TiO$_2$ nanotube arrays with Pt nanoparticles, prepared using a bulk technique taken from the article ‘Ta$_2$O$_5$- 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

Nanisland 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 J 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
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
E-mail nano@iop.org
iopscience.org/nano
## CONTENTS

### B I O L O G Y  A N D  M E D I C I N E

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using carbon nanotubes to induce micronuclei and double strand breaks of the DNA in human cells</td>
<td>8</td>
</tr>
<tr>
<td>Jelena Cveticanin, Gordana Joksic, Andreja Leskovac, Sandra Petrovic, Ana Valenta Sobot and Olivera Neskovic</td>
<td></td>
</tr>
<tr>
<td>Platinum nanoparticles: a promising material for future cancer therapy?</td>
<td>8</td>
</tr>
<tr>
<td>Erika Porcel, Samuel Liehn, Hynd Remita, Noriko Usami, Katsumi Kobayashi, Yoshiya Furusawa, Claude Le Sech and Sandrine Lacombe</td>
<td></td>
</tr>
<tr>
<td>The nanostructure effect on the adhesion and growth rates of epithelial cells with well-defined nanoporous alumina substrates</td>
<td>8</td>
</tr>
<tr>
<td>S H Chung, S J Son and J Min</td>
<td></td>
</tr>
<tr>
<td>Directional neurite growth using carbon nanotube patterned substrates as a biomimetic cue</td>
<td>9</td>
</tr>
<tr>
<td>Min Jee Jang, Seon Namgung, Seunghun Hong and Yoonkey Nam</td>
<td></td>
</tr>
<tr>
<td>Immobilization of motile bacterial cells via dip-pen nanolithography</td>
<td>9</td>
</tr>
<tr>
<td>Dorjderem Nyamjav, Sergey Rozhok and Richard C Holz</td>
<td></td>
</tr>
<tr>
<td>An insight into the metabolic responses of ultra-small superparamagnetic particles of iron oxide using metabonomic analysis of biofluids</td>
<td>10</td>
</tr>
<tr>
<td>Jianghua Feng, Huili Liu, Limin Zhang, Kishore Bhakoo and Lehui Lu</td>
<td></td>
</tr>
</tbody>
</table>

### E L E C T R O N I C S  A N D  P H O T O N I C S

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonvolatile memory devices based on few-layer graphene films</td>
<td>10</td>
</tr>
<tr>
<td>Yong-Joo Doh and Gyu-Chul Yi</td>
<td></td>
</tr>
<tr>
<td>Flexible organic light-emitting diodes with transparent carbon nanotube electrodes: problems and solutions</td>
<td>11</td>
</tr>
<tr>
<td>Liangbing Hu, Jianfeng Li, Jun Liu, George Gruner and Tobin Marks</td>
<td></td>
</tr>
<tr>
<td>High yield fabrication of chemically reduced graphene oxide field effect transistors by dielectrophoresis</td>
<td>11</td>
</tr>
<tr>
<td>Daeha Joung, A Chunder, Lei Zhai and Saiful I Khondaker</td>
<td></td>
</tr>
<tr>
<td>Large-scale patterned multi-layer graphene films as transparent conducting electrodes for GaN light-emitting diodes</td>
<td>12</td>
</tr>
<tr>
<td>Gunho Jo, Minhyeok Choe, Chu-Young Cho, Jin Ho Kim, Woojin Park, Sangchul Lee, Woong-Ki Hong, Tae-Wook Kim, Seong-Ju Park, Byung Hee Hong, Yung Ho Kahng and Takhee Lee</td>
<td></td>
</tr>
<tr>
<td>Multicolour luminescence from InGaN quantum wells grown over GaN nanowire arrays by molecular-beam epitaxy</td>
<td>12</td>
</tr>
<tr>
<td>R Armitage and K Tsubaki</td>
<td></td>
</tr>
<tr>
<td>Solid-state dye-sensitized solar cells based on ZnO nanocrystals</td>
<td>12</td>
</tr>
<tr>
<td>M Boucharef, C Di Bin, M S Boumaza, M Colas, H J Snaith, B Ratier and J Bouclé</td>
<td></td>
</tr>
<tr>
<td>Tunable-white-light-emitting nanowire sources</td>
<td>13</td>
</tr>
<tr>
<td>Keumyoung Seo, Taekyung Lim, Sangdan Kim, Hong-Lee Park and Sanghyun Ju</td>
<td></td>
</tr>
<tr>
<td>ZnO nanotube-based dye-sensitized solar cell and its application in self-powered devices</td>
<td>13</td>
</tr>
<tr>
<td>Jingbin Han, Fengru Fan, Chen Xu, Shisheng Lin, Min Wei, Xue Duan and Zhong Lin Wang</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Customizable in situ TEM devices fabricated in freestanding membranes by focused ion beam milling</td>
<td>14</td>
</tr>
<tr>
<td>Anders Lei, Dirch Hjorth Petersen, Timothy John Booth, Lasse Vinther Homann, Christian Kallesoe, Ozlem Sardan Sukas, Yvonne Gyristing, Kristian Molhave and Peter Boggild</td>
<td></td>
</tr>
<tr>
<td>Site-directed delivery of ferritin-encapsulated gold nanoparticles</td>
<td>14</td>
</tr>
<tr>
<td>B Zheng, I Yamashita, M Uenuma, K Iwahori, M Kobayashi and Y Uraoka</td>
<td></td>
</tr>
<tr>
<td>Fullerene monolayer formation by spray coating</td>
<td>14</td>
</tr>
<tr>
<td>J Červenka and C F J Flipse</td>
<td></td>
</tr>
<tr>
<td>Synthesis of TiO₂ nanoframe and the prototype of a nanoframe solar cell</td>
<td>15</td>
</tr>
<tr>
<td>Ying Chen, Ho-Cheol Kim, Jim McVittie, Chiu Ting and Yoshio Nishi</td>
<td></td>
</tr>
<tr>
<td>Biofabrication methods for the patterned assembly and synthesis of viral nanotemplates</td>
<td>15</td>
</tr>
<tr>
<td>K Gerasopoulos, M McCarthy, P Banerjee, X Fan, J N Culver and R Ghodssi</td>
<td></td>
</tr>
<tr>
<td>The facile fabrication of tunable plasmonic gold nanostructure arrays using microwave plasma</td>
<td>16</td>
</tr>
<tr>
<td>Chuen-Yuan Hsu, Jing-Wen Huang, Shangjr Gwo and Kuan-Jiuh Lin</td>
<td></td>
</tr>
<tr>
<td>Ultrafast direct imprinting of nanostructures in metals by pulsed laser melting</td>
<td>16</td>
</tr>
<tr>
<td>Bo Cui, Chris Keimel and Stephen Y Chou</td>
<td></td>
</tr>
<tr>
<td>The fabrication of a patterned ZnO nanorod array for high brightness LEDs</td>
<td>16</td>
</tr>
<tr>
<td>Hyounghwan Park, Kyeong-Jae Byeon, Ki-Yeon Yang, Joong-Yeon Cho and Heon Lee</td>
<td></td>
</tr>
<tr>
<td>Direct-write fabrication of a nanoscale digital logic element on a single nanowire</td>
<td>17</td>
</tr>
<tr>
<td>Somenath Roy and Zhiqiang Gao</td>
<td></td>
</tr>
<tr>
<td>The fabrication of silicon nanostructures by focused-ion-beam implantation and TMAH wet etching</td>
<td>17</td>
</tr>
<tr>
<td>Päivi Sieviilä, Nikolai Chekurov and Ilkka Tittonen</td>
<td></td>
</tr>
</tbody>
</table>
### Sensing and Actuating

