft (Germany); Kourosh Kalantar-Zadeh, Sharath Sriram, Madhu Bhaskaran, RMIT Univ. (Australia)

Recently many functionalities only associated with rigid electronics have been demonstrated on a flexible substrate, projecting that flexible devices have a high potential to replace rigid electronics in the long run. Applications such as flexible batteries 1, field effect transistors 2 or terahertz metamaterials 3 show that multifunctional platforms are possible in the near future. Currently numerous complicated techniques are used to fabricate these applications. To overcome this hurdle a ubiquitous process is required to unite different functionalities on one substrate. The presented novel process allows high temperature processed oxides to be transferred to a flexible substrate with standard micro fabrication methods.

In this presentation, we demonstrate this technique by transferring indium tin oxide (ITO) and zinc oxide (ZnO) thin films to polydimethylsiloxane (PDMS) substrates. Both oxides are processed above the temperature limit of PDMS and are transferred by casting PDMS on the fabricated structures and pealing the layers off the rigid substrate using the weak adhesion interface of platinum to silicon. Furthermore, feature sizes down to 2.5µm with standard photolithographic methods are easily achieved.

Resistance vs strain measurements were carried out for the transferred ITO layers on PDMS. It was shown that conductivity was maintained up to strain levels of 15%. The phenomenon of overlap of micro tectonic plates was discovered and studied using a stretching stage in combination with a scanning electron microscope. The ubiquity of this process was demonstrated by transferring ZnO thin films to PDMS without changing process parameters. X-ray diffraction results indicate the ZnO films were (002) oriented and the crystallinity of the transferred thin films was the same as the as-deposited thin films.

In conclusion we demonstrate a ubiquitous technique to transfer patterned functional layers to PDMS. The integration of high temperature processed oxide layers with flexible substrates allows us to overcome current limitations in fabrication of stretchable microelectronic devices.

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8923-60, Session 13

Patterning of monolithic diamond films by inductively coupled plasma reactive ion etching

Wei Tong, Kumaravelu Ganesan, Kate Fox, Olga Shimoni, Steven Prawer, The Univ. of Melbourne (Australia)

Diamond is an optimal candidate for use in electronics, optoelectronics, and advanced biomedical devices due to its outstanding electrical properties, biocompatibility, chemical inertness and mechanical stability. To fabricate such diamond-based electronic devices, the patterning of the diamond film is possibly the most potent strategy. To further improve the performances of the corresponding devices, these patterns must be precise and clear from undesirable diamond continuation. In addition, careful attentions should be paid to the fabrication processes to avoid damaging the substrate.

Diamond devices comprise both ultrananocrystalline (UNCD) and polycrystalline diamond (PCD) deposited using microwave plasma enhanced chemical vapor deposition to facilitate controlled regions of electrical conduction and insulation. In order to fabricate the device, an initial PCD film was deposited on a sacrificial silicon substrate and an aluminum etch mask was defined by photolithography and lift-off technique.. Using inductively coupled plasma reactive ion etching (ICP-RIE) and by carefully controlling the etching parameters, the PCD film was selectively etched away to expose Si substrate without damaging it Nitrogen-doped ultrananocrystalline diamond (N-UNCD) was then deposited on top to produce conducting regions in the device. Finally, the sacrificial Si substrate was etched away using HF/HNO3 acid. In this way, a monolithic diamond structure was fabricated with two types of diamond on a single surface. The resulting surface microstructure and bonding status were analyzed using scanning electron microscopy, optical profilometry and Raman spectroscopy. The patterns were found precise and the whole surface was smooth, implying that Si substrate was not etched during ICP-RIE.

8923-61, Session 14

Plasmonics for high quantum efficiency III-V semiconductor nanowires *(Invited Paper)*

Sudha Mokkapati, The Australian National Univ. (Australia)

We demonstrate increase in radiative efficiency of III-V semiconductor nanowires by coupling them to plasmonic cavities. For GaAs core-AlGaAs shell-GaAs cap nanowires, we demonstrate multi-colour emission from the nanowires without any quantum confinement, by coupling them to plasmonic nanoparticles. The AlGaAs shell in the nanowires coupled to plasmonic nanoparticles passivates the GaAs core, and also emits efficiently at shorter wavelengths compared to the core. While the GaAs core emits light predominantly polarized parallel to the axis of the nanowire, the AlGaAs shell emits light polarized perpendicular to the axis of the nanowire. We will discuss the origin of this polarization response and show that the relative emission intensity from the core and shell can be tuned. Results for InP nanowires and nanowires with GaAs/AlGaAs quantum wells will also be discussed.

We will discuss the advantages and limitations of coupling nanowires to plasmonic cavities for increasing the radiative efficiency in the nanowires. We will identify the modes responsible for radiative efficiency enhancement for the different nanowire-plasmonic cavity coupled systems.

8923-62, Session 14

Hybridization in 3D: optical and plasmonic elements

Lorenzo Rosa, Gediminas Gervinskas, Albertas ?ukauskas, Swinburne Univ. of Technology (Australia); Mangirdas Malinauskas, Vilnius Univ. (Lithuania); Etienne Brasselet, Univ. Bordeaux 1 (France); Saulius Juodkazis, Swinburne Univ. of Technology (Australia)

Femtosecond laser fabrication has been used to make hybrid refractive and diffractive micro-optical elements in photo-polymer SZ2080. For applications in micro-fluidics, arrays of axicon lenses were fabricated, for generation of light intensity patterns extending through the entire depth of a typically tens-of-micrometers deep channel. Further hybridisation of axicon with a plasmonic slot is demonstrated numerically and experimentally. Spiralling chiral grooves were inscribed into a 50-nm-thick gold coating sputtered over polymerized micro-axicon lenses, using a focused ion beam. This demonstrates possibility of hybridisation between optical and plasmonic 3D micro-optical elements. Numerical modelling of optical performance by 3D-FDTD method is presented.

Focused ion-beam milling over arrays of nano-particles has been recently demonstrated [1] and shows a principle applicable for fabrication of arrays of high-fidelity and quality nano-structures. For centro-symmetric lenses and axicons [2], a chiral groove inscription has to be perfectly centred and this can be achieved by the demonstrated principle [1], now applied to a non-flat 3D optical element. The functionality of the 3D chiral groove over an axicon lens was numerically investigated by 3D-FDTD method: the near-field distribution is analysed for focal and dark spots (for trapping of metallic and dielectric nano-particles), which are characterized for trapping force and stiffness through a custom developed Lorentz force formalism.

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8923-63, Session 14

Ultra-compact plasmonic nanoring laser

Chee-Wei Lee, Qian Wang, Gurpreet Singh, A*STAR - Data Storage Institute (Singapore); Seng-Tiong Ho, Northwestern Univ. (United States)

Ultra-small nanolaser sources are of great interest over recent years due to their potential application in optical interconnects, data storage and sensors. In this work, we presented design and analysis of metallic-semiconductor nanoring laser lasing at around 1450 nm wavelength, utilizing a body-of-revolution finite-difference-time-domain (BOR-FDTD) simulation incorporated with semi-classical multilevel model for semiconductor gain medium and Drude–Lorentz model for metal, which is developed for efficient simulation of disk/ring plasmonic laser. As compared to other literatures, our nanoring laser works in radial mode with resonance cycle, m=1, which could facilitate potential in-plane out-coupling, and is wafer bonded onto Si platform for potential electronic-photonic integration. The total footprint, the physical device volume and the effective mode volume of the nanolaser are only about 0.038 µm2, 1.1(?/2n)3 and 0.001(?/2n)3, respectively, where n is the average refractive index of the gain medium. To the best of our knowledge, our nanolaser is the smallest reported to date.

8923-64, Session 15

High resolution, large range, position sensing technique for MEMS cantilevers

Gino Putrino, Adrian Keating, Mariusz Martyniuk, Lorenzo Faraone, John M. Dell, The Univ. of Western Australia (Australia)

MEMS-based biological and chemical sensors have gained increasing attention due to their ability to provide a technique for high-precision (zepto-gram), label-free sensing. However, to date, the widespread application of this class of sensors has been impeded in part by the lack of a technology capable of performing high resolution measurements of large arrays of the MEMS devices. We present an experimental demonstration of a technology capable of filling that need.

MEMS-based sensors consist of either free-standing microcantilevers or microbridges, coated in a functionalization substance which preferentially bonds to the chemicals being searched for. MEMS sensors have two modes of operation: static (where height position is measured) and dynamic (where resonance frequency is measured).

To measure the state of the cantilevers, our design integrates a silicon photonics waveguide and diffraction grating beneath the sensing cantilever. By making the underside of the cantilever reflective, a resonant optical micro-cavity is formed beneath the cantilever. The amount of light coupled back into the waveguide from the grating is an extremely sensitive measure of the position of the cantilever.

Silicon photonics optical components were fabricated using deep ultra-violet (DUV) lithography. Microcantilevers were then fabricated above these components using surface micromachining. The optical output from the waveguide was measured for various cantilever height positions.

8923-65, Session 15

PiezoMEMS autofocus lens for next-generation smart devices

John Phair, poLight AS (Norway)

poLight AS, a Norwegian-based start-up company, has developed the world's first piezo-actuated autofocus lenses without moving parts, called the TLens®. The proprietary technology enables the production of wafer-scale active optic components based on deformable polymers. poLight's TLens® offers some crucial advantages to the camera module market thanks to its extremely small size (<4.2mm x 4.2mm x 0.5mm), high optical quality (megapixel independent and HD compatible) and speed of focus. These features, combined with its reflow-compatible manufacturing, positions the TLens as the ideal solution for the latest camera phone applications such as videos with continuous-autofocus. The presentation will discuss the recent progress poLight is making in bringing the production of the piezo-actuated TLens to market. An overview of the status of piezoMEMS for the TLens® will cover the key areas of interest such as test, measurement, integration.

8923-66, Session 15

Effect of surfaces on thermoelastic damping of a rectangular nanobeam

Saurabh Dixit, Mandar M. Inamdar, Dnyanesh N. Pawaskar, Indian Institute of Technology Bombay (India)

We investigate the role of surfaces on thermoelastic damping of flexural nanobeams. Due to high surface to volume ratio at nanometer length scales, surfaces significantly influence thermal and mechanical properties of these structures. In the past, the role of surfaces on thermoelastic damping in vibrating nanobeams has been discussed by considering only mechanical interactions between surfaces and the rest of bulk without accounting for thermal interactions. In this paper we account for heat flow between the surfaces and the bulk and derive a coupled thermo-mechanical heat equation for such a thermoelastic surface. A closed form analytical expression for the quality factor of a vibrating rectangular nanobeam has been obtained using modified thermal boundary conditions for the bulk under adiabatic surface conditions. We have also derived an expression for the surface heat capacity using a modified Debye model which is necessary to impose thermal boundary conditions at the surface-bulk interface. Using our model, we predict the frequency at which maximum dissipation occurs and the corresponding quality factor. We find that these quantities depend on both mechanical and thermal properties of the surface; in particular we observe that this surface effect is inversely proportional to beam thickness and also depends upon the operating frequency. We note that the coupled heat equation for a surface derived in the present work can be applied to any generic thermoelastic surface.

8923-67, Session 15

Silicon bi-layer films for low temperature MEMS

Kirsten L. Brookshire, Ramin Rafiei, Dhirendra K. Tripathi, Dilusha K. K. M. B. Silva, John Bumgarner, Robert W. Basedow, Yinong Liu, Lorenzo Faraone, The Univ. of Western Australia (Australia)

When operating MEMS devices at low-temperature, the thermal dependence of material properties has a large impact on device performance and stability. This work focuses on specific material properties of PECVD Si, the primary material used to build many MEMS devices. The finite element modeling software CoventorWare®, in conjunction with experimental data, were used to develop a realistic model of mechanical performance of these materials at low temperature.

To enable the development of an accurate model across a wide range of temperatures, a careful study of the temperature dependence of Young's modulus E, Poisson's ratio ?, and the coefficient of thermal expansion ? for PECVD Si was carried out. This was achieved by characterizing the curvature of bi-layer thin film samples. Measurements were made by combining a cryostat with a (NewView 6K) Zygo optical profilometer. Using this system, we were able to measure material parameters, from room temperature, down to approximately 100 K. The films used for this study were 850 nm of PECVD deposited silicon on 330 ?m Si(100), 70 ?m Si(100), 330 ?m Si(110), and 100 ?m Ge substrates.

Extraction of the material properties (E, ?, and ?) from the curvature measurements followed the technique proposed by Zhao et al. [1] Extracted parameters were used in CoventorWare® to confirm results through matched curvature values. These material parameters are being used to enable the performance prediction of simple MEMS structures for a wide range of temperatures.

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8923-69, Session 16

Towards capture and time resolved analysis of PCR amplification products using PDMS microfluidic devices

Dmitriy Khodakov, Renzo Fenati, Adrian Linacre, Flinders Univ. (Australia); Amanda V. Ellis, Flinders Univ. (Australia) and Flinders Ctr. for Nanoscale Science and Technology (Australia)

The development and application of new DNA genotyping approaches and microdevices offer a solution to simpler, cheaper and faster front-end DNA analysis. This highly attractive modern microfluidic technology includes nano-scale architectures for analyte manipulation, identification and differentiation.

The work to be presented here describes the development of a new approach for time resolved analysis of multiple polymerase chain reaction (PCR) products. The approach is based on hybridisation of the double-stranded (ds) PCR products with capture probes immobilised onto a surface of micro-beads trapped in a microfluidic channel. Subsequent releasing of the PCR products for CE analysis is carried out using a method which involves a non-enzymatic DNA strand displacement reaction. Also known as toehold-mediated displacement, the reaction occurs between a ds-DNA with strands of unequal length and another single-stranded (ss)-oligonucleotides using a toehold structure, as a trigger point, enabling DNA re-hybridisation in a "base-by-base" programmable controlled manner. The approach has been applied to the amplification, capture and time-lapse release of medically and forensically relevant genes used in human DNA genotyping. Subsequent capillary electrophoresis (CE) analysis of the released PCR products showed highly specific hybridisation and releasing of the captured double-stranded PCR products. Fabrication of the microfluidic device using soft-lithographic techniques is also described.

8923-70, Session 16

Development of glucose microsensors integrated with bio-functionalized zinc oxide nanorods

Archana Komirisetty, Frances Williams, Aswini K. Pradhan, Norfolk State Univ. (United States)

This paper presents the development of glucose microsensors that are integrated with advanced nano-materials, bio-coatings and electronics to create novel devices that are highly sensitive, inexpensive, accurate, and reliable. Nanotechnology provides for the miniaturization and improved performance of these devices. Since the sensors include nanostructures with features that are closer to that of biological and chemical species, they are highly sensitive and selective and have fast response times and linearity. The devices developed in this paper are based on electrochemical sensing using a working electrode with bio-functionalized zinc oxide (ZnO) nanorods. Among all metal oxide nanostructures, ZnO nanomaterials have properties that are favorable for bio-sensing applications including high isoelectric point (IEP), fast electron transfer, non-toxicity, biocompatibility, and chemical stability. Amperometric enzyme electrodes based on glucose oxidase (GOx) were used due to their stability and high selectivity to glucose. The microsensor consists of an insulating layer (silicon dioxide), platinum working and counter electrodes (with a titanium adhesion layer), and a silver/silver chloride reference electrode. The ZnO nanorods were grown by the hydrothermal technique due to its simple and controllable process. GOx was immobilized by physical adsorption and characterized by Fourier transform infrared spectroscopy (FTIR). The sensor's electrical response due to changing glucose concentrations was measured via cyclic voltammetry and is also presented in this paper.

8923-71, Session 16

Speech assistance devices controlled by neck myoelectric signal -compact pump system for regeneration of laryngeal tone

Katsutoshi Ooe, Takayuki Yamamoto, Daiichi Institute of Technology (Japan)

There are many patients who lost their voice caused by laryngeal cancer, laryngeal injury, using of artificial ventilator by progressive neurogenic diseases, and so on. For these patients, we researched about the reconstruction of their speech function. Most of the patients lost only their sound source of voice, for reconstruction of their voice, it is important that their sound source is reconstructed. In our previous research, we developed a control unit for the artificial larynx controlled by neck myoelectric signal. The control signal was detected from the sternohyoideus, one of the cervical muscles, and the availability for control signal was evaluated. After that, we started to develop the speech assistance devices with above-mentioned control unit.

In this report, we describe about the development of compact pump system that is one of the speech assistance devices. The patients who use the artificial ventilator lost the airflow as the power source that generates the vibration of vocal cords. Therefore, our proposed pump system aimed to generate the airflow of substitution. Until now, the medical oxygen tank is used as the source of the airflow, however, it is too heavy to carry and it is not easy to control the start/stop of airflow. The prototype of our pump system uses some micro-pump units, and the size is enough small for portable. Furthermore, it can generate enough airflow to generate the laryngeal tone and it can be controlled easily by our control unit.

8923-72, Session 16

Gen silencing using siRNA

Sarah Masoumi, James Friend, Leslie Y. Yeo, RMIT Univ. (Australia); Christina Cortez-Jugo, Monash Univ. (Australia)

Regulation of gene expression using small interfering RNA (siRNA) is a promising strategy for research and treatment of various diseases. In this process, siRNA triggers the sequence-dependent degradation of a target RNA within the cellular environment. Thus siRNAs can be used to fight the expression of deleterious gene(s) causing disease. Despite their huge beneficial potential, the use of siRNA as drugs presents two major problems: the difficulties to identify optimal delivery systems and the possible induction of different unwanted side effects. In order to begin gene silencing, siRNA needs to be delivered to the cytosol. The first obstacle is endocytosis. The chemical environment faced by the endocytosed objects also depends on the specific pathways. Due to the large size, negative charge and other chemical properties, siRNA cannot easily enter the cells. One technique to deliver siRNA is to engagement its anionic property to electrostatically complex it with cationic lipids or polymers and create lipid- or polymer based particles. The goal of this research is to develop a delivery system using cationic polyethylenimine (PEI). Acoustic waves are used to nebulize and nano-sizing of the siRNA-PEI complex to increase and speed up of the delivery. Fluorescence microscopy and gel-plate reader are used to determine the predominant pathways in the siRNA delivery using PEIs vehicle. Also Zeta potentiometer is used to measure the size and potential of particles to calculate the efficiency of different pathway in each process. It is expected that PEIs enter the cells through multiple endocytosis pathways simultaneously.

8923-212, Session 16

Building plasmonic nanoparticle superlattices with soft ligands *(Invited Paper)*

Wenlong Chen, Monash Univ. (Australia)

Hard" microelectronics and "soft" biology play with different materials by different rules but they meet at the nanoscale. On one hand, we are seeing fast-growing nanotechnologies to make electronic materials smaller and smaller (metallic nanoparticles, quantum dots, carbon nanotubes, etc.); on the other hand, we understand better and better biological building blocks represented by DNA, RNA, protein and polysaccharide. Now the electronic building blocks (usually hard materials) and biological building blocks (usually soft materials) meet at the nanoscale. Thus, the nanoscale regime provides an ideal platform for us to interface electronic materials with biological system to design the powerful nanobionic materials that possess both "nano" and "bio" functions to design lightweight, foldable and adaptive devices.

In this talk, I will discuss our recent research activities in interfacing hard metallic nanoparticles with soft ligands including DNA, polymer and alkyl molecules. Firstly, I will describe synthesis of high-quality "hard" plasmonic nanoparticles (including nanospheres, nanorods, nanocages, nanocubes, and nanowires). Secondly, I will cover the conjugation of "soft ligands" to "hard" particles as well as controlled assembly into free-standing thinnest possible superlattice nanomembranes. Thirdly, I will describe our experimental and theoretical studies on plasmonic and mechanical properties of 2D superlattices. Finally, I will introduce our recent success in integration of soft superlattices into lightweight, foldable optoelectronic devices.

8923-73, Session 17

Measuring the electrical properties of semiconductor nanowires using terahertz conductivity spectroscopy *(Invited Paper)*

Hannah J. Joyce, Univ of Oxford (United Kingdom) and Univ. of Cambridge (United Kingdom); C. J. Docherty, Univ of Oxford (United Kingdom); Chaw Keong Yong, Univ. of Oxford (United Kingdom); Jennifer Wong-Leung, Qiang Gao, The Australian National Univ. (Australia); Suriati Paiman, The Australian National University (Australia); Hark Hoe Tan, Chennupati Jagadish, The Australian National Univ. (Australia); James Lloyd-Hughes, Laura M. Herz, Michael B. Johnston, Univ. of Oxford (United Kingdom)

III–V nanowires, such as GaAs, InAs and InP nanowires, exhibit outstanding potential as nanocomponents for future electronic and optoelectronic devices. A crucial step in the development of these novel nanowire-based devices is the accurate measurement of nanowire electronic properties. Unfortunately, measuring nanowire electrical properties using traditional contact-based techniques is challenging: forming electrical contacts to nanoscale structures is technically difficult and introduces artifacts.

To avoid these problems, non-contact probes of nanowire conductivity are highly advantageous. Optical pump–terahertz probe (OPTP) spectroscopy is one such non-contact probe, and is sensitive to carrier transport and dynamics at room temperature. It is therefore ideally suited to studies of nanowires.

A comparative study was performed on GaAs, InAs and InP nanowires using OPTP spectroscopy, measuring carrier mobility, carrier lifetime, surface recombination velocity and doping concentration. The photoconductivity spectra of GaAs, InAs and InP nanowires all exhibited a pronounced Lorentzian response, characteristic of localised surface plasmon modes. InAs nanowires exhibited the highest electron mobilities of 6000 cm2V-1s-1 which indicates their suitability for high mobility devices. InP nanowires exhibited the longest photoconductivity lifetimes of over 1 ns and an extremely low surface recombination velocity of 170 cm/s. This makes InP nanowires promising for applications which require long carrier lifetimes, such as photovoltaics. These findings will guide the choice of nanowires for different applications and enable nanowire growers to optimise material quality for device applications.

8923-75, Session 17

THz photomixer with a sub-50 nm nanoelectrode gap on low temperature grown GaAs

Gediminas Seniutinas, Gediminas Gervinskas, Swinburne Univ. of Technology (Australia); Ar?nas Krotkus, Ctr. for Physical Sciences and Technology (Lithuania); Gediminas Molis, TeraVil Ltd. (Lithuania); Gintaras Valu?is, Ctr. for Physical Sciences and Technology (Lithuania); Saulius Juodkazis, Swinburne Univ. of Technology (Australia)

Photoconductive antenna emitters are common source of the pulsed and continuous wave terahertz (THz) radiation. To reach mW level of THz emission different nanostructures such as nanoelectrodes and nanogratings have been introduced to employ plasmonic effects for power boosting in photomixing devices [1,2]. We fabricated photomixers operating at wavelengths above 800 nm using combined nano-lithographical approaches on low temperature grown GaAs substrate. Meander THz antenna and sub 100 nm gold nanoelectrodes are patterned using electron beam lithography and standard lift-off procedure. Sub 50 nm plasmonic gap is then opened by direct ion beam milling [3] of fabricated structures.

We show the current fabrication limit of the nanoelectrodes. The electrodes can be trenched into LT-GaAs substrate by adding an Ar+ etching step. Trenching increases contact area between gold nanoelectrodes and substrate enabling more electrons to reach antenna. Nanostructures also increase photogenerated carrier collection, hence, electrical current flowing in antenna and radiated THz power. Potential applications of such THz emitters and possibilities to form micro-optical elements directly onto the chip for handling the emission are presented.

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8923-76, Session 17

Appearance of localized excitons in narrow GaAs/AlGaAs core-multi shell quantum well tubes

Leigh M. Smith, Teng Shi, Howard E. Jackson, Univ. of Cincinnati (United States); Jan M. Yarrison-Rice, Miami Univ. (United States); Bryan M. Wong, Sandia National Labs., California (United States); Nian Jiang, Qiang Gao, Hark Hoe Tan, Chennupati Jagadish, The Australian National Univ. (Australia); Joanne Etheridge, Monash Univ. (Australia)

Recently, Fickenscher et al. [Nano Letters 13, 1016 (2013).] has shown that one can create strongly confined quantum states within a core-multishell structure which defines a narrow GaAs well wrapped around the GaAs core and embedded within a thick AlGaAs shell. They showed that the electronic structure, ground and excited states can be understood within simple calculations of the quantum states. More complex finite element calculations show that the confined ground states are strongly confined to the corners of the hexagonally symmetric quantum well, and so define quantum wires which run along the length of the nanowires along its corners.

