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Highlights 2010

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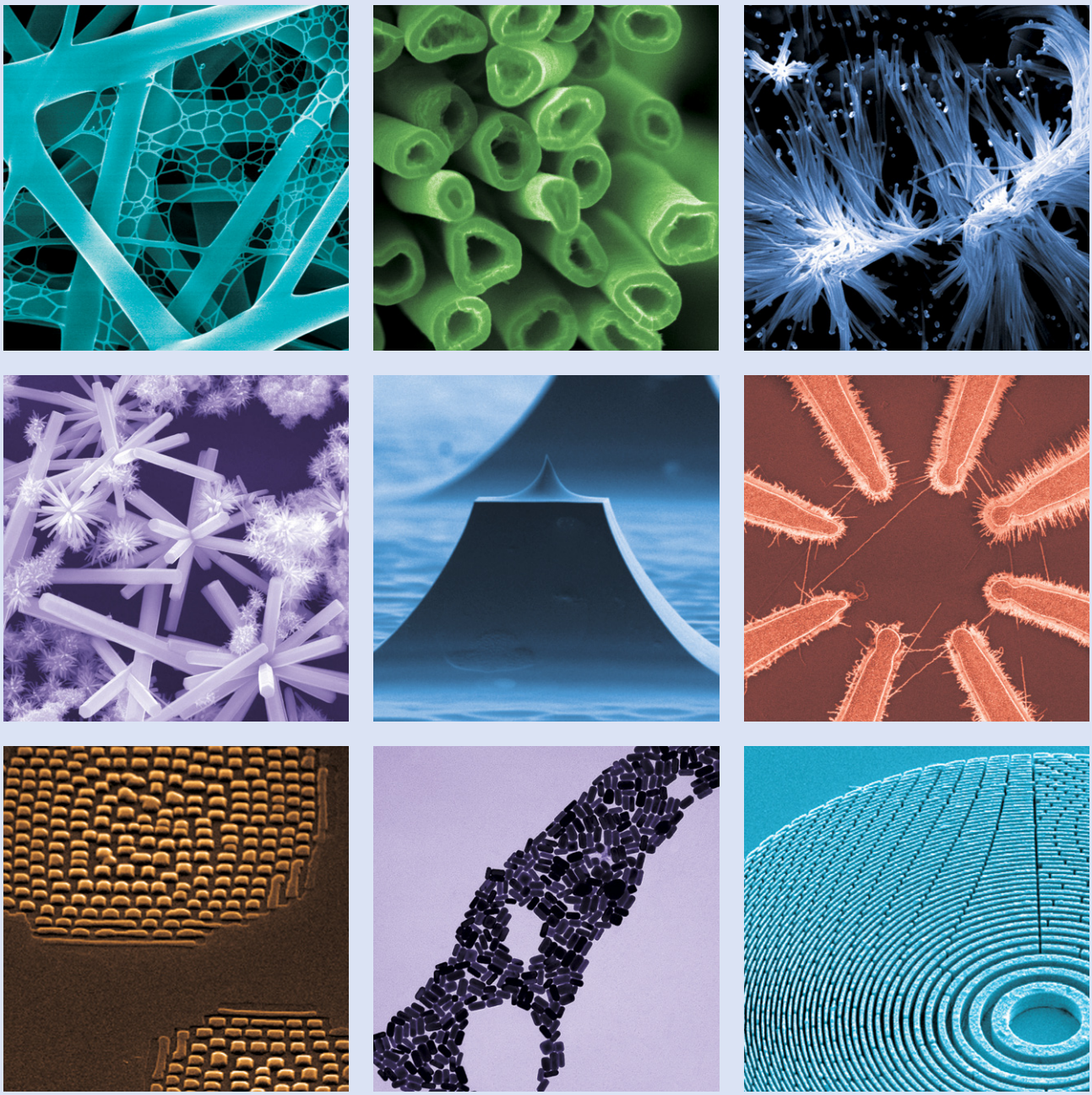

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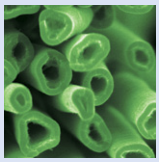
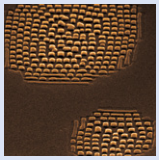
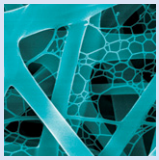


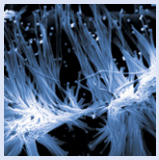
TiO_2 nanotube arrays with Pt nanoparticles, prepared using a bulk technique taken from the article 'Ta_2O_5- and TiO_2-based nanostructures made by atomic layer deposition' by **Marianna Kemell, Emma Härkönen, Viljami Pore, Mikko Ritala and Markku Leskelä** 2010 *Nanotechnology* **21** 035301



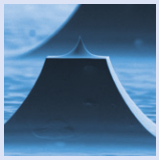
Nanoisland pattern transfer to polydimethylsiloxane (PDMS) taken from the article 'Nanoimprinting using self-assembled ceramic nanoislands' by **Lawrence Burr Zimmerman, M D Rauscher, J Ellis, P Boukany and L James Lee** 2010 *Nanotechnology* **21** 045304



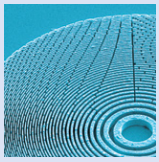
FE-SEM image of PAA fibrous membrane taken from the article 'A highly sensitive humidity sensor based on a nanofibrous membrane coated quartz crystal microbalance' by **Xianfeng Wang, Bin Ding, Jianyong Yu, Moran Wang and Fukui Pan** 2010 *Nanotechnology* **21** 055502



An array of CdTe nanowires taken from the article 'Multisegment CdTe nanowire homojunction photodiode' by **Elena Matei, Lucian Ion, Stefan Antohe, Reinhard Neumann and Ionut Enculescu** 2010 *Nanotechnology* **21** 105202

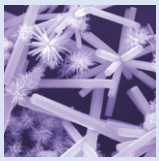


SEM image showing a completed silicon chip made via the microfabrication process taken from the article 'Fabrication of co-axial field emitter tips for scanning probe energy loss spectroscopy' by **Mi Yeon Song, Alex P G Robinson and Richard E Palmer** 2010 *Nanotechnology* **21** 155304

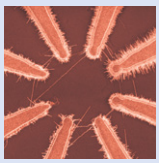


SEM image of 1 μm thick Fresnel zone plates fabricated by electroplating Au in PMMA molds taken from the article 'Direct e-beam writing of dense and high aspect ratio nanostructures in thick layers of PMMA for electroplating' by **Sergey Gorelick, Vitaliy A Guzenko, Joan Vila-Comamala and Christian David** 2010 *Nanotechnology* **21** 295303

TEM images of monodispersed PEGylated gold nanorods taken from the article 'Biocompatible PEGylated gold nanorods as colored contrast agents for targeted *in vivo* cancer applications' by **Atcha Kopwitthaya, Ken-Tye Yong, Rui Hu, Indrajit Roy, Hong Ding, Lisa A Vathy, Earl J Bergey and Paras N Prasad** 2010 *Nanotechnology* **21** 315101



SEM image of ZnO nanorods grown for a seeded hydrothermal mixture taken from the article 'Laser-assisted hydrothermal growth of size-controlled ZnO nanorods for sensing applications' by **S J Henley, J Fryar, K D G I Jayawardena and S R P Silva** 2010 *Nanotechnology* **21** 365502



Single-walled nanotubes with diameters that can be tuned in different segments by fast temperature control in laser-assisted chemical vapour deposition taken from the article 'Diameter modulation by fast temperature control in laser-assisted chemical vapor deposition of single-walled carbon nanotubes' by **M Mahjouri-Samani, Y S Zhou, W Xiong, Y Gao, M Mitchell, L Jiang and Y F Lu** 2010 *Nanotechnology* **21** 395601

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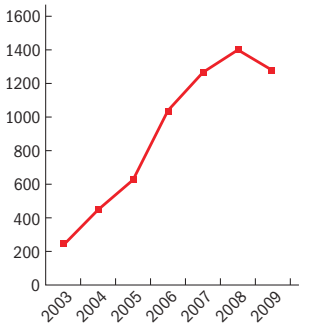

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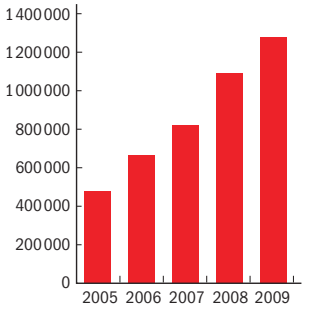

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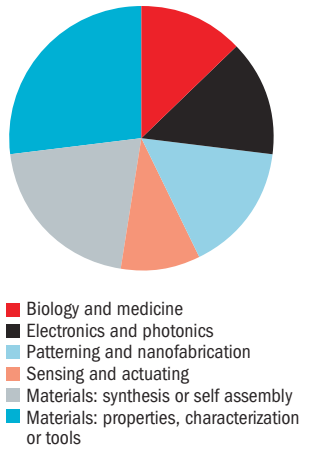

Professor Mark Reed
Editor-in-chief, Nanotechnology
E-mail **nano@iop.org**
iopscience.org/nano

Dear colleagues,

It's now 50 years since Nobel prize laureate Richard Feynman suggested 'There's plenty of room at the bottom' in a speech now often considered to have driven the development of nanotechnology (R P Feynman 'There's plenty of room at the bottom' *Engineering and Science* **23** 22, Caltech, February 1960). Work in nanoscience and technology continues to represent a hotbed of research activity, with new nanomaterials and tools spurring on ever more ingenious technological innovations and unveiling deeper insights into the behaviour of systems with nanoscale features.

This year the interest in graphene was formally commemorated when the Nobel Prize in Physics was awarded 'for groundbreaking experiments regarding the two-dimensional material graphene' (http://nobelprize.org/nobel_prizes/physics/laureates/2010). Of its many fascinating properties, the electrical characteristics of graphene have proved particularly inspiring. In this highlights brochure, advances in achieving high-yield and large-scale production of graphene-based LED and field-effect-transistor devices are reported, as well as non-volatile memory devices based on few-layer-graphene films. For further reports on non-volatile memory based on nanostructures, keep an eye out for the *Nanotechnology* special issue on the topic, to be published in early 2011. Carbon nanotubes are also the focus of a lot of exciting developments, such as the CNT-based neuronal network engineering method demonstrated by scientists in Korea, a comparison of ITO- and carbon-nanotube-based flexible organic LED devices by a collaboration of researchers in the US, and the development of vacuum pressure and flow velocity sensors using batch-processed and cost-effective carbon-nanotube devices.

A multidisciplinary approach is still very much integral to research in nanotechnology, and the crossover of expertise from bioscience to electronics and photonics and other disciplines is high. Work by researchers in Korea has demonstrated a simple and versatile approach for implementing the *Tobacco mosaic virus* in the synthesis of nanomaterials for applications in gas-sensing, Li-ion battery electrodes and superhydrophobic and superhydrophilic surfaces. Also in this brochure, Kathryn M Mayer and colleagues from Rice University in the US exploit the plasmon resonance of gold bipyramids to detect antibody-antigen unbinding events at the single-molecule level – an important single-molecule detection technique that operates at long timescales and under relatively natural conditions.

The 20th anniversary has provided an ample opportunity to celebrate the journal's progress since its launch in 1990. So far *Nanotechnology* remains the only peer reviewed journal in its field that is published weekly, and the fast receipt-to-first-decision times ensure that we provide a valuable portal to the very latest top research. Of course the most important attribute of the journal is the quality of the research reported in it, as exemplified in this selection of highlights from 2010. Large credit is due to all the researchers who have contributed their time and expertise in peer review, thus ensuring that *Nanotechnology* only publishes the very best papers. We are also heartily grateful to all the authors who have chosen *Nanotechnology* as the platform for disseminating their research.

Professor Mark Reed
Editor-in-chief, Nanotechnology

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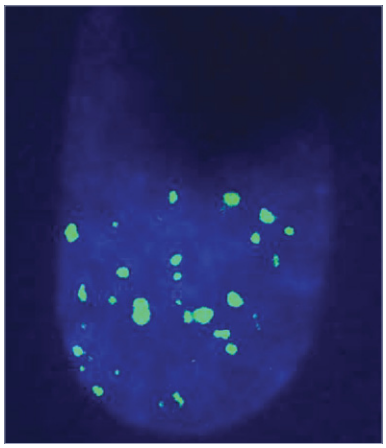
BIOLOGY AND MEDICINE

Using carbon nanotubes to induce micronuclei and double strand breaks of the DNA in human cells

Jelena Cveticanin, Gordana Joksic, Andreja Leskovac, Sandra Petrovic, Ana Valenta Sobot and Olivera Neskovic
Vinca Institute of Nuclear Sciences, PO Box 522, Belgrade, Serbia

Carbon nanotubes are unique one-dimensional macromolecules with promising applications in biology and medicine. Since their toxicity is still under debate, here we present a study investigating the genotoxic properties of purified single wall carbon nanotubes (SWCNTs), multiwall carbon nanotubes (MWCNTs), and amide functionalized purified SWCNTs on cultured human lymphocytes employing cytokinesis block micronucleus assay and enumeration of γH2AX foci as a measure of double strand breaks (DSBs) of the DNA in normal human fibroblasts. SWCNTs induce micronuclei (MN) formation in lymphocytes and decrease the proliferation potential (CBPI) of cells. In a fibroblast cell line the same dose of SWCNTs induces γH2AX foci 2.7-fold higher than in a control. Amide functionalized purified SWCNTs behave differently: they do not disturb the cell proliferation potential of harvested lymphocytes, but induce micronuclei to a higher extent than SWCNTs. When applied on fibroblasts, amide functionalized SWCNTs also induce γH2AX foci, 3.18-fold higher than the control. The cellular effects of MWCNTs display the broad spectrum of clastogenic properties seen as the highest incidence of induced lymphocyte micronuclei and anaphase bridges among nuclei in binucleated cells. Surprisingly, the incidence of induced γH2AX foci was not as high as was expected by the micronucleus test, which indicates that MWCNTs act as clastogen and aneugen agents simultaneously. Biological endpoints investigated in this study indicate a close relationship between the electrochemical properties of carbon nanotubes and observed genotoxicity.

J Cveticanin *et al* 2010 *Nanotechnology* **21** 015102



Functionalized SWCNTs attached on nuclei (black shadow): the induced γH2AX foci are observed below the shadow.

Platinum nanoparticles: a promising material for future cancer therapy?

Erika Porcel[1], Samuel Liehn[1], Hynd Remita[2], Noriko Usami[3], Katsumi Kobayashi[3], Yoshiya Furusawa[4], Claude Le Sech[1] and Sandrine Lacombe[1]
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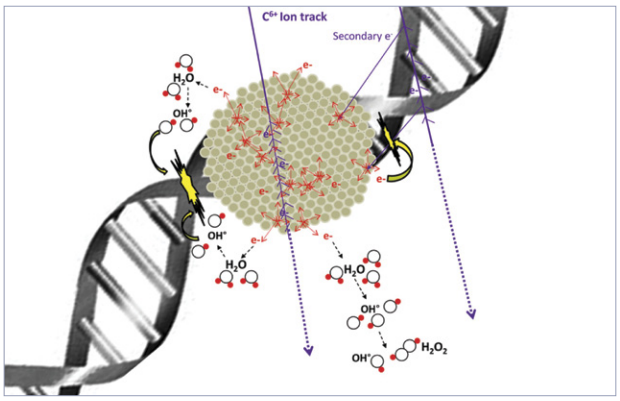
[2] Laboratoire de Chimie Physique (UMR 8000), Université Paris-Sud 11, CNRS, 91405 Orsay Cedex, France
[3] Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization, Oho, Tsukuba, Ibaraki 305-0801, Japan
[4] Research Center for Charged Particle Therapy, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba 263-8555, Japan

Recently, the use of gold nanoparticles as potential tumor selective radiosensitizers has been proposed as a breakthrough in radiotherapy. Experiments in living cells and *in vivo* have demonstrated the efficiency of the metal nanoparticles when combined with low energy x-ray radiations (below conventional 1 MeV Linac radiation). Further studies on DNA have been performed in order to better understand the fundamental processes of sensitization and to further improve the method. In this work, we propose a new strategy based on the combination of platinum nanoparticles with irradiation by fast ions effectively used in hadron therapy. It is observed in particular that nanoparticles enhance strongly lethal damage in DNA, with an efficiency factor close to 2 for double strand breaks. In order to disentangle the effect of the nano-design architecture, a comparison with the effects of dispersed metal atoms at the same concentration has been performed. It is thus shown that the sensitization in nanoparticles is enhanced due to auto-amplified electronic cascades inside the nanoparticles, which reinforces the energy deposition in the close vicinity of the metal. Finally, the combination of fast ion radiation (hadron therapy) with platinum nanoparticles should strongly improve cancer therapy protocols.