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-down fabricated silicon nanowire sensors for real-time chemical detection</td>
<td>17</td>
</tr>
<tr>
<td>Inkyu Park, Zhiyong Li, Albert P Pisano and R Stanley Williams</td>
<td></td>
</tr>
<tr>
<td>L-cysteine functionalized gold nanoparticles for the colorimetric detection of Hg(^{2+}) induced by ultraviolet light</td>
<td>18</td>
</tr>
<tr>
<td>Fang Chai, Chungang Wang, Tingting Wang, Zhanfang Ma and Zhongmin Su</td>
<td></td>
</tr>
<tr>
<td>A highly sensitive humidity sensor based on a nanofibrous membrane coated quartz crystal microbalance</td>
<td>18</td>
</tr>
<tr>
<td>Xianfeng Wang, Bin Ding, Jinyong Yu, Moran Wang and Fukui Pan</td>
<td></td>
</tr>
<tr>
<td>Fabrication of color changeable polystyrene spheres decorated by gold nanoparticles and their label-free biosensing</td>
<td>18</td>
</tr>
<tr>
<td>Yuetong Xia, Wensheng Lu and Long Jiang</td>
<td></td>
</tr>
<tr>
<td>Batch-processed carbon nanotube wall as pressure and flow sensor</td>
<td>19</td>
</tr>
<tr>
<td>Jungwook Choi and Jongbaeg Kim</td>
<td></td>
</tr>
<tr>
<td>L-cysteine-capped CdTe QD-based sensor for simple and selective detection of trinitrotoluene</td>
<td>19</td>
</tr>
<tr>
<td>Yufang Chen, Zhang Chen, Yejuan He, Hailian Lin, Pengtao Sheng, Chengbin Liu, Shenglian Luo and Qingyun Cai</td>
<td></td>
</tr>
<tr>
<td>Calibration of optically trapped nanotools</td>
<td>19</td>
</tr>
<tr>
<td>A single molecule immunoassay by localized surface plasmon resonance</td>
<td>20</td>
</tr>
<tr>
<td>Kathryn M Mayer, Feng Hao, Seunghyun Lee, Peter Nordlander and Jason H Hafner</td>
<td></td>
</tr>
</tbody>
</table>

### Materials: Synthesis or Self-Assembly

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-assembled growth of catalyst-free GaN wires by metal–organic vapour phase epitaxy</td>
<td>20</td>
</tr>
<tr>
<td>R Koester, J S Hwang, C Durand, D Le Si Dang and J Eymery</td>
<td></td>
</tr>
<tr>
<td>Si nanocrystal synthesis in HfO(_2)/SiO(_2)/HfO(_2) multilayer structures</td>
<td>21</td>
</tr>
<tr>
<td>M Perego, G Seguini, C Wiemer, M Fanciulli, P-E Coulon and C Bonafos</td>
<td></td>
</tr>
<tr>
<td>Self-assembled GaAs/AlGaAs coupled quantum ring-disk structures by droplet epitaxy</td>
<td>21</td>
</tr>
<tr>
<td>C Somaschini, S Bietti, S Sanguinetti, N Koguchi and A Fedorov</td>
<td></td>
</tr>
<tr>
<td>Ordering of monodisperse Ni nanoclusters by templating on high-temperature reconstructed (\alpha