We have recently used high resolution spatially resolved photoluminescence and photoluminescence excitation to study localized states which appear in these nanowires when the well width gets smaller than 5 nm. In these narrower wells a large number of ultranarrow emission lines appear on the high energy side of the luminescence band emitted from single nanowires, indicating these quantum dots are not the lowest energy state in the system. Spatially-resolved PL shows that these quantum dots are localized randomly along the length of the wire, while measurements as a function of temperature show that these localized states disappear at temperatures above 50 to 100 K. These results will be compared with simple quantum calculations to gain insights into the nature of these unusual quantum dots in nanowire heterostructures.

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8923-77, Session 17

Extending device performance in photonic devices using piezoelectric properties

Gregory E. Triplett, Univ. of Missouri-Columbia (United States)

The impact of piezoelectric effects that ultimately lead to frequency mixing have been studied and verified using select photonic device designs. In typical photonic device structures, the theoretical limits for conduction and valence band offsets in lattice-matched semiconductor structures have placed boundaries on the wavelength ranges attainable for each system. Some groups have deployed non-traditional approaches such as strain compensation, where limits on physical distortion are related to misfit dislocation generation, and have extended the wavelength range. In this work, the theoretical limits are further extended through the coupling of strong electric fields and higher wave functions that increase transition energies, thus realizing the once unattainable ranges for photonic devices that have the potential for higher performance at room temperature. Metrics that were under study include dipole strength, oscillator strength, and offset of energy transitions, which are strongly correlated with induced piezoelectric effects. Unique photonic designs were simulated, modeled, and then fabricated using solid-source molecular beam epitaxy into photonic devices and demonstrate that piezoelectric effects introduce another degree of freedom in device design. The initial designs produce “lambda” wavelength, and the introduction of the piezoelectric effect resulted in “lambda/2” wavelength. Taking advantage of these induced electric fields, for example, creates new opportunities for conventional semiconductor systems (III-V, II-VI) to enhance its relevance for potential use in spectrally, temporally, and spatially resolved systems.

8923-78, Session 18

The sound of nano

Matthew Clark, Richard J. Smith, Fernando Perez-Cota, Leonel Marques, Kevin F. Webb, Jon Aylott, The Univ. of Nottingham (United Kingdom)

Ultrasound is widely used for imaging, measurement and diagnostics in the MHz region and is perhaps most familiar as a medical or non destructive imaging tool. In the MHz frequency range the wavelength is typically measured in microns and is many times longer than the wavelength of visiblelight, limiting its resolution to objects much larger than the nano-scale.

It is possible to perform ultrasonic imaging and measurement at much higher frequencies, in the GHz region. Here the acoustic wavelength is typically less than that of light permitting the higher resolutions than optical microscopy and the ability to probe micro and nano-scale objects.

At these high frequencies ultrasonics has much to offer the nano-world as a powerful diagnostic tool - it could be used in circumstances where optical microscopy, electron microscopy and probe microscopy cannot, such as inside living objects.

Despite the potential that ultrasonics offers for imaging and measurement at the micro and nano-scale, performing ultrasonics at the nano-scale is hampered by many problems that render the techniques typically used in the MHz region impractical.

In this paper we discuss some of the practical problems standing in the way of nano-ultrasonics and some of the solutions, especially the use of pico-second laser ultrasonics and development of nano-ultrasonic transducers and their application to ultrasonic imaging inside living cells.

8923-79, Session 18

Ultra-stable atomic force microscope with integrated laser inteferometry

Jan Herrmann, Bakir Babic, Christopher H. Freund, Malcolm A. Lawn, Magnus T. L. Hsu, Terry G. McRae, Malcolm B. Gray, Victoria A. Coleman, National Measurement Institute of Australia (Australia)

Accurate length measurement at the nanoscale, traceable to the SI metre, is critical for the development and effective support of nanoscience and nanotechnology. At the National Measurement Institute, a primary standard for dimensional measurement at the nanoscale is being realised with a metrological scanning probe microscope (mSPM).

The design of the mSPM follows metrological principles to achieve accurate position measurement, within an addressable volume of 100 µm x 100 µm x 25 µm, with a target combined uncertainty of 1 nm.

The mSPM operates in non-contact frequency modulation dynamic atomic force microscopy mode, with a tip mounted on a tine of a piezoelectric quartz tuning fork (QTF) acting as the force sensor. The shift of the QTF resonance frequency due to interaction with the sample surface is used as the error signal in a feedback loop to control the out-of-plane motion of the translation stage. The motion of the stage is measured by five laser interferometers, one for each translation axis and two to monitor parasitic rotations. These plane mirror heterodyne differential interferometers achieve traceability of the mSPM displacement measurements to the SI definition of the metre via the wavelength of a Zeeman-split frequency stabilised HeNe laser. The phase is measured using an all-digital phase meter. The contribution of the cyclical error of the interferometry system to the displacement measurement is of the order of 100 pm. Sub-nm stability over days of operation and successful imaging based on interferometry signals have been demonstrated.

8923-81, Session 18

Quantitative measurements of two photon action and scattering cross sections of single gold nanorods

Arif M. Siddiquee, Adam B. Taylor, James W. M. Chon, Swinburne Univ. of Technology (Australia)

Photoluminescence of gold nanorods can be excited nonlinearly using two-photon absorption, the emission is broad and does not present the problems of blinking or bleaching found in most fluorescent emitters. Due to its chemically inert, blinking/bleaching-free, non-linear behaviour gold nanorods can be used as a Two Photon Excited Luminescence(TPL) markers on targeted cancer cell imaging. The TPL brightness of individual gold nanorods is characterized by calculating their TPL action cross section(TPACS). Here we used single particle detection methods to measure the absolute values of TPACS of single gold nanorods. In our estimate we found a TPACS of 3.51 X 10^6 GM for a single gold nanorod's of 51nm average length and 22nm average width for excitation on resonance with the longitudinal surface plasmon resonance(SPR).We also performed the quantitative measurement of scattering cross sections of the same particles. Our estimation of scattering cross section of a single gold nanorod is about on the order of 10^(-16) m^2 which is also consistent with the other reported values. In this report, we explore the correlation between the TPACS and scattering cross section of gold nanorods simultaneously and demonstrate the size effect on TPACS and scattering cross section by analysing the variation of aspect ratio and volume of each nanorod seperately.

8923-82, Session 18

Characterisation of individual crystallographic defects using coherent x-ray diffractive imaging

Brian Abbey, La Trobe Univ. (Australia)

X-rays are an essential characterisation tool in materials science due to their ability to non-destructively probe the internal structure of optically opaque samples. Until recent improvements in the resolution of X-ray techniques were realised however, scientists often had to interpret data that represented an average of a large number of different material states within the measurement volume. Hence, for example, characterising sub-grain deformation structure and single defects was beyond the reach of most X-ray imaging techniques. That has changed over the past decade with the advent of high resolution X-ray detectors, hard X-ray micro or nano focusing and the development of coherent X-ray diffractive imaging which allows nanometre scale imaging of thick specimens. Here we discuss recent results from the characterisation of individual crystallographic defects using coherent X-ray diffractive imaging. This information has fundamental implications for the in-situ study of dislocation structure formation and ultimately for optimising the performance of nanoelectronic devices.

8923-83, Session 18

X-ray diffraction microscopy of magnetic microstructure

Grant A. van Riessen, Ashish Tripathi, Mark Junker, La Trobe Univ. (Australia)

An in-vacuum soft X-ray microscope was recently commissioned at an undulator beamline of the Australian Synchrotron. The coherent X-ray source, with tunability in wavelength and polarisation, allows a range of experiments in resonant and magnetic scattering, and imaging techniques based on holography or coherent diffraction. Here we report recent progress combining coherent diffraction imaging (CDI), which is a method developed for very high resolution microscopy without lenses, with resonant magnetic scattering in order to visualise magnetic structure at the nanoscale. Through various implementations of scanning CDI with both linearly and elliptically polarised X-rays, we can obtain element specific information about the amplitude and phase of domain structures across large areas of thin amorphous films. The ability to probe buried structures on nanometer length scales and, potentially, subpicosecond time scales, will greatly enhance our understanding of technologically important materials and devices.

8923-84, Session 19

Ultrafast vaporization dynamics of laser-activated polymeric microcapsules *(Invited Paper)*

Michel Versluis, Univ. Twente (Netherlands)

Precision control, both in space and time, of vaporization using illumination of localized optical absorbers dispersed in (metastable) liquids has many potential applications, but is not well understood. Here, we study the nanoseconds vapor bubble dynamics of laser-heated single oil-filled microcapsules using combined optical and acoustical detection. Pulsed laser excitation leads to controlled vapor formation and collapse and a simple physical model describes the observed radial dynamics and resulting acoustic pressures. Remarkably, CW laser excitation resulted in sustained oscillations, which we explain by a sequence of vaporization/condensation cycles, a result of the movement of absorbing microcapsule fragments in and out of the laser beam. A model invoking rapid thermal diffusion from the polymer shell into the oil core and surrounding water revealed the physical mechanisms behind the onset of vaporization. Excellent agreement was observed between the modeled dynamics of the water-vapor interface and experiment.

8923-85, Session 19

Microfluidic devices using thiol-ene polymers

Simon J. Bou, Amanda V. Ellis, Flinders Univ. (Australia)

Off stoichiometric thiol-enes (OSTEs) which exhibit rapid UV curing, low volume shrinkage and optical transparency have been recently developed for use in a new polymeric microfluidic platform.1 The OSTE pre-polymer can be cast onto standard SU-8/ silicon masters and polymerised using a UV-lamp, making it ideal for rapid prototyping. Due to the off stoichiometric ratios, the mechanical properties of the OSTE polymer can be modified allowing for the tuning of the polymers physical properties for fabrication of microfluidic devices. Here, we investigate the bulk and surface characteristics of 90% excess thiol (OSTE-90), and 30 % excess allyl (OSTE Allyl-30) fabricated OSTE polymers. Three polymers OSTE-90, OSTE Allyl-30 and OSTE-50 were produced via free radical step-growth polymerisation. The three OSTE polymers were transparent but differed in their stiffness. Each were characterised using attenuated total reflectance Fourier transform infra-red spectroscopy (ATR-FTIR), dynamic mechanical analysis (DMA) and cross polarisation-magic angle spinning solid state 13C NMR spectroscopy (CP-MAS). Hydrophobic/hydrophilic studies were investigated by comparing water contact angle of the three OSTE polymers to the most widely used polymer in microfluidic devices - polydimethyl siloxane (PDMS). We report on the development of a novel colorimetric test for thiol functionality on the surface of the OSTE polymers and also subsequent surface modifications using gold nanoparticles and thiolated DNA. Evidence of modification of the OSTE platform is shown by UV-Vis spectroscopy, atomic force microscopy, sheet resistance and fluorescence microscopy. The results show the versatility of the OSTE polymers and highlight their potential for future microfluidic diagnostic platforms.

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8923-86, Session 19

A microfluidic platform to study the mechano sensational properties of ion channels

Sara Baratchi, Francisco J. Tovar-Lopez, Khashayar Khoshmanesh, Megan Grace, William Darby, Peter McIntyre, Arnan Mitchell, RMIT Univ. (Australia)

Microfluidic platforms have been widely considered as an enabling technology for studying the ion transport phenomena of cells under precisely controlled shear stresses. In this work, we report the application of a customized microfluidic system to study the effect of mechanical stimulation (shear stress) on the intracellular calcium levels of endothelial cells. Further, we report the importance of transient receptor potential vaniloid 4 (TRPV4) ion channels on endothelial cell mechanosensitivity.

Here, we report the design, numerical simulation, and fabrication of a unique microfluidic platform to analyse the response of endothelial cells a range of shear stresses in one field of view. Applying this system, we show the kinetics of calcium signalling at different shear stresses in endothelial cells and elucidate the threshold of their response. Further, we show that shear stress-induced elevation of intracellular calcium levels, requires extracellular calcium and that the elevation can be prevented by exposure to ruthenium red, a non-selective inhibitor or TRP ion channels. The results demonstrate that the microfluidic system has unique capabilities for analysis of shear stress on adhesive cells and that it should be amenable to moderate throughput applications.

8923-87, Session 19

Flow through a microfluidic chip induced by a distal surface acoustic wave atomizing suction pump

Jessica K. Underwood, Peggy P. Y. Chan, Leslie Y. Yeo, James Friend, RMIT Univ. (Australia)

There is a strong demand for economical and efficient point-of-care chemical and biological testing, such as that provided by 'lab-on-a-chip' devices. Ideally, such devices would be all-in-one, hand-held units. However, to-date researchers have failed to bring this concept to fruition due to difficulties in miniaturizing pumps required to drive microfluidic processes. In this first proof-of-concept, we demonstrate the ability to drive flow through a microfluidic Polydimethylsiloxane (PDMS) chip using a surface acoustic wave (SAW) atomizing pump. The PDMS chip was fabricated using standard photolithography and soft photolithography techniques before being bonded to glass via exposure to oxygen plasma. The SAW atomizing pump was fabricated on a lithium niobate (LiNbO3) piezoelectric substrate. Utilizing a signal generator and a 10W amplifier, SAWs were excited from the interdigital transducer (IDT) via input signals at a resonance frequency of approximately 30MHz and amplitude of 800mV. The proximal end of a 5cm long piece of 0.6mm diameter tubing was connected to the outlet of a microfluidic channel, which had a reservoir at its inlet. The distal end of the piece of tubing contained a 1cm wick of hydrophilic thread, which acted to maintain the meniscus of the water-primed circuit. As the wick was placed in contact with the LiNbO3 substrate and power was applied to the IDT, continuous 'atomization' of the water prime was seen until the reservoir was emptied. To the best of our knowledge, this is the first true SAW atomizing pump to provide continuous flow at adequate flow rates and pressures and is small enough to fit in a hand-held, point-of-care device.

8923-89, Session 20

Light trapping and solar energy harvesting in thin film photonic crystals *(Invited Paper)*

Sajeev John, Univ. of Toronto (Canada)

Photonic crystals are widely known for their light-trapping capabilities. This is often associated with the occurrence of a photonic band gap or other suppression in the electromagnetic density of states [1-3]. This enables guiding of light on an optical micro-chip and unprecedented forms of strong-coupling between light and matter. In the past, practical applications of these effects have focussed on information technology. More recently, an important opportunity has emerged in the area of energy technology. This arises from lighttrapping in the higher bands of a photonic crystal, where the electromagnetic density of states is enhanced rather than suppressed. This enables unprecedented strong absorption of sunlight in a material with weak intrinsic absorption [4].

We describe designs of 3D photonic crystal silicon-based solar cells that enhance the overall absorption of sunlight using architectures consisting of less than 1 micron (equivalent bulk thickness) of silicon. These crystals trap light through a parallel-to-interface negative refraction (PIR) effect and other optical resonances that occur over a broad angular and frequency range [4]. These 3D photonic crystals exhibit an enhanced electromagnetic density of states, consisting of slow group velocity modes, in which the flow of energy is transverse to the depth of a thin film of material. In the case of a modulated nanowire photonic crystal solar cell, it is possible to absorb roughly 75% of all available sunlight in the wavelength range of 400-1100 nm, using one micron of silicon [5, 6]. In the case of conical nano-pore silicon photonic crystal, roughly 85% of all available sunlight is absorbed [7] and power conversion efficiency in the range of 17.5%-22.5% is predicted [8]. With combined plasmonic and photonic crystal light trapping, the fraction of absorbed sunlight exceeds 90% [9]. The power conversion efficiencies of these sub-micron photonic crystals rival those of present-day solar cells using up to 300 microns of silicon. These photonic crystals offer additional opportunities for solar spectral reshaping to rival and possibly surpass the Shockley-Queisser power conversion efficiency limit.

8923-90, Session 20

Nano inverted pyramid texturing by laser interference lithography for silicon solar cells

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Advanced Materials and Nanotechnology (New Zealand)

We report here for the first time on the fabrication of inverted nano pyramid textured silicon solar cell. The nanopyramid photonic structures were fabricated by interference lithography and subsequent pattern transfer dry etching and KOH etching. The reflectivity of the 700nm inverted pyramid silicon was below 10% over the entire visible region with the lowest value of 3.77% near the band edge of silicon where the absorption of bare silicon is usually low. The short circuit current density enhancement of 10.6% has been achieved with nano pyramid texturing compared to planar reference cell.

In the present work, the standard tri-layer resist stack (photoresist/ SiO2/AZBarli II) was used on thermally grown silicon oxide coated silicon wafer for Lloyd's mirror interference lithography to fabricate 500nm nanoholes array on photoresist. The pattern was transferred to thermal silicon oxide layer by couple of reactive ion etching steps. Finally, 700nm inverted nanopyramids were fabricated by KOH etching. After oxide mask removal etching and standard RCA cleaning, the emitter junction of solar cell was formed by spin-on dopant method. The junction diffusion was carried out at 950oC in nitrogen ambient for 15 minutes, followed by dipping in dilute 10% hydrofluoric acid. The aluminum was sputtered as front contact and back contact using DC magnetron sputtering. Finally, Solar cells were annealed in forming gas at 435oC for 30 minutes to improve the ohmic contact between silicon and aluminum. The current-voltage characteristics were tested under dark condition and under standard AM1.5G illumination using a solar simulator.

8923-91, Session 20

Ion-beam and plasma etching of a conical-pores photonic crystal for thin-film solar cell

Gediminas Gervinskas, Lorenzo Rosa, Saulius Juodkazis, Swinburne Univ. of Technology (Australia)

We show a fabrication technique of photonic crystals for thin-film silicon solar cells. The pattern [1] is capable of sunlight absorbance beyond the statistical ray trapping. A slanted cone-shaped pore lattice in the substrate, which achieves a theoretical 85% absorbance in visible and IR, is fabricated by 3D precision milling. Slanted cones are approximated by a stack of circle-shaped milled disks. A 3D finite difference time domain FDTD modelling was used to estimate performance of solar cells as their actual shape is affected by ion milling protocol. Plasma etching approach for a simplified version of conical holes was tested experimentally and by FDTD. We discuss challenges in a large area fabrication of efficient solar energy harvesting patterns.

The ion milling technique permits fabrication of patterns whose performance (FDTD modelled) is comparable to the ideal theoretical structure [1]. Further simplification of fabrication can be achieved by plasma etching.

[1] Eyderman et al., J. Appl. Phys., vol. 113, p. 154315 (2013)

8923-92, Session 20

Growth of CZTS by co-sputtering of metallic & sulfide targets and sulfurization for solar cell applications

Nadarajah Muhunthan, Vidya N. Singh, National Physical Lab. (India)

Earth abundant Copper-Zinc-Tin-Sulfur (CZTS) is an important class of material for the development of low cost and sustainable thin film solar cells. The fabrications of CZTS thin films are by magnetron co sputtering techniques and sulfurization. The co-sputtering was performed by simultaneously sputtering the metallic and sulfide targets. We used Cu target connected to DC power supply and ZnS & SnS targets to RF power supply. The sulfurization process was carried out to introduced the H2S gas dilute with Argon gas (H2S-15% & Ar2-85%) the flow rate of 15.5 sccm. The furnace temperature was kept at 550 oC for 35 minutes.

In order to study its structure and to establish the best growth precursors, Raman spectroscopy shift(336 cm-1) and Glancing Insistent XRD analysis indicingate that the growth film shows a single CZTS phase with good crystallinity, strong orientation along (112) plane and energy dispersive X-ray spectroscopy (EDS) analysis the elemental compassions of Cu,Zn,Sn &S and conform the CZTS structure again. SEM analysis reveals a homogeneous, compact surface morphology and large columnar grains throughout thickness for the film. The grown CZTS film demonstrates an optical absorption coefficient of higher than 104 cm-1 and optical band gap of 1.50 eV. The photoconductivity measurements at different temperatures shows that the effect of changing resistance low at 300 K. These optical and electrical properties are suitable for a thin film solar cell fabrication.

8923-93, Session 20

Potential of hafnium nitride for the hot carrier solar cell

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The Hot Carrier solar cell is a third generation photovoltaic concept which has the potential to achieve high efficiencies, exceeding the Shockley-Queisser limit for a conventional p-n junction solar cell [1-3]. The theoretical efficiencies achievable for the Hot Carrier solar cell is 65% for non-concentrated solar radiation and 85% for maximally concentrated light, very close to the limits of an infinite tandem solar cell [4]. The approach of the Hot Carrier solar cell is to extract carriers generated before thermalisation to the bandgap edge occurs when their excess energy is lost to the environment as heat. To achieve this, the rate of carrier cooling in the absorber must be slowed down sufficiently enough to allow carriers to be collected while they are hot. This work investigates using hafnium nitride as such an absorber to restrict mechanisms of carrier cooling. Hafnium nitride's phononic properties, where a large 'phononic band gap' exist can reduce the carrier cooling rate by means of a phonon bottleneck such that optical phonons cannot decay into acoustic phonons by means of the Klemens' mechanism [5]. Optical phonon-electron scattering can maintain a hot electron population while acoustic phonons are irrecoverable and lost as heat. The electronic and phononic properties of hafnium nitride are evaluated for their suitability to be used in a Hot Carrier solar cell absorber. Recent work on the fabrication of hafnium nitride at UNSW will be presented.

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8923-94, Session 21

Terahertz detection with graphene devices

(Invited Paper)

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Graphene has unusual promise as a broad-band photonic material. Its gapless electronic structure allows photoabsorption across a wide spectral range. Strong electron-electron interactions rapidly thermalize electron-hole pairs before recombination, and weak electron-phonon interactions allow the thermal energy to be retained in the electron system. We study hot-electron photodetection using two techniques. Bilayer graphene with perpendicular electric field has a bandgap and strongly temperature-dependent resistance, suitable for bolometric detection of light energy. We show that cryogenic bilayer graphene bolometric photodetectors can be competitive with the best cryogenic photodetectors of THz and millimeter wave light[1]. We also study photodetection using the hot electron photothermoelectric effect, which to first order gives a temperature-independent signal and is useful at room temperature. We demonstrate room-temperature detection of THz radiation[2] with sensitivity >100 V/W and noise equivalent power of <100 pW/Hz1/2, competitive with the best commercial room temperature THz detectors. However our device is ~7 orders of magnitude faster, with characteristic timescales <100 ps[3]. We expect that patterning graphene into micro- or nano-ribbons will create plasmon resonances at THz frequencies greatly enhancing the coupling to THz light.

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8923-95, Session 21

Influence of different reduction processes on the chemical nature, electrical conductivity and electrochemical double layer capacitance of reduced graphene oxide

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Reduction of a colloidal suspension of exfoliated graphene oxide sheets generally results in their aggregation and subsequent formation of a highly conductive and high surface area carbon material consisting of thin graphene based sheets, which is known as reduced graphene oxide (RGO). However, there are different reduction processes reported in the literature, which reports different electrical conductivity and electrochemical double layer capacitance values for the same RGO material. Hence, there are large discrepancies in the reported electrical conductivity (varies in the range 2 S/m2-16000 S/m2) and/or electrochemical capacitance (varies from a few mF/g to several hundreds of F/g) values for RGO and/or nanocomposites of RGO. Thus there is a definite necessity to systematically investigate and obtain a mechanistic understanding about the influence of different reduction processes on the chemical nature, electrical conductivity and electrical double layer capacitance of RGO. In this study, we have reduced the colloidal suspension of graphene oxide using five most common reduction processes. The morphology and the chemical nature of the resulted RGO powders were analysed by scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), attenuated total reflectance-Fourier transformed infrared spectroscopy (ATR-FTIR) and Raman spectroscopy. The electrical conductivity of the different powders has been measured using a source measuring unit. The electrochemical double layer capacitance of these RGO powders in 1 M Na2SO4 have been analysed using cyclic voltametry (CV), electrochemical impedance spectroscopy (EIS) and Galvanostatic charge discharge.