E Porcel *et al* 2010 *Nanotechnology* **21** 085103



Fast processes ($t < 10^{-12}$ s) involved in platinum nanoparticles excited by ionizing radiations.

The nanostructure effect on the adhesion and growth rates of epithelial cells with well-defined nanoporous alumina substrates

S H Chung[1], S J Son[2] and J Min[2]
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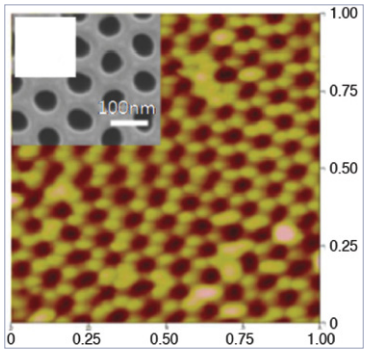
[2] College of BioNano Technology, Kyungwon University, Gyeonggi-Do 461-701, Korea

We systematically analyzed the adhesion and the proliferation of cells on various nanoporous alumina surfaces to understand the effects of nanostructured surfaces on cell behavior. Various nanoporous surfaces were fabricated using the anodizing method and characterized by atomic force microscopy and scanning electron microscopy. The adhesion rate and proliferation rate of cells as functions of pore size and depth were statistically investigated using a colorimetric method. The adhesion rate of cells was not affected by the depth of the nanoporous surface whereas the proliferation of cells dramatically increased when the aspect ratio of the nanopore was near unity. This phenomenon was further verified by comparing the change in roughness of the cytoplasmic layer of cells adhered on a nanoporous surface with that of a bare nanoporous surface. The proliferation of cells was also influenced by the pore size of the nanoporous surface because the nanostructure could control the interaction between extracellular matrix (ECM) molecules and the surface. In conclusion, the nanostructured surfaces affected cell adhesion and proliferation by increasing the surface area to which the cells could adhere, and the interactions between small ECM molecules were influenced by the sufficiently small structures of the nanosurface.

S Chung *et al* 2010 *Nanotechnology* **21** 125104



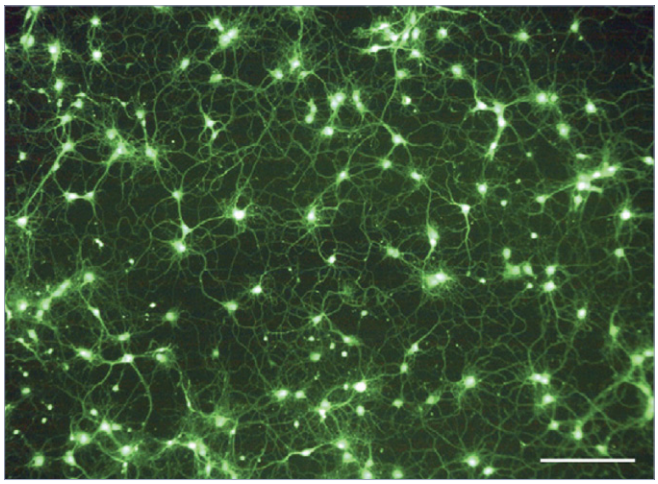
Atomic force microscopy image of alumina template as a function of pore sizes, in this case 50 nm. Inner square shows a scanning electron microscope image.

Directional neurite growth using carbon nanotube patterned substrates as a biomimetic cue

Min Jee Jang[1], Seon Namgung[2], Seunghun Hong[2,3] and Yoonkey Nam[1]
[1] Department of Bio and Brain Engineering, KAIST, Daejeon, Korea
[2] Department of Physics and Astronomy, Seoul National University, Seoul, Korea
[3] Department of Biophysics and Chemical Biology, Seoul National University, Seoul, Korea

Researchers have made extensive efforts to mimic or reverse-engineer *in vivo* neural circuits using micropatterning technology. Various surface chemical cues or topographical structures have been proposed to design neuronal networks *in vitro*. In this paper, we propose a carbon nanotube (CNT)-based network engineering method which naturally mimics the structure of extracellular matrix (ECM). On CNT patterned substrates, poly-L-lysine (PLL) was coated, and E18 rat hippocampal neurons were cultured. In the early developmental stage, soma adhesion and neurite extension occurred in disregard of the surface CNT patterns. However, later the majority of neurites selectively grew along CNT patterns and extended further than other neurites that originally did not follow the patterns. Long-term cultured neuronal networks had a strong resemblance to the *in vivo* neural circuit structures. The selective guidance is possibly attributed to higher PLL adsorption on CNT patterns and the nanomesh structure of the CNT patterns. The results showed that CNT patterned substrates can be used as novel neuronal patterning substrates for *in vitro* neural engineering.

M J Jang *et al* 2010 *Nanotechnology* **21** 235102



Neuronal networks cultured on a CNT/OTS patterned substrate at 7 days *in vitro*. Scale bar is 100 μm.

Immobilization of motile bacterial cells via dip-pen nanolithography

Dorjderem Nyamjav[1], Sergey Rozhok[2] and Richard C Holz[1,2]
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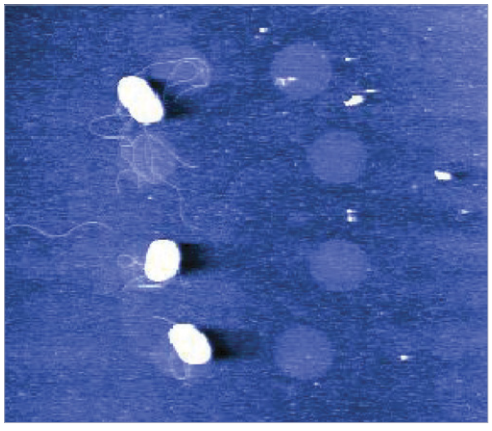
[2] Department of Chemistry and Institute for Nanotechnology, Northwestern University, 2145 Sheridan, Road, Evanston, IL 60208-3113, USA

A strategy to bind bacterial cells to surfaces in a directed fashion via dip-pen nanolithography (DPN) is presented. Cellular attachment to pre-designed DPN generated microarrays was found to be dependent on the shape and size of the surface feature. While this observation is likely due in part to a dense, well formed mercaptohexadecanoic acid (MHA) monolayer generated via DPN, it may also simply be due to the physical shape of the surface structure. Motile Pseudomonas aeruginosa bacterial cells were observed to bind to DPN generated mercaptohexadecanoic acid/poly-L-lysine (MHA/PLL) line patterns, 'blocks' made up of eight lines with 100 nm spacings, with ~80% occupancy. Cellular binding to these 'block' surface structures occurs via an electrostatic interaction between negatively charged groups on the bacterial cell surface and positively charged poly-L-lysine (PLL) assemblies. These data indicate that these DPN generated 'block' surface structures provide a promising footprint for the attachment of motile bacterial cells that may find utility in cell based biosensors or single cell studies.

D Nyamjav *et al* 2010 *Nanotechnology* **21** 235105



Lateral force microscopy image of DPN-generated MHA–PLL dot patterns after the addition of *E. coli* K12 bacteria.

An insight into the metabolic responses of ultra-small superparamagnetic particles of iron oxide using metabonomic analysis of biofluids

Jianghua Feng[1,2,5], Huili Liu[2], Limin Zhang[2], Kishore Bhakoo[3] and Lehui Lu[4]
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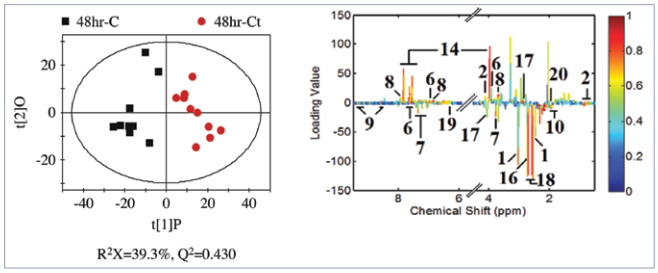
[2] State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences,Wuhan 430071, People's Republic of China
[3] Singapore Bioimaging Consortium, Agency for Science, Technology and Research (A*STAR) 138667, Singapore
[4] State Key Laboratory of Electroanalytical Chemistry, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun, Jilin 130022, People's Republic of China

Ultra-small superparamagnetic particles of iron oxides (USPIO) have been developed as intravenous organ/tissue-targeted contrast agents to improve magnetic resonance imaging (MRI) *in vivo*. However, their potential toxicity and effects on metabolism have attracted particular attention. In the present study, uncoated and dextran-coated USPIO were investigated by analyzing both rat urine and plasma metabonomes using high-resolution NMR-based metabonomic analysis in combination with multivariate statistical analysis. The wealth of information gathered on the metabolic profiles from rat urine and plasma has revealed subtle metabolic changes in response to USPIO administration. The metabolic changes include the elevation of urinary α-hydroxy-n-valerate, o- and p-HPA, PAG, nicotinate and hippurate accompanied by decreases in the levels of urinary α-ketoglutarate, succinate, citrate, N-methylnicotinamide, NAG, DMA, allantoin and acetate following USPIO administration. The changes associated with USPIO administration included a gradual increase in plasma glucose, N-acetyl glycoprotein, saturated fatty acid, citrate, succinate, acetate, GPC, ketone bodies (β-hydroxybutyrate, acetone and acetoacetate) and individual amino acids, such as phenylalanine, lysine, isoleucine, glycine, glutamine and glutamate and a gradual decrease of myo-inositol, unsaturated fatty acid and triacylglycerol. Hence USPIO administration effects are reflected in changes in a number of metabolic pathways including energy, lipid, glucose and amino acid metabolism. The size- and surface chemistry-dependent metabolic responses and possible toxicity were observed using NMR analysis of biofluids. These changes may be attributed to the disturbances of hepatic, renal and cardiac functions following USPIO administrations. The potential biotoxicity can be derived from metabonomic analysis and serum biochemistry analysis. Metabonomic strategy offers a promising approach for the detection of subtle physiological responses on mammalian metabolism, and can be employed to investigate the potential adverse effects of other nanoparticles and nanomaterials on the environment and human health.

J Feng *et al* 2010 *Nanotechnology* **21** 395101



O-PLS-DA score plot and corresponding coefficient plot of group derived from 1H-NMR spectra of rat urine.

Nonvolatile memory devices based on few-layer graphene films

Featured on nanotechweb.org

Yong-Joo Doh[1,2] and Gyu-Chul Yi[3]
[1] Department of Display and Semiconductor Physics, Sejong Campus, Korea University, Chungnam-Do 339-800, Republic of Korea
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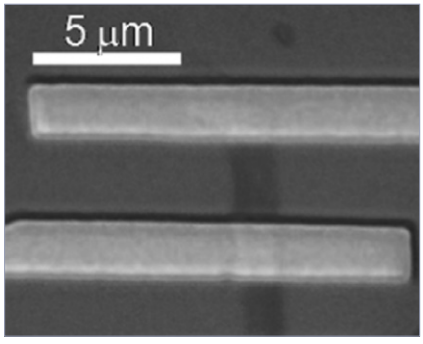
[3] Department of Physics and Astronomy and National Creative Research Initiative Center for Semiconductor Nanorods, Seoul National University, Seoul 151-747, Republic of Korea

We report on the electrical characteristics of few-layer graphene (FLG) field-effect devices with their various thicknesses. In combination with a ferroelectric polymer layer of poly(vinylidene fluoride/trifluoroethylene) [P(VDF/TrFE)], FLG/ferroelectric devices exhibited nonvolatile resistance changes due to a polarization switching of the P(VDF/TrFE) layer. The bistability and retention properties were highly sensitive to the FLG thickness, which is attributed to a charge screening effect in FLG films.

Y-J Doh *et al* 2010 *Nanotechnology* **21** 105204



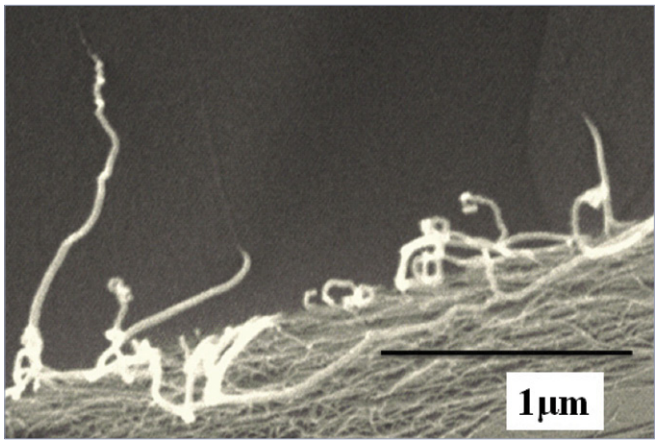
Optical microscope image of a typical FLG device. The scale bar represents 5 μm.

Flexible organic light-emitting diodes with transparent carbon nanotube electrodes: problems and solutions

Liangbing Hu[1], Jianfeng Li[2], Jun Liu[2], George Grüner[1] and Tobin Marks[2]
[1] Department of Physics, University of California, Los Angeles, CA 90095, USA
[2] Department of Chemistry, Northwestern University, Evanston, IL 60208-3113, USA

We study in detail here the application of transparent, conductive carbon single-wall nanotube (SWNT) networks as electrodes in flexible organic light-emitting diodes (FOLEDs). Overall comparisons of these networks to the commonly used electrodes poly(3,4-ethylenedioxythiophene): poly(styrene sulfonate) (PEDOT:PSS) and indium tin oxide (ITO) are made, and SWNT networks are shown to have excellent optical and superior mechanical properties. The effects of protruding nanotubes, rough surface morphology, and SWNT network–adjacent layer dewetting are shown to be problematic, and approaches for addressing these issues are identified. The mechanical properties of SWNT networks and ITO are compared, and SWNT networks are shown to exhibit more durable sheet conductance under bending, which leads to bendable FOLEDs. We demonstrated FOLEDs with SWNT network anodes that exhibit outstanding light output and meet display requirements. SWNT-based FOLEDs show comparable lifetime performances to ITO-based devices. The promise and the remaining challenges for implementing SWNT networks in organic light-emitting diodes are discussed.

L Hu *et al* 2010 *Nanotechnology* **21** 155202



Scanning electron microscopy image of a SWNT surface with occasional protruding tubes created during deposition or film handling.

High yield fabrication of chemically reduced graphene oxide field effect transistors by dielectrophoresis

Daeha Joung[1,2], A Chunder[1,3], Lei Zhai[1,3] and Saiful I Khondaker[1,2]
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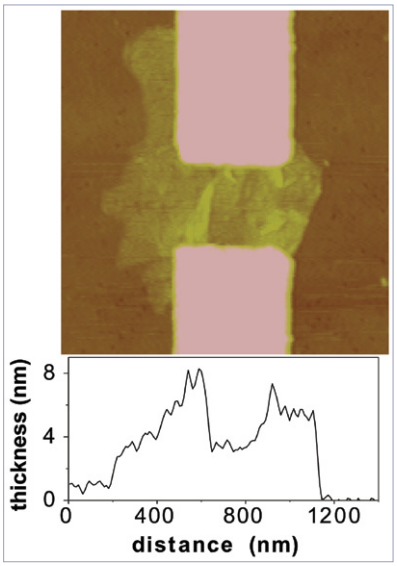
[2] Department of Physics, University of Central Florida, Orlando, FL 32826, USA
[3] Department of Chemistry, University of Central Florida, Orlando, FL 32826, USA

We demonstrate high yield fabrication of field effect transistors (FET) using chemically reduced graphene oxide (RGO) sheets. The RGO sheets suspended in water were assembled between prefabricated gold source and drain electrodes using ac dielectrophoresis. With the application of a backgate voltage, 60% of the devices showed p-type FET behavior, while the remaining 40% showed ambipolar behavior. After mild thermal annealing at 200 °C, all ambipolar RGO FET remained ambipolar with increased hole and electron mobility, while 60% of the p-type RGO devices were transformed to ambipolar. The maximum hole and electron mobilities of the devices were 4.0 and 1.5 $cm^2 V^{-1} s^{-1}$ respectively. High yield assembly of chemically derived RGO FET will have significant impact in scaled up fabrication of graphene based nanoelectronic devices.

D Joung *et al* 2010 *Nanotechnology* **21** 165202



Tapping-mode atomic force microscopy image of an RGO device assembled via DEP along with its height profile. The thickness varies from 2 to 10 nm in the channel, indicating that up to 10 layers of RGO sheets have been assembled in the channel.

Large-scale patterned multi-layer graphene films as transparent conducting electrodes for GaN light-emitting diodes

Featured on nanotechweb.org

Gunho Jo[1], Minhyeok Choe[1], Chu-Young Cho[1], Jin Ho Kim[3], Woojin Park[1], Sangchul Lee[2], Woong-Ki Hong[1], Tae-Wook Kim[1], Seong-Ju Park[1,2], Byung Hee Hong[3], Yung Ho Kahng[1] and Takhee Lee[1,2]

[1] Department of Materials Science and Engineering, Gwangju Institute of Science and Technology, Gwangju 500-712, Korea
[2] Department of Nanobio Materials and Electronics, Gwangju Institute of Science and Technology, Gwangju 500-712, Korea
[3] Department of Chemistry and SKKU Advanced Institute of Nanotechnology, Sungkyunkwan University, Suwon 440-746, Korea

This work demonstrates a large-scale batch fabrication of GaN light-emitting diodes (LEDs) with patterned multi-layer graphene (MLG) as transparent conducting electrodes. MLG films were synthesized using a chemical vapor deposition (CVD) technique on nickel films and showed typical CVD-synthesized MLG film properties, possessing a sheet resistance of ~620 Ω/□ with a transparency of more than 85% in the 400–800 nm wavelength range. The MLG was applied as the transparent conducting electrodes of GaN-based blue LEDs, and the light output performance was compared to that of conventional GaN LEDs with indium tin oxide electrodes. Our results present a potential development toward future practical application of graphene electrodes in optoelectronic devices.

G Jo *et al* 2010 *Nanotechnology* **21** 175201

Photograph showing an LED with tip probes attached after applying an input current of 100 μA.

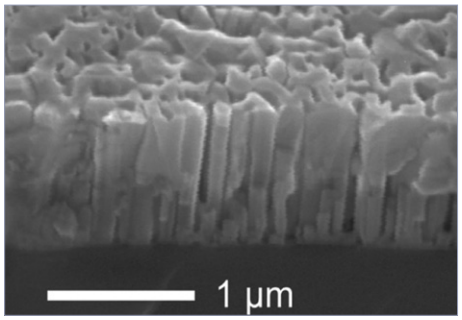
Multicolour luminescence from InGaN quantum wells grown over GaN nanowire arrays by molecular-beam epitaxy

Featured on nanotechweb.org

R Armitage and K Tsubaki
Advanced Technology Development Laboratory, Panasonic Electric Works Co. Ltd, 1048 Kadoma, Osaka 571-8686, Japan

The luminescence of InGaN single quantum wells grown by molecular-beam epitaxy under fixed conditions over a series of c-axis GaN nanowire arrays with different geometrical parameters was studied. For arrays with variable GaN average wire diameters and fixed wire densities, the InGaN luminescence peak shifted to higher energy with decreasing wire diameter. It is shown that this trend cannot be attributed to lateral quantum confinement or diameter-dependent InGaN strain. For arrays with variable wire densities and fixed average diameters, the InGaN emission appeared as two distinct bands of different colours, the relative intensities of which depended on the wire density. By optimizing both the GaN wire density and InGaN growth conditions, the colours of the two different bands were combined to realize phosphor-free white light-emitting diodes. The mechanisms for the dependence of the InGaN luminescence on the geometrical parameters of the GaN nanowire array are discussed.

R Armitage *et al* 2010 *Nanotechnology* **21** 195202



Scanning electron microscopy image showing a continuous GaN:Mg top contact layer grown on GaN nanowires.

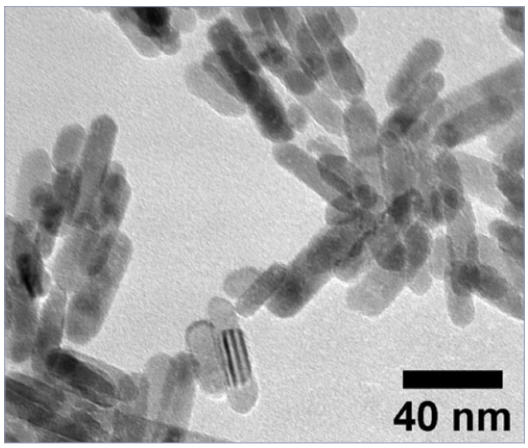
Solid-state dye-sensitized solar cells based on ZnO nanocrystals

M Boucharef[1,2], C Di Bin[1], M S Boumaza[3], M Colas4, H J Snaith[5], B Ratier[1] and J Bouclé[1]

[1] XLIM UMR 6172, Université de Limoges/CNRS, 123 Avenue Albert Thomas, F-87060 Limoges Cedex, France
[2] Université Mentouri Constantine, Route Ein El Bey, 25017 Constantine, Algeria
[3] Université 8 Mai 1945, BP 401, 24000 Guelma, Algeria
[4] SPCTS, CNRS UMR 6638, Université de Limoges, 123 Avenue Albert Thomas, F-87060 Limoges Cedex, France
[5] Department of Physics, Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

We report on the development of solution-processed ZnO-based dye-sensitized solar cells. We fabricate mesoporous ZnO electrodes from sol–gel processed nanoparticles, which are subsequently sensitized with conventional ruthenium complexes and infiltrated with the solid-state hole transporter medium 2, 2', 7, 7'-tetrakis-(*N*, *N*-di-*p*-methoxyphenylamine)-9, 9'-spirobifluorene (spiro-OMeTAD). Starting from ZnO nanorods synthesized from solution, we investigate the porous ZnO film morphology using various precursor formulations. The nature of the polymeric additive used in the initial ZnO formulation, as well as the ZnO electrode sintering treatment, is varied and its influence on device performance and charge dynamics, probed by transient perturbation techniques, is discussed. We show that using ethyl-cellulose in the initial ZnO formulation is responsible for an improved dye loading on the ZnO porous electrode, while a gradual sintering step at 350 °C is suitable for the proper removal of the organic phases that can be found in the ZnO films after their deposition by spin-coating. Using only 800 nm thick porous ZnO electrodes sensitized by N719, the best performing device exhibits a short-circuit current density of 2.43 mA cm^{-2} under simulated solar emission of (100 mW cm^{-2}), associated with an overall power conversion efficiency of 0.50%.

M Boucharef *et al* 2010 *Nanotechnology* **21** 205203



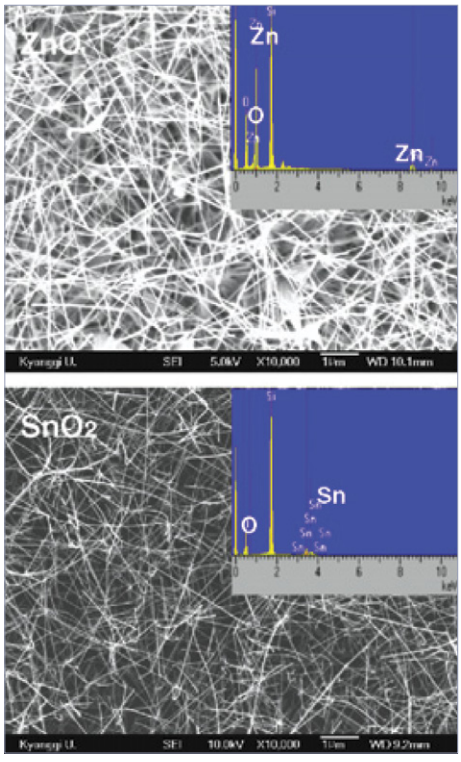
Transmission electron microscopy image of the ZnO nanorod sample 13×50 nm synthesized from solution.

Tunable-white-light-emitting nanowire sources

Keumyoung Seo, Taekyung Lim, Sangdan Kim, Hong-Lee Park and Sanghyun Ju
Department of Physics, Kyonggi University, Suwon, Gyeonggi-Do 443-760, Republic of Korea

Tunable-white-light-emitting materials are developed by combining two single-crystal oxide nanowire materials—ZnO and SnO_2—having different light emissions. The tuning of white-light emission from cool white to warm white is achieved for the first time by adjusting the growth sequence and growth time of the ZnO and SnO_2 nanowires. Combined ZnO:SnO_2 nanowire arrays yield a desired emission color from (0.30, 0.31) to (0.35, 0.37) and a white luminescence of ~100 cd m^{-2}, whose reproducibility can be controlled accurately. These results pave a new way to understand and generate a desired white-light emission, which is a key technology in large-area planar display devices, including flexible and/or transparent display devices.

K Seo *et al* 2010 *Nanotechnology* **21** 255201



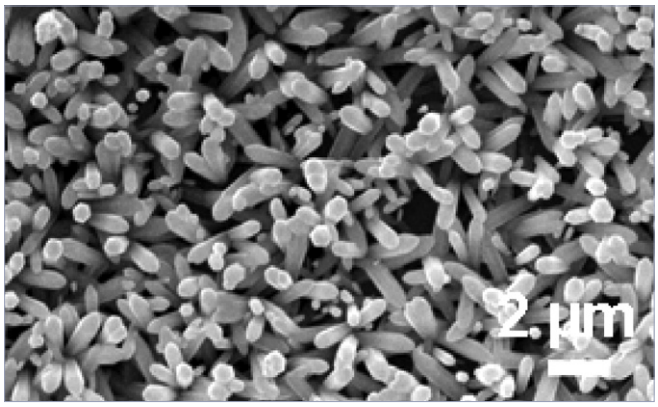
Field-emission scanning electron microscopy images of ZnO nanowires (D ~70 nm) and SnO_2 nanowires (D ~40 nm). The images in the inset show EDS data for ZnO and SnO_2.

ZnO nanotube-based dye-sensitized solar cell and its application in self-powered devices

Jingbin Han[1,2], Fengru Fan[1], Chen Xu[1], Shisheng Lin[1], Min Wei[2], Xue Duan[2] and Zhong Lin Wang[1]
[1] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0245, USA
[2] State Key Laboratory of Chemical Resource Engineering, Beijing University of Chemical Technology, Beijing 100029, People's Republic of China

High-density vertically aligned ZnO nanotube arrays were fabricated on FTO substrates by a simple and facile chemical etching process from electrodeposited ZnO nanorods. The nanotube formation was rationalized in terms of selective dissolution of the (001) polar face. The morphology of the nanotubes can be readily controlled by electrodeposition parameters for the nanorod precursor. By employing the 5.1 μm-length nanotubes as the photoanode for a dye-sensitized solar cell (DSSC), a full-sun conversion efficiency of 1.18% was achieved. Furthermore, we show that the DSSC unit can serve as a robust power source to drive a humidity sensor, with a potential for self-powered devices.

J Han *et al* 2010 *Nanotechnology* **21** 405203



Top-view scanning electron microscopy image of ZnO nanorod array obtained by passing a charge density of 2.5 C cm^{-2}.

Nanotechnology special issues in 2010

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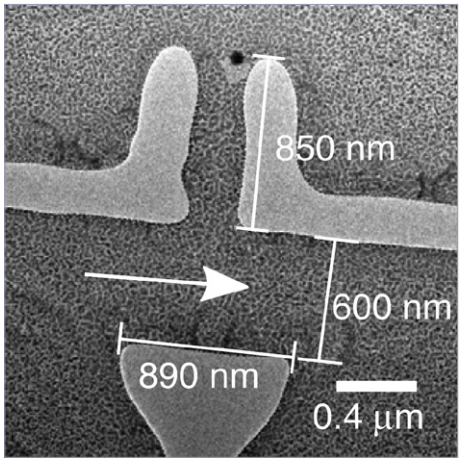
PATTERNING AND NANOFABRICATION

Customizable *in situ* TEM devices fabricated in freestanding membranes by focused ion beam milling

Anders Lei[1], Dirch Hjorth Petersen[1], Timothy John Booth[1], Lasse Vinther Homann[1], Christian Kallesoe[1], Ozlem Sardan Sukas[1], Yvonne Gyrsting[2], Kristian Molhave[1] and Peter Boggild[1]
[1] DTU Nanotech, Department of Nano- and Microtechnology, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark
[2] DTU Danchip, National Center for Micro- and Nanofabrication, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

Nano- and microelectromechanical structures for *in situ* operation in a transmission electron microscope (TEM) were fabricated with a turnaround time of 20 min and a resolution better than 100 nm. The structures are defined by focused ion beam (FIB) milling in 135 nm thin membranes of single crystalline silicon extending over the edge of a pre-fabricated silicon microchip. Four-terminal resistance measurements of FIB-defined nanowires showed at least two orders of magnitude increase in resistivity compared to bulk. We show that the initial high resistance is due to amorphization of silicon, and that current annealing recrystallizes the structure, causing the electrical properties to partly recover to the pristine bulk resistivity. *In situ* imaging of the annealing process revealed both continuous and abrupt changes in the crystal structure, accompanied by instant changes of the electrical conductivity. The membrane structures provide a simple way to design electron-transparent nanodevices with high local temperature gradients within the field of view of the TEM, allowing detailed studies of surface diffusion processes. We show two examples of heat-induced coarsening of gold on a narrow freestanding bridge, where local temperature gradients are controlled via the electrical current paths. The separation of device processing into a one-time batch-level fabrication of identical, generic membrane templates, and subsequent device-specific customization by FIB milling, provides unparalleled freedom in device layout combined with very short effective fabrication time. This approach significantly speeds up prototyping of nanodevices such as resonators, actuators, sensors and scanning probes with state-of-art resolution.

A Lei *et al* 2010 *Nanotechnology* **21** 405304



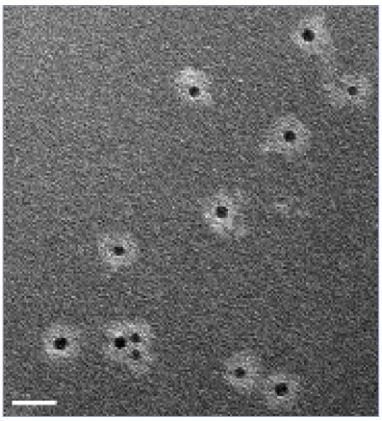
An image of the heating element used to form gold clusters. The arrow shows the direction the current will flow when applied.

Site-directed delivery of ferritin-encapsulated gold nanoparticles

B Zheng[1,2], I Yamashita[1], M Uenuma[1,2], K Iwahori[1,3], M Kobayashi[1] and Y Uraoka[1,2]
[1] Graduate School of Materials Science, Nara Institute of Science and Technology, 8916-5 Takayama, Ikoma, Nara 630-0192, Japan
[2] CREST, Japan Science and Technology Agency, 4-1-8 Honcho, Kawaguchi, Saitama, 332-0012, Japan
[3] PRESTO, Japan Science and Technology Agency, 4-1-8 Honcho, Kawaguchi, Saitama, 332-0012, Japan

Newly designed porter proteins, which catch gold nanoparticles and deliver the nanoparticles selectively to a silicon dioxide (SiO_2) surface under the specific conditions were reported. Recombinant apoferritin subunits, each of which has gold-binding peptide and titanium-binding peptide at the C- and N-terminus, respectively, can efficiently encapsulate a gold nanoparticle. The bio-conjugate, a nanogold and surrounding mutant protein subunits, had a property which can deliver itself to the SiO_2 surface through the interaction. In theory, our genetically manipulated apoferritin subunits can encapsulate gold nanoparticles of various sizes, which is a promising property for applications involving surface plasmon resonance.