8923-96, Session 21

Simultaneous Raman and electrical transport measurements of disordered graphene in situ in ultra-high vacuum

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Resonant Raman scattering in graphene gives unique information about disorder, as the D peak is observed only in the presence of disorder which produces intervalley scattering of the electrons. The nature of disorder in graphene prepared by various techniques and on various substrates of the subject of significant research, with significant attention being paid to scattering by charged impurities; resonant scatterers due to vacancies, chemisorbed impurities, etc.; and non-resonant short-range impurities. In order to study the e?ect of these types of disorder on graphene's electronic properties and Raman spectra simultaneously, we have developed a facility combining thermal deposition, ion bombardment, electrical transport and micro-Raman measurements in an ultra high vacuum environment. We will discuss the capabilities of this facility and present the results of Raman and electrical transport measurements on controllably disordered graphene.

8923-97, Session 21

Synthesis of patched or stacked graphene and hBN flakes: an emerging route to hybrid structure discovery

Soo Min Kim, Korea Institute of Science and Technology (Korea, Republic of)

Two-dimensional (2D) materials such as graphene and hexagonal boron nitride (hBN) have attracted significant attention due to their remarkable properties. Numerous interesting graphene/hBN hybrid structures have been proposed but their implementation has been very limited. In this work the synthesis of patched structures through consecutive chemical vapor deposition (CVD) on the same substrate was investigated. Both in-plane junctions and stacked layers were obtained. For stacked layers, depending on the synthesis sequence, in one case, turbostratic stacking with random rotations were obtained. In another, AA-like stacking between graphene and hBN was observed, with lattice orientation mis-alignment consistently to be <1°. Raman characterizations not only confirmed that hBN is a superior substrate but also revealed for the first time that a graphene edge with hBN passivation displays reduced D band intensity compared to an open edge. These studies pave the way for the proposed well-ordered graphene/hBN structures, and outline exciting future directions for hybrid 2D materials.

8923-98, Session 21

Synthesis of hexagonal boron nitride and its applications

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Hexagonal boron nitride (hBN), isomorph of graphene/graphite, has been highlighted due to its potential applications including the substrate for two dimensional electronics and the dielectric layer for top gate devices. However, the synthesis of large area of hBN with high crystallinty is still challenge. In this presentation, we explore the recent trend of the synthesis of hBN by chemical vapor deposition and its applications.[1-5] Second, the difficulty of high quality of hBN synthesis with large area is addressed. Our understanding will be helpful to synthesize the high quality of hBN.

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8923-3, Session PTues

Fabrication of Fresnel zone plate lens in fused silica glass using femtosecond laser lithography technology

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(Korea, Republic of); Md. Shamim Ahsan, Gwangju Institute of Science and Technology (Korea, Republic of) and Khulna Univ. (Bangladesh); Young-Chul Noh, Gwangju Institute of Science and Technology (Korea, Republic of); Hun-Kook Choi, Jin-Tae Kim, Chosun Univ. (Korea, Republic of); Myeong-Jin Ko, Korea Institute of Industrial Technology (Korea, Republic of)

This paper demonstrates maskless formation of Fresnel zone plate lens on the surface of a fused silica glass substrate using femtosecond laser lithography technology. The lens consists of a series of concentric rings, which has been fabricated on the glass substrate by femtosecond laser writing followed by chemical etching. The fabricated Fresnel zone plate lens has a focal length of 25 mm. Femtosecond laser lithography technique offers smooth patterning of materials compared to traditional femtosecond laser writing. As a consequence, the fabricated Fresnel zone plate lens yields considerably high diffraction efficiency. In order to investigate the optical performance of the lens, we focused the Fresnel zone plate lens on some printed micro-letters. The image of the micro-letters is clearly observed through the lens, which indicates excellent focusing and imaging capability of our Fresnel zone plate lens. The proposed maskless technology is simple compared to other lithography techniques, which shows great potential for small-scale manufacturing of similar kinds of optical devices. We strongly believe that, femtosecond laser lithography technology will find broader applications in the field of optics and photonics.

8923-107, Session PTues

On-chip optical nano-scale displacement sensor

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One of the major critical issues that limit the operating speed of the Atomic Force Microscopy (AFM) is the relatively large size of the micro-cantilever. The current size of the cantilever is limited by the optical beam dimension that is required by the Optical Beam Deflection (OBD) detection system.

This paper proposes a new on-chip optical displacement sensing mechanism with self-actuating characteristic to overcome the existing shortcomings and increase the operational speed of the AFM. This mechanism could allow significantly smaller cantilever beams to be made with high sensitivity and implementations of parallel imaging through array of cantilevers. The sensor consists of input and output cantilevered silicon waveguides separated by a small airgap. An optical power is coupled to the input waveguide and detected at the output waveguide. The waveguides are incorporated with slanted grating to increase the optical power coupling to and from the sensor. The out-of-plane deflection is measured from the change in the received power. A piezo-electric thin film actuator is integrated with the input cantilevered silicon waveguide to allow self-actuating feature for z-scanning. Theoretical, FDTD (Finite Difference Time Domain) optical simulations, and ANSYS multi-physics simulations have been performed to study the sensors behavior. The results show that with an input silicon waveguide cantilever of 12µm long, 200nm wide, and 180nm thick with piezo-electric layer of 6µm long and 0.25µm thick, a sensitivity of less than 0.1nm, bandwidth of 6.25MHz in air and 0.195N/m spring constant. The result is promising as it leads to high speed self-sensing and actuating cantilever that enables not only a high speed AFM but also large area scanning through parallel imaging.

8923-148, Session PTues

Analysis of deep submicron device parameters using t-sizing through circuit simulator

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The variations that are seen in the semiconductor fabrication process causing changes in threshold voltage, oxide thickness, channel length, interconnect wire width, thickness, etc. is referred as process variation. Optimization of CMOS circuit is to discover the variation in physical parameters which affects the circuit performance such delay, power dissipation. Circuit delay is particularly sensitive to process variations because it is dependent on a number of other variation-sensitive parameters. Variation in delay also changes the dynamic power dissipation. This is the reason for considering process variation effect in estimating the power. In the proposed work using T-sizing we analyze the parameter variations, such as voltage, current, frequency and temperature. To predict electrical behavior of the device we have developed a compact model.

8923-149, Session PTues

What happens when we slowly touch a water surface?

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Capillary phenomena has become powerful tools to develop microfluidic devices, with applications ranging from sample loading to liquid handling to molecular combing. We investigate the capillary dynamics caused by a slow contact between a solid body and a liquid body, which results not only in the well-known capillary bridging but also in the generation of capillary waves at the interface. Analysis of the energy landscape reveals how the property of the solid, liquid, and gas affect the capillary waves. We discuss how to use this process to develop novel devices at the micro- and nano-scale.

8923-150, Session PTues

A laser based technique for fabricating microchannels on glass substrates for biomedical applications on cell culture

Daniel Nieto Garcia, María Teresa Flores-Arias, Univ. de Santiago de Compostela (Spain)

A new method for fabricating microfluidic microchannels on soda-lime glass has been developed. It consists of a combination of the laser direct write technique for fabricating the microchannels and a thermal treatment for reshaping and or improving the morphological qualities of the generated microchannels. The proposed technique allows us to obtain microchannels with a minimum diameter of 8 µm and depth of 1.5 µm. For planar microfluidic devices, surface roughness and geometry after laser ablation are the major factors that can affect the performance of the devices. A decrease of the roughness average generated after laser ablation, of two orders of magnitude reaching values of the order of the unprocessed glass, has been obtained thanks to the thermal treatment. The advantage of the process we propose comes from the simplicity and speed of the pattern transfer to the substrate, even in the production of more complex structures. Even though microfluidic structures are often produced using polydimethylsiloxane (PDMS), the use of glass material results in a more stable system which enables long term investigations. The ability to fabricate glass microfluidic systems using the technique presented makes glass attractive for many applications in which speed and economy of production are desired. The fabricated microchannels find major applications in the development of in vitro physiological systems for being used in the development of a complex dynamic model system for evaluating the precise disease events in the areas of cardiology, nephrology and oncology.

8923-151, Session PTues

Design and analysis of low power nanoscale DRAM cell

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This paper describes capacitor and voltage scaling analysis for low power DRAM cell. The 3tn_xC (a three NMOS transistor DRAM cell with explicit storage node capacitance) DRAM cell has been designed at 90nm and 65nm technology node, using TANNER EDA tool. With this analysis we found that our design at 65nm as compared to 90nm has less power consumption. Simulation results obtained through our

proposed design provides lower power consumption in terms of write power reduction up to an average of 20%, power supply reduction up to 18.1%, significantly small reduction in read power at 65nm DRAM cell as compared to the 3tn_xC DRAM cell at 90nm technology node.

8923-152, Session PTues

Immobilization of lipase and keratinase on functionalized SBA-15 nanostructured materials

Hy G. Le, Phuong T. Dang, Tuan A. Vu, Hoa T. K. Tran, Vietnamese Academy of Science and Technology (Viet Nam)

SBA-15 nanostructured materials were synthesized via hydrothermal treatment and were functionalized with 3-aminopropyltriethoxysilane (APTES). The obtained samples were characterized by different techniques such as XRD, BET, IR and DTA. After functionalization, it showed that these nanostrucrured materials were still maintained the hexagonal pore structure of the parent SBA-15. The model enzyms chosen in this study were lipase and keratinase. Lipase was a biocatalyst for hydrolyzation of long chain triglycerides or methyl esters of long chain alcohols and fatty acids; keratinase is a proteolytic enzyme that catalyzes the cleavage of keratin. The functionalized SBA-15 mesoporous materials were used to immobilize lipase and keratinase, giving higher activity than that of the unfunctionalized pure silica SBA-15 ones. This might be due to the enhancing of surface hydrophobicity upon functionalization. The surface functionalization of the nanostructured silicas with organic groups can enhance the interaction between enzyme and the supports and consequently increasing the operational stability of the immobilized enzyme. The enzymatic activity of lipase on functionalized SBA-15 materials was higher than that of karatinase. This might be explained by the difference in size of enzymes.

Keywords: Enzyme immobilization, lipase, keratinase, functionalization SBA-15, nanostructured materials

8923-153, Session PTues

Additive manufacturing of lab-on-a-chip devices

Feng Zhu, RMIT Univ. (Australia); Niall MacDonald, RMIT Univ. (Australia) and Univ. of Glasgow (United Kingdom); Jonathan M. Cooper, Univ. of Glasgow (United Kingdom); Donald Wlodkowic, RMIT Univ. (Australia)

This work describes a preliminary investigation of commercially available 3D printing technologies for rapid prototyping and low volume fabrication of Lab-on-a-Chip devices. The main motivation of the work was to use off-the-shelf 3D printing methods to rapidly and inexpensively build microfluidic devices with complex geometric features and reduce the need to use clear room environment and conventional microfabrication techniques.

Both multi-jet modelling (MJM) and stereolithography (SLA) processes were explored. MJM printed devices were fabricated using a HD3500+ (3D Systems) high-definition printer using a thermo-polymer VisiJet Crystal (3D Systems) substratum that allows for a z-axis resolution of 16 µm and 25 µm x-y accuracy. SLA printed devices were produced using a Viper Pro (3D Systems) stereolithography system using Watershed 11122XC (DSM Somos) and Dreve Fototec 7150 Clear (Dreve Otoplastik GmbH) resins which allow for a z-axis resolution of 50 µm and 25 µm x-y accuracy.

Fabrication results compared favourably with other forms of rapid prototyping such as laser cut PMMA devices and PDMS moulded microfluidic devices of the same design. Both processes allowed for fabrication of monolithic, optically transparent devices with features in the 100 µm range requiring minimal post-processing. Optical polymer qualities following different post-processing methods were also tested in both brightfield and fluorescence imaging of transgenic zebrafish embryos. Finally, we show that only ethanol-treated Dreve Fototec 7150 Clear resign proved to be non-toxic to both human cell lines and fish embryos in fish toxicity assays (FET) requiring further investigation of 3D printing materials.

8923-154, Session PTues

A high-throughput lab-on-a-chip interface for zebrafish embryo tests in drug discovery and ecotoxicology

Feng Zhu, RMIT Univ. (Australia); Jin Akagi, Chris J. Hall, Kathryn Crosier, Philip Crosier, The Univ. of Auckland (New Zealand); Donald Wlodkowic, RMIT Univ. (Australia)

Drug discovery screens performed on zebrafish embryos mirror with a high level of accuracy the tests usually performed on mammalian animal models, and the fish embryo toxicity assay (FET) is one of the most promising alternative approaches to acute ecotoxicity testing with adult fish. Notwithstanding this, conventional methods utilizing 96-well microtiter plates and manual dispensing of fish embryos are very time-consuming. They rely on laborious and iterative manual pipetting that is a main source of analytical errors and low throughput.

In this work, we present development of a miniaturised and high-throughput Lab-on-a-Chip (LOC) platform for automation of FET assays. The 3D high-density LOC array was fabricated in poly(methyl methacrylate) (PMMA) transparent thermoplastic using infrared laser micromachining while the off-chip interfaces were fabricated using additive manufacturing processes (FDM and SLA). The system's design facilitates rapid loading and immobilization of a large number of embryos in predefined clusters of traps during continuous microperfusion of drugs/toxins. It has been conceptually designed to seamlessly interface with both upright and inverted fluorescent imaging systems and also to directly interface with conventional microtiter plate readers that accept 96-well plates. We also present proof-of-concept interfacing with a high-speed imaging cytometer Plate RUNNER HD® capable of multispectral image acquisition with resolution of up to 8192 x 8192 pixels and depth of field of about 40 ?m. Furthermore, we developed miniaturized and self-contained analytical device interfaced with a miniaturized USB microscope. This system modification is capable of performing rapid imaging of multiple embryos at a low resolution for drug toxicity analysis.

8923-155, Session PTues

Immobilization of zebrafish larvae on a chip-based device for environmental scanning electron microscopy (ESEM) imaging

Jin Akagi, RMIT Univ. (Australia); Chris J. Hall, Kathryn Crosier, Philip Crosier, The Univ. of Auckland (New Zealand); Donald Wlodkowic, RMIT Univ. (Australia)

Small vertebrate model organisms have recently gained popularity as attractive experimental models that enhance our understanding of human tissue and organ development. Laser microsurgery on zebrafish larvae combined with Scanning Electron Microscopy (SEM) imaging can in particular provide accelerated insights into the tissue regeneration phenomena. Conventional SEM exposes, however, specimens to high vacuum environments, and often requires labor-intensive and time-consuming pretreatments and manual positioning. Moreover, there are virtually no technologies available that can quickly immobilize the zebrafish larvae for high definition SEM imaging.

This work describes the proof-of-concept design and validation of a microfluidic chip-based system for immobilizing zebrafish larvae and it's interfacing with Environmental Scanning Electron Microscope (ESEM) imaging. The Lab-on-a-Chip device was fabricated using a high-speed infrared laser micromachining and consists of a reservoir with multiple semispherical microwells, which hold the yolk of zebrafish larvae, and drain channels that allow to remove excess of medium during imaging. Paper filter is used to actuate the chip and immobilization of the larvae by gentle suction occurs during water drainage. The trapping region allows multi specimens to be positioned in various positions. The chip is inserted directly inside the ESEM and imaged in a near 100% humidity atmosphere. This facilitates ESEM imaging of untreated biological samples.

8923-156, Session PTues

Microfluidic EmbryoSort technology: towards in flow analysis, sorting and dispensing of individual vertebrate embryos

Nurul M. Fuad, Donald Wlodkowic, RMIT Univ. (Australia)

The demand to reduce numbers of laboratory animals has facilitated the emergence of surrogate models such as tests performed on zebrafish (Danio rerio) or African clawed frog's (Xenopus levis) eggs, embryos and larvae. Those two model organisms are becoming increasingly popular replacements to current adult animal testing in toxicology, ecotoxicology and also in drug discovery. Zebrafish eggs and embryos are particularly attractive for toxicological analysis due their large size (diameter 1.6 mm), optical transparency, large numbers generated per fish and very straightforward husbandry. The current bottleneck in using zebrafish embryos for screening purposes is, however, a tedious manual evaluation to confirm the fertilization status and subsequent dispensing of single developing embryos to multitier plates to perform toxicity analysis. Manual procedures associated with sorting hundreds of embryos are very monotonous and as such prone to significant analytical errors due to operator's fatigue.

In this work, we present a proof-of-concept design of a continuous flow embryo sorter capable of analyzing, sorting and dispensing objects ranging in size from 1.5 – 2.5 mm. The prototypes were fabricated in poly(methyl methacrylate) (PMMA) transparent thermoplastic using infrared laser micromachining. The application of additive manufacturing processes to prototype Lab-on-a-Chip sorters using both fused deposition manufacturing (FDM) and stereolithography (SLA) were also explored. The device operation was based on a revolving receptacle capable of receiving, holding and positioning single fish embryos for both interrogation and subsequent sorting. The actuation of the revolving receptacle was performed using a DC motor and/or microservo motor. The system was designed to separate between fertilized (LIVE) and non-fertilized (DEAD) eggs, based on optical transparency using infrared (IR) emitters and receivers.

8923-157, Session PTues

Preparation and evaluation of transmission-mode AlGaN photocathode

Guanghui Hao, Mingzhu Yang, XinLong Chen, Benkang Chang, Nanjing Univ. of Science and Technology (China)

AlGaN photocathodes are of interest due to their potential capability for low dark-current densities and high sensitivities in the ultraviolet spectral region. The transmission-mode AlGaN photocathode samples were grown on the sapphire substrate with different emission layer thickness and doped structures were cleaned by chemical solution and 710oC heat clean about 20min in ultrahigh vacuum system. When the samples cooled to the room temperature, they had obtained an atomically clean surface. Soon the samples were activated by Cs/O alternately. And multi-information system had detect and record the information of preparation AlGaN photocathode including the heating temperature, vacuum degree, cesium and oxygen source current, activate photocurrent, and spectral response. According to the photocurrent changes, the O source switched at ON or OFF. The spectrum response was measured for the wavelength between 240nm and 400nm when the photocurrent of AlGaN photocathode was not increased any more in the last Cs/O alternately, then the spectral response was converted to the quantum efficiency of photocathode. The cut-off wavelength of the AlGaN photocathodes were 315 nm, and the highest spectrum response appeared at 300nm.The parameters of the AlGaN photocathode were gotten from fit the quantum efficiency curves by the quantum efficiency formula of transmission-mode AlGaN photocathodes. And the main factors affected the quantum efficiency mostly, including electron diffusion length, electron escape probability active layer thickness and the back-interface recombination velocity, were analysed and discussed. This work could provide some reference for optimizing performance of the solar-blind AlGaN photocathodes.

8923-158, Session PTues

Transmission-mode Ga1-xAlxAs photocathode made for detecting 532nm light

XinLong Chen, Jing Zhao, Benkang Chang, Yuan Xu, Guanghui Hao, Nanjing Univ. of Science and Technology (China)

The traditional negative electron affinity GaAs photocathodes have a wide spectral response ranging from 400 nm to 1000 nm. The GaAs photocathodes are widely used in the area of night vision, but not applicable for the field of ocean exploration because the seawater is a good window to 532 nm light. For obtaining the suitable photocathode, the p-type zinc (Zn)-doped transmission-mode GaAlAs photocathode sample using exponential-doping technique is grown by metal organic chemical vapor deposition. The Al component of GaAlAs emission and GaAlAs window layers are designed to be 0.63 and 0.79, respectively. The transmission-mode Ga1-xAlxAs photocathode module was treated by chemical cleaning, heat cleaning, and Cs/O activation in sequence. During the activation process, the photocurrent was monitored when the photocathode was illuminated by a halogen tungsten lamp. The operating current of the Cs and O sources, and the photocurrent of the photocathode was controlled and monitored by a self-developed multi-information measurement system. After the Cs/O activation, the photocathode module was manufactured into photodiode, and the quantum efficiency curve was measured using the multi-information measurement system. The experimental results show that the quantum efficiency of the prepared transmission-mode Ga1-xAlxAs photocathode reaches the maximum at about 532 nm. Besides, we did some simulations of quantum efficiency curves by the transmission-mode quantum efficiency formula, and analyzed the effects of the performance parameters on quantum efficiency such as the back interface recombination velocity, the electron diffusion and drift length, and the surface escape probability.

8923-159, Session PTues

Infrared eye tracker in an oculary clinical setting

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Infrared eye tracker is demonstrated in providing a more objective and quantitative results of the cover test measurement in eye care practices. The use of an infrared eye tracker, Tobii X120 (Tobii Technology AB, Sweden, sampling rate of 120Hz) is exploited and combined with the traditional fundamental technique in measuring eye alignment, the cover test. The eye tracker does not require the use of head gear or the chin rest as the algorithms used allows for head movements of 30 x 22 x 30 cm at a distance of 70cm. This feature in an eye tracker is also an added value as it will allow a more natural behaviour in the eye examination and be seen as a patient-friendly instrument. The objective cover test is performed using a custom made occluder that allows the infra red light to pass through, simultaneously measuring both eyes' positions at a time. The objective cover test findings from the eye tracker are compared with the subjective cover test measurements using alternating prism neutralised cover test, performed by a skilled optometrist. The statistical analysis comparing the subjective cover test to the objective cover test finding from the infrared eye tracker yielded a high correlation of 0.96. This implies that the objective cover test measurements, performed with the infrared eye tracker, showed good agreement with the cover test findings from the optometrist. Using an eye tracker would make available to the clinician a simple system for making quantitave measurements when performing the cover test in eye examination.

8923-160, Session PTues

Optimization of MEMS based micropump for drug delivery application

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Microfluidics have revolutionize bio-chemical analysis and their evaluation in various applications. The usage of micropump has been pivotal in microfluidic system as its control the transport of fluids in microscale. The work presented in this paper are studies of micropump optimization via design and simulation for drug delivery application. Three important parts of micropump that are investigated are diaphragm, valve and actuator using MEMS-Pro. 3D model of the micropump are analyzed, using SAMCEF, based on differential pressure to determine the deflection of inlet and outlet valve. Based on this study, the optimized pressure for inlet and output valve is at pressure 10MPa and 20MPa respectively. The deflection of inlet valve is 5.22 µm and bending angle is 0.98°. Meanwhile, the deflection for output valve is 10.76 µm with bending angle is 1.95°.

8923-161, Session PTues

The application and quantitative testing of 150 million pixel CMOS image sensor

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Abstract: With the needs of high time resolution, high spatial and high spectral resolution development in geostationary orbit. Photodetector pixel size has gradually become the bottleneck of the space exploration technology. Shanghai Institute of Technical Physics of Chinese Academy of Science has made a new breakthrough in CMOS image sensor area. The scale of its new CMOS image sensor achieves 12.5K * 12.5K. The detector has been successfully imaging on the ground. In the application process, presents a systematic test and measurement methods to deal with the time noise, dark current, fixed pattern noise, MTF and other parameters of the detector. The test results are below. The MTF of the detector is 0.565 which is measured at 57.21/mm Nyquist frequency. The number of saturated electrons reaches 8.9 ? 104. The total number of transient noise electrons is smaller than 16. The signal to noise ratio is 46dB. Through comprehensive analysis and measurement, it shows that the overall performance of the 12.5K*12.5K detector among the same types of products is in the leading position currently.

8923-162, Session PTues

A simplified approach for integrating capacitively coupled contactless conductivity detection with lab-on-chip devices using injected gallium electrodes

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Capacitively coupled contactless conductivity detection (C4D) and its integration with Lab-on-a-Chip (LOC) systems has been well studied. However, most reported methods require multi-step electrode patterning/fabrication processes which in turn leads to difficulty in consistently aligning detection electrodes. These limitations have the potential to compromise analytical performance of the electrodes and increase the time and cost of device production.

Here we demonstrate a simplified approach for C4D electrode integration with poly(dimethylsiloxane) (PDMS) electrophoresis LOC devices by utilising ‘injected’ gallium electrodes. The developed fabrication process is fast, highly reproducible, and eliminates difficulties with electrode alignment. Using this approach C4D can be readily achieved in any microchip by simply adding extra ‘electrode’ channels to the microchip design. This design flexibility allows for straightforward optimisation of electrode parameters such as orientation, length and distance from separation channel. Evaluation of the electrodes for quantitative analytical detection of electrophoretically separated lithium, sodium and potassium ions will be presented showing the system offers competitive detection limits.

8923-163, Session PTues

Effect of mesh element type of finite element model on unimorph cantilever vibration

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Knowledge on Finite Element Model (FEM) or also known as Finite Element Analysis is a must before the simulation is performed. The finite elements in the physical structure are joined by nodes and both nodes and finite elements make up the mesh. The mesh density is determined by the number of elements used in the particular mesh. There are several types of mesh that must be chosen appropriately such as Parabolic Hexahedral, Linear Hexahedral and Parabolic Tetrahedral. Meshing types and densities are important to ensure an accurate result particularly in a stress, and strain analysis since they are determined by the displacement of each node in the physical structure. The study on the accuracy on an analysis is also known as a mesh convergence study and element aspect ratios must be refined consistently. This paper discusses the mesh refining process of unimorph cantilever vibration where the determination of stress distribution is very essential. Mesh elements and densities (Depth (µm) x Length (µm)) used in the mesh convergence study of unimorph cantilever vibration are Parabolic Hex with the densities of 1 x 40, 1 x 80, 1 x 160, 2 x 80, 1 x 320, Linear Hex with the densities of 1 x 40, 1 x 80, 1 x 160, 2 x 80, 1 x 320 and Parabolic Tet with the densities of 10, and 5.

8923-164, Session PTues

Metal-oxide-semiconductor field-effect transistors operated by surface plasmon polaritons

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On-chip optical interconnections in microprocessors have attracted attention for their high-speed and large-capacity data processing capabilities. Although the integration of micro-scale photonic devices into electronic circuits has been limited because of the diffraction limit of light, miniaturization of photonic devices has been achieved by using surface plasmon polaritons (SPPs) that confine the optical energy into nano-scale regions. We have also developed a silicon-based Schottky-type photodetector based on SPP excitation (termed a plasmonic detector), with a structure that offers a simple fabrication process, and with sensitivity at the telecommunication wavelength of 1550 nm, which is scarcely absorbed by silicon. In addition, we have demonstrated the first monolithic integration of this plasmonic detector with metal-oxide-semiconductor field-effect transistors (MOSFETs).

In this report, the operational characteristics of the integrated device are discussed in detail. In the plasmonic detector, nano-slits were used to excite SPPs at the Au/Si interface. Electric field intensity profiles for the SPP modes on different geometries were clarified by using the finite-difference time-domain method.

The plasmonic detector with nano-slits was integrated with MOSFETs on the same silicon substrate by using a lift-off process and focused ion beam milling, and exhibited Schottky characteristics with a series resistance of 1.2 k? and a dark current of 1.7 nA (under reverse bias of 5.0 V). The photocurrent generated by the plasmonic detector (responsivity of 24.2 nA/mW) was enhanced dramatically by the MOSFETs.

These results represent a major step toward on-chip optical interconnections using SPPs for future high-performance computing applications.

8923-165, Session PTues

Sensitivity improvement of Schottky-type plasmonic detector

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A surface plasmon polariton (SPP) is a compression wave of electrons propagating in a metal surface that makes it possible to confine light energy into nano-regions beyond the diffraction limit. Because of this advantage, various plasmonic devices (including transmitters, detectors, waveguides, and modulators) are expected as components for future high-density optoelectronic integrated circuits. Of these devices, Schottky-type plasmonic detectors have attracted particular attention, because these devices display sensitivity in the telecommunication wavelength range and can be integrated into silicon-based electronic circuits with a simple fabrication process. We have also developed an Au/Si Schottky-type plasmonic detector with nano-slits that excites SPPs at the Au/Si interface.

In this report, we demonstrate a novel nano-slit arrangement that provides a sensitivity improvement for the detector. By using the finite-difference time-domain method, we have clarified that a higher electric field intensity in the SPP mode on the lower side (Au/Si interface) is generated by positioning the slits with twice the period of the SPP wavelength at the Au/Si interface. With this slit period, weaker SPP mode intensity on the upper side (air/Au interface) and stronger light transmission through the slits has also been confirmed. In our experiments, nano-slits with different slit periods were formed on the Au film in the detector, and the slit pitch dependence of the photocurrent was measured. The experimental results showed similar tendencies to the results of the simulations.

This novel nano-slit arrangement can provide an efficient plasmonic detector for future high-speed data processing applications.

8923-166, Session PTues

Standard microelectronic processes compatible porous silicon gratings with high extinction of 0th order mode transmission

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Porous silicon (PS) transmission gratings models are designed and optimized to achieve high 1st order transmission efficiency through changes to the thickness and refractive index. The models predict a high extinction of 0.01% for the 0th order mode and up to 70% for the 1st order diffraction transmission efficiency. Porous gratings formed on thick PS layer (2.2µm) are studied by addressing issues of photoresist pore filling during photolithography. Standard photolithography processes are employed to fabricate designed gratings on N2 passivated porous films using spin-on glass (SOG) to fill the pores of PS prior to photoresist/SOG and subsequent SOG removal by HF dip. This technique makes PS structures compatible with standard microelectronic processes and available to achieve high thickness. Models are built to understand the relationship of PS refractive index, thickness and anodization conditions. The main factors contributing to high PS gratings diffractive efficiency are discussed, including refractive index, thickness, duty cycle and period, to optimize designed structures. Optical thickness reductions (OTR) during fabrication processes are considered to form PS layer with desired refractive index and thickness. The patterning process with photoresist is studied to acquire desired side wall angle and improve structure quality. Photolithography on these multilayer (SOG/PS/Si) structures is presented and the subsequent pattern transfer into the films using reactive ion etching (RIE) is discussed. The gratings with period down to 4µm are designed to operate at 1565nm, which reduces scattering losses and allows backside detection.

8923-167, Session PTues

Method for evaporating silicon to form low dimensional Si lattice structures

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Physical deposition by evaporation is a convenient and cost effective method for generating thin layers of material. In this work, we utilise an electron-beam evaporation system retrofitted with a rotating shutter to control and reduce the deposition rate of materials. Under optimal conditions the evaporator is able to achieve a minimum deposition rate of 1 A/s. In order to reduce the deposition rate further, a rotating shutter was designed and retrofitted to the evaporator. The rotating shutter consists of a metal plate with a slit opening of 6° and 36°. This corresponds to a reduction in deposition rate of 1/60 and 1/10, respectively. By rotating the shutter and keeping a target fixed behind the shutter, we can control the deposition onto the target and achieve a reduced deposition rate of 1 A/min. By using this modified system, we deposited various thicknesses of Si onto mica sheets and diamond. In situ deposition is monitored using a quartz thickness monitor. After evaporation, film thickness is measured using a spectroscopic ellipsometer. Using this modification, we aim to achieve deposition of a single monolayer of silicon onto Ag (111). Also, we are able to repeatedly deposit alternating thin layers of silicon and silicon dioxide to form a Si/SiO2 superlattice. This work is expected to contribute significantly towards the fabrication of low dimensional silicon devices.

8923-168, Session PTues

Catalytic pyrolysis of biomass by novel nanostructured catalysts

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Nanostructured catalysts were successfully prepared by acidification of diatomites, bentonites and the regeneration of used FCC catalysts. The obtained samples were characterized by IR, XRD, SEM, EDX, MAS-NMR (27Al and 29Si), NH3-TPD and tested in catalytic pyrolysis of biomass (rice straw). The results showed that the similar bio-oil yield of 41,4% can be obtained by pyrolysis in presence of catalysts at 450oC as compared to that of the pyrolysis without catalyst at 550oC. The bio-oil yield reached a maximum of 42,55 % at the pyrolysis temperature of 500oC with catalytic content of 20%. Moreover, the pyrolysis bio-oil with high performances such as high ratio of H/C, low ratio of O/C and high heating values were obtained in presence of novel catalysts (acidified diatomites, bentonites and regenerated FCC catalysts). This clearly indicated high application potential of these new nanostructured catalysts.

8923-169, Session PTues

High-speed camera observation of multi-component droplet coagulation in an ultrasonic standing wave field

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It is well-known that an acoustic levitator can be used to aggregate small particles near the nodes of a standing pressure field in a gaseous or liquid fluid.

Furthermore it is possible to atomize liquids on a vibrating surface.

For creating an ultrasonic standing wave field in air a sound source and a plane reflecting surface were arranged vertically facing each other in a distance of n λ/2 so that n pressure nodes can be used for levitation. We have used a conventional ultrasonic processor constructed for homogenizing fluids with a frequency of 24 kHz, whose oscillation amplitude could be controlled by the input power.

Firstly a water droplet was directly introduced into one node in order to optimize the ultrasonic standing wave field by adjusting the distance and the acoustic intensity. For the experiment we deposited some amount of at least two different liquids respectively an emulsion of it simultaneously and consecutively on the vibrating surface of the ultrasonic horn.

Using a high-speed camera we observed the complete atomization and the subsequent coagulation of the spray droplets into single large levitated droplets near each pressure node resolved in space and time.

In case of subsequent atomization of two components the spray droplets of the second component were deposited on the surface

of the previously coagulated droplet of the first component without mixing.

8923-170, Session PTues

Fabrication and replication of micro-optical structures for growth of GaN-based light emitting diodes

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GaN light emitting diodes (LEDs) on sapphire substrates can be improved by micro-patterning substrate to perform epitaxial over-growth which drastically reduces defects density in the light emitting region [1]. We patterned Al2O3 with focused ion beam and show a successful overgrowth of GaN. The exact shape of pattern milled into Al2O3 was replicated into a 0.4-mm-thick shimm of Ni by electroplating. The same technique is used to replicate flat micro-optical elements Fresnel-axicons defined by electron beam lithography on sub-mm areas without stitching errors (Raith EBL) [2]. Shimming of micro-optical elements opens possibility to make replicas and use them for optically-functionalized micro-fluidic chips.

Focused ion beam was used to create patterns of grooves of sub-15 nm width on nanoparticles of sub-wavelength size [3]. Shimming such nano-3D relief structures is promising for creation of substrates for surface enhanced Raman scattering. Shimms of nano-patterns made in Ni further reduces costs as compared with nano-imprint which is a material specific technique. The demonstrated shimming of micro-optical elements, micro-patches for epitaxial overgrowth, an nano-patterned surfaces into a Ni film facilitates new applications in micro-opto-fluidics. It can be potentially used or large area fabrication of gratings and retro-reflectors.

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8923-171, Session PTues

NUC and blind pixel eliminating in the DTDI application

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AS infrared CMOS Digital TDI (Time Delay and integrate) has a simple structure, excellent performance and flexible operation, it has been used in more and more applications. Because of the limitation of the Production process level, the plane array of the infrared detector has a large NU (non-uniformity) and a certain blind pixel rate. Both of the two will raise the noise and lead to the TDI works not very well. In this paper, for the impact of the system performance, we analyze the most important elements. They are the NU of the optical system, the NU of the Plane array and the blind pixel in the Plane array. Here we use a reasonable algorithm which considers the background removal and the linear response model of the infrared detector to do the NUC (Non-uniformity correction) process when the infrared detector array is used as a Digital TDI. In order to eliminate the impact of the blind pixel we introduce a concept of surplus pixel method, through the method we can make sure to improve the SNR (signal to noise ratio) and does not change the spatial and temporal resolution. Finally we use a MWIR (Medium wave infrared) to do the experiment and the result proves the effectiveness of the method.

8923-172, Session PTues

Characterization of single nanoantennas with various configurations

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Plasmonic modes of various single nanoantennas are investigated through far-field scattering measurements and near-field simulations. Plasmonic nanoantennas are known for their capability of concentrating far-field excitation into an extremely small region below diffraction limit. This feature enables them to amplify the interaction with emitters located within the concentrated field. In addition, they can also “broadcast” the emission close to them into the far-field region under the suitable coupling conditions. This is also the reason the term “antenna” is used. However, most related studies have only focused on the dipole mode or the coupled dipole mode of nanoantennas. Observation of the dipole mode is relatively straightforward and the mode is usually utilized for the nanoantenna smaller than the wavelength. In the optical regime, the modes other than dipole modes are also significant to the behavior of the nanoantenna. These modes may also affect the coupling to quantum emitters around the nanoantennas. In this work, the nanoantennas consisting of nanoparticles and ultra thin films are fabricated. The whole size of the nanoantenna is around 100 nm. The characterization is performed through the far-field scattering patterns of the nanoantenna and comparison with scattering simulations. The near-field simulation is also used to identify the modes. The different configurations of nanoantenna result in the various hybrid modes in the nanoantennas. Compare to the (coupled) dipole mode, those hybrid modes have distinct field distribution varying with the structure of the nanoantenna. The characterization of these plasmonic modes may be used for the design of active plasmonic devices which involve the related position between the active material and the field of the nanoantenna.

8923-173, Session PTues

Enhanced efficiency of ZnO nanowire arrays dye-sensitized solar cells assisted by embedded metal nanoparticles

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We demonstrated the enhanced efficiency of ZnO nanowire arrays dye-sensitized solar cells with embedded metal nanoparticles (NPs). Metal NPs-embedded ZnO nanowires were grown by two step growth method, gold NPs were used in this work and deposited on ZnO nanowire between two ZnO growth sequences. Transmission Electron Microscopy (TEM) analysis confirmed the formation of the heterostructure, Au NPs can be fully embedded into single crystalline ZnO nanowires, the sizes of Au NPs are ranging from 5-10 nm and the ZnO shell is around 15 nm. The lengths of the ZnO nanowire arrays can be controlled from few um to tens of um by varying growth conditions.

The dye-sensitized solar cells (DSSCs) were further packaged with gold NPs embedded ZnO (Au NPs@ZnO) nanowire arrays. The J-V characteristics of DSSCs using bare ZnO and Au@ZnO nanowire arrays with different lengths were measured. Compared with bare ZnO nanowire arrays, the power conversion efficiencies increase 20-40 % using Au@ZnO nanowire arrays, that is, DSSCs with metal NPs assistance demand much less thickness to maintain the same efficiency as conventional DSSCs. As result, the enhancements of efficiency may be attributed to the surface Plasmon resonance of Au NPs.

8923-174, Session PTues

A waveguide based microfluidic application

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Microfluidics is based on the performance of fluids in a microenvironment. As the microfluidics research advances in the cellular behaviour, the need for improved micro devices grows. This work introduces the design and fabrication of a micro ridge waveguide to be employed in fluids manipulations. Then it investigates the characteristics of the device in order to control the movement of the fluids on top of the ridge of the waveguide. The elastic vibration is excited along the ridge of the guide with the use of thickness poled lead zirconate titanate (PZT) elements attached to both sides of the waveguide. To excite anti-symmetric or flexural mode in the ridge of the guide, the propagation velocity has been kept significantly below the Rayleigh wave velocity. The velocity reduction of 15% is achieved with the high aspect ratio ridge (H/W =3) design. A 3D model of the micro waveguide has also been developed to determine the vibration characteristics; the natural frequency and the considered mode of the micro waveguide using finite element analysis. The results from the experiments have been compared with the data from the simulation at a frequency of the order of 1MHz and they are in good agreements. The travelling wave along the ridge of the guide is able to transmit strong vibration to the fluid atop of the substrate. The results represents a promising approach in fluids manipulations in one dimensional environment with the strong confined energy, at smaller scale with higher vibration displacement.

8923-175, Session PTues

Long-wavelength infrared Fabry-Perot etalon for multi-spectral thermal imaging

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Multi-spectral thermal imaging systems, that collect information at several difference spectral bands across long-wave infrared (LWIR: 8-12 ?m) region, provide the capability of extracting spectral signatures of materials and enable object identification. It is a field of increasing interest to many applications such as biological and chemical detection, military target recognition and mining. Micro-electromechanical systems (MEMS)-based Fabry-Perot filters can be deployed to make existing systems compact and portable. This paper presents design, fabrication and characterization of MEMS-based FP filters. The fabricated device consists of a bottom Bragg mirror formed of ZnS-Ge-ZnS, a quarter-wavelength Ge top mirror, and an air cavity in-between, whose length is then adjusted for wavelength tuning purpose. High percentage transmission of 85% and a relatively broad bandwidth of 500 nm across a wide tuning range from 8 to 12 ?m have been achieved. Optical and mechanical modelling is in close agreement with the measured characteristics.

8923-176, Session PTues

Targeted sacrificial layer etching for MEMS release using microfluidic channels

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A microfluidics based targeted etchant delivery and masking approach to wet etching has been used to control the etch progression of a porous silicon (PS) sacrificial layer during the release of silicon nitride (SiNx) microbeams using dilute potassium hydroxide (KOH). A reusable 3-input open-channel polydimethylsiloxane (PDMS) microfluidic cassette was used to form a dynamically controllable fluid etch mask to control the location of the etchant during the wet release process.

In contrast conventional release techniques which use solid masking and homogeneous etching environments, microfluidic devices can utilise laminar flows to generate heterogeneous etching conditions which can be controlled in real-time by altering the composition and flow rates of the fluids passing through specific inlets. The fluid nature of the heterogeneous flow can be used to target etch specific areas of sacrificial material or conversely, dynamically mask specific areas both above and below suspend structures. As a result of this control, structures with anchor geometries not achievable using conventional release techniques were created.

Not only does this method require small volumes of etchant fluid, it is also suitable for use on samples which may be sensitive to the chemical and/or physical rigors of photolithographic patterning, such as porous silicon.

Microfluidic based release etching, using dynamically controlled fluid masks, provides a valuable addition to the suite of microchannel based fabrication techniques, enabling new pathways for device fabrication not achievable using conventional techniques.

8923-177, Session PTues

Darkfield microspectroscopic analysis of gold nanorods in spiral ganglion neurons

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The strong light extinction of Au nanoparticles in the near infrared (NIR) window in biological tissues has benefited many biomedical applications, including cancer treatments and drug delivery. Gold nanorods (Au NRs) exhibit a distinct surface plasmon resonance in the NIR that can be tuned by changing the NR aspect ratio. Previous studies have shown that Au NRs exposed to 780 nm laser light in the NG108-15 cell line can promote neuronal differentiation [1] and generate Ca2+ activity [2] that may be related to infrared nerve stimulation [3]. In this study, spiral ganglion neurons (SGNs) have been exposed to Au NRs to explore the effects of light stimulation on primary cells. Primary cell cultures are often complicated by the heterogeneous cell population. Therefore dark-field microspectroscopy has been used to map the distribution and spectrum of nanorods in the SGNs. The results, in terms of the spectral profiles, were compared between different SGN cells in vitro. In all cases, the collected scattering spectra showed a typical gold nanorod spectrum, in which two resonant bands can be observed. A shift in the peak positions was also apparent, suggesting changes in the refractive index that affects the NR spectral characteristics in the cellular environment. Having confirmed the association of the Au NRs with the SGNs, it is possible to measure the amount of heat due to light absorption. Efforts to measure the heating by means of an open electrode pipette will be described. The potential to selectively trigger electrophysiological responses in the SGNs by the Au NR heating will also be discussed.

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8923-178, Session PTues

Nanocrystallic thin films statistical structural analysis by the automatic image processing

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In this paper we demonstrate the powerful new algorithm for automatic analysis of the nanocrystallic samples. The method can be outlined as following: (1) filtration of the image in the Fourier domain (2) normalization with the bidimensional Hilbert transform, so-called vortex transform (3) local diffraction pattern frequency estimation by the novel finite difference operator (4) morphological filtration for the elements segmentation (5) construction of the sample features statistics.

Algorithm is capable of performing a comprehensive analysis of geometrical properties of the registered structures, such as elements density, size and, in common case of imaging with electron

microscope, diffraction patterns periods. Corresponding to d-space (distance between parallel atomic planes) characteristic to given crystallographic structure, the latter gives an interesting tool for the material recognition and characterization. The method does not demand an extensive human operator intervention, thus it is well-suited for the routine characterization of the microscopic images for the materials research applications.

We demonstrate the algorithm performance on the High Resolution Transmission Electron Microscope images of thin Zn-Ir-Si-O films. As multiple crystallographic structures may emerge in such samples, automatic analysis based on image processing proves useful to determine the statistics of crystal types as a function of sample preparation parameters. We compare the algorithm with the method based on the Continuous Wavelet Transform to find that it offers comparable processing quality while profoundly reducing the computation time.

8923-179, Session PTues

Formation of cylindrical micro-lens array in fused silica glass using laser irradiations

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In this article, we report the development of cylindrical-shaped micro-lens array on the surfaces of fused silica glass using laser writing technology. Initially, femtosecond laser pulses have been irradiated on the target glass substrates to pattern periodic micro-lines. Afterwards, laser beam from a CO2 laser source is applied on the patterned fused silica glass surfaces, the purpose of which is to polish the micro-patterned surfaces. As a consequence, periodic cylindrical micro-lenses are evolved on the glass surfaces. The micro-lenses show great consistency in size and shape throughout the sample area. A suitable control over the irradiation conditions of the laser beams enables us to control the period and dimensions of the micro-lenses. We also investigate various optical properties of the micro-lenses evolved fused silica glass samples including the diffraction pattern, diffraction efficiency, and reflectance property of light. The cylindrical micro-lens array can diffract light with moderate diffraction efficiency. We also detected a significant reduction of light reflectance from the micro-lenses grown substrates. It is possible to engineer this kind of structure on a variety of transparent materials over a large area. We strongly believe that, the patterned structures and our fabrication technique will find applications in a diverse field of science and technology.

8923-180, Session PTues

Micro flexible robot hand using electro-conjugate fluid

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An electro-conjugate fluid (ECF) is a kind of functional fluid, which produces a flow (ECF flow) when subjected to high DC voltage. Since it only requires a tiny electrode pair in micrometer order to generate the ECF flow, the ECF is a promising micro fluid pressure source. This study proposes a novel small-size robot hand using the ECF.

The robot hand mainly composed of five flexible actuators and a ECF flow generator. The flexible actuator, works as a finger, is made of silicone rubber having several chambers in series along its axis. When the actuator is driven by negative pressure, the chambers deflate, because the thickness of chamber wall is appropriately designed, resulting in making the actuator bend. On the other hand, the ECF flow generator has a needle-ring electrode pair inside. When putting the ECF flow generator into the ECF and applying voltage of 6.0 kV to the electrode pair, we can obtain the pressure of approximately 30 kPa. Using the components mentioned above, we developed the robot hand. The height, the width and the mass of the robot hand are approximately 47 mm, 35 mm and 6.3 g, respectively.

Since the actuator is flexible, the robot hand can grasp various objects with various shapes without complex controller. Furthermore, by using the ECF as a micro pressure source, the robot hand does not require any external pressure sources. Hence, we can easily downsize the entire system in comparison with other pressure driven robot hands.

8923-181, Session PTues

Probe beam current effect of the subsidiary electrode in a newly developed source lens structure of the microcolumn

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We developed a new source lens structure with the insertion of a subsidiary electrode between the extractor and anode in the source lens of the micro electron column. The noticeable effect of a subsidiary electrode insertion was a drastic increasing of the probe beam current that crucial factor for the performance of a micro electron column. According to the Fowler Nordheim theory, we employed the field enhancement factor as a reference for comparing to other different structures of source lens. At the same field enhancement factor of 3.95, the probe beam current according to the driving voltage applied to the control electrode showed a drastic increase compared to that of the conventional structures investigated in this work. At the driving voltage of the subsidiary electrode was in the range over -800V, the probe beam current was about three times higher than that of the conventional micro electron column. This high probe current in the newly developed source lens structure can be attributed to the suppression of the electron beam divergence by the subsidiary electrode which causes the enhancement of current passing through limiting aperture of the source lens. The working distance was assumed to be 2 mm. Considering the weakness of the micro electron column that has suffered during last twenty years such as low probe beam current and productivity, the effect of the subsidiary electrode insertion was impressive and prospective.