B Zheng *et al* 2010 *Nanotechnology* **21** 045305



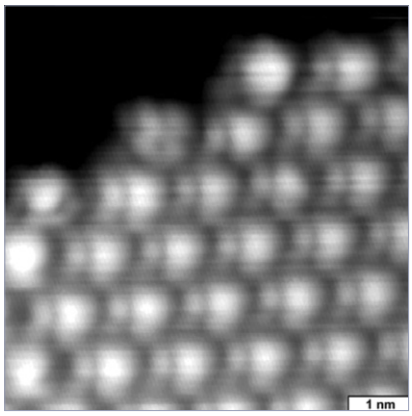
Transmission electron microscopy image of a conjugate of TFG protein and gold nanoparticles. Sample was stained by 3% phosphotungstic acid. Bar size: 20 nm.

Fullerene monolayer formation by spray coating

J Červenka[1,2] and C F J Flipse[2]
[1] Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnick à 10, CZ-162 53 Prague 6, Czech Republic
[2] Department of Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Many large molecular complexes are limited in thin film applications by their insufficient thermal stability, which excludes deposition via commonly used vapour phase deposition methods. Here we demonstrate an alternative way of monolayer formation of large molecules by a simple spray coating method under ambient conditions. This technique has been successfully applied on C_{60} dissolved in toluene and carbon disulfide. Monolayer thick C_{60} films have been formed on graphite and gold surfaces at particular deposition parameters, as confirmed by atomic force and scanning tunnelling microscopies. Structural and electronic properties of spray coated C_{60} films on Au(111) have been found comparable to thermally evaporated C_{60}. We attribute the monolayer formation in spray coating to a crystallization process mediated by an ultrathin solution film on a sample surface.

J Červenka *et al* 2010 *Nanotechnology* **21** 065302



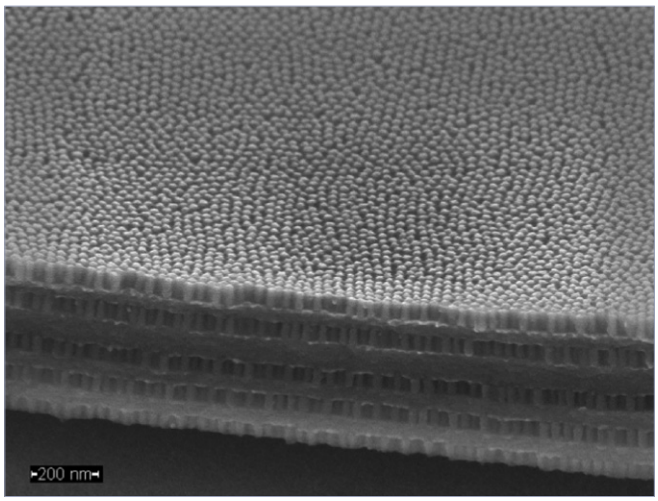
High-resolution scanning tunnelling microscopy image of C60 spray coated on Au(111) at 5 K obtained with the scanning tunnelling parameters: U = 2.5 V and I = 85 pA.

Synthesis of TiO_2 nanoframe and the prototype of a nanoframe solar cell

Ying Chen[1], Ho-Cheol Kim[2], Jim McVittie[1], Chiu Ting[1] and Yoshio Nishi[1]
[1] Department of Electrical Engineering, Stanford University, Stanford, CA 94305, USA
[2] IBM Research Division, Almaden Research Center, San Jose, CA 95120, USA

Nanoframes containing 20 nm diameter TiO_2 nanowire arrays were synthesized with polymer templates via cathodic sol–gel deposition followed by 450 °C sintering. Raman spectra indicated that they are composed of pure anatase TiO_2. The nanowire array inside the nanoframe was confirmed to be single crystalline by high resolution TEM. Dye-sensitized solar cells based on this nanoframe were fabricated and the effects of the top cover in the nanoframe, which is the only difference between nanoframe cells and nanowire cells, were investigated. The results show that the top cover does not prevent the I^- and I_3^- ions underneath from diffusing freely in the electrolyte and causes no deterioration of the cell performance. The nanoframe cell is a promising device in which nanowire arrays are strengthened and the effective internal surface area has the potentiality to be increased without sacrificing the advantages of nanowire cells compared to nanoparticle cells.

Y Chen *et al* 2010 *Nanotechnology* **21** 185303



Multi-layer TiO_2 structure. (Note: The multi-layer structure in the picture was produced accidentally. We are still looking for a method to consistently reproduce the multi-layer structure. But this accident gives strong evidence that the multi-layer structure can be very sturdy and its fabrication is highly possible.)

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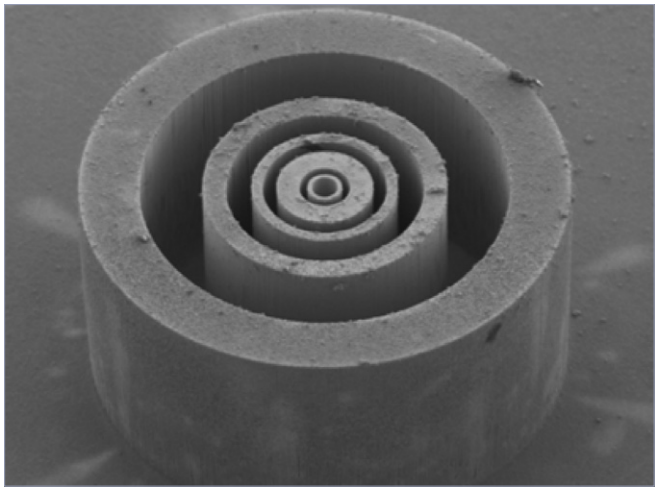
Biofabrication methods for the patterned assembly and synthesis of viral nanotemplates

K Gerasopoulos[1,2,3], M McCarthy[4], P Banerjee[2,3], X Fan[3,5], J N Culver[6] and R Ghodssi[1,2,3,5]
[1] MEMS Sensors and Actuators Laboratory (MSAL), University of Maryland, College Park, MD 20742, USA
[2] Department of Materials Science and Engineering, University of Maryland, College Park, MD 20742, USA
[3] Institute for Systems Research, University of Maryland, College Park, MD 20742, USA
[4] Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
[5] Department of Electrical and Computer Engineering, University of Maryland, College Park, MD 20742, USA
[6] Center for Biosystems Research, University of Maryland Biotechnology Institute, MD 20742, USA

This paper reports on novel methodologies for the patterning and templated synthesis of virus-structured nanomaterials in two- and three-dimensional microfabricated architectures using the *Tobacco mosaic virus* (TMV). The TMV is a high aspect ratio biological molecule which can be engineered to include amino acids with enhanced binding properties. These modifications facilitate self-assembly of the TMV onto various substrates and enable its use as a template for the synthesis of nanostructured materials. This work focuses on the combination of this bottom-up biologically inspired fabrication method with standard top-down micromachining processes that allow direct integration of the virus-structured materials into batch-fabricated devices. Photolithographic patterning of uncoated as well as nickel-coated TMV nanostructures has been achieved using a lift-off process in both solvent and mild basic solutions and their assembly onto three-dimensional polymer and silicon microstructures is demonstrated. In addition to these patterning techniques, *in situ* formation of metal oxide TMV coatings in patterned microfabricated environments is shown using atomic layer deposition directly on the nickel-coated viruses. The biofabrication 'process toolbox' presented in this work offers a simple and versatile alternative for the hierarchical patterning and incorporation of biotemplated nanomaterials into micro/nanofabrication schemes.

K Gerasopoulos *et al* 2010 *Nanotechnology* **21** 055304



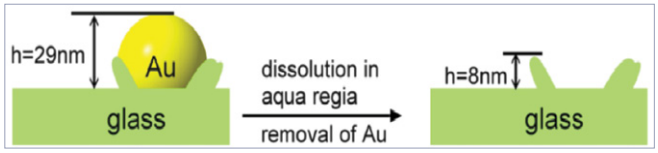
Scanning electron microscopy image of three-dimensional microstructures etched in silicon covered with nickel-coated TMV.

The facile fabrication of tunable plasmonic gold nanostructure arrays using microwave plasma

Chuen-Yuan Hsu[1], Jing-Wen Huang[1], Shangjr Gwo[2] and Kuan-Jiuh Lin[1]
[1] Department of Chemistry, National Chung Hsing University, Taichung 402, Taiwan
[2] Department of Physics, National Tsing Hua University, Hsinchu 300, Taiwan

Fabrication of isolated noble metal nanoparticles embedded in transparent substrates is the fasting growing demand for innovative plasmonic technologies. Here we report a simple and effective methodology for the preparation of highly stable plasmonic nanoparticles embedded in a glass surface. Size-controllable (10–70 nm) Au nanoparticles were rapidly prepared when subjected to the home-microwave plasma. Accordingly, the optical extinction maximum of the localized surface plasmon resonance (LSPR) can be systematically tuned in the range 532–586 nm. We find that the plasmonic structures are exceedingly stable toward immersion in ethanol solvents and pass successfully the adhesive tape test, which makes our system highly promising for efficient transmission-LSPR nanosensors. Besides, the attractive features of substrate-bound plasmonic nanostructures include its low cost, versatility, robustness, reusability and a promising ability to make a multi-arrayed LSPR biochip.

C-Y Hsu *et al* 2010 *Nanotechnology* **21** 035302



Schematic illustration of the difference of the average height between nanoparticles and ring-like structures.

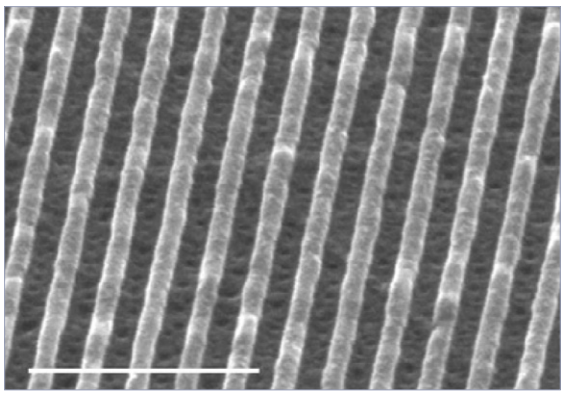
Ultrafast direct imprinting of nanostructures in metals by pulsed laser melting

Featured on nanotechweb.org

Bo Cui, Chris Keimel and Stephen Y Chou
Nanostructure Laboratory, Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA

We report a method of one-step direct patterning of metallic nanostructures. In the method, termed laser assisted direct imprinting (LADI), the surface of a metal film on a substrate is melted by a single excimer laser pulse and subsequently imprinted within ~100 ns using a transparent quartz mold, while the substrate is kept at a low temperature and in a solid phase. Using LADI, we imprinted gratings with ~100 nm linewidth, 100 nm depth, and 200 nm pitch, as well as isolated mesas of ~20 μm size, in Al, Au, Cu and Ni thin films. We found that the quartz mold was able to imprint metals even at temperatures higher than its melting point. The technique could be extended to other metals regardless of their ductility and hardness, and would find applications in photonic and plasmonic device production.

B Cui *et al* 2010 *Nanotechnology* **21** 045303



Scanning electron microscopy image of 200 nm period metal gratings in nickel patterned by LADI with a laser fluence of 0.41 J cm^{-2}. Scale bar is 1 μm.

The fabrication of a patterned ZnO nanorod array for high brightness LEDs

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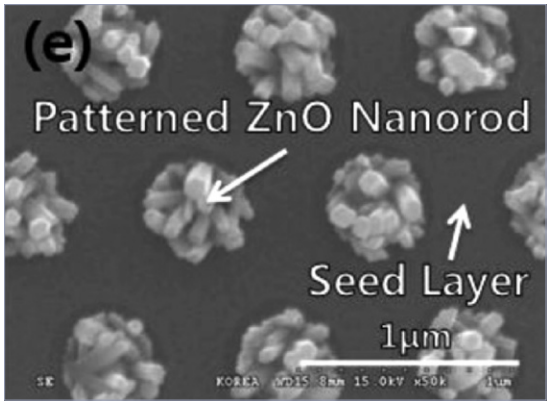
Hyoungwon Park, Kyeong-Jae Byeon, Ki-Yeon Yang, Joong-Yeon Cho and Heon Lee
Department of Materials Science and Engineering, Korea University, 5-1 Anam-Dong, Seongbuk-Ku, Seoul 136-701, Korea

In this study, a patterned ZnO nanorod array was formed on the ITO layer of GaN-based light-emitting diodes (LEDs), to increase the light extraction efficiency of the LED. The bi-layer imprinted resin pattern was used for selective growth of the ZnO nanorod array on the ITO layer. Compared to conventional LEDs grown on patterned sapphire substrate (PSS), the deposition of the blanket ZnO layer on the ITO layer increased the light extraction efficiency of the LED by about 10%. Further growth of the ZnO nanorod layer on the blanket ZnO layer increased the light extraction efficiency of the LED by about 23%. In the case that a patterned ZnO nanorod layer was formed on a blanket ZnO layer, the light extraction efficiency increased by about 34%. These enhancements of the device were caused by modulation of the refractive-index in ZnO layers and the surface roughening effects because of the unique design of the pattern, which was nanostructure-in-nanopattern, resulting in the formation of many escape cones on the LED surface.

H Park *et al* 2010 *Nanotechnology* **21** 355304



Scanning electron micrograph of a selectively grown ZnO nanorod array on the ITO electrode after removing the imprinted polymer pattern.

Direct-write fabrication of a nanoscale digital logic element on a single nanowire

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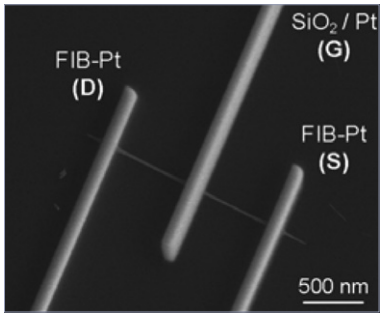
Somenath Roy and Zhiqiang Gao
Institute of Bioengineering and Nanotechnology, 31 Biopolis Way, 138669, Singapore

In this paper we report on the 'direct-write' fabrication and electrical characteristics of a nanoscale logic inverter, integrating enhancement-mode (E-mode) and depletion-mode (D-mode) field-effect transistors (FETs) on a single zinc oxide (ZnO) nanowire. 'Direct-writing' of platinum metal electrodes and a dielectric layer is executed on individual single-crystalline ZnO nanowires using either a focused electron beam (FEB) or a focused ion beam (FIB). We fabricate a top-gate FET structure, in which the gate electrode wraps around the ZnO nanowire, resulting in a more efficient gate response than the conventional back-gate nanowire transistors. For E-mode device operation, the gate electrode (platinum) is deposited directly onto the ZnO nanowire by a FEB, which creates a Schottky barrier and in turn a fully depleted channel. Conversely, sandwiching an insulating layer between the FIB-deposited gate electrode and the nanowire channel makes D-mode operation possible. Integrated E- and D-mode FETs on a single nanowire exhibit the characteristics of a direct-coupled FET logic (DCFL) inverter with a high gain and noise margin.

S Roy *et al* 2010 *Nanotechnology* **21** 245306



Scanning electron microscopy image of an enhancement-mode FET device on a ZnO nanowire. The source [S] and drain [D] electrodes were fabricated by FIB-deposited Pt, while the gate [G] Pt electrode is lying on an *in situ* deposited SiO_2 layer on the ZnO nanowire surface.

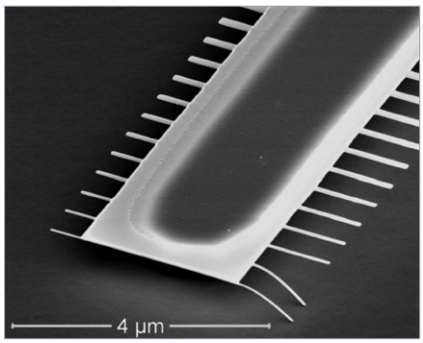
The fabrication of silicon nanostructures by focused-ion-beam implantation and TMAH wet etching

Featured on nanotechweb.org

Päivi Sievilä, Nikolai Chekurov and Ilkka Tittonen
Department of Micro and Nanosciences, Helsinki University of Technology, PO Box 3500, FI-02015 TKK, Finland

Local gallium implantation of silicon by a focused ion beam (FIB) has been used to create a mask for anisotropic tetramethylammonium hydroxide (TMAH) wet etching. The dependence of the etch stop properties of gallium-doped silicon on the implanted dose has been investigated and a dose of 4×10^{13} ions cm^{-2} has been determined to be the threshold value for achieving observable etching resistance. Only a thin, approx. 50 nm, surface layer is found to be durable enough to serve as a mask with a high selectivity of at least 2000:1 between implanted and non-implanted areas. The combined FIB–TMAH process has been used to generate various types of 3D nanostructures including nanochannels separated by thin vertical sidewalls with aspect ratios up to 1:30, ultra-narrow (approx. 25 nm) freestanding bridges and cantilevers, and gratings with a resolution of 20 lines μm^{-1}.

P Sievila *et al* 2010 *Nanotechnology* **21** 145301



Series of freestanding cantilevers on (100) Si substrate. The implantation dose was 4×10^{15} ions cm^{-2}. The length of the cantilevers is 0.5 μm (left) and 1 μm (right), the thickness approx. 50 nm and the width of the narrowest beams 35 nm. The two bridges adhere to the substrate because of stiction deriving from the drying step of the wet release process.

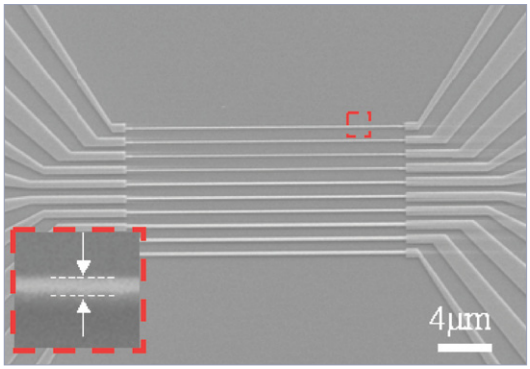
SENSING AND ACTUATING

Top-down fabricated silicon nanowire sensors for real-time chemical detection

Inkyu Park[1], Zhiyong Li[2], Albert P Pisano[3] and R Stanley Williams[2]
[1] Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejon, 305-701, Korea
[2] Information and Quantum System Lab, Hewlett-Packard Laboratories, Palo Alto, CA 94304, USA
[3] Berkeley Sensor and Actuator Center and Department of Mechanical Engineering, University of California at Berkeley, Berkeley, CA 94720, USA

Silicon nanowire (SiNW) sensors have been developed by using top-down fabrication that is CMOS (complementary metal–oxide–semiconductor) compatible for resistive chemical detection with fast response and high sensitivity. Top-down fabrication by electron beam lithography and reactive ion etching of a silicon on insulator (SOI) substrate enables compatibility with the CMOS fabrication process, accurate alignment with other electrical components, flexible design of the nanowire geometry and good control of the electrical characteristics. The SiNW sensors showed a large operation range for pH detection (pH = 4–10) with an average sensitivity of $(\Delta R/R)/\mathrm{pH} = 2.6\%/\mathrm{pH}$ and a rise time of 8 s. A small pH level difference ($\Delta\mathrm{pH} = 0.2$) near neutral pH conditions (pH = 7) could be resolved with the SiNW sensors. The sensor response to the presence of alkali metal ions and the long term drifting effects were also investigated.

I Park *et al* 2010 *Nanotechnology* **21** 015501



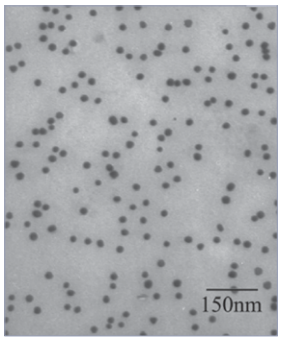
Silicon nanowire sensor arrays fabricated by the top-down nanofabrication process (inset: 50 nm width).

L-cysteine functionalized gold nanoparticles for the colorimetric detection of Hg^{2+} induced by ultraviolet light

Fang Chai[1,2], Chungang Wang[1], Tingting Wang[1], Zhanfang Ma[3] and Zhongmin Su[1]
[1] Institute of Functional Material Chemistry, Faculty of Chemistry, Northeast Normal University, Changchun 130024, People's Republic of China
[2] Department of chemistry, Harbin Normal University, Harbin 150500, People's Republic of China
[3] Department of Chemistry, Capital Normal University, Beijing 100037, People's Republic of China

A simple, cost-effective yet rapid and sensitive colorimetric sensor for the detection of Hg^{2+} using L-cysteine functionalized gold nanoparticles induced by ultraviolet radiation was developed. The sensitivity and selectivity of detection was also investigated. The L-cysteine modified gold nanoparticles can be induced to aggregate quickly in the presence of Hg^{2+}, especially with the assistance of ultraviolet radiation. The presence of Hg^{2+} can be monitored by the colorimetric response of gold nanoparticles. The detection of Hg^{2+} could be realized, after measuring the UV–vis spectra, with a detection limit of 100 nM. The selectivity of this method has been investigated by other divalent metal ions. The effective colorimetric sensor can be used for on-site and real-time Hg^{2+} detection.

F Chai *et al* 2010 *Nanotechnology* **21** 025501



Transmission electron microscopy image of the 16 nm Cys-GNPs.

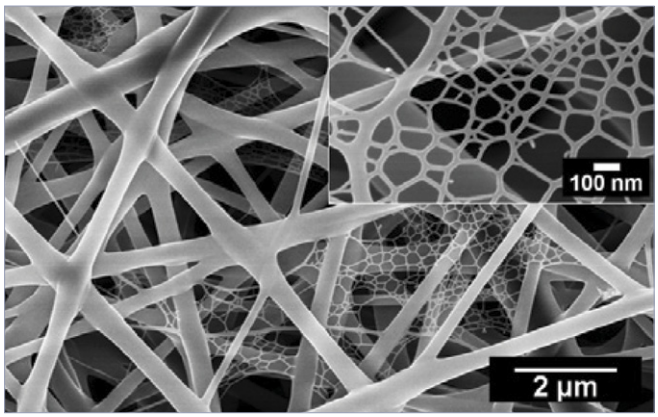
A highly sensitive humidity sensor based on a nanofibrous membrane coated quartz crystal microbalance

Featured on nanotechweb.org

Xianfeng Wang[1,2,3], Bin Ding[1,2], Jianyong Yu[2], Moran Wang[4] and Fukui Pan[5]
[1] State Key Laboratory for Modification of Chemical Fibers and Polymer Materials, College of Materials Science and Engineering, Donghua University, Shanghai 201620, People's Republic of China
[2] Nanomaterials Research Center, Modern Textile Institute, Donghua University, Shanghai 200051, People's Republic of China
[3] College of Textiles, Donghua University, Shanghai 201620, People's Republic of China
[4] Los Alamos National Laboratory, Los Alamos, NM 87545, USA
[5] College of Textiles and Fashion, Qingdao University, Qingdao 266071, People's Republic of China

A novel humidity sensor was fabricated by electrospinning deposition of nanofibrous polyelectrolyte membranes as sensitive coatings on a quartz crystal microbalance (QCM). The results of sensing experiments indicated that the response of the sensors increased by more than two orders of magnitude with increasing relative humidity (RH) from 6 to 95% at room temperature, exhibiting high sensitivity, and that, in the range of 20–95% RH, the Log(Δf) showed good linearity. The sensitivity of fibrous composite polyacrylic acid (PAA)/poly(vinyl alcohol) (PVA) membranes was two times higher than that of the corresponding flat films at 95% RH. Compared with fibrous PAA/PVA membranes, the nanofibrous PAA membranes exhibited remarkably enhanced humidity sensitivity due to their high PAA content and large specific surface area caused by the formation of ultrathin nanowebs among electrospun fibers. Additionally, the resultant sensors exhibited a good reversible behavior and good long term stability.

X Wang *et al* 2010 *Nanotechnology* **21** 055502



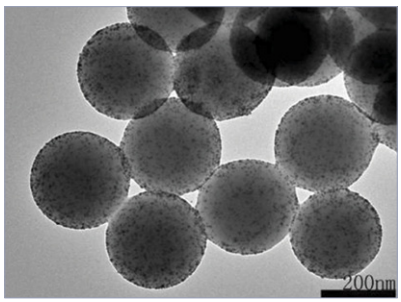
Field-emission scanning electron microscopy images of PAA fibrous membranes.

Fabrication of color changeable polystyrene spheres decorated by gold nanoparticles and their label-free biosensing

Yuetong Xia, Wensheng Lu and Long Jiang
Beijing National Laboratory for Molecular Science, Institute of Chemistry, Chinese Academy of Sciences, Beijing 100190, People's Republic of China

A novel and simple method for gold nanoshell synthesis with controllable core and shell sizes is reported here. A new 'tree-shape' surfactant bis(amidoethyl-carbamoylethyl) octadecylamine (C18N3) was synthesized and used as the glue for the fast combination of gold nanoparticles and the subsequent gold shell outside. The functionalized polystyrene (PS) cores were covered by a surfactant (PS@C18N3) bilayer. The presence of the surfactant double layer played the role of 'glue' in this method, so that upon controlling the amount of surfactant, it was possible to achieve: the manipulation of gold seed density on the PS@C18N3 spheres, the preparation of PS@Au hybrid structures, and a red-shift in the extinction absorption from 520 to 750 nm. Besides, the as-prepared PS@Au composites supported on a glass substrate exhibited excellent effectiveness in the molecular recognition of human-immunoglobulin G (h-IgG) and goat anti-human-immunoglobulin G (goat anti-h-IgG), showing a rapid response within 20 min with a low detection limit of 10 ng ml^{-1}. This demonstrates that PS@Au prepared and assembled using our method is potentially useful as a nanosensor platform for immunoassay.

Y Xia *et al* 2010 *Nanotechnology* **21** 085501



Transmission electron microscopy image showing gold shell growth using LPS@C18N3@Au seed.

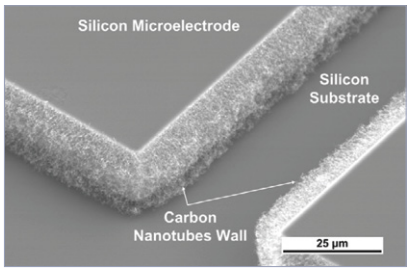
Batch-processed carbon nanotube wall as pressure and flow sensor

Featured on nanotechweb.org

Jungwook Choi and Jongbaeg Kim
School of Mechanical Engineering, Yonsei University, 262 Seongsanno, Seodaemun-gu, Seoul 120-749, Republic of Korea

A pressure and flow sensor based on the electrothermal-thermistor effect of a batch-processed carbon nanotube wall (CNT wall) is presented. The negative temperature coefficient of resistance (TCR) of CNTs and the temperature dependent tunneling rate through the CNT/silicon junction enable vacuum pressure and flow velocity sensing because the heat transfer rate between CNTs and the surrounding gas molecules differs depending on pressure and flow rate. The CNT walls are synthesized by thermal chemical vapor deposition (CVD) on an array of microelectrodes fabricated on a silicon-on-insulator (SOI) wafer. The CNTs are self-assembled between the microelectrodes and substrate across the thickness of a buried oxide layer during the synthesis process, and the simple batch fabrication results in high throughput and yield. A wide pressure range, down to 3×10^{-3} from 10^5 Pa, and a nitrogen flow velocity range between 1 and 52.4 mm s^{-1}, are sensed. Further experimental characterizations of the bias voltage dependent response of the sensor as a vacuum pressure gauge are presented.

J Choi *et al* 2010 *Nanotechnology* **21** 105502



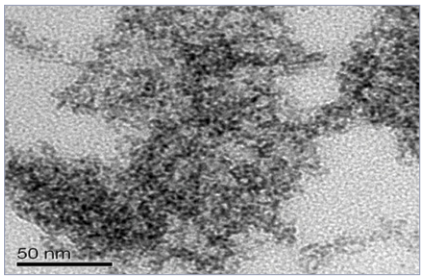
Scanning electron microscopy image of the silicon microelectrode, silicon substrate, and CNT wall.

L-cysteine-capped CdTe QD-based sensor for simple and selective detection of trinitrotoluene

Yufang Chen[1], Zhang Chen[1], Yejuan He[1], Hailan Lin[1], Pengtao Sheng[1], Chengbin Liu[1], Shenglian Luo[1,2] and Qingyun Cai[1]
[1] State Key Laboratory of Chemo/Biosensing and Chemometrics, Department of Chemistry, Hunan University, Changsha 410082, People's Republic of China
[2] School of Environment and Chemical Engineering, Nanchang Hangkong University, Nanchang 330063, People's Republic of China

Trinitrotoluene, usually known as TNT, is a kind of chemical explosive with hazardous and toxic effects on the environment and human health. National and societal security concerns have dictated an increasing need for the analytical detection of TNT with rapidity, high sensitivity and low cost. This work demonstrates a novel method using L-cysteine-capped CdTe quantum dots (QDs) to assay TNT, based on the formation of a Meisenheimer complex between TNT and cysteine. The fluorescence (FL) of quantum dots quench because electrons of the QDs transfer to the TNT molecules via the formation of a Meisenheimer complex. TNT can be detected with a low detection limit of 1.1 nM. Studies on the selectivity of this method show that only TNT can generate an intense signal response. The synthesized QDs are excellent nanomaterials for TNT detection. In addition, TNT in soil samples is also analyzed by the proposed method.

Y Chen *et al* 2010 *Nanotechnology* **21** 125502



High-resolution transmission electron microscopy image of CdTe QDs.

Calibration of optically trapped nanotools

D M Carberry[1], S H Simpson[1], J A Grieve[1], Y Wang[2,3], H Schäfer[2], M Steinhart[2], R Bowman[4], G M Gibson[4], M J Padgett[4], S Hanna[1] and M J Miles[1]
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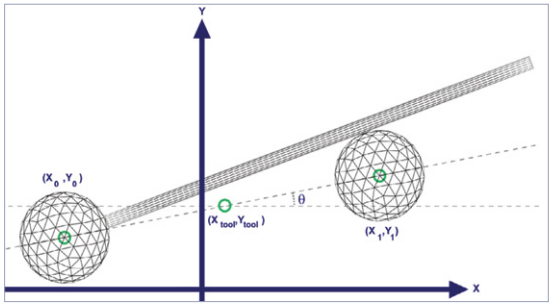
[2] Institute for Chemistry, University of Osnabrueck, Osnabrueck, Germany
[3] State Key Laboratory of Materials-Oriented Chemical Engineering, College of Chemistry and Chemical Engineering, Nanjing University of Technology, Nanjing, People's Republic of China
[4] SUPA, Department of Physics and Astronomy, University of Glasgow, Science Road, Glasgow G12 8QQ, UK

Holographically trapped nanotools can be used in a novel form of force microscopy. By measuring the displacement of the tool in the optical traps, the contact force experienced by the probe can be inferred. In the following paper we experimentally demonstrate the calibration of such a device and show that its behaviour is independent of small changes in the relative position of the optical traps. Furthermore, we explore more general aspects of the thermal motion of the tool.

D Carberry *et al* 2010 *Nanotechnology* **21** 175501



A schematic of the fabricated nanotool is shown. The coordinate system (x, y) is defined such that the average position of the tool is equal to zero, $\langle x_{tool}, y_{tool}, \theta_{tool} \rangle = (0, 0, 0)$. The green circles represent the location of the relevant coordinate, and the subscripts refer to the position of the tool, microsphere 0, or microsphere 1. θ_{tool} is the angle of the tool, relative to the *x*-axis.