8923-182, Session PTues

Shape optimization of electrostatically driven microcantilevers using simulated annealing to enhance static travel range

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The objective of this paper is to present a systematic development of the generic shape optimization of electrostatically actuated microcantilever beams for extending their static travel range. Electrostatic actuators are widely used in micro electro mechanical system (MEMS) devices because of low power density and ease of fabrication. However, their useful travel range is often restricted by a phenomenon known as pull-in instability. The Rayleigh- Ritz energy method is used for computation of pull-in parameters which includes electrostatic potential and fringing field effect. Appropriate width function and linear thickness functions are employed along the length of the non-prismatic beam to achieve enhanced travel range. Parameters used for varying the thickness and width functions are optimized using simulated annealing with pattern search method towards the end to refine the results. Appropriate penalties are imposed on the violation of volume, width, thickness and area constraints. Nine test cases are considered for demonstration of the said optimization method. The results indicate that around 26% increase in the travel range of a non-prismatic beam can be achieved after optimization compared to that in a prismatic beam having the same volume. Our results also show an improvement in the pull-in displacement of around 5% compared to that of a variable width constant thickness actuator. We show that simulated annealing is an effective and flexible method to carry out design optimization of structural elements under electrostatic loading.

8923-183, Session PTues

Optical and thermal characterization on micro-optical elements made by femtosecond laser writing

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Femtosecond laser polymerization of photonic crystals, hybrid refractive and diffractive micro-optical elements which can be easily integrated into complex 3D geometries of micro-fluidic chips is demonstrated. Direct laser writing provides accessible and fast formation of 3D structures within a drop-casted photo-resist on any surfaces: transparent dielectrics, conductive indium tin oxide films, metal coatings, and complex 3D nano-structured surfaces such as black-Si as well as on optical fiber tips [1]. Thermal properties of such 3D optical elements and patterns was investigated by thermal imaging under illumination by visible light. Temperature diffusivity of photonic crystals and laser structured polymers and glasses has been determined [2].

We describe peculiarities of irradiation control required to fabricate 3D polymer optical elements without the use of a photo-sensitizer on very different substrates using femtosecond laser irradiation. Speed up of the laser writing by a factor of 100 was achieved for simple lens designs via a surface shell-definition and subsequent UV exposure followed after development. Thermal imaging allows a simple in situ judgement on 3D fabrication quality of photonic crystals and is faster and more informative as compared with scanning electron imaging. Thermal imaging can be used for thermal sensing applications using nano-patterned surfaces [3] and could be extended for photonic crystal structures.

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8923-184, Session PTues

Single-step passivation (SSP) and antireflection coating for radiation resistant mono-crystalline silicon solar cell

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Silicon based solar cells have been fabricated by using silicon dioxide in single-step passivation as well as an antireflective coating (ARC). The results were obtained with non-texturized surface of monocrystalline silicon p-type (100) substrate and compared with the as-grown Si solar cell. Effects of Single-Step Passivation (SSP) and ARC layer on the performance of solar cell were characterized through electrical (AM 1.5G, 100 mW/cm2) optical and morphological measurements. Al-alloyed back surface field (BSF) was also successfully fabricated in combination with SiO2 (SSP) layer and more than 70% increase in conversion efficiency was observed as compared to the as-grown Si solar cell. Morphological and structural measurements for BSF and SiO¬2 film were carried out by atomic force microscopy (AFM), field emission scanning electron microscopy (FESEM) and X-ray diffraction analysis. A reflection spectrum of SiO2 film was also measured which shows the minimum reflection of 0.06% at 520 nm with an average reflection of 11.6% (within the 400-1000 nm range). Low contact resistance and surface recombinations was also observed due to the aluminum silicon-alloying as BSF which results in radiation hardened solar cell. The results indicate the potential of SiO2 (ARC and passivation layer) in combination with BSF, for the production of high efficiency radiation resistant low cost silicon solar cells.

8923-185, Session PTues

Governing equations for electro-conjugate fluid flow

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An electric-conjugation fluid(ECF) is a kind of dielectric liquid, which generates a powerful flow when high DC voltage is applied with tiny electrodes. This study deals with the derivation of the governing equations for electro-conjugate fluid flow based on the Korteweg-Helmholtz(KH) equation which shows the force in dielectric liquid subjected to high DC voltage. The governing equations consist of Gauss's law, charge conservation with charge recombination, KH equation, continuity equation and incompressible Navier-Stokes equations. KH equation consists of coulomb force, dielectric constant gradient force and electrostriction force. The governing equation gives the distribution of electric field, charge density and flow velocity by analyzing numerically. In this study, direct numerical simulation(DNS) is used in order to get these distribution at arbitrary time. This study also deals with the measurement of ECF flow generated with a symmetrical pole electrodes pair which are made of 0.3mm diameter piano wire. Working fluids are dibutyle decanedioic acid(DBD) and FF-1EHA2. Both of them are ECF family but have different flow characteristics. DBD flows from the positive electrode to the negative electrode but FF-1EHA2 flows from the negative to the positive electrode and generates a impinging jet. The governing equation successfully reproduce these flows by the numerical analysis.

8923-186, Session PTues

Adapting semiconductor device fabrication processes to make micro-structured surfaces for algal biofilm studies

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Cells move on surfaces by locally extending their membranes and interact with surface physical cues at the micrometer and nanometer scales. This has prompted interest in areas ranging from tissue engineering to controlled algae growth. Cells of microorganisms tend to accumulate particularly on large surfaces, making it important to fabricate large-area micro- and nano-textured surfaces to understand their behavior on such periodic small features. In this research, conventional semiconductor (SC) device fabrication processes have been utilized along with hot-embossing technique to produce consistent patterns on large areas to primarily study algal biofilm growth from planktonic systems. For micrometer-scale patterns, SU-8 resist has been hardened to withstand hot-embossing temperature and force. By doing this, the etching step was eliminated from the conventional SC device fabrication process. Silicon micromachining is another method that is adapted from the semiconductor field to create V-groove micrometer patterns. This V-groove design has been chosen to study algae's interaction with edges after observing algae's profound response to edges of polymer substrates in preliminary experiments. Hot-embossing force and temperature are studied for transferring consistent patterns from resist-based and etched masters to poly-methyl methacrylate substrates. Initial results from biofilm growth kinetics study show an increase in algal biomass accumulation on embossed deep V-groove substrates over other substrates compared in this study.

8923-187, Session PTues

Anti-reflection properties of spherical top nanowire arrays for solar cell applications

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Nanowire (NW)/nanopillar (NP) semiconductors has unique optical and electrical properties which are attractive for photovoltaic applications. Important parameters such as diameter, length and array density of

the NW have been studied for years. Additional to these parameters, in this study we demonstrated via simulations and experiments that different top shape of the NW gave different optical response. In the simulations, optical performance of NW with flat top and spherical top were investigated. The simulated 3D model has a carbon nanotube/ amorphous silicon coaxial structure with total diameter of 760nm. Our results show that when the spacing of the NW array is getting smaller and smaller, the influence of the top shape on the NW array's reflectance is becoming more and more significant. For narrow spacing arrays (<1000nm), NW array with spherical top gives better antireflection performance than the flat top NW array. This is due to the biomimetic antireflection (AR) effect introduced by the spherical top. For large spacing arrays (~2000nm), this AR effect was almost eliminated. This is ascribed to the low volume concentration of the spherical top on the planar surface. In addition, reflection spectra of NW array under non-normal incidence condition and with structural defects were presented. Our simulated result matched well with the experimental data by taking into account of these factors.

8923-190, Session PTues

Development of a multi-electrode system for non-destructive and contactless wafer evaluation

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With the miniaturization of CMOS, the gate insulator has extremely become thin until reaching the EOT (equivalent oxide thickness) of less than 1nm in order to keep maintaining high-speed performances of devices and low electric energy consumption. Since the gate insulator is so thin, leakage current increases and the gate dielectric breakdown can easily occur. This affects the reliability of semiconductor devices. To make good devices, it is necessary to use technologies for the evaluation of the gate insulator reliability.

TDDB (Time Dependent Dielectric Breakdown) lifetime has been one of the main factors for this evaluation. In this case, a wafer is destroyed in order to be evaluated, which reduces the semiconductor yield. To solve this problem, we propose a new technique for the evaluation of the gate insulator which is a non-destructive and contactless measurement method, and thus an appropriate method for inline processes.

A voltage is applied on a Si/SiO2 specimen. A voltage source electrode and the specimen are not in contact(10micron gap). After the it is charged, the specimen is irradiated by a xenon-flash-lamp. Since the energy of this pulsed light is beyond 4eV, electrons are emitted and move from Si to SiO2. It is possible to estimate the condition(the electrical conductivity) of the insulator using this phenomenon.

A multi-electrode system was developed for mass production. With this system, one is able to evaluate 10 thousand points over a 12-inch wafer in 1 minute.

8923-191, Session PTues

Development of a multi-flash lamp in pulse photo conductivity method

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In the manufacturing field of semiconductor devices, improvement of yield and increase of throughput is very important issue. Therefore, in the evaluation of semiconductor devices, a method using a light source is frequently used for in-line measurement. In our laboratory, we propose Pulsed Photo Conductivity Method (PPCM) as a device evaluation method for non-destructive and non-contact measurement. To inspect the whole wafer in one minute using PPCM evaluation equipment, high repetition frequency lamp is required .In general, laser is used as light source in device evaluation using light. Laser has a high repetition frequency, but the cost is very high compared with other light sources.

Therefore, in this study, we developed a multi-flash system to be used for PPCM evaluation equipment. This system is a high repetition frequency and cheaper. In this study, the maximum repetition frequency of an L11035 Hamamatsu xenon flash lamp used is 530Hz which is not high. Therefore, we developed a light source with high repetition frequency by using several xenon flash lamps in this system.

8923-192, Session PTues

Probing the electronic structure in GaAs nanowire rotational twin superlattices

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Gold catalyzed GaAs nanowires are grown using the vapor liquid solid technique in a MOCVD reactor. When doped with Zn acceptors very regular rotational twin superlattices (RTSL) can be produced with controlled periods. Detailed single nanowire photoluminescence measurements at 10 K show that in addition to the usual Zincblende (ZB) free exciton emission at 1.515 eV there is a prominent broad emission line approximately 40 to 50 meV lower in energy. Power dependent single NW PL shows that the shape and relative intensities of these two lines does not depend on laser excitation power suggesting that the low energy peak is not due to an impurity since it cannot be saturated.

In a ZB GaAs nanowire the rotational twin results in a 180 degree rotation of the stacking sequence around the [111] growth direction. At the boundary between the extended ZB segments this rotation results in one to several monolayers of Wurtzite (WZ) symmetry. The band offsets between ZB and WZ GaAs are approximately 100 meV resulting in a type-II arrangement where the electrons are confined to the extended ZB segments and the holes are confined to the very narrow WZ segments. Simple quantum calculations of this arrangement are used to provide some evidence as to the nature of the low energy emission lines which is consistent with the experimental observations.

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8923-193, Session PTues

Particle separation with travelling surface acoustic waves

Jan M. Behrens, RMIT Univ. (Australia)

Manipulation of microscale particles and cells is an important task for lab-on-a-chip devices for application in biological application and medical diagnostics, such as cell detection and separation. In the last years several methods have been discovered working with standing surface acoustic (SSAW) wave phenomenon's to separate particles in microchannels using the effect of alignment along pressure nodes, and transport to a certain node depending on the acoustic radiation force on the particle. There have been approaches to prevent the creation of standing waves for example by creating channels with trapezoidal walls in Lithium Niobate, but these are expensive and not easy to fabricate. We try to do the same by using an acoustic diffuser to reflect the wave, a technique with has been used in architectural acoustics for centuries, for example in opera houses. The advantage of using travelling waves is that particles will not align along pressure nodes and can therefore be continuously separated by their size and form; also it allows steering of particles by changing the power of the SAW.

8923-194, Session PTues

Investigating extremely low resistance ohmic contacts to silicon carbide using a novel test structure

Yue Pan, Fahid Algahtani, Patrick W. Leech, Geoffrey K. Reeves, RMIT Univ. (Australia); Philip G. Tanner, Griffith Univ. (Australia); Anthony S. Holland, RMIT Univ. (Australia)

Like all semiconductor devices, low resistance Ohmic contacts to silicon carbide (SiC) are required to minimise power losses in SiC devices. Highly doped epitaxial SiC samples were each coated with 200nm of nickel and patterned using a novel two-electrode ohmic contact test structure. Results obtained for sheet resistance of the active SiC layer agreed with Van der Pauw measurements and like the specific contact resistivity measurements, were consistent across many samples. Sheet resistance was 28 Ohms per square (independent of heat treatment) and the specific contact resistivity varied with varying heat treatments from low 10E-6 to 10E-7 Ohm cm2. The convenience and sensitivity of the test structure allowed for ease of determination of the appropriate heat treatment, to minimise the specific contact resistivity. Materials analysis was conducted to demonstrate the high crystal quality, low surface roughness, and appropriate stoichiometry of the SiC layer. The electrodes fabricated were exact in dimensions and these could be conveniently measured. The accurate measurement of electrode dimensions using a scanning electron microscope resulted in highly consistent results to be determined from electrical measurements using electrodes of different dimensions. Being circular electrodes allowed for accurate fabrication of such electrodes using contact lithography. Scaling behaviour is discussed as it allows for extension of the test structure to electrodes with different dimensions and for contacts with different electrical properties.

8923-195, Session PTues

Non-thermal effects of microwaves on biological activity of Collagenase enzyme and growth rate of yeast cells

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Radiofrequency/Microwave (RF/MW) radiation has been integrated in almost every aspect of today's modern life and applied in radar, telecommunication, and food technology, and health care. However, the increasing rate of exposures to RF/MW radiation, especially exposures from mobile phones, has raised health concerns and stimulated much research into biological and health effects of microwave radiation. Our previous studies [1] showed that low power MW can modulate L-lactate Dehydrogenase enzyme biological activity but little is known about the actual mechanisms behind this phenomenon. One hypothesis is that low power MW can induce dipole oscillations in a protein's active site and thus, can alter its function. In this study we investigated the non-thermal effects of low power MW radiation on the Collagenase enzyme and yeast Saccharomyces Cerevisiae strains type II. Collagenase enzyme and yeast cells were continuously exposed to microwaves at the frequency of 968MHz and power of 10dBm using the designed and constructed Transverse Electro-Magnetic (TEM) cell. The generated electromagnetic field was simulated using ANSYS HFSS software prior to fabrication in order to make sure that a uniform homogeneous field is formed inside the TEM cell. A spectrophotometer (Ocean Optics) was used to measure the changes in absorption characteristics of Collagenase enzyme and growth rate of yeast cells induced by applied MW exposures. The experimental results are compared with the control group of unexposed samples (sham-exposed) showing the changes in enzyme activity and growth rate of yeast cells under the experimental conditions. The findings are presented and discussed in detail.

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8923-196, Session PTues

Influence of technique on the measured particle size distribution of complex nanoparticle systems

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Accurate and reliable characterisation of nanoparticles is crucial for both industrial applications and studies of their toxicological and environmental impacts. Particle size distribution (PSD) has been widely recognised as one of the key parameters that should be reported and studied when considering nanoscale systems. Determining the PSD of nanoscale systems presents numerous challenges, including resolution and detection limits of available instrumentation, statistical relevance (in single-particle methods), required prerequisite knowledge (for example, optical properties), and accounting for or overcoming matrix effects. All characterization instrumentation has inherent advantages, limitations and biases. To best understand what these are, a combination of different measurement techniques should be applied to a well-controlled system. Here, we present results from a comprehensive comparison study of PSD measurements of four nanoparticle suspensions using six different characterisation techniques.

The four samples employed in this study comprised aqueous suspensions of citrate stabilised gold colloids; two with mono-modal PSDs (nominal mean diameters: 20 nm and 100 nm), and two with bi-modal PSDs. The bi-modal samples were produced by mixing the mono-modal samples in ratios to generate equal peak heights in intensity-weighted light scattering PSD measurements and in number-weighted PSD measurements. The measurement techniques used in this study included dynamic light scattering, atomic force microscopy, transmission electron microscopy, differential centrifugation sedimentation, particle tracking analysis and flow-field flow fractionation.

8923-197, Session PTues

Improved geometrical design of the circular transmission line model ohmic contact test structure

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The specific contact resistance, of an ohmic contact interface, is an important characteristic in semiconductor design and requires an effective and accurate means of measurement. Obtaining accurate values of the specific contact resistance of ohmic metal to semiconductor contacts will allow more accurate modelling and indication of the suitability of particular metal-semiconductors contacts in semiconductor devices. Many researchers have investigated the simplification of the CTLM. These modified methods have made solutions to the analytical description of the CTLM pattern simpler to calculate. However, they have not increased the accuracy of results obtained; they have often made the method less accurate.

This paper proposes a method to determine the design of a CTLM in order to ensure accurate results are obtained. Through analytical and finite element modelling it has been shown that the accuracy of the measurements obtained using a particular CTLM pattern, depends on the geometry chosen. This is accomplished by determining which geometry will yield the most sensitive measurement when compared to the sheet resistance and specific contact resistance of an ohmic contact sample. Contact end resistance is the most useful parameter obtained from CTLM measurements but it is typically a relatively small value and prone to error due to measurement of small voltages. This paper presents improved design of CTLM test structures by solving the analytical expressions for contact end resistance in order to maximise the associated voltage measurements and the solutions are demonstrated using finite element modelling.

8923-198, Session PTues

Characterization of optical polarization converters made by femtosecond laser writing

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Form birefringence of nano-gratings recorded inside silica by femtosecond-laser pulses has been used to create micro-optical elements which can convert polarization of an incoming light and

via spin-orbital coupling generate optical vortices [1]. For opto-mechanical applications in microfluidics, such optical generators were recorded inside a base-plate of a channel at a 10 micrometers depth. The optical-vortex converters show scattering and defect-related absorption. Thermal annealing from as low as 100oC/1hour showed a 10% reduction of scattering at the used 532 nm wavelength. Evolution of the fluorescence spectra and lifetime with annealing shows how to improve the efficiency of nanograting based optical devices.

Fluorescence life-time imaging (FLIM) at 457 nm excitation revealed a complex stretched exponential behaviour of the 650 nm non-bridging oxygen hole centers. FLIM allowed to measure typical lifetimes in the range of 3 ns to 30 microseconds. Interestingly, a fluorescence image of a vortex-generator around 650 nm band showed a spiralling intensity distribution (generator was made for 532 nm). Discussion how the form birefringence affects defect-related fluorescence will be presented together with guidelines for reduction of defect related scattering and absorption. The absorption is due to vacancies and interstitials created under intense irradiation by fs-laser pulses and mitigation of their effects is an technologically important issue [2].

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8923-200, Session PTues

Optimising the thermal budget for forming of nickel germanide on crystalline germanium

Fahid Algahtani, Anthony S. Holland, Elena Pirogova, RMIT Univ. (Australia)

Germanides are conveniently formed by heating a metal layer on germanium. Many metals form germanides this way and nickel germanide in the form of NiGe is advantageous for use in germanium semiconductor devices as it has a low resistivity comparable to that of NiSi which is a well known electrical contact material in silicon devices. Other forms of nickel germanide, other than NiGe, are not desirable as they have higher resistivities. However, NiGe conveniently forms at the lowest temperatures of 400C and lower. Here we report on the thermal budget required to form NiGe on n and p-type germanium at low temperatures (less than 400C) and report on the temperature duration required for fully reacting Ni of different thicknesses to form NiGe. Ni thicknesses of 50nm to 500nm were deposited on crystalline germanium and heat treatments undertaken on several samples of each thickness for time durations at different temperatures of 1 minute to 10 hour. Long durations were required for the lowest temperature of formation.

Electron microscopy micrographs in plan and cross-section views clearly show polycrystalline and smooth surface germanide layers. The interface with the germanium is not as smooth as the surface and is rougher for thicker nickel used. This was observed by TEM cross-section imaging and by selective etching of the NiGe layers and subsequent AFM imaging. All NiGe that were fully formed had resistivities varying from 14 to 20 micro ohm cm, as determined using a modified Van der Pauw technique.

8923-201, Session PTues

Detection of harmful algal bloom causing microalgae using covalently immobilised capture oligonucleotide probes on glass and PDMS surfaces

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Harmful algal blooms (HABs) form when there is an abnormal increase in natural phytoplankton or microalgae growth in waterways. This increase in cellular mass can have devastating effects in the environment including sea-life mortality and the release of biotoxins [1]. Alexandrium catenella, a dinoflagellate that has been linked to red tide HAB formations, is a source of biotoxins such as saxitoxin and gonyautoxin. Consumption of these toxins can lead to paralytic shellfish poisoning (PSP) which can be fatal in some cases. Many other marine microorganisms with similar morphology are not biotoxin producers. Analysis via traditional light microscopy methods is unable to discriminate between these species [2]. Therefore it cannot be used to predict if a bloom will be, or is, toxic. Species specific detection of the algae is essential for preventative action to be undertaken [3].

Hybridisation based detection methods employ an oligonucleotide probe to capture a complementary nucleic acid strand within the sample matrix. These probes can be designed to target specific genetic sequences within the organism and can be highly selective. We report the immobilisation of a synthetic oligonucleotide probe specific for Alexandrium catenella. We demonstrate the successful covalent immobilisation of the oligonucleotide probe to PDMS and glass surfaces. The immobilised sequence is shown to capture the target sequence successfully.

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8923-202, Session PTues

Rapid formation of controlled size and morphology spheroids by surface acoustic wave microfluidic device (SAW) versus liquid overlay method

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In this study, we developed a novel and rapid method to create in vitro three-dimensional (3D) spheroids using a surface acoustic wave (SAW) device. A SAW device with single-phase unidirectional transducer electrodes (SPUTD) on lithium niobate substrate was fabricating using standing UV photolithography and wet-etching techniques. To generate spheroids, the SAW device was loaded with medium containing human breast carcinoma (BT474) cells, an oscillating electrical signal at resonant frequency was supplied to the SPUDT to generate acoustic radiation in the medium. Spheroids with uniform size and shape can be obtained using this method in less than 1 minute, and the size of the spheroids can be controlled through adjusting the seeding density and input power. The resulting spheroids were allowed for further cultivation and were monitored using optical microscope. The viability and actin organisation of the spheroids were assessed using live/dead staining and actin cytoskeleton staining, respectively. Compare to spheroids generated using liquid overlay method, the SAW generated spheroids exhibited higher circularity and higher viability. The F-actin of spheroids appears to colocalize in aggregates compared to that of untreated cells, indicating that mature spheroids can be obtained using this method. This spheroid generating method can be useful for a variety of biological studies and clinical applications.

8923-203, Session PTues

Four point probe geometry modified correction factor for determining resistivity

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It is well known that the four-point probe technique for determining sheet resistance (Rsh), requires samples with dimensions much greater than the spacing between the four probes, in order to use the relevant equation, with its exact correction factor. On standard four-point probe equipment, the probe spacing is typically 0.5mm, and requires samples to be 15mm x 15mm in size. Using finite element modelling and experimental results for samples of different geometry, different areas and thickness we demonstrate how correction factors vary and can be selected even for samples where the probes are close to

the samples edges. Two extremes with regard to sample thickness for four-point probe measurements, are well reported and these are the case of thin films (thickness less than 0.1 of probe spacing) and secondly the case of semi-infinitely thick samples (thickness greater than five times the probe spacing). In this paper we report on the use of four-point probe for all sample thicknesses, and all sample areas. The results are of benefit to researchers who work with small semiconductor samples where only a relatively small piece is available for probing and will likely have thicknesses greater than thin films but not semi-infinite (as is the case for most substrates). Results are presented for finite element modelling in the form of curves that enable correction factors to be obtained for any geometry. Finite element results were verified using experimental measurements on samples of varying geometry and resistivities.