A single molecule immunoassay by localized surface plasmon resonance

Kathryn M Mayer[1,2], Feng Hao[1,2], Seunghyun Lee[2,3], Peter Nordlander[1,2] and Jason H Hafner[1,2,3]
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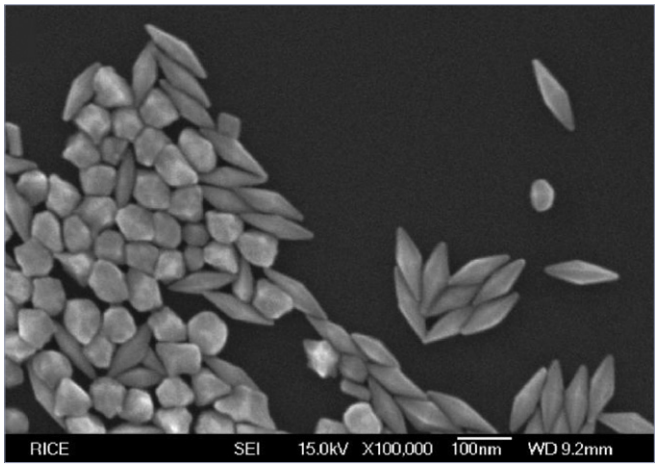
[2] Laboratory for Nanophotonics, Rice University, 6100 Main Street, Houston, TX, USA
[3] Department of Chemistry, Rice University, 6100 Main Street, Houston, TX, USA

Noble metal nanoparticles exhibit sharp spectral extinction peaks at visible and near-infrared frequencies due to the resonant excitation of their free electrons, termed localized surface plasmon resonance (LSPR). Since the resonant frequency is dependent on the refractive index of the nanoparticle surroundings, LSPR can be the basis for sensing molecular interactions near the nanoparticle surface. However, previous studies have not yet determined whether the LSPR mechanism can reach the ultimate sensing limit: the detection of individual molecules. Here we demonstrate single molecule LSPR detection by monitoring antibody–antigen unbinding events through the scattering spectra of individual gold bipyramids. Both experiments and finite element simulations indicate that the unbinding of single antigen molecules results in small, discrete < 0.5 nm blue-shifts of the plasmon resonance. The unbinding rate is consistent with antibody–antigen binding kinetics determined from previous ensemble experiments. According to these results, the effective refractive index of a single protein is approximately 1.54. LSPR sensing could therefore be a powerful addition to the current toolbox of single molecule detection methods since it probes interactions on long timescales and under relatively natural conditions.

K Mayer *et al* 2010 *Nanotechnology* **21** 255503



Scanning electron microscopy image showing gold bipyramid structure.

Did you know?

Nanotechnology received more than **16 000** citations in 2009.

MATERIALS: SYNTHESIS OR SELF-ASSEMBLY

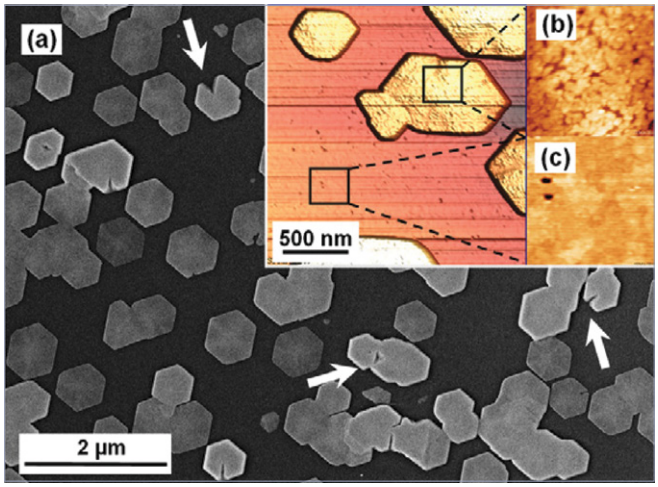
Self-assembled growth of catalyst-free GaN wires by metal–organic vapour phase epitaxy

Featured on nanotechweb.org

R Koester[1], J S Hwang[2], C Durand[1,3], D Le Si Dang[2] and J Eymery[1]
[1] Equipe mixte CEA-CNRS 'Nanophysique et semiconducteurs', CEA, INAC, SP2M, NPSC, 17 rue des Martyrs, 38054 Grenoble cedex 9, France
[2] Equipe mixte CEA-CNRS 'Nanophysique et semiconducteurs', Institut Néel-CNRS, 25 rue des Martyrs, BP 166 Fr-38042 Grenoble Cedex 9, France
[3] Equipe mixte CEA-CNRS 'Nanophysique et semiconducteurs', Université Joseph Fourier, Grenoble, France

A catalyst-free method for growing self-assembled GaN wires on c-plane sapphire substrates by metal–organic vapour phase epitaxy is developed. This approach, based on *in situ* deposition of a thin SiN_x layer (~2 nm), enables epitaxial growth of c-oriented wires with 200–1500 nm diameters and a large length/diameter ratio (>100) on c-plane sapphire substrate. Detailed study of the growth mechanisms shows that a combination of key parameters is necessary to obtain vertical growth. In particular, the duration of the SiN_x deposition prior to the wire growth is critical for controlling the epitaxy with the substrate. The GaN seed nucleation time determines the mean size diameter and structural quality, and a high Si-dopant concentration promotes vertical growth. Such GaN wires exhibit UV-light emission centred at ~350 nm and a weak yellow band (~550 nm) at low temperature.

R Koester *et al* 2010 *Nanotechnology* **21** 015602



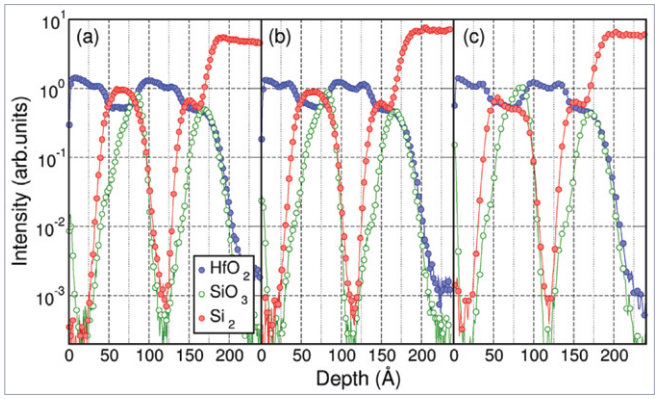
Study of the nucleation seed defects for 100 s nucleation time at 1000 °C without silane flow. (a) scanning electron micrograph showing the hexagonal-shaped seeds and the usual defects indicated by white arrows. The inset shows (b) atomic force microscopy images of seeds (height about 50–200 nm, and 0.8 nm RMS) and (c) in-between the seeds (0.2 nm RMS).

Si nanocrystal synthesis in $HfO_2/SiO/HfO_2$ multilayer structures

M Perego[1], G Seguini[1], C Wiemer[1], M Fanciulli[1,2], P-E Coulon[3] and C Bonafos[3]
[1] Laboratorio Nazionale MDM CNR-INFM, Via C. Olivetti 2, I-20041 Agrate Brianza (MI), Italy
[2] Dipartimento di Scienza dei Materiali, Universit`a degli Studi di Milano-Bicocca, I-20126 Milano, Italy
[3] nMat Group, CEMES-CNRS, rue J. Marvig 29, Toulouse FR-31055, France

The synthesis of two-dimensional arrays of Si nanocrystals in an HfO_2 matrix has been achieved by deposition of $HfO_2/SiO/HfO_2$ multilayer structures followed by high temperature (1100 °C) thermal treatment in nitrogen atmosphere. Silicon out-diffusion from the SiO layer through the HfO_2 films has been shown to be the limiting factor in the formation of the Si nanocrystals. Suitable strategies have been identified in order to overcome this limitation. Si nanocrystal formation has been achieved by properly adjusting the thickness of the SiO layer.

M Perego *et al* 2010 *Nanotechnology* **21** 055606



ToF-SIMS profile of the HfO_2/4 nm thick SiO/HfO_2 multilayer structure without SiO_2 capping layer before (a) and after thermal treatment at 600 °C (b) and 900 °C (c) in N_2 atmosphere for 60 min. The intensity of the Si_2^- signal at the surface increases with the annealing temperature.

Self-assembled GaAs/AlGaAs coupled quantum ring-disk structures by droplet epitaxy

C Somaschini[1], S Bietti[1], S Sanguinetti[1], N Koguchi[1] and A Fedorov[2]
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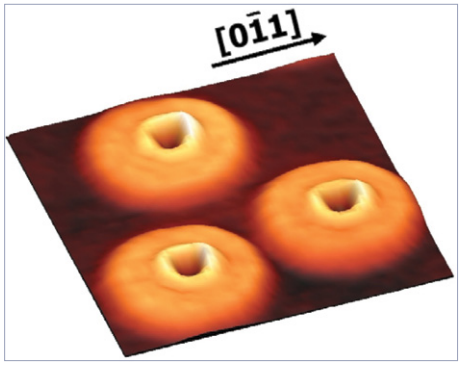
[2] CNISM, L-NESS and Dipartimento di Fisica del Politecnico di Milano, Via Anzani 42, I-22100 Como, Italy

The fabrication, by droplet epitaxy, of a class of quantum nanostructures characterized by a regular, nanometres high, flat disks with a diameter of hundreds of nanometres and a hole at the centre encircled by a ring a few nanometres high, is presented here. A detailed analysis of the growth kinetics performed via *in situ* and *ex situ* probes allows us to propose a working model for the formation of these structures.

C Somaschini *et al* 2010 *Nanotechnology* **21** 125601



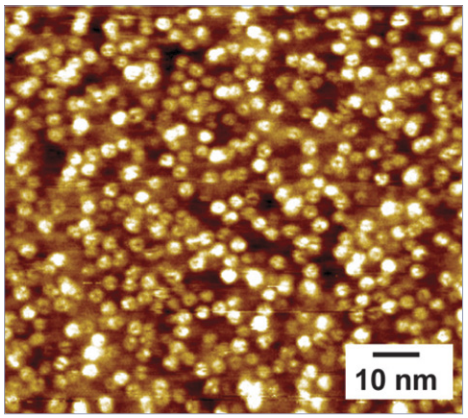
480×480 nm atomic force microscopy image of a typical CRD.

Ordering of monodisperse Ni nanoclusters by templating on high-temperature reconstructed α-Al_2O_3(0001)

K Venkataramani[1], S Helveg[2], B Hinnemann[2], M Reichling[3], F Besenbacher[1] and J V Lauritsen[1]
[1] Interdisciplinary Nanoscience Center (iNANO) and Department of Physics and Astronomy, Aarhus University, Aarhus C, DK 8000, Denmark
[2] Haldor Topsøe A/S, 2800 Kongens Lyngby, Denmark
[3] Fachbereich Physik, Universität Osnabrück, 49076 Osnabrück, Germany

We demonstrate that the characteristic $\sqrt{31}\times\sqrt{31}R9°$ reconstructed surface of α-alumina (Al_2O_3) acts as a nanotemplate for the growth of well-ordered monodisperse arrays of Ni nanoclusters. Due to the insulating nature of the substrate we use dynamic scanning force microscopy operated in the non-contact mode (NC-AFM) to characterize the nanotemplate, to examine the size and distribution of metallic clusters on the surface and to investigate their position with respect to the surface atomic structure. The present NC-AFM results for the interaction of Ni with α-Al_2O_3 are supported by density functional theory (DFT) calculations. The ability of α-Al_2O_3(0001) to act as a nanotemplate is attributed to a spatially modulated affinity towards the accommodation of Ni into the top layer by substituting the surface Al atoms at certain sites on the $\sqrt{31}\times\sqrt{31}R9°$ reconstructed surface formed by high-temperature annealing. The insulating template, demonstrated for Al_2O_3, may be a generally attractive system for the study of nanostructures which need to be isolated from a conducting bulk.

K Ventataramani *et al* 2010 *Nanotechnology* **21** 265602



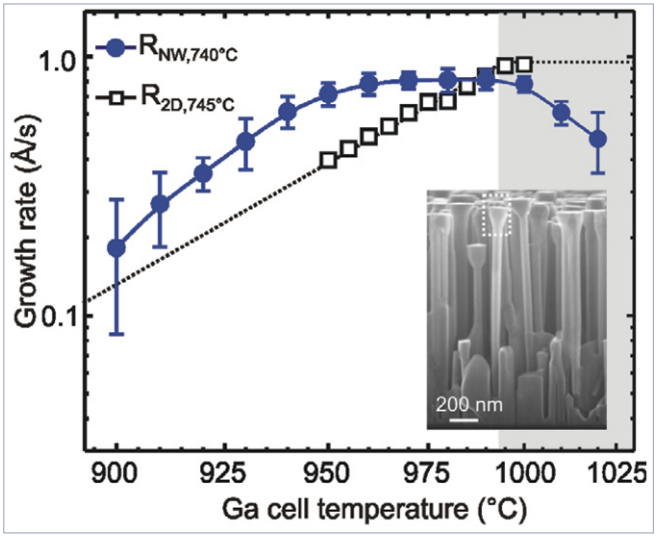
NC-AFM image of Ni deposited at room temperature on the clean α-Al_2O_3(0001) surface.

Identification of III–N nanowire growth kinetics via a marker technique

R Songmuang[1], T Ben[2], B Daudin[3], D González[2] and E Monroy[3]
[1] CEA-CNRS Group Nanophysics and Semiconductors, Institute Néel, 25 Rue des Martyrs, 38042, Grenoble cedex 9, France
[2] Departamento de Ciencia de los Materiales e I. M. y Q. I., Facultad de Ciencias, Universidad de Cádiz, Campus Río San Pedro, 11510 Puerto Real, Spain
[3] CEA-CNRS Group Nanophysics and Semiconductors, CEA-Grenoble INAC/SP2M, 17 Rue des Martyrs, 38054 Grenoble cedex 9, France

By using a marker technique based on nanowire (NW) heterostructure, we have identified the Ga-limited and N-limited GaN NW growth regimes, which are shifted in comparison to those in two-dimensional GaN layers. The results show that the Ga atoms diffusing along NW sidewalls have a significant contribution to the NW vertical growth. By reducing the substrate temperature, Ga-rich conditions locally activate the lateral growth. In contrast to Ga atoms, the contribution of Al and N adatom diffusion to the NW vertical growth is negligible. Finally, the control of GaN/AlN heterostructures in NWs is demonstrated.

R Songmuang *et al* 2010 *Nanotechnology* **21** 295605



Growth rate comparison between GaN in NWs grown at T_{sub} = 740 °C and R2D measured at T_{sub} = 745 °C as a function of *T*Ga. The grey shading represents the regime where the impinging Ga flux is higher than the active N flux at T_{sub} = 745 °C. The inset is a scanning electron microscopy image of a NW ensemble.

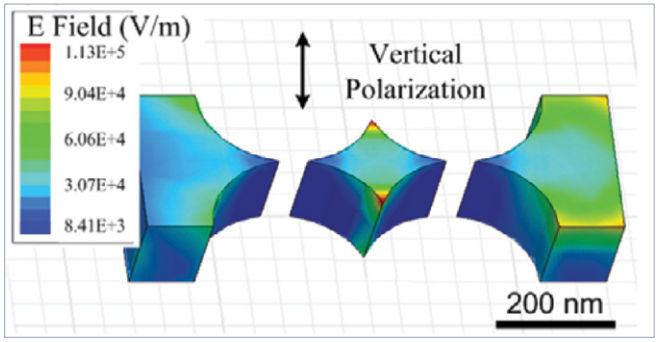
Towards carbon-nanotube integrated devices: optically controlled parallel integration of single-walled carbon nanotubes

Featured on nanotechweb.org

Y S Zhou[1], W Xiong[1], Y Gao[1], M Mahjouri-Samani[1], M Mitchell[1], L Jiang[2] and Y F Lu[1]
[1] Department of Electrical Engineering, University of Nebraska-Lincoln, Lincoln, NE 68588-0511, USA
[2] Department of Mechanical and Automation Engineering, Beijing Institute of Technology, Beijing 100081, People's Republic of China

Where it starts and where it goes? Controlled integration of single-walled carbon nanotubes (SWNTs) into pre-designed nano-architectures is one of the major challenges to be overcome for extensive scientific research and technological applications. Various serial assembly techniques have been proposed and developed. However, they are still a long way from practical applications due to the drawbacks on reliability, yield and cost. Here we demonstrate a laser-based strategy to achieve parallel integration of SWNTs into pre-designed nano-architectures through an optically controlled *in situ* growth process. Optical driving forces originated from tip-induced optical near-field enhancement and laser beam polarization were applied in this study to realize the controlled placement of SWNTs at designated sites following wanted orientations on the nanometer scale. Parallel integration of SWNT arrays was achieved by adjusting laser beam diameter to cover interested nano-architectures. The laser-based process suggests an efficient and cost-effective approach for fabricating and integrating SWNT-based devices and circuits.