8923-204, Session PTues

Modelling and fabrication of thermally actuated micropores for biological sensing

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The aim of this project is to model and fabricate a new design of thermally actuated micropore for biological detection. The design consists of a bimaterial cantilever type pore structure fabricated on thin membrane, and has the potential to capture and release biological cells without repercussions while being relatively low cost and easy to operate. FEA analysis of the design demonstrates that distributions of deflection and stress are consistent with predicted values from theoretical models.

An optimisation model incorporating both deflection and stress is proposed, and multiple materials have been assessed to achieve optimal performance. Prototype of the design is fabricated on silicon nitride membrane followed by testing and discussions.

8923-205, Session PTues

Assessment of GeB doped silica optical fiber for the application of remote radiation sensing system

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A flat optical fiber (FF) with nominal dimensions of (0.08 x10.00 x 10.00) mm3 of pure silica SiO2 and GeO2 with Boron doped silica fiber SiO2 was selected for this research. The FF sample was annealed at 400oC for one hour before irradiated. Kinetic parameters and dosimetric glow curve of TL response and sensitivity were studied with respect to the electron beam of high dose of micro beam irradiation of 1.0 kGy, 5.0 kGy, 10.0 kGy, 50.0 kGy, 100.0 kGy, 500.0 kGy, and 1.0 MGy using Singapore Synchrotron Light Source's (PCIT) beamline. The PCIT operates at 500mA current with real time current range from 90-100mA, dose rate of 3.03 MGy/hour and energy at 8.9KeV. The source to Source Surface Distance (SSD) was at 6.0 cm, with a field size of 20mm ? 8mm diameter of a half circle. The proposed FF shows the excellent TL response for high energy irradiation and good reproducibility and exhibits a very low rate of fading and low variation background signal. From these results, the proposed FF can be used as a radiation dosimeter in remote radiation sensing and favorably compares with the widely used of LiF based dosimeter on common medical radiotherapy application.

8923-206, Session PTues

Hydrophobicity studies of polymer thin films with varied CNT concentration

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Fabrication of polydimethylsiloxane (PDMS) and multiwalled carbon nanotubes (MWCNT) hybrid thin film variations on glass to produce hydrophobic surfaces is presented in this paper. There are three important parameters studied in producing hydrophobic surfaces based on the hybrid thin films; concentration of PDMS (10:1, 30:1 and 50:1), concentration of MWCNT and droplet sizes. The resulting hybrid thin films shows that hydrophobicity increased with increasing cross linker and MWCNT percentage in the PDMS solution. The hybrid thin films produced can be potentially tailored to the application of biosensors, MEMS and even commercial devices.

8923-207, Session PTues

Investigation of amorphisation of germanium using modelling and experimental processes

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Crystalline germanium substrates were ion implanted with germanium ions at a series of three energies (550keV, 1MeV and 2MeV) and the dose was 1E15 cm-2 for each implantation energy. This process was also modelled using the ion implantation software TRIM (Transport of Ions in Matter). Cross-sectional TEM micrographs of the implanted samples clearly show the amorphous and crystalline regions. The boundary of the amorphous region is approximately 1.4 microns below the surface. Using the TRIM results we were able to demonstrate the dose threshold for amorphisation. Electron diffraction images taken at different depths below the software surface are also used to demonstrate the comparison between modelling and experimental results.

While the cross-section TEM micrographs clearly show the amorphisation boundaries, there is also evidence of some sub-amorphous crystal damage below the amorphisation boundary. Electron diffraction is used to demonstrate solid phase epitaxy occurring after heat treatment of samples, within the amorphised region. TRIM analysis is presented showing collision damage events versus depth and this is related to the occurrence of localised solid phase epitaxy realised as short range crystal growth deep in the amorphised layer.

8923-208, Session PTues

Preparation of Cu2O/TiO2 nanotube heterojunction arrays with enhanced photoelectrocatalysis performance

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In recent years, various methods have been widely investigated to improve the photocatalysic efficience of TiO2¬[1].Among those methods, combination with narrow-band gap semiconductor to form a heterjunction structure may provide an effective way to obtain higher photoactivity[2].Cuprous oxide(Cu2O), a p-type semiconductor with bandgap 2.1eV, is a promising material for enhancing charge separation efficiency deposited with TiO2 nanotube arrays, owing to their higher conduction and valence bands compared with TiO2[3]. In this paper, highly ordered TiO2 nanotube arrays (TNTs) were fabricated by two-step anodization process in the electrolyte containing 0.15M NH4F and 3 vol%H2O in ethylene glycol solution. The Cu2O nanoparticles were deposited into the as-prepared TNTs via electrochemical deposition method in a three-electrode cell (the TNTs, Ag/AgCl and graphite performed as working electrode, reference electrode and counter electrode, respectively).The electrolyte containing 0.15 M copper sulfate and 0.5 M patassium sodiun tartrate was adjusted to pH 11.0 with 5 M NaOH. The samples morphology was examined by field-emission scanning electron microscopy (FESEM), the crystalline phases and composition of Cu2O/TNTs heterojunction were analyzed by X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS), respectively. UV-visible diffuse reflectance spectra (DRS) of samples were measured using a UV-vis

spectrophotometer. The photocatalytic and photoelectrocatalytic activities of Cu2O/TNTs heterojunction were measured by degradation of methyl orange (MO) under simulated visible light and the photochemical and photoelectrochemical properties of samples were evaluated by measuring the photocurrent response under intermittent Xe lamp irradiation. Consequently, the Cu2O nanoparticles had been deposited into TNTs inner surface and interface with uniform distribution. The Cu2O/TNTs composite exhibited better photocatalytic degradation activity to MO than pure TNTs. Furthermore, the Cu2O/TNTs heterojunction displayed excellent photochemical and photoelectrochemical catalytic performance under visible light.

8923-209, Session PTues

Green synthesis of silver nanoparticles as antibacterial agent using Rhodomyrtus tomentosa acetone extract

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In the present study, the capability of Rhodomyrtus tomentosa acetone extract (RAE) for the production of silver nanoparticles has been explored for the first time. Silver nanoparticles with a surface plasmon resonance band centered at 420-430 nm were synthesized by reacting RAE with aqueous silver nitrate (AgNO3). Reaction time, temperature, concentration of AgNO3 and RAE could accelerate the reduction rate of Ag+ and affect AgNPs size. The nanoparticles were found to be 10-30 nm in size and spherical in shape. XRD data demonstrated crystalline nature of AgNPs dominated by (200) facets. FTIR results showed decrease in intensity of peaks at 3394, 1716 and 1618 cm-1 indicating the involvement of O-H, carbonyl group and C=C stretching with the formation of AgNPs with RAE, respectively. The C-O-C and C-N stretching suggested the presence of many phytochemicals on the surface of the nanoparticles. High negative zeta potential values confirmed the stability of AgNPs in water. In vitro antibacterial activity of AgNPs was tested against Staphylococcus aureus using broth microdilution method. AgNPs capped with RAE demonstrated profound antibacterial activity against the organisms with minimum inhibitory concentration and minimum bactericidal concentration in the range between 3.1-6.2 and 6.2-50 ?gmL-1, respectively. The synthesized nanoparticles could be applied as an effective antimicrobial agent against staphylococcal infections.

8923-210, Session PTues

Spectroscopic modeling of water molecule

Rostyslav Danylo, Boris A. Okhrimenko, National Taras Shevchenko Univ. of Kyiv (Ukraine)

This research is devoted to the vibrational spectroscopy inverse problem solution that gives a possibility to design a molecule and make conclusions about its geometry. The valent angle finding based on the usage of inverse spectral vibrational spectroscopy problem is a well-known task [1]. 3N-matrix method [2] was chosen to solve the proposed task. The usage of this method permits to make no assumptions about the molecule force field, besides it can be applied to molecules of matter in liquid state.

8923-214, Session PTues

Graphene-polymer multilayer heterostructure for THz metamaterials

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The plasmon in graphene has attracted increasing research interests because of many desirable properties such as strong confinement and low loss.1-3 The wavelength of graphene plasmons was experimentally observed at the order of 200 nanometres, more than 40 times smaller than the wavelength of illumination which is in the terahertz (THz) regime.4, 5 Patterning graphene into micro-ribbons6 or photonic-crystal-like structures7 could induce plasmon resonance in THz range, which affords a new type of THz metamaterials. Graphene plasmonics is very promising to make transformation optics8 due to its tunability via chemical modification or electrical gating. One important aspect of graphene plasmonic is to enhance the plasmon resonance and control the coupling effect among adjacent layers.9

Here we fabricate graphene/polymer multilayer heterostructure with controlled separation and systematically investigate the optical response as well as plasmon coupling between graphene sheets. Monolayer graphene is grown by chemical vapour deposition (CVD) and chemically doped by acid during the wet-transfer process so as to enhance the carrier density. A vacuum-based Fourier Transform Infrared Spectroscopy (FTIR) and Variable-Angle Spectroscopic Ellipsometer (VASE) were used to study the THz transmittance and polarized reflectance in visible range. Anomalous transmission of light was experimentally observed in THz range. A theoretical model based on the transfer matrix method (TMM)10 was applied to understand the fundamental physics behind. The graphene/polymer multilayers could be a promising platform to filter infrared and terahertz waves and to tailor the propagation and diffraction of light along the graphene sheets deeply below the sub-diffraction-limit.

8923-99, Session 22

Electrically stable, solution-processed amorphous oxide thin-film transistors through UV-Ozone assisted sol-gel approach

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We have explored the use of UV-ozone treatment as a complimentary step towards the formation of amorphous indium zinc oxide based thin-film transistors using a thermally-assisted sol-gel approach. This treatment was found to effectively remove a significant portion of carbonacious ligands complexing the metal centers in as-deposited thin-films. This enabled the rate of extended metal oxide formation to be enhanced during a subsequent thermal annealing stage. Field effect transistors fabricated using such amorphous metal oxide films exhibited significant enhancements to the mobility and on-off ratios compared to those which were only thermally treated. Typical mobilities of >30 cm2/Vs with on-off ratios of 10^6 could be achieved at processing temperatures as low as 300°C when a UV-ozone processing step was included. Stress tests of such transistors exhibited stability factors comparable to analogues sputtered amorphous metal oxides. All these factors highlight that using a simple UV-ozone treatment prior to thermal annealing of a sol-gel derived thin film, is highly beneficial for developing transistors with high performance at lower processing temperatures and with high intrinsic electronic stability.

8923-100, Session 22

Controlling polarity of organic bulk heterojunction field effect transistors via solvent additives

Jung Hwa Seo, Dong-A Univ. (Korea, Republic of); Bright Walker, Ulsan National Institute of Science and Technology (Korea, Republic of)

We report on the influence of the solvent additives DIO and CN on the energy levels, charge transport properties and phase distribution of the DTTDPP:PC71BM BHJ system. The polarities of BHJ FET devices without additives and with DIO and CN are p-type, n-type and bipolar, respectively, regardless of their energetic levels of the DTTDPP, PC71BM and their blend. The polarity of the devices was determined by the phase distribution of each component, which was controlled via processing additives. Compared to the pristine blend film, the use of DIO led to film properties consistent with DTTDPP aggregation within

a continuous PC71BM phase, while the introduction of CN gives rise to the even distribution of donor/acceptor phases on the dielectric/active layer interface. It is confirmed that desirable, interpenetrated phase separation behavior is achieved with CN additive by XPM analysis together with the corresponding OFET characteristics. Our findings indicate that (i) additives do not affect the HOMO/LUMO levels of DTTDPP, PC71BM or blends of the two materials, (ii) a proper selection of additives can lead to efficient charge transport, and (iii) the use of additives critically influences the film morphology and mixing of donor/acceptor materials, allowing significant improvements in device performance.

8923-101, Session 22

Conduction mechanisms and resistive switching in RF magnetron sputtered SrTiO3 epitaxial ultra-thin films and multilayer structures

Hussein Nili Ahmadabadi, Philipp Gutruf, Kourosh Kalantar-Zadeh, Madhu Bhaskaran, Sharath Sriram, RMIT Univ. (Australia)

Impurity driven conduction mechanisms in binary and ternary transition metal oxides are the subject of rigorous research since these phenomena form the underlying working principles of resistive switching and memristive devices. Transition metal perovskite oxides of ABO3 crystal structure and in particular, SrTiO3 (STO), are known to possess fast, repeatable and highly scalable conduction switching characteristics as a result of doping with either natural oxygen deficiencies and A-site/B-site cations both in bulk and thin film forms.

This study aims to establish a synthesis route for memristive devices with optimized resistive switching characteristics based on ultra-thin STO thin films and multi-layered structures. RF magnetron sputtering with control over deposition parameters (i.e. process gas, RF power, substrate temperature) is employed to synthesize highly crystal STO thin films and multilayered structures on platinised silicon substrates at room and high temperatures. The process allows the control over thickness, structure and composition of the layered structures and therefore serves as a natural route for engineering defect driven conduction mechanisms in such functional oxides. These layered structures are then utilized as functional perovskite oxide layers in two electrode devices with cross-bar configuration. The voltage-current characteristics of scalable cross-bar devices, subject to a variety of parameters such as device size (functional area between top and bottom electrodes), defect/impurity concentration in functional oxide layers, oxide layers' thickness and crystal structure provides significant insights into the conduction and switching mechanisms, and the interplay between structural and functional properties in such devices.

8923-102, Session 22

Novel single dot test structure for determining specific contact resistivity

Yue Pan, Anthony S. Holland, RMIT Univ. (Australia)

Ohmic contacts between metal and semiconductor are extremely important for both the performance and study of semiconductors and semiconductor devices. Ohmic contact resistance can limit the performance of semiconductor devices. Specific contact resistivity (SCR) is an important parameter, which quantifies a metal-semiconductor ohmic contact. There are many methods to determine ?c, and one commonly used method is the circular transmission line model (CTLM). The CTLM consists of a central dot contact with two circular and concentric contact rings. The advantage of the CTLM is to simplify the sample preparation process, and it is suitable for irregular and small samples. In this paper we discuss the single dot test structure which is similar to the CTLM but has only two electrodes and is more convenient to use as the equations used for accurately deternmining SCR are much simpler.

The analytical equations for determining specific contact resistivity using the single dot test structure are developed and their accuracy is compared to finite-element modeling (FEM) results for typical metal-semiconductor parameters. Geometry effects on determining the specific contact resistivity and scaling behavior of the structure are also discussed in this paper. Experimental results were obtained for metal contacts to Si and SiC to demonstrate the accuracy of this novel test structure. Confidence in the value of specific contact resistivity obtained by this test structure can be increased by using several test structures where the geometry of the electrodes is changed.

8923-103, Session 23

Plasmonics: the convergence between optics and electronics *(Invited Paper)*

Timothy J. Davis, Commonwealth Scientific and Industrial Research Organisation (Australia)

No Abstract Available

8923-104, Session 23

Vanadium dioxide thickness effects on tunable optical antennas

Stuart K. Earl, Timothy D. James, The Univ. of Melbourne (Australia); Robert E. Marvel, Vanderbilt Univ. (United States); Daniel E. Gomez, Commonwealth Scientific and Industrial Research Organisation (Australia) and The Univ. of Melbourne (Australia) and Melbourne Ctr. for Nanofabrication (Australia); Timothy J. Davis, Commonwealth Scientific and Industrial Research Organisation (Australia) and Melbourne Ctr. for Nanofabrication (Australia); Jason G. Valentine, Richard F. Haglund Jr., Vanderbilt Univ. (United States); Ann Roberts, The Univ. of Melbourne (Australia)

Plasmonic antennas and metamaterials are currently being applied to a wide variety of situations, from sensing and communications to probing the quantum realm. While a significant amount of research has been done on tuning the resonances during the design phase, once fabricated they are intrinsically of a passive nature, lacking a way to modulate their resonances. The ability to reversibly "tune" these plasmonic resonances once the antennas are made would increase their potential range of application.

To introduce a measure of post-fabrication dynamic tunability of their resonances, we have fabricated a variety of optical antennas on a range of thicknesses of Vanadium Dioxide thin films supported by a substrate. The presence of the Vanadium Dioxide, a phase change material transitioned by heat, external stress, applied voltage/current and light itself, permits a dynamical, easily reversible modulation of the plasmonic resonances of the antennas it supports.

Here we present our latest developments, showcasing the reversible nature of the tuning mechanism, and suggesting a range of applications for which these materials are suitable. In addition, we compare the behaviour of the single antennas using near-normal incidence dark-field microscopy to that of periodic arrays of identical antennas to explore the effect of changing the thickness of the underlying Vanadium Dioxide layer on both single particle and antenna array resonance shifts.

8923-105, Session 23

Electron-beam lithography of plasmonic nanorod arrays for multilayered optical storage

Adam B. Taylor, Pierrette Michaux, James W. M. Chon, Swinburne Univ. of Technology (Australia)

Here, we demonstrate optical recording on EBL fabricated arrays of gold nanorods. Gold nanorods prepared via EBL provide an excellent medium for optical data storage, as the laser scattering from a nanorod is largely reduced after its melting by a laser pulse, yielding an effective method for both the recording a reading of data. In extending these arrays of aligned nanorods to a multilayer optical data storage (ODS) configuration, readout signal traversing the layers will encounter large extinction due to the scattering and absorption by the nanorods. This extinction can be mitigated with a set of techniques: modifying the alignment angle of the nanorods, detuning the laser polarisation,

and changing the thickness of the nanorods to some optimal value for each layer.

We will also present a technique for the experimental creation of multi-layer nanorod arrays using the EBL process, using a spacer layer large enough to ensure each layer can be individually resolved without cross-talk. This is achieved using a 12 µm thick spacing layer composed of the photopolymer SU-8. We have previously demonstrated creation of 16 layer nanorod media using this technique with wet chemical synthesized nanorods.

EBL has been used to create arrays of gold nanorods, which have been shown to work well as an ODS media.

Theory has been presented showing the full potential of these aligned nanorods in a multilayer media, and this will be compared with experimental results in the paper we will present.

8923-106, Session 24

Micromachined sensors operating in the infrared *(Invited Paper)*

Adrian Keating, Univ of Western Australia (Australia)

This talk presents a range of micromachined sensor technologies and operating modalities based on detection of infrared light. These technologies include microspectrometers, waveguide sensors and diffraction gratings. Micromachined parallel plate tuneable microcavities have been used to create microspectrometers suitable for object identification, gas sensing or soil monitoring in the short-wave (1.6-2.5 ?m) and mid-wave (3-5 ?m) infrared. Highly sensitive optical waveguides with cantilevers integrated into or above the waveguide are demonstrated for application in biological, gas, chemical and mechanical detection sensing systems. A deflection noise density of 16 fm/√Hz is estimated based on our designs, comparable to be best atomic force microscopy systems. Brownian motion limited performance is observed in these sensors and the technology can be optically actuated allowing the possibility of all-optical fiber fed sensors suitable for remote operation. These sensors can be operated from 1550-1610 nm, allow interrogation of large arrays of sensors on a single chip by utilising wavelength division multiplexing techniques. Finally, transmission through diffraction gratings micromachined from porous silicon with a pitch of 4 micron are demonstrated at a wavelength of 1550 nm. A significant change in the diffraction efficiency is demonstrated from exposure to isopropanol solvent vapour as a result of the induced index change in the porous structure due to it's large surface to volume ratio.

8923-108, Session 24

A Versatile Instrumentation System for MEMS-Based Device Optical Characterization

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The last three decades has seen major leaps in transitioning the science and art of spectroscopy from the laboratory to the field. As such, spectroscopic imaging continues to play an ever increasing role in today's world for many applications including agriculture, mineralogy, and environment.

More evolved spectral imaging systems may be realized through the use of MEMS optical transmittance devices with focal plane arrays. However, their wider application will benefit from knowledge of their optical properties at high spatial resolution and over a wide range of operating conditions. At The University of Western Australia we have built an experimental system for calibrated optical transmittance measurements with high spatial resolution and high spectral accuracy. Measurements can be carried out across a wide range of temperatures and with a spectral sensitivity ranging from visible to LWIR.

Prior to the development of the full system, a prototype system had been built for high spatial resolution room temperature measurements, though with a spectral range limited to NIR. The capabilities of both systems will be illustrated using recent results from MEMS devices.

8923-109, Session 25

Label-free single-cell analysis *(Invited Paper)*

Lydia L Sohn, UC Berkeley (United States)

Numerous methods have been developed to characterize cells for size, shape, and specific cell-surface markers. However, most of these methods rely upon exogenous labeling of the cells and are better suited for large cell populations (>10,000). In this talk, I will describe a label-free method of single cell screening my research group has developed. Our method is based on measuring a current pulse when a cell transits a microchannel. The pulse magnitude corresponds to cell size and the pulse width, to the cell's transit time across the channel. When the channel is functionalized with antibodies corresponding to specific epitopes on the surface of a cell, specific interactions between the antibody and the epitope cause the cell to slow down, leading to a longer pulse duration. Thus, cell-surface markers can be identified. I will discuss the utility of this technique by showing how we have been able to quantify the surface-marker expression of functional organ stem cells directly isolated from their micro-anatomical niche—something of which standard technologies cannot presently do. I will also show how, with the simple insertion of "nodes" along the channel, we are now able to screen for as many as n > 5 cell-surface markers in a single pass, making us competitive with multi-color flow cytometry. I will discuss our current efforts in using our multi-marker screening technique to immunophenotype patients with acute promyelocytic leukemia.

8923-110, Session 25

Buried picolitre fluidic channels in single-crystal diamond

Michelle A. Strack, Barbara A. Fairchild, Andrew D. C. Alves, The Univ. of Melbourne (Australia); Philipp Senn, The Univ. of Melbourne (Australia) and Bionics Institute (Australia); Brant C. Gibson, RMIT Univ. (Australia) and The Univ. of Melbourne (Australia); Steven Prawer, The Univ. of Melbourne (Australia); Andrew D. Greentree, RMIT Univ. (Australia)

Diamond is an extreme material that has the ultimate properties across range of metrics. In particular, diamond's hardness, chemical and bio-inertness, bio-fouling resistance, transparency and quantum-active colour centres, single it out for a range of novel applications [1]. Here we show the generation of sub-surface nanofluidic channels from single crystal diamond. To make the channels, we used a combination of ion-beam induced damage and annealing to create a buried, etchable graphitic layer in the diamond. Laser milling was then used to connect to that layer, and subsequent electro-chemical etching used to remove the graphitic material. These processes are extensions of the well-known diamond lift-off technique used to create thin diamond membranes [2, 3]. We show the generation of channels 100-200 nm thick, 100 ?m wide, 300 ?m long, which have a total volume around 3 pl, and around 3 microns below the diamond surface, which we characterize by infiltrating with fluorescent dyes.

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8923-111, Session 25

How to fabricate robust microfluidic systems for a dollar

Florian Lapierre, Commonwealth Scientific and Industrial Research Organisation (Australia); Neil Cameron, Department of Chemistry & Biophysical Sciences Institute (United Kingdom); John Oakeshott, Tom Peat, CSIRO (Australia); Yonggang Zhu, Commonwealth Scientific and Industrial Research Organisation (Australia)

Since the past decade, microfluidics has demonstrated a sea of applications in the field of biotechnology and energy. One branch of the microfluidic domain includes the emulsion study for various applications including cosmetic, food, mining, and therefore, offers a great interests for biology and chemistry industries [1]. For this reason, we have reported lately monodisperse water-in-oil microemulsion generated in microdevices [2-3]. These systems produced aqueous bioreactors in the range of 500nm to 10s µm diameter in an oil environment. However, an increasing demand for larger emulsion droplets has led us to investigate new techniques for fabricating fluidic devices. We report in this presentation an easy, cheap, reproducible and fast technology for generating emulsions in the range of 100s µm and much higher throughout. Simply using pipette tips and tubing, water-in-oil emulsions were created successfully with high throughput (up to mL/h) and with a range of 50µm to 500µm diameter droplets. This emulsion technique is currently used for various applications such as hydrogel, porous materials manipulation and cell culture in beads.

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8923-112, Session 25

Fabrication of scale-like microcantilevers for cell capturing

Boyin Liu, Jing Fu, Monash Univ. (Australia); Anthony Somers, Deakin Univ. (Australia); Murat S. Muradoglu, Tuch W. Ng, Monash Univ. (Australia)

The micro-domain provides excellent conditions for performing biological experiments on small populations of cells and has given rise to the proliferation of so-called lab-on-a-chip devices. Here, the creation of scale-like cantilevers, inspired by biomimetics, on chemically robust planar silicon nitride (Si3N4) film using focused ion beam machining is described. Using SEM and optical profilometry imaging, regular tilting of the cantilever with almost no warping of the cantilever was uncovered. Finite element analysis showed that the scale-like cantilever has stresses more evenly distributed along the edge than rectangular cantilevers. It also had a major advantage in that the degree of deflection could be simply tuned by changing the central angle without changing the effective trapping length. From a piling simulation conducted, it was found that a random delivery of simulated particles on to the scale-like obstacle should create a triangular collection. In the experimental trapping of polystyrene beads in suspension, the basic triangular piling structure was observed, but with extended tails and a fanning out around the obstacle. This was attributed to the aggregation tendency of polystyrene beads that acted on top of the piling behavior. In the experiment with bacterial cells, there was strong material collection all around the edge of the cantilever with very little pile up due to electrostatic surface adhesion. Overall, the fabricated scale-like cantilever architectures offer a novel and effective way to trap small populations of material in suspension.

8923-113, Session 25

Nanoimprint Lithography for Microfluidics Manufacturing

Gerald Kreindl, EV Group (Austria)

Micro and nano total analysis system fabrication technology has opened-up the development of a variety of bio- and chemical applications such as microfluidic and lab-on-a-chip devices. Nanoimprint lithography's (NIL) unique advantage is that topological-, chemical- and biological patterns can be generated at the micro- and nanometer scale which enable researchers to understand and manipulate basic biological and chemical processes to improve modern medical devices. Thus the ability to control fabrication processes and maintain resolution flexibility could lead to new devices with innovative properties such as increased analyzing speed and sensitivity. Several patterning techniques allow the fabrication of arbitrary or periodic patterns with sub micron resolution; however, polymer based devices require low cost and high throughput production solutions. Nanoimprint is a flexible and easily accessible production patterning technique for types of materials normally used in the microfluidic space, for example thermoplastic polymer sheets and spin-on thermoplastic layers. This technology enables the creation of 2- and 3-dimensional structures for large polymer channels (>100 µm) down to the fabrication of sub 100 nm features for bio- or chemical sensing. All these skills are making NIL an ideal solution for the development and production of next generation micro and nano total analysis systems.

Many of the global challenges being faced could potentially be resolved through harnessing the outputs of these enabling technologies, and through successful translation and commercialization of new products, services and systems. Imprint lithography in general enable and demonstrated the fabrication of next generation device with enhanced performance and reduce costs at the same time. This makes imprint an ideal supporting manufacturing technology to drive the commercialization of micro- and nanotechnology for medical and biological applications.

8923-114, Session 26

Nanophotonic light trapping for high efficiency solar cells *(Invited Paper)*

Kylie R Catchpole, Australian National University (Australia)

Light trapping is of fundamental importance in many types of solar cells to allow maximum efficiencies, and hence lowest costs, to be reached. We show that that light trapping can lead to substantial efficiency increases using rear surface scattering, near-field enhancement and for tandem solar cells.

A doubling of the photocurrent due to light trapping is demonstrated by the combination of silver nanoparticles with a highly reflective back scatterer on the rear of a silicon thin film solar cell. Modelling indicates that adding plasmonic nanoparticles to the back scatterer widens the angular distribution of scattered light such that over 80% of long wavelength light is scattered outside the Si/air loss cone and trapped in the cell, compared to 30% for the titania alone.

We also propose a planar ultra-thin absorber concept exploiting plasmonic resonance absorption enhancement. We calculate a maximum absorption of 90% for TM polarized normally incident light in a 5 nm thin-film absorber with a single-pass absorption of only 1.7%. This corresponds to an effective path length enhancement of 135 times. Broadband and wide-angle absorption is demonstrated.

Tandem solar cells based on crystalline silicon present a practical route toward low-cost cells with efficiencies above 30%. We evaluate inorganic thin-film top cells in a tandem stack with a high-efficiency c-Si bottom cell. We show when light trapping is incorporated, even relatively low quality earth-abundant semiconductor materials with luminescence efficiencies of 10-5 and diffusion lengths below 100nm are compatible with tandem cell efficiencies above 30%.

8923-115, Session 26

Light trapping for >30% tandem solar cells built on c-Si

Niraj N. Lal, Thomas P. White, Kylie R. Catchpole, The Australian National Univ. (Australia)

Industrial silicon solar cells are rapidly approaching the 25% laboratory cell efficiency record that has stood for over 15 years. To further reduce the cost per Watt of solar energy, future industries will look towards technologies that go beyond 25%. Leveraging the success of c-Si solar cells, one such approach is to utilise high-bandgap earth-abundant semiconductors in top tandem cells placed above an underlying silicon cell. To achieve efficient tandems solar cells based on such materials, it is important to understand the effect of optical design on device performance.

We present key design parameters for optimising light distribution in these devices using simple analytical models. The parasitic light absorption of two transparent conducting layers is found to require top-cell efficiencies greater than 15% to achieve a break-even tandem efficiency of 25%. Low-pass intermediate reflectors are observed to be detrimental to tandem performance, and single-pass absorption is identified to be preferable to Lambertian light trapping with losses. Clear design principles are outlined to avoid these losses and simple light trapping mechanisms are proposed that distribute light effectively across the tandem cell.

We present detailed Figure of Merit calculations for various light trapping mechanisms, outline a broad overview of top cell requirements to reach specific target efficiencies, and identify key design recommendations that will enable the field to get there.

8923-116, Session 26

Improved metal nanoparticle fabrication for solar cell applications

Tristan L. Temple, Macquarie Univ. (Australia) and CSIRO (Australia); Svetlana Dligatch, Commonwealth Scientific and Industrial Research Organisation (Australia)

Metal nanoparticles can strongly scatter and/or absorb light due to the excitation of localized surface plasmons (LSPs). Scattering of light can be used to improve absorption within solar cells by increasing the optical pathlength. Conventional light-trapping schemes require texturing of the semiconductor layer, which can deteriorate the device performance. Metal nanoparticles remove this need, but introduce additional design and fabrication complexity. The optical properties are dependent on the size, shape and arrangement of the metal nanoparticles, and the large parameter space makes optimisation challenging.

Metal island films can be fabricated over a large-area at low-cost. The size, shape and arrangement of the nanoparticles is dependent on both the deposition and the anneal conditions. We show that parameters such as the substrate type, metal, deposition rate, film thickness and anneal temperature all influence the morphological and hence the optical properties of the metal island film. We present a combinatorial approach to process optimisation which is based on the deposition of layers with a graded thickness profile. This enables the rapid fabrication and testing of a wide range of metal island film parameters.

Furthermore we report on the influence of bombardment by Ar ions after metal island film growth. Ion-bombardment of a silver island film results in a gradual milling of the nanoparticles, which reduces the lateral size and changes the overall shape from hemispherical to disc-like. The change of shape shifts the resonance, reduces particle-particle interaction and also changes the optical coupling to the solar cell.

8923-117, Session 26

Plasmonic nanoparticles enhanced dye sensitized solar cells

Qi Xu, Fang Liu, Yuxiang Liu, Weisi Meng, Yidong Huang, Tsinghua Univ. (China)

Here we present investigations on utilizing three different kinds of plasmonic nanoparticles (NPs) to enhance the optical absorption and power conversion efficiency (PCE) of dye sensitized solar cells (DSCs).

As a novel metal-organic core-shell NPs structure, Au@PVP NPs present not only the chemical stability to iodide/triiodide electrolyte, but also the adhesiveness to dye molecules, which could help to localize most of dye molecules around plasmonic NPs, hence increasing the optical absorption consequently the power conversion efficiency (PCE) of the DSCs by 30% from 3.3% to 4.3%.

To realize broadband optical absorption enhancement of DSCs, the Au-Ag alloy popcorn-shaped nanoparticles (NPs) are proposed and fabricated. Both simulation and experimental results indicate that, the irregular popcorn-shaped alloy NP perform a pronounced absorption enhancement in a broadband wavelength range due to the excitation of localized surface plasmon (LSP) in different wavelengths. The power conversion efficiency (PCE) of DSCs is enhanced by 32% from 5.94% to 7.85% which results from the broadband LSP enhancement of the popcorn NPs.

An aluminum (Al) NPs enhanced DSC structure is proposed and realized. Compared with the traditional plasmonic metal NPs, such as gold NPs, aluminum NPs has lower work function which would result to reduce the recombination of carriers within the photoanodes and the chemical stability in electrolyte. Both photovoltaic and photochemical characterization demonstrate that the DSCs incorporated with Al NPs present a good performance in the optical absorption efficiency as well as the PCE, and the PCE is improved by 12% from 6.15% to 6.89%.

8923-118, Session 26

Ageing effects on plasmonic properties for solar cell applications

Supriya Pillai, Yang Yang, Yajie Jiang, Martin A. Green, The Univ. of New South Wales (Australia)

Metal nanoparticles are known for their unique optical properties due to surface plasmon excitations. The far field and near field effects from these metal particles have been captured to enhance efficiency of thin film solar cells by way of light trapping. Our group has extensively studied the different design parameters for a plasmon enhanced solar cell like effect of metal size/shape, location, effect of dielectric layer thickness and also the effect of plasmons on the electrical properties like passivation of cells. Whilst identifying and minimising parasitic absorption losses in these metal particles are important and is attracting lot of attention, we choose to look at a more interesting issue of ageing effects. Plasmonics at the moment promises efficiency enhancements exceeding 30% including associated losses in metals. However as is needed for solar cells, the technologies incorporated have to stand the test of time. In this work we look at the age effects on the plasmon performance by analysing our cells over time. Our preliminary results show that plasmons supported by silver metal nanoparticles can degrade by upto 10% with time. Metal nanoparticles when exposed to air can get tarnished easily causing degradation of the plasmonic properties [1]. This will result in weakening of the scattering and reduce light trapping effects. We also look at ways of minimizing the ageing losses by overcoating. MgF2 is used as the dielectric film to overcoat metal nanoparticles preventing degradation and also to isolate MNP layer from the back surface reflector of cells. Our results show that such a rear scheme brings an additional current enhancement of upto 4% over interested wavelength region improving over time.

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8923-119, Session 27

Carbon nanotube and graphene: from fluid phases to multifunctional materials *(Invited Paper)*

Matteo Pasquali, Rice Univ. (United States)

Carbon Nanotubes (CNTs) and graphene have remarkable electrical, thermal, and mechanical properties, more so than previously known polymers and colloids. Realizing these properties in applications requires understanding and control of fluid phases. Yet, this is almost an oxymoron because dispersing CNTs and graphene into fluids is exceedingly difficult.

CNTs and graphene should be viewed as hybrids between polymers and colloids. At low concentration, CNTs form complex fluids with intriguing properties. In crowded environments (e.g., gels), CNTs reptate like stiff polymers; surprisingly, their small bending flexibility enhances rotational diffusion and decouples it from the network pore size. In strong acids, CNTs and graphene dissolve spontaneously. At low concentration, these solutions can be processed into transparent, conducting films, coatings, and highly porous three-dimensional structures. At high concentration, CNTs and graphene form liquid crystals that can be spun into macroscopic fibers. High quality CNTs yield high-performance multi-functional fibers that combine the specific strength, stiffness, and thermal conductivity of carbon fibers with the specific electrical conductivity of metals. These fibers are positioned for high-value applications, such as aerospace electronics and field emission, and can evolve into engineered materials with broad long-term impact, from consumer electronics to long-range power transmission.

8923-120, Session 27

Tunable reduction and amorphisation of graphene oxide films by focused ion beam irradiation

Derrek E. Lobo, Jing Fu, Mainak Majumder, Monash Univ. (Australia)

Graphene has risen to prominence as a versatile and scientifically intriguing material with tremendous potential. Making its fabrication a key research area extensively worked on by the scientific community at large. An intriguing and innovative rout to its synthesis is the spatially patterned reduction of the electrically insulating graphene oxide (GO) to the conductive reduced-graphene oxide (rGO).

This method opens up a top down fabrication approach for all-carbon based electronic devices with the ability to directly write conductive pathways into an electrically insulating material. The use of focused ion beam (FIB) irradiation to achieve this has been proven1. Here we explore the sensitivity of this approach, analysing the key parameter of ion dosage.

Presented are the results of a systematic study where the ion dosage was varied from 0-0.204nC/μm2, with analysis of Raman spectroscopy and atomic force microscopy (AFM) to determine the effect on the surface morphology of the sample. We demonstrate that increasing dosage results in the preferential reduction of the GO being overridden by amorphisation of the sample, leaving us with two regimes, one where the major effect of ion irradiation is preferential removal of oxygen resulting in rGO and another where there is an increase in damage to the sample, leading to major disruptions of the carbon lattice and hence amorphisation. Transition between these regimes is gradual allowing for us to tune the effect of the irradiation, a key aspect in using the FIB for the fabrication of micro to nanoscale patterns, to suit desired application.

8923-121, Session 27

New efficient p-n heterojunction of BiOI/TiO2 nanotube arrays with enhanced visible-light photoelectrocatalytic activities

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BiOI is a promising visible-light response photocatalyst with a narrow band-gap of 1.94 eV. TiO2 nanotubes arrays (TNTAs) has attracted tremendous interest due to its huge specific surface area, highly ordered structure, superior light energy trapping and charge separation and transfer characteristics in photocatalysis, sensing and photovoltaics. In this paper, a new efficient p-n heterojunction of BiOI/TNTAs with high visible-light photoelectrocatalytic (PEC) activities was achieved via potentiostatic anodization of Ti foils followed by sequential chemical bath deposition method. The obtained samples were characterized by X-ray diffraction, electron microscopy, UV-Vis diffuse reflectance spectroscopy and Nitrogen adsorption-desorption isotherms. The PEC activities toward degradation of methyl orange (MO) solution under visible-light irradiation (? > 400 nm) by p-n junction of BiOI/TNTAs was further investigated. The results demonstrate that TNTAs consisting of separated nanotubes with large intertube gaps was first fabricated via increasing the water proportion in electrolyte to 8 vol% and BiOI nanoflakes were loaded uniformly onto both inner and outer surface of TiO2 nanotubes. The junction of 5-BiOI/TNTAs with 5 deposition cycles showed much higher PEC and PC activities as well as great stability due to the synergetic effects of several factors including strong visible absorption by BiOI, large tube spacing between separated nanotubes for more facile penetration of dye solution, large specific surface area for increasing the contact between dye molecules and catalyst, and the formation of p-n junction for effectively separation of photogenerated electron-hole pairs. The proposed mechanism responsible for the enhanced performance was further confirmed by the transient photocurrent response test.

8923-122, Session 27

Surface acoustic waves-assisted technique for generation of individual carbon nanotubes and their shear-induced alignment

Morteza Miansarigavzan, Monash Univ. (Australia); Aisha Qi, RMIT Univ. (Australia); Mainak Majumder, Monash Univ. (Australia); James Friend, RMIT Univ. (Australia)

Carbon nanotubes are widely known to agglomerate and consequently be difficult to separate without substantial manipulation. Surface acoustic waves (SAWs) have fascinatingly been found to rapidly deagglomerate large aggregates of multi-walled carbon nanotubes (CNTs), with approximate diameter of 10s of nanometers, and furthermore assist to align debundled CNTs in an entirely dry process. This technique allows separation of larger CNTs from individual and submicron size bundles by ejection of large CNT bundles when exposed to high impact forces caused by high acceleration of SAWs on the piezoelectric substrate (LiNbO3). Shear-induced alignment of the CNTs over a substrate with centimeter length scale could be obtained during the deagglomeration process. The whole process completes within less than 10s. The images captured by scanning electron microscopy were post-processed using a Matlab code to estimate the CNT yield and degree of alignment. To analyze the effect of SAW on the CNTs, the Raman spectroscopy was used, and it has been found that CNTs are not affected by SAWs since there was no remarkable change in the intensity of the D band. A unique and simple approach, it offers a broad collection of advantages by avoiding surface modification and immersion to rapidly separate and align large numbers of CNTs.

8923-123, Session 27

Porous CNTs/chitosan composite with lamellar structure prepared by ice-templating

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Chitosan possesses beneficial properties such as its biodegradability, biocompatibility, and adsorption of metallic ions, which make it attractive in various applications. In addition, besides excellent mechanical and electrical properties, carbon nanotubes have been reported to be biocompatible platforms for neuronal growth and differentiation. In this work, porous carbon nanotubes/chitosan (CNTs/CHI) composites are prepared by unidirectional freezing CNTs dispersion in chitosan aqueous solution and subsequent freeze drying, which is named as ice-templating. Two types of macroscopic morphologies with high and low aspect ratio are produced by immersion freezing and one-side contact freezing respectively. The influences of experimental factors such as freezing rate and concentration to the micro-structure of products are investigated. The SEM characterization indicates that the produced CNTs/CHI composites are composed of a three dimensional network with lamellar structure and macropores in micron scale, and the products by two freezing styles have different structural characters. The specific surface area of the produced porous CNTs/CHI composite is up to 30m2/g. The porous CNTs/CHI composite has a high porosity and good mechanical strength, which makes it having very good permeability and processability. It is anticipated that the CNTs/CHI composites have various applications such as conductive network in polymer, biological carrier, catalyst supports, adsorbents, and permeable membranes.

8923-124, Session 28

Molecular motors-powered devices: twenty years after *(Invited Paper)*

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Molecular level biological motility is central to cellular motion, muscle contraction, cell division and a multitude of other critical biological processes. Protein molecular motors are natural nano-machines that convert the chemical energy obtained from the hydrolysis of adenosine triphosphate (ATP) into mechanical work. Remarkably, protein molecular motors differ fundamentally from artificial devices in that the conversion from chemical energy to mechanical energy is done directly, rather than via an intermediary state as in e.g., heat for thermal engines. This fundamental difference results in a far better efficiency (close to 100%, for both linear and rotary motors) of these natural mechanical devices compared to artificial ones. This exceptional efficiency, together with the small scale of protein molecular motors, has prompted an increasing number of studies focused on their integration in hybrid micro- and nanodevices. However, and despite tremendous progress in the engineering of molecular motors, much needs to be learnt from Nature, in particular regarding the cooperative behaviour of molecular motors in vivo, before coming even close to the same efficiency in in vitro devices. The contribution will review the progress made from the first attempt in to integrate molecular motors in artificial devices in 1995; and the challenges and opportunities ahead.

8923-125, Session 28

Integrated microdroplet-based system for enzyme synthesis and sampling

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Microdroplets in microfludic devices are emerging as a powerful technique for a range of screenings and analyses. In these systems, monodispersed aqueous microdroplets of picoliters to nanoliters volume are formed in an immiscible oil phase within a microfluidic channel. The microdroplets can contain various reagents for chemical reactions and can be regarded as a discrete bioreactor [1,2].

We presents here an integrated microfluidic platform for the synthesis, screening and sorting of libraries of variants of a specific enzyme. The enzymes are synthesized inside an emulsion of microdroplet bioreactors from a DNA source using in vitro transcription and translation. Moreover, this system integrates bioreactors observation and control via an Arduino board. This interface allows the communication between camera, syringe pumps and high power supply in order to interact with the bioreactors. Therefore, each bioreactor is sorted depending on their fluorescence activity (and so, on the ability for the enzyme to be synthetised and to react with a specific substrate).

Therefore, this micro-droplet based system integrates the essential steps from the enzymes' synthesis to the selection of the best genes (producing the highest enzyme activity) inside a single and unique device. An overview of the system will be presented as well as its limitations.

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8923-126, Session 28

A microfluidic device for studying cell signalling with multiple inputs and adjustable amplitudes and frequencies

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In its survival, cells build intracellular networks of signal cascades upon the reception of certain extracellular changes which initiate cell responses. It is believed that cells respond in accordance with the specificity of the stimulus as well as its intensity. However, the way in which cells sense multiple inputs is less understood. Moreover, the temporal aspect of stimulus, which involves the modulation of amplitude (intensity), frequency of signals and relative phase (between two inputs), have raised an urge to explore cell signalling pathways due to the complexity of many unpredicted signalling pathways. Two hormones, Epidermal Growth Factor (EGF) and Nerve Growth Factor (NGF) will be used in this research as cell stimulants. Even though they share the same signal transduction pathway, they give different cellular outcomes, proliferation and differentiation respectively. Extensive study has been done to answer the main reason behind the difference. Nonetheless, the study of temporal effect of those two hormones in combination toward cells has not yet been established.

This research tries to scrutinize the effect of amplitude and frequency modulation of EGF and NGF toward PC 12 cells using a microfluidic device. The PDMS microfluidic system, produced through a photolithography and soft lithography process, is set to have a controllable temporal pattern in delivering the multiple stimulants through the structure shape modification and programmable delivery system. It is expected that the research will produce a unique microfluidic system that accommodate the combinatorial temporal effect of EGF and NGF which will significantly affect our understanding of cell signalling, especially in relation to cancer treatment (proliferation) and brain development (neurite outgrowth).

8923-127, Session 28

Micro pore arrays in free standing cyclic olefin copolymer membranes: fabrication and surface functionalization strategies for in-vitro barrier tissue models

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In vitro barrier tissue models rely on porous membranes with specific requirements. The membrane needs to (1) have pores which are smaller than the endothelial cell nucleus to prevent transfer of cells from one compartment to another (2) be thin enough to allow efficient mass transport (3) be fabricated with a simple, low-cost method as the experiments require single use components (4) be made of a material which is optically transparent for direct visualization and with low autofluorescence for imaging by fluorescence microscopy (5) have surface chemistry suitable for efficient cell proliferation. COC comes forward as an ideal thermoplastic material with its ease of fabrication, biocompatibility, and optical properties. We have developed a simple hot embossing based fabrication method to create free standing COC membranes with controllable pore size and membrane thickness. First indentations are created by hot embossing on a spin coated COC/poly vinyl alcohol (PVA) layer. The residual layer in the indented areas was removed with brief oxygen plasma etching step. The membrane was released in water by dissolving sacrificial PVA layer. Finally, the membrane was integrated with a microfluidic chip allowing seeding and culturing of cells on the membrane. The microfluidic chip was fabricated with polydimethy siloxane allowing direct visualization for time lapse imaging and fluorescent characterization. Endothelial cells (HUVEC) were cultured on the membrane indicated efficient proliferation and monolayer formation. The successful adhesion and proliferation of HUVEC suggests this membrane should be a useful component for building in vitro tissue models.

8923-128, Session 28

Modeling of the blood-brain barrier under flow: a microfluidic approach

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The blood-brain barrier (BBB) is a specialized interface between the circulation and the brain tissue that controls and regulates the brain environment comprising of specialized endothelial cells (ECs) that are supported by astrocytes, pericytes, microglia and neurons to form the "neurovascular unit". Static BBB models using Transwells are more

commonly used, with a major drawback that cells are cultured in the absence of shear stress that is normally present in brain capillaries. A dynamic model using standard microfluidics is developed to provide adequate shear stress conditions and also enables co-culturing of human ECs and astrocytes, the two key cell types of the BBB. The ECs in the microchannels are maintained on a porous membrane under regulated shear conditions in close proximity to astrocytes for 3 days. The model provides cells with a microenvironment highly similar to the one presented in brain capillaries and planar design optimized for excellent imaging capability. The ECs and astrocytes are examined by phase-contrast microscopy to assess general morphology and confluence. The formation of tight junctions was tested by staining of actin filaments (using fluorescent phalloidin) and by immunostaning of the tight junction protein ZO-1. Cells in the microchannel appeared healthy and confluent, with some polarization of the ECs in the direction of the flow. Localization of actin filaments and ZO-1 to cell-cell boundaries indicated the presence of tight junctions between ECs in our model. These promising results prove the feasibility of our approach and lay solid foundation for embedding microfluidic devices in future BBB research.