Y S Zhou *et al* 2010 *Nanotechnology* **21** 315601



Electrical field distribution within the electrodes with the laser beam polarization normal to the electrode tip pair.

Formation and electrical transport properties of pentacene nanorod crystal

M Akai-Kasaya[1], C Ohmori[1], T Kawanishi[1], M Nashiki[1], A Saito[1], M Aono[2] and Y Kuwahara[1]
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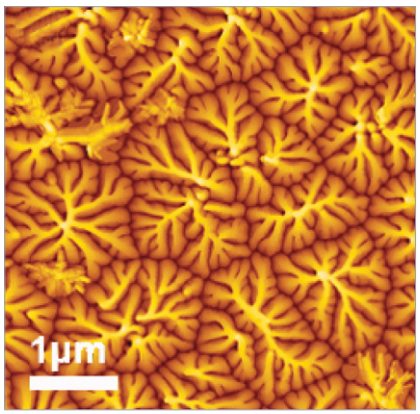
[2] Nano System Functionality Center, National Institute for Materials Science (NIMS), 3-13 Sakura, Tsukuba, Ibaraki 305-0003, Japan

The monophasic formation of an uncharted pentacene crystal, the pentacene nanorod, has been investigated. The restricted formation of the pentacene nanorod on a bare mica surface reveals a peculiar surface catalytic crystal growth mode of the pentacene. We demonstrated the charge transport measurements through a single pentacene nanorod and analyzed the data using a periodic hopping conduction model. The results revealed that the pentacene nanorod has a periodic conductive node within their one-dimensional crystal.

M Akai-Kasaya *et al* 2010 *Nanotechnology* **21** 365601



Topographic tapping mode atomic force microscopy image. *c*-axis-oriented pentacene thin film deposited onto a mica surface kept at RT in a vacuum formed using a diffusion pump with a base pressure of 5×10^{-5} Pa.

Self-induced growth of vertical free-standing InAs nanowires on Si(111) by molecular beam epitaxy

Featured on nanotechweb.org

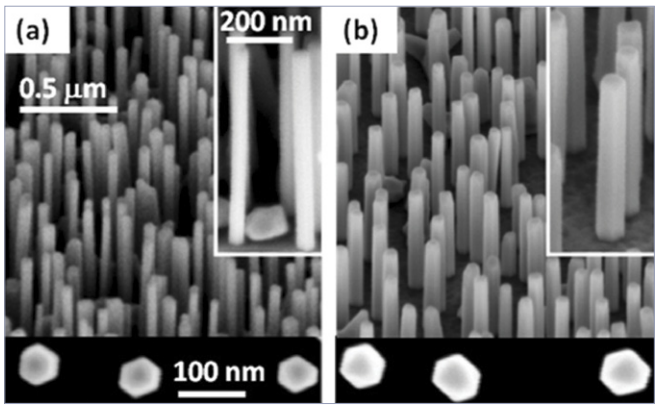
G Koblmüller[1], S Hertenberger[1], K Vizbaras[1], M Bichler[1], F Bao[2], J-P Zhang[2] and G Abstreiter[1]

[1] Walter Schottky Institut and Physik Department, Technische Universität München, 85748 Garching, Germany

[2] Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences, 215125 Suzhou, People's Republic of China

We report self-induced growth of vertically aligned (i.e. along the [111] direction), free-standing InAs nanowires on Si(111) substrates by solid-source molecular beam epitaxy. Implementation of an ultrathin amorphous SiO_x mask on Si(111) facilitated epitaxial InAs nanowire growth, as confirmed by high-resolution x-ray diffraction 2θ–ω scans and transmission electron microscopy. Depending on growth temperature (in the range of 400–520 °C) substantial size variation of both nanowire length and diameter was found under preservation of uniform, non-tapered hexagon-shaped geometries. The majority of InAs nanowires exhibited phase-pure zinc blende crystal structure with few defective regions consisting of stacking faults. Photoluminescence spectroscopy at 20 K revealed peak emission of the InAs nanowires at 0.445 eV, which is ~30 meV blueshifted with respect to the emission of the bulk InAs reference due to radial quantum confinement effects. These results show a promising route towards integration of well-aligned, high structural quality InAs-based nanowires with the desired aspect ratio and tailored emission wavelengths on an Si platform.

G Koblmüller *et al* 2010 *Nanotechnology* **21** 365602



Scanning electron micrographs of InAs nanowires grown on Si(111) at temperatures of (a) 430 °C and (b) 505 °C. Magnified areas (insets) and top-view images (bottom) show the nanowire/substrate interface and hexagonal geometry, respectively.

Thermal conductivity of multi-walled carbon nanotube sheets: radiation losses and quenching of phonon modes

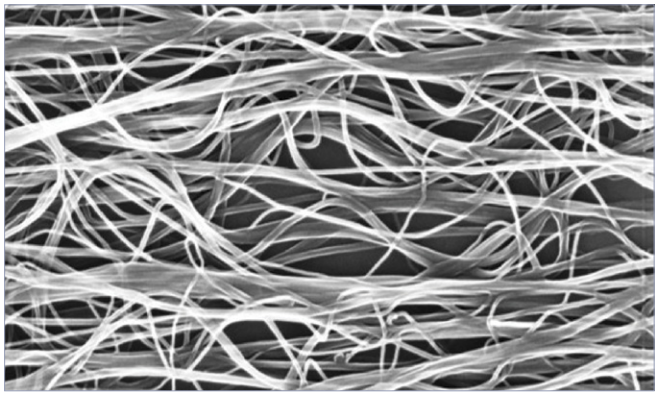
Ali E Aliev[1], Marcio H Lima[1], Edward M Silverman[2] and Ray H Baughman[1]

[1] Alan G MacDiarmid NanoTech Institute, University of Texas at Dallas, Richardson, TX 75083, USA

[2] Northrop Grumman Space Technology, Redondo Beach, CA 90278, USA

The extremely high thermal conductivity of individual carbon nanotubes, predicted theoretically and observed experimentally, has not yet been achieved for large nanotube assemblies. Resistances at tube–tube interconnections and tube–electrode interfaces have been considered the main obstacles for effective electronic and heat transport. Here we show that, even for infinitely long and perfect nanotubes with well-designed tube–electrode interfaces, excessive radial heat radiation from nanotube surfaces and quenching of phonon modes in large bundles are additional processes that substantially reduce thermal transport along nanotubes. Equivalent circuit simulations and an experimental self-heating 3ω technique were used to determine the peculiarities of anisotropic heat flow and thermal conductivity of single MWNTs, bundled MWNTs and aligned, free-standing MWNT sheets. The thermal conductivity of individual MWNTs grown by chemical vapor deposition and normalized to the density of graphite is much lower ($\kappa_{MWNT} = 600 \pm 100\ W\,m^{-1}\,K^{-1}$) than theoretically predicted. Coupling within MWNT bundles decreases this thermal conductivity to $150\ W\,m^{-1}\,K^{-1}$. Further decrease of the effective thermal conductivity in MWNT sheets to $50\ W\,m^{-1}\,K^{-1}$ comes from tube–tube interconnections and sheet imperfections like dangling fiber ends, loops and misalignment of nanotubes. Optimal structures for enhancing thermal conductivity are discussed.

A E Aliev *et al* 2010 *Nanotechnology* **21** 035709



Scanning electron microscopy image of a free-standing MWNT sheet.

Influence of electrode size and geometry on electrochemical experiments with combined SECM–SFM probes

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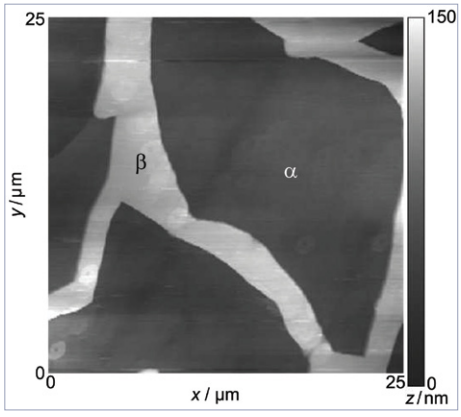
Sascha E Pust[1], Marc Salomo[2], Egbert Oesterschulze[2] and Gunther Wittstock[1]
[1] Carl von Ossietzky University of Oldenburg, Faculty of Mathematics and Science, Center of Interface Science (CIS), Department of Pure and Applied Chemistry, D-26111 Oldenburg, Germany
[2] Physik und Technologie der Nanostrukturen, Nano+Bio Center, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Gold electrodes integrated into silicon scanning force microscopy (SFM) probes allow the acquisition of spatially correlated data for sample morphology (via SFM) and local electrochemical reactivity via scanning electrochemical microscopy (SECM). The lateral resolution of both techniques is controlled by different properties of the integrated probes. The topographic tracking provided by the SFM mechanism allows the realization of very small working distances for the SECM measurements. Microfabrication technology was used in order to reduce the size of the active electrode area of the tip into the sub-100 nm regime. The functionality of the probes was tested using electrochemical methods. Experiments revealed that the response could be quantitatively compared to numerical simulation. The low working distance, in combination with the small size of the active electrode area, allows for high lateral resolution in the SECM images. This is illustrated with different model substrates that cover a range of different rate constants and illustrate the dependence of the SECM contrast on the local kinetics of the sample in the sub-micrometre size range.

S E Pust *et al* 2010 *Nanotechnology* **21** 105709



SECM–SFM topographical image of a coarse-grained Ti-6Al-4V specimen in a solution of 2 mM $[Ru(NH_3)_6]Cl_3$ in 0.1 M KCl. The image was scanned from right to left.

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New insights into the use of magnetic force microscopy to discriminate between magnetic and nonmagnetic nanoparticles

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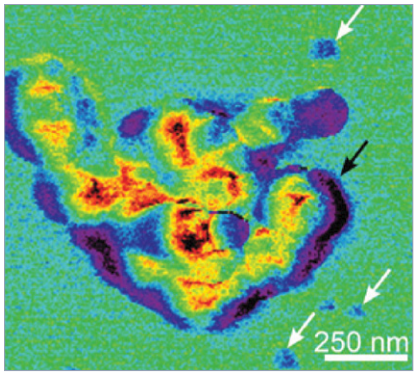
Cristina S Neves[1], Pedro Quaresma[1,2], Pedro V Baptista[2], Patrícia A Carvalho[3], João Pedro Araújo[4], Eulália Pereira[1] and Peter Eaton[1]
[1] Requimte/Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, 4169-007 Porto, Portugal
[2] CIGMH/Departamento de Ciências da Vida, FCT-UNL, 2829-516 Caparica, Portugal
[3] Departamento de Engenharia de Materiais, IST, Avenida Rovisco Pais 1049-100 Lisboa, Portugal
[4] IFIMUP, Rua do Campo Alegre, 678, 4169-007 Porto, Portugal

Magnetic force microscopy (MFM) is a very powerful technique, which can potentially be used to detect and localize the magnetic fields arising from nanoscopic magnetic domains, such as magnetic nanoparticles. However, in order to achieve this, we must be able to use MFM to discriminate between magnetic forces arising from the magnetic nanoparticles and nonmagnetic forces from other particles and sample features. Unfortunately, MFM can show a significant response even for nonmagnetic nanoparticles, giving rise to potentially misleading results. The literature to date lacks evidence for MFM detection of magnetic nanoparticles with nonmagnetic nanoparticles as a control. In this work, we studied magnetite particles of two sizes and with a silica shell, and compared them to nonmagnetic metallic and silica nanoparticles. We found that even on conducting, grounded substrates, significant electrostatic interaction between atomic force microscopy probes and nanoparticles can be detected, causing nonmagnetic signals that might be mistaken for a true MFM response. Nevertheless, we show that MFM can be used to discriminate between magnetic and nonmagnetic nanoparticles by using an electromagnetic shielding technique or by analysis of the phase shift data. On the basis of our experimental evidence we propose a methodology that enables MFM to be reliably used to study unknown samples containing magnetic nanoparticles, and correctly interpret the data obtained.

C Neves *et al* 2010 *Nanotechnology* **21** 305706



MFM phase shift images at lift heights of 15 nm containing a cluster of Fe_3O_4 NPs (black arrow) and scattered AuNPs (some examples with white arrows).

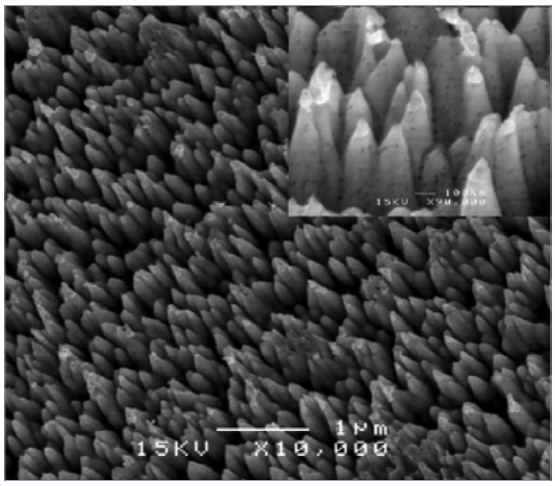
Aligned gold nanoneedle arrays for surface-enhanced Raman scattering

Yong Yang[1,2], Masaki Tanemura[3], Zhengren Huang[1], Dongliang Jiang[1], Zhi-Yuan Li[4], Ying-ping Huang[5], Go Kawamura2, Kohei Yamaguchi[3] and Masayuki Nogami[2]

[1] State Key Laboratory of High Performance Ceramics and SuperfineMicrostructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, People's Republic of China
[2] Department of Materials Science and Engineering, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan
[3] Department of Environmental Technology, Graduate School of Engineering, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan
[4] Institute of Physics, Chinese Academy of Sciences, Beijing 100080, People's Republic of China
[5] Engineering Research Center of Eco-environment in Three Gorges Reservoir Region, Ministry of Education, China Three Gorges University, Hubei Yichang 443002, People's Republic of China

A simple Ar^+ -ion irradiation route has been developed to prepare gold nanoneedle arrays on glass substrates for surface-enhanced Raman scattering (SERS)-active substrates. The nanoneedles exhibited very sharp tips with an apex diameter of 20 nm. These arrays were evaluated as potential SERS substrates using malachite green molecules and exhibited a SERS enhancement factor of greater than 10^8, which is attributed to the localized electron field enhancement around the apex of the needle and the surface plasmon coupling originating from the periodic structure. This work demonstrates a new technique for producing controllable and reproducible SERS substrates potentially applicable for chemical and biological assays.

Y Yang *et al* 2010 *Nanotechnology* **21** 325701



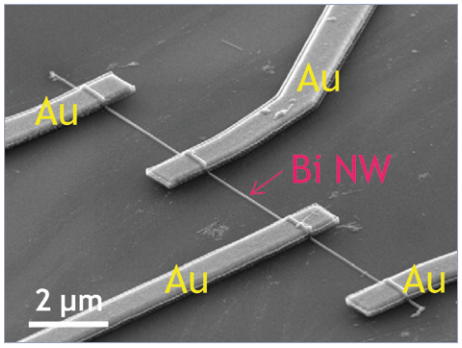
Scanning electron microscopy image of an Au nanoneedle array prepared by an Au film with a thickness of 400 nm. The inset is the high-resolution SEM image of several Au nanoneedles observed at a tilt angle of 45°.