8923-129, Session 29

Bright and stable quantum dots and their application to display *(Invited Paper)*

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Recently, we demonstrated large size quantum dot-light emitting diode (QD-LED) TVs with color reproducibility of 100% compared to the NTSC (National Television Systems Committee) color space in CIE 1931.(1) To prepare the white backlight unit, red and green light emitting QDs were employed as color converters in blue LEDs. The QDs are required to be highly luminescent and stable against different chemical surroundings, thermal curing condition, and intensive radiation. We have designed novel QD structures with specifically tuned wavelengths and improved stability. (2,3) In addition, the reaction parameters were optimized for more reliable and scalable synthetic process.(4-6) We also prepared QD-silica composite that was homogeneously doped with up to 20wt% QDs using highly compatible ligands. The external efficacies of red and green QD-LEDs reached up to 89% and 63% respectively. And, the white QD-LED for display backlight, made with separately encapsulated in silica composite, showed the highest efficacy (47lm/W) ever reported. (7)

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8923-130, Session 29

Proposal of a Si based device for multiplexing conversion between PDM and MDM

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A novel concept for a compact silicon-on-insulator (SOI) device used to perform the conversions between the polarization division multiplexing (PDM) and the mode division multiplexing signals (MDM) is proposed and theoretically demonstrated. The proposed device can be useful for accommodating the future fiber optic communication networks which utilizing multiple multiplexing techniques. The detailed design is given and simulated by utilizing a structure combining a two dimensional (2D) grating coupler and a two-mode multiplexer. The 2D grating coupler is used to couple the PDM signals from the fiber into the SOI chip and demultiplex the signals with orthogonal polarization states. The demultiplexed signals (both fundamental modes) share the same TE polarization in the waveguide and then transmit into the mode multiplexer, which will convert the fundamental modes into first order or keep unchanged, according to the input ports. Thus it will be able to obtain the MDM signals consisting of one fundamental and one first-order modes carrying the information from original PDM signals. Vice versa, by exchanging the input and output ports of the proposed device the contrary conversion from the MDM to PDM can also be achieved. Moreover, the structure of the mode multiplexer is specifically designed to improve the fabrication tolerance. The 3D finite difference time domain (FDTD) simulation method is utilized to validate the feasibility of the proposed structure, and the simulation results show the good performance of the device.

8923-131, Session 29

Planar optofluidic sensing platform exploiting the transition between trapping and discrete diffraction in waveguide arrays

Eike Zeller, Geethaka C. Devendra, Thach G. Nguyen, Arnan Mitchell, RMIT Univ. (Australia)

In recent years, the research area of optofluidics has emerged, investigating the integration photonics and microfluidics. Optofluidic devices have enabled fluid sensors with extraordinary sensitivities [1]. Hence, numerous optofluidic sensing concepts have been demonstrated with application in fields such as label-free biosensing [2].

Coupled waveguide arrays are a field of active research [3] due to the extraordinary capabilities for light manipulation. In homogenous waveguide arrays light couples between waveguides and thereby spreads laterally. This process is called discrete diffraction. Light can also be trapped within a defect waveguide that exhibits a geometry different to the other waveguides [4].

Here we show a novel planar optofluidic refractive index sensing platform based on a tunable coupled waveguide array. We show the transition between trapping of light in a defect waveguide and discrete diffraction. The defect waveguide is engineered such that, at a particular wavelength, light is trapped in it. An increase in wavelength stops the confinement in the defect waveguide and allows the lateral spreading of light via discrete diffraction. A change in the fluid's refractive index shifts the spectral location of this transition.

The waveguide arrays are fabricated in UV-curable epoxy polymers using standard photolithography techniques. Experimental results show a sensitivity in the order of a 1000 nm shift per refractive index unit and agree well with performed beam propagation simulations.

In conclusion, we demonstrate a novel refractive index sensing platform based on the fluid tunable transition between trapping and discrete diffraction in waveguide arrays. The platform is compatible with aqueous solutions, making it an interesting candidate to be used for label-free biosensing.

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8923-132, Session 29

Chiral elements and dual systems: towards the design of an omnidirectional optical active media

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Helicity defined as the projection of the total angular momentum onto the direction of linear momentum has been revealed as the magnitude behind the preservation of electromagnetic duality. Such magnitude is naturally preserved in vacuum, but we will show the possibility and benefits of preserving the electromagnetic duality in matter.

The consequence of preserving the helicity shows how to generalize the Kerker conditions. We will show that tuning properly the angular momentum and the focusing of light any sphere can be excited to behave as a dual or anti-dual. Being the scattering in the backward or forward direction null, respectively. This information will be given by the Mie coefficients.

Moreover, the helicity also allow us to design a system where the angular scattering through a chiral medium does not dependent of incident polarization of light. Yet, traditionally the only requirement considered for designing a system for having optical activity is the geometrical property of lack of all mirror symmetries. However, this requirement only fulfils the condition for a polarization independent optical active response when the chiral elements are distributed randomly oriented, and only in the forward and backward scattering directions. In this context, we will present the importance of the invariance of electromagnetic duality transformation and lack of any mirror symmetries for the design and control of optical active medium.

Finally, we aim to show the path for an optimal design of optical active media by combining dual elements in chiral media. This result will be relevant for chiral metamaterials.

8923-133, Session 29

Steady state design of photonic transistor to achieve a switching gain>=3 dB

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A recently proposed two-staged photonic transistor that provides switching gain is based on the directional coupler with an active arm and a passive arm in each stage. The manipulation of optical interference through optically-controlled gain caused the switching. In the first stage, a long wavelength input signal pulse depletes carriers to change absorption and switch a short wavelength beam into the second stage. In the second stage, the switched short wavelength beam fills the conduction band with carriers to increase the gain seen by another long wavelength pump beam to switch it as the output signal. Through a suitable design of intensity and wavelength of the interacting beams and the length of each stage, photonic transistor exhibits switching gain and hence can drive multiple stages (high fan-out and cascadability). The smaller the detuning of wavelength between the interacting optical fields or shorter the photonic transistor length, smaller is the cumulative change in linear absorption/gain, manifesting in a smaller switching gain. Since the short wavelength beam fills the conduction band with carriers, its intensity depends on the ground state absorption of the medium, ?0. And, since the long wavelength beam depletes carriers filled by the short wavelength beam, its wavelength depends on the gain of the pumped medium, g0. In this paper, we show that the operational intensities of photonic transistor must be such that |?0L1|>27 and g0L2>3.2 to achieve a gain>3dB, where L1 and L2 are the length of 1st and 2nd stages respectively.

8923-134, Session 30

Hydrothermal method for piezoelectric materials and their applications *(Invited Paper)*

Takeshi Morita, The Univ. of Tokyo (Japan)

The hydrothermal method utilizes chemical reactions in solutions, which enables low reaction temperature, three-dimensional substrate availability, and automatic polarization alignment during the process. In this presentation, powder synthesis, the piezoelectric thin films deposition, and their applications are introduced. As the piezoelectric materials, a polycrystalline lead zirconate titanate (PZT) film, an epitaxial lead titanate (PbTiO3) thin film, KNbO3 films and lead-free piezoelectric powders (KNbO3 and NaNbO3) powders were synthesized by the hydrothermal method. In addition, the ultrasonic assisted hydrothermal method was developed in order to enhance the chemical reactions. As a result, a 156 ?m thickness of KNbO3 was realized that was 5 times thicker than that without ultrasonic irradiation.

8923-135, Session 30

Investigation of periodically poled 128° YX-cut LiNbO3 achieved with UV direct-written technique for SAW generation

Andreas Boes, Didit Yudistira, Amgad Rezk, RMIT Univ. (Australia); Elisabeth Soergel, Rheinische Friedrich-Wilhelms-Univ. Bonn (Germany); Scott A. Wade, Swinburne Univ. of Technology (Australia); James Friend, Arnan Mitchell, RMIT Univ. (Australia)

Previously it has been reported that periodic domain inversion in Z-cut lithium niobate (LiNbO3) can be used to generate surface acoustic wave (SAW), where the domain inversion was achieved using electric field poling technique. Its applications in the integrated optics have been reported, but, in many other SAW applications such as in Microfluidics, 128° YX LiNbO3 is preferable because it has the largest coupling constant. However, in 128° YX LiNbO3 domain inversion cannot be achieved using the aforementioned technique due to the inclined polarization axis. It has been recently reported that a strongly focused UV laser beam can invert locally the polarization on the non-polar faces of lithium niobate. In this contribution we investigate the feasibility of employing periodically poled 128° YX-cut LiNbO3 fabricated with UV direct writing for SAW generation.

The inverted domains were obtained by scanning a focused continuous UV laser beam (? = 244 nm, I = 3.2 x 10^5 W/cm^2, d = 6 µm) perpendicular to the x-axis across the crystal surface. The scanning velocity was maintained constant at 0.1 mm/s for the given laser parameters. The achieved domain pattern was then visualized with a piezoresponse force microscopy (PFM) and revealed by hydrofluoric acid (HF) etching, and subsequent SEM imaging. This allowed us to retrieve information about the shape, the depth and the width of domain, which were then used as parameters in the design and simulation. Numerical simulation was performed using finite element analysis to determine the influence of these parameters on the SAW generation.

8923-136, Session 30

SAW generation in acoustic superlattice lithium niobate: methods of converting bound acoustic resonances to propagating waves

Didit Yudistira, Andreas Boes, James Friend, Arnan Mitchell, RMIT Univ. (Australia)

Acoustic superlattice (ASL) transducer has been known as an alternative means to generate high surface acoustic wave (SAW). However, due to the presence of SAW band gap in the ASL structure, originated from polariton-based mechanism, the generated SAW is a non-propagating wave, hence, limiting its applictions. A way to engineer the ASL structure to allow the convertion from bound acoustic resonance to propagating waves are required. In this paper we present a number of techniques for releasing these bound acoustic waves from the ASL transducer. We present rigorous numerical analysis and also progress towards practical realisation and demonstration.

8923-137, Session 30

Characterization and modeling of nitrogen-vacancy color center patterning in diamond by scanning focused helium ion beam

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Previously, ion implantation and electron irradiation have been demonstrated to create N-V centers in diamond [1], however there are still significant challenges for accurately patterning N-V centers. A number of methods for creating N-V centers have been proposed, including nitrogen implantation[2], electron irradiation, the recently reported mask based ion implantation[3], etc..

In this work, we demonstrate formation of N-V centers in diamond with arbitrary high-resolution patterns by directly exposing the diamond (with nitrogen impurity) using a scanning focused helium ion beam and subsequent annealing. The spatial distribution of N-V centers patterned by the focused helium ion beam is characterized by both fluorescence confocal microscope and super-resolution microscope. A numerical model combining Monte Carlo simulation of the lattice vacancy creation by helium ions and diffusion of created vacancies during annealing is presented to compare with the experimental characterization. Both experimental characterization and numerical model show that one advantage of our method is that the injected helium ions have a small interaction volume in the diamond substrate, therefore diamond lattice vacancies created by helium ions have a small spread in both lateral and vertical dimensions. Our work provides a promising approach to local placement of NV color centers with high spatial accuracy.

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8923-138, Session 30

Non-intrusive tuneable resonant microwave cavity for optically detected magnetic resonance of NV centres in nanodiamonds

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This paper presents a non-intrusive measurement approach of the Optically Detected Magnetic Resonance (ODMR) in nitrogen vacancy (NV) centres in nanodiamonds, based on a specifically designed dielectric microwave resonator.

Typically ODMR in NV centres in diamond is achieved by applying a microwave field delivered by micron-size wires, strips, coplanar or antenna, directly created in very close proximity of deposited nanodiamonds on a coverglass. The microwave field then couples evanescently with the ground state spin transition of NV centre (2.87 GHz at zero B field), which results in a reduction of photoluminescence detected from the defects. Our method based on the construction of a dielectric resonator allows detecting NV spins in nanodiamonds without the constraints associated to the stripe lines, providing also a wider volume of possible interaction. We design and build an open tuneable Transverse Electric Mode dielectric-loaded cavity to respond to the need of a non-intrusive ODMR of single NV centres in diamond. We demonstrate that the resonator can detect single NV centre spins in nanodiamonds using less microwave power than other methods. This method can achieve higher precision measurement of ODMR of paramagnetic defects spin transition in the micro to millimetre-wave frequencies. Due to recent exciting applications in the use of nanodiamonds containing NV for spin labelling in biological systems at the single spin and single particle level, our approach would permit to track NV centres in biological solutions rather than simply on a surface.

8923-28, Session 31

Fabrication and micro-patterning of polymeric electrospun nanofibers for biomedical applications *(Invited Paper)*

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Biological applications have the need for the development of artificial scaffolds capable of recreating the conditions necessary for bone tissue regrowth. Developing such artificial scaffolds that mimic the architecture of bone tissue at the nanoscale level is one of the major focuses in the field of tissue engineering. The nanoscale topography of such scaffold surface is critical for the capacity of osseointegration and these features make polymeric fibers excellent candidates for fabrication of implant surfaces and for controlled prosthetic drug delivery. The procedures for creating such scaffolds require the fabrication and micropatterning of nanoscale polymeric electrospun fibers. Our current research project at the Stem Cell Instrumentation Foundry (SCIF) in the University of California, Merced, will focus on the development of such scaffolds with aligned polymeric nanofibers composed of SU-8, an epoxy based negative photoresist. The electrospinning process is a simple, versatile, and widely used method of producing nanofibers by applying a high voltage (typically 5-30 kV) to create an electrically charged jet of a polymer solution, which solidifies to leave a polymer fiber. These nanofibers will then be patterned by photolithography and/or by using near field electrospinning technology. We aim to show that the electrospun biocompatible polymer retains its photoresist properties and that it can be micropatterned to create nanoscaffolds. Such patterned nanofibers will then be functionalized by adhering cells and by incorporating various growth factors. The optical analysis of the patterned nanofibers will be performed using confocal microscopy and the correlation of cell differentiation and proliferation with respect to the topography of the patterned functionalized nanofibers will be analyzed for scaffolding as well as implantable medical device applications.

8923-140, Session 31

A fabrication method of out-of-plane stretchable electrodes based on PDMS

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We developed two types of stretchable electrodes based on PDMS substrate using MEMS fabrication processes of out-of-plane structures. One has a straight metal line attached and suspended alternately on the substrate along its length while the other has a serpentine metal line suspended above the substrate along its entire length. Suspended metal lines were created on a parylene layer that was deposited and patterned on the sacrificial photoresist pattern on PDMS substrate. The metal lines were covered by a second parylene layer, thereby encapsulated and electrically insulated. The removal of photoresist left the parylene-encapsulated metal lines suspended. The former, the stretchable electrode with straight line, was designed for use in highly integrated devices and devices demanding relatively small deformations. On the other hand, the latter, the stretchable electrode with serpentine line, was intended for devices that require large deformations. In serpentine electrodes, the parylene layer was attached with PDMS substrate through parylene posts located nearby the metal line, which restrained lateral movements of the metal line. The static/dynamic stretch tests of the fabricated electrodes were performed using our custom-designed test module to characterize the stretchability of the fabricated electrodes. The fabricated electrodes were also twisted from 0° to 360°. From these results, the proposed two types of stretchable electrodes would contribute to stretchable applications such as wearable electronics, biomedical device etc. The selection of more appropriate electrodes among the two types of proposed designs depends on the required stretchability and device dimension.

8923-141, Session 31

Three-dimensional cell patterning in hydrogel by ultrasound standing waves

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Micropatterning allows the direct control of spatial organisation of cells at the micrometer-scale, making it possible to reproducibly engineer cell microenvironments. Micropatterned structures have been used for various applications including cell-matrix interactions study and tissue engineering. In this study, a simple, rapid, & cost-effective method to achieve cell alignment in three dimensions (3D) is presented. Coupling ultrasound standing wave field with a novel hydrogel system, PC12 cells are immobilised in an extracellular matrix (ECM) mimic within minutes. Acoustic radiation forces associated with ultrasound standing wave field align cells in suspension to be spaced at half-wavelength intervals. In order to retain these alignments after the removal of aforementioned forces, gelatin-hydroxyphenylpropionic acid (Gtn-HPA) hydrogel (previously developed by Wang et al., 2010) is employed. The unique gelation properties of Gtn-HPA hydrogel facilitate the immobilisation of cells, in which the gelation time can be tuned to complement the short period of time required to attain cell alignments. At this point in time, study shows immobilised PC12 cells remain viable after 5 days. Differentiation of PC12 cells will be proceeded from this stage, it is expected that ultrasound exposure will enhance the neurite growth. Finally, the simplicity of abovementioned techniques in controlling the spatial organisation of cells proves its potential as a promising alternative for in vitro tissue regeneration.

References:

L.S. Wang, J.E. Chung, P.P.Y. Chan, M. Kurisawa, Biomaterials 31: 1148-1157, 2010.

8923-142, Session 32

Enhanced spontaneous emission from nanocavities, nanowires, and nano-emitters *(Invited Paper)*

Masaya Notomi, NTT Basic Research Labs (Japan)

We review our recent studies on enhanced spontaneous emission from several different nanophotonic systems. We first show extremely fast spontaneous emission from Si by a combination of Cu color centers and Si photonic crystal high-Q nanocavities. Secondly, we show that high-Q nanocavity formation by placing InP nanowires in a Si photonic crystal waveguide and demonstrate large and controllable Purcell enhancement of emission from InAsP quantum disks in them. Thirdly, we present large spontaneous emission control in buried InGaAsP quantum-well nanowire structures in InP photonic crystals. Device application of related structures will be also discussed.

8923-143, Session 32

Group theory of chiral photonic crystals with 4-fold symmetry: S-parameters of eight-fold intergrown Gyroid nets

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Optical dielectric and metallic materials consisting of a single srs or Gyroid net exhibit circular dichroism, i.e. the difference in transmission rates for left- and right-circularly polarised light. We demonstrate that a chiral photonic crystal composed of eight equal-handed copies of the same srs net, interthreaded such that cubic symmetry is maintained shows a different and remarkable behavior: For normal incidence no circular polarization effects can be observed in the reflectance spectrum; further, there is no polarisation conversion at all frequencies and no circular dichroism at low frequencies, where all higher Bragg orders are evanescent, in the transmission spectrum. We show with a group theoretical approach in combination with a scattering matrix treatment that this behaviour is fully characterized by the presence of a four-fold rotational symmetry in this so-called 8-srs material, and indeed in any other lossless chiral medium. Nevertheless, even if the 8-srs is realised as a non-conducting dielectric photonic crystal, its spatial chirality leads to particularly strong rotary power, comparable in magnitude to the optical activity observed in metallic metamaterials yet without the associated transmission losses even for an 8-srs photonic crystal slab that is only a few unit cells thick. Combined with the absence of circular birefringence and polarization conversion at low frequencies this makes a very good optical rotator. Therefore, the 8-srs structure lends itself as a useful design for optical micro-materials that change the polarization state and can be fabricated with established methods like direct laser writing at telecommunication wave-lengths [Turner et. al, Optics Express 19 (2011)].

8923-144, Session 32

Silver nanowire on a dielectric substrate as an optical nano polariser

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Finite length metallic NWs are very promising plasmonic structures due to their strong polarisability compared to spherical shapes as well as their tunable resonant frequencies. Multimode surface plasmon propagation along a free standing NW is changed to single mode propagation when the NW is placed on a substrate due to the symmetry breaking from the latter [1]. The polarisation of the single mode of the NW on a substrate is theoretically analysed using the Eigen mode solver of COMSOL Multiphysics thereby giving an insight to the dominant linear polarisation of the mode. With this theoretical understanding, single mode plasmonic distribution along a substrate supported NW is imaged in the far-field and in the near-field, so as to demonstrate the potential of a substrate supported NW to serve as a linear polariser. The mapping of the near-field plasmonic propagation on a substrate supported NW using an in-plane polarisation sensitive probe imaged the existence of single mode along the NW length [2]. Such a NW based polariser is believed to have significant effect on NW based active optical networks.

8923-145, Session 33

Transfer printed nanomembranes for silicon photonics, flexible electronics and optoelectronics *(Invited Paper)*

Weidong Zhou, Univ of Texas at Arlington (United States); Zhenqiang Ma, University of Wisconsin-Madison (United States)

Crystalline semiconductor nanomembranes (NMs), which are transferable, stackable, bondable and manufacturable, offer unprecedented opportunities for unique electronic and photonic devices for vertically stacked high density photonic/electronic integration, high performance flexible electronics, and adaptive flexible/conformal photonics. Over the last few years, we have been carrying out research on various photonic and electronic devices, based on transfer printing techniques and heterogeneous integration of III-V/Si material systems. In this talk, we will review some of the research accomplishments we made over the last few years on

this emerging and exciting field, with focuses on stamp-assisted transfer-printed photonic crystal nanomembrane lasers on Si for Si photonics, Fano resonance photonic crystal membrane reflectors and filters, and high speed flexible RF electronics, etc. The convergence of semiconductor nanomembranes and Fano resonance photonic crystals and metamaterials will also be discussed, with potential applications in the areas of 3D Si CMOS photonics, flexible, bio-inspired/integrated photonic/electronic systems, and multi-spectral multi-color infrared imaging and smart sensing systems, etc.

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8923-146, Session 33

Photoluminescence emitted from dendritic ZnO with hierarchical nanostructures

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Zinc oxide (ZnO) is a semiconducting and piezoelectric material for various potentials applications, such as piezoelectric transducers, transparent conducting oxide, optical waveguide, gas sensors and surface acoustic wave devices. Due to the direct band-gap with wide bandgap energy of 3.37 eV and high exciton-binding energy of 60 meV, ZnO makes it a promising candidate for photonic applications, such as UV laser and UV light-emitted diodes (LEDs). In recent years, researchers focused on the fabrication of variety morphologies of ZnO nanostructures and their photoluminescence (PL) are also observed. Here, we have successfully used a template-based synthesized method and the assistance of atomic layer deposition to fabricate dendritic ZnO with hierarchical nanostructures. The morphology of such particular dendritic ZnO nanostructures is characterized by scanning electron microscopy and transmission electron microscopy. The novel optical properties of the dendritic ZnO nanostructures are measured by micro-PL setup. The PL emission from the dendritic ZnO nanostructures could extend the potential applications in ZnO-based heterojunction LEDs, which will be discussed in detail. The particular fabrication method for growing ZnO nanostructures could help inspire the discovery of the novel optical or electrical properties.

8923-147, Session 33

Electrodeposition and characterization of Sb-doped ZnO nanostructures

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Large scale Sb-doped ZnO nanorod arrays were grown utilizing electrochemical solution method with suitable combination of Zn(NO3)2, HMT and SbCl3 precursors. The influences of the pH value and the substrate on the morphology and the crystallization of Sb-doped ZnO nanorods were investigated in detail. It was found that the hexagonal wurtzite structures with high quality can be fabricated under the pH value of 5. Well crystallized Sb-doped ZnO could be grown on flexible conductive woven fibers, ITO conductive glass substrates and commercial AZO conductive glass substrates and the crystallographic orientation of nanorods strongly relied on the substrate type. Besides, a hierarchical branch-like Sb-doped ZnO structure was also obtained via a two-step electrodeposition method. In this two-step process, a thin ZnO seed layer was firstly spin-coated on the as deposited Sb-doped nanorod arrays and then the second electrodeposition carried out based on the first step growth. The formed Sb-doped ZnO nanorods were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Characteristics of luminescence and crystal qualities were represented by the room temperature photoluminescence (PL) spectroscopy. A bound exciton emission band around 3.34 eV and an intensive broad emission band were observed. It was found that the preparation condition had an effect on the luminescent intensity of the ultraviolet (UV) peak and the defect-related luminescence peak. The Sb-ZnO nanorods prepared under the optimized growth conditions showed an intense UV emission with small spreading in the visible region, demonstrating their good crystal quality.