Direct observation of the semimetal-to-semiconductor transition of individual single-crystal bismuth nanowires grown by on-film formation of nanowires

Seunghyun Lee, Jinhee Ham, Kyejin Jeon, Jin-Seo Noh and Wooyoung Lee
Department of Materials Science and Engineering and Nanomedical National Core Research Center (NCRC), Yonsei University, 262 Seongsanno, Seodaemun-gu, Seoul 120-749, Korea

We have systematically investigated the semimetal-to-semiconductor transition of individual single-crystalline Bi nanowires. For this work, we developed a technique to reduce the diameter of Bi nanowires grown by our unique on-film formation of nanowires (OFF-ON) method. Cooling down the substrate temperature during Bi film deposition by use of liquid nitrogen, film structures with small-sized grains were obtained. Through thermal annealing of these fine-granular Bi films, single-crystalline Bi nanowires can be produced with minimum diameter of ~20 nm. Elaborative nanofabrication techniques were employed to shape state-of-the-art four-probe devices based on the individual small diameter Bi nanowires. Diameter-dependent transport measurements on the individual Bi nanowires revealed that the semimetal-to-semiconductor transition really occurred at about $d_w = 63$ nm. Moreover, band structure calculations supported this occurrence of the semimetal-to-semiconductor transition.

S Lee *et al* 2010 *Nanotechnology* **21** 405701



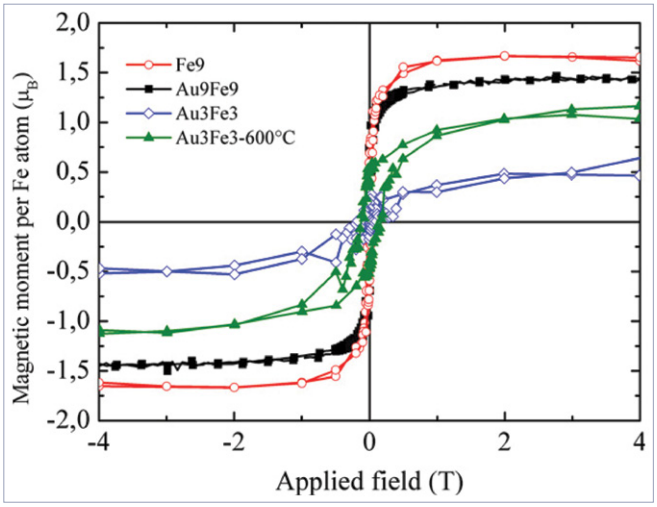
Scanning electron microscopy image of four-probe device based on an individual Bi nanowire to investigate its transport properties.

Coupling between magnetic and optical properties of stable Au–Fe solid solution nanoparticles

C de Julián Fernández[1], G Mattei[2], E Paz[3], R L Novak[1], L Cavigli[4], L Bogani[1], F J Palomares[3], P Mazzoldi[2] and A Caneschi[1]
[1] INSTM RU at the Department of Chemistry of the University of Firenze, via della Lastruccia 3, 50019 Sesto Fiorentino, Italy
[2] Department of Physics, CNISM and University of Padova, via Marzolo 8, 35131 Padova, Italy
[3] Instituto de Ciencia de Materiales de Madrid (CSIC), Cantoblanco, 28049 Madrid, Spain
[4] Department of Physics–LENS, University of Florence, via Sansone 1, 50019 Sesto Fiorentino, Italy

Au–Fe nanoparticles constitute one of the simplest prototypes of a multifunctional nanomaterial that can exhibit both magnetic and optical (plasmonic) properties. This solid solution, not feasible in the bulk phase diagram in thermal equilibrium, can be formed as a nanostructure by out-of-equilibrium processes. Here, the novel magnetic, optical and magneto-optical properties of ion-implanted Au–Fe solid solution nanoparticles dispersed in a SiO_2 matrix are investigated and correlated. The surface plasmon resonance of the Au–Fe nanoparticles with almost equicomposition is strongly damped when compared to pure Au and to Au-rich Au–Fe nanoparticles. In all cases, the Au atoms are magnetically polarized, as measured by x-ray magnetic circular dichroism, and ferromagnetically coupled with Fe atoms. Although the chemical stability of Au–Fe nanoparticles is larger than that of Fe nanoparticles, both the magnetic moment per Fe atom and the order temperature are smaller. These results suggest that electronic and magnetic properties are more influenced by the hybridization of the electronic bands in the Au–Fe solid solution than by size effects. On the other hand, the magneto-optical transitions allowed in the vis–nIR spectral regions are very similar. In addition, we also observe, after studying the properties of thermally treated samples, that the Au–Fe alloy is stabilized, not by surface effects, but by the combination of the out-of-equilibrium nature of the ion implantation technique and by changes in the properties due to size effects.

C de Julián Fernández *et al* 2010 *Nanotechnology* **21** 165701



Hysteresis loops measured at 3 K of the Au_9Fe_9, Au_3Fe_3 and Fe_9 as-implanted samples, and of the Au_3Fe_3 sample after 1 h thermal treatment at 600 °C.

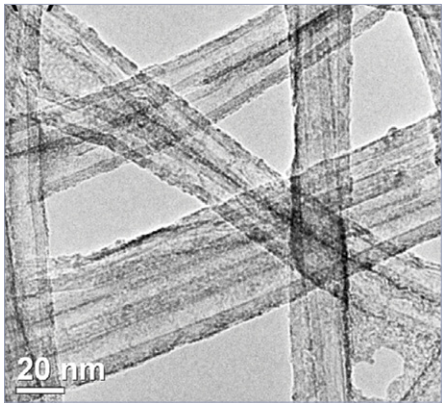
High-performance supercapacitors using a nanoporous current collector made from super-aligned carbon nanotubes

Featured on nanotechweb.org

Ruifeng Zhou, Chuizhou Meng, Feng Zhu, Qunqing Li, Changhong Liu, Shoushan Fan and Kaili Jiang
Department of Physics and Tsinghua-Foxconn Nanotechnology Research Center, Tsinghua University, Beijing 100084, People's Republic of China

Nanoporous current collectors for supercapacitors have been fabricated by cross-stacking super-aligned carbon nanotube (SACNT) films as a replacement for heavy conventional metallic current collectors. The CNT-film current collectors have good conductivity, extremely low density (27 μg cm^{-2}), high specific surface area, excellent flexibility and good electrochemical stability. Nanosized active materials such as NiO, Co_3O_4 or Mn_2O_3 nanoparticles can be directly synthesized on the SACNT films by a straightforward one-step, *in situ* decomposition strategy that is both efficient and environmentally friendly. These composite films can be integrated into a pseudo-capacitor that does not use metallic current collectors, but nevertheless shows very good performance, including high specific capacitance (~500 F g^{-1}, including the current collector mass), reliable electrochemical stability (< 4.5% degradation in 2500 cycles) and a very high rate capability (245 F g^{-1} at 155 A g^{-1}).

R Zhou *et al* 2010 *Nanotechnology* **21** 345701



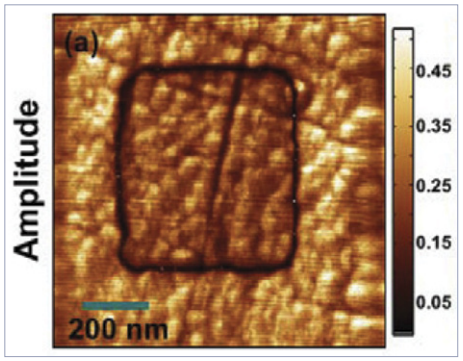
Transmission electron microscopy image of several CNTs covered with a layer of NiO nanoparticles.

Resolution theory, and static and frequency-dependent cross-talk in piezoresponse force microscopy

S Jesse[1], S Guo[1], A Kumar[1], B J Rodriguez[2], R Proksch[3] and S V Kalinin[1]
[1] The Center for NanophaseMaterials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[2] Conway Institute of Biomolecular and Biomedical Research, University College Dublin, Belfield, Dublin 4, Republic of Ireland
[3] Asylum Research, Santa Barbara, CA 93117, USA

Probing the functionality of materials locally by means of scanning probe microscopy (SPM) requires a reliable framework for identifying the target signal and separating it from the effects of surface morphology and instrument non-idealities, e.g. instrumental and topographical cross-talk. Here we develop a linear resolution theory framework in order to describe the cross-talk effects, and apply it for elucidation of frequency-dependent cross-talk mechanisms in piezoresponse force microscopy. The use of a band excitation method allows electromechanical/electrical and mechanical/topographic signals to be unambiguously separated. The applicability of a functional fit approach and multivariate statistical analysis methods for identification of data in band excitation SPM is explored.

S Jesse *et al* 2010 *Nanotechnology* **21** 405703



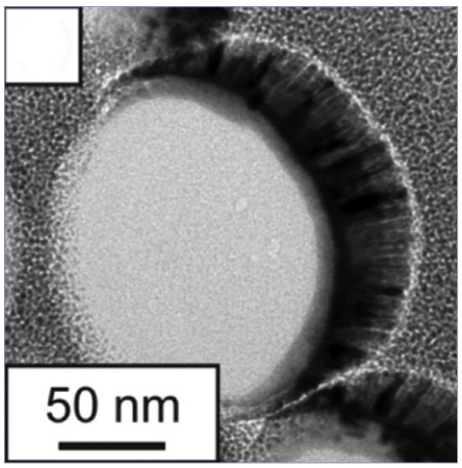
The piezoresponse force microscopy amplitude for a given frequency reconstructed from the simple harmonic oscillator fit parameter.

Nanocap arrays of granular CoCrPt:SiO_2 films on silica particles: tailoring of the magnetic properties by Co^+ irradiation

P Krone[1], C Brombacher[1], D Makarov[1], K Lenz[2], D Ball[2], F Springer[3], H Rohrmann[4], J Fassbender[2] and M Albrecht[1]
[1] Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany
[2] Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf e.V., PO Box 51 01 19, D-01314 Dresden, Germany
[3] Department of Physics, University of Konstanz, D-78457 Konstanz, Germany
[4] OC Oerlikon Balzers AG, LI-9496 Balzers, Liechtenstein

An approach for tailoring the magnetic properties by ion irradiation of granular perpendicular CoCrPt:SiO_2 films grown on silica particles with sizes down to 10 nm was investigated. The as-prepared samples reveal an intriguing scaling dependence of the coercive field and remnant magnetization: both parameters are found to decrease with decreasing particle size. However, Co^+ irradiation at a low fluence of 0.5×10^{14} cm^{-2} already results in an opposite scaling behavior. It is assumed that this modification is due to the enhancement of the intergranular magnetic exchange coupling of the granular CoCrPt:SiO_2 film initiated by Co^+ irradiation resulting in a modified reversal behavior. Further increase of the irradiation fluence beyond 1.6×10^{14} ions cm^{-2} leads to a degradation of the magnetic layer properties, lowering the remnant magnetization and the coercive field in the easy-axis direction. Moreover, the local magnetic properties of the samples were analyzed by magnetic force microscopy revealing magnetic multi-domain cap structures.

P Krone *et al* 2010 *Nanotechnology* **21** 385703



Cross-sectional transmission electron microscopy image of a magnetic cap grown on a 160 nm SiO_2 particle.

Nitrogen doping of nanoporous WO_3 layers by NH_3 treatment for increased visible light photoresponse

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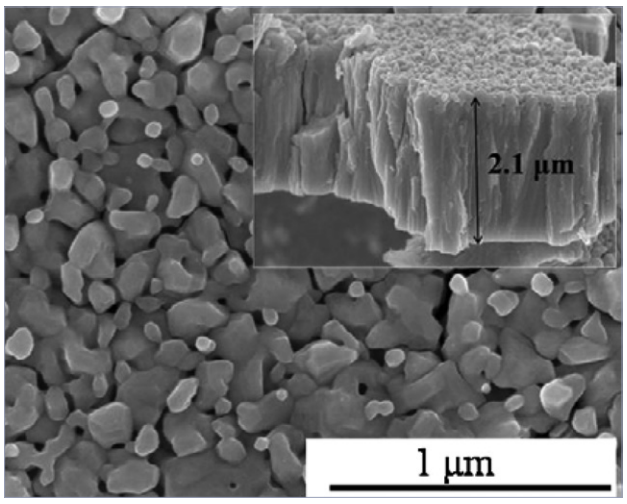
Yoon-Chae Nah, Indhumati Paramasivam, Robert Hahn, Nabeen K Shrestha and Patrik Schmuki
Department of Materials Science,WW4-LKO, University of Erlangen-Nuremberg, Martensstraße 7, 91058 Erlangen, Germany

Nanoporous WO_3 layers were grown by electrochemical anodization of W in a fluoride containing electrolyte. These layers were exposed to a thermal treatment in NH_3 to achieve nitrogen doping of the material. The morphology, crystal structure, composition and photoresponse of pure and nitrogen doped WO_3 were compared using scanning electron microscopy, x-ray diffraction, x-ray photoelectron spectroscopy, and photoelectrochemical measurements. The results clearly show that successful nitrogen doping into WO_3 layers can be achieved by controlling the temperature and time during the NH_3 treatment. Most importantly, it is demonstrated that for the nitrogen doped WO_3 layers the photocurrent is significantly enhanced in the visible light region.

Y-C Nah *et al* 2010 *Nanotechnology* **21** 105704



Scanning electron microscopy (SEM) images of WO_3 layers after annealing at 450 °C in air for 1 h followed by a NH_3 treatment at 600 °C. The treatment time is 4 h for all the samples. The inset shows a cross-sectional SEM image.

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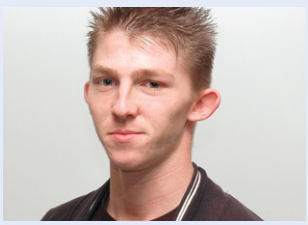

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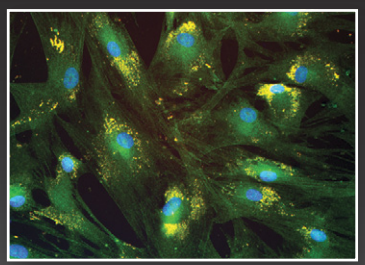
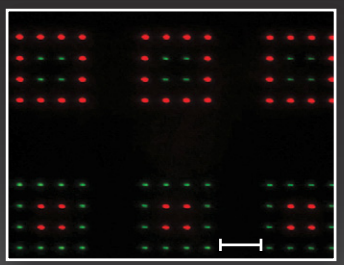


Stem cell adhesion and spreading on a patterned substrate.



Multiplexing of PEG dot arrays deposited onto a glass slide. Scale bar = 20 µm.

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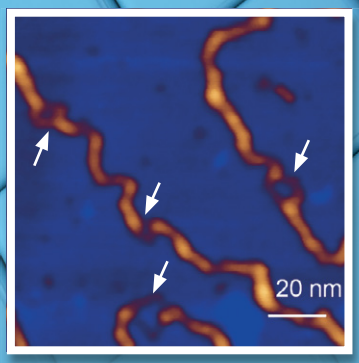
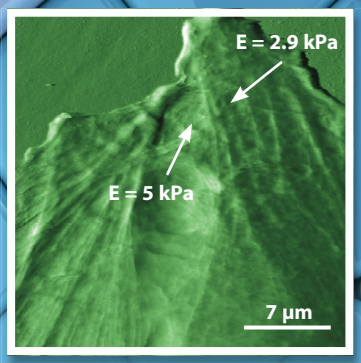
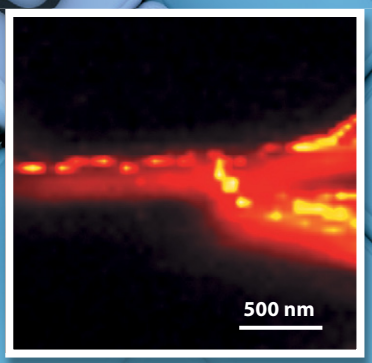


DNA molecule imaged by AFM. Uncoiled regions are marked by arrows.



Live cell imaged by AFM in physiological conditions. Two points of surface differ in stiffness.



Bundle of carbon nanotubes imaged by tip-enhanced Raman microscopy.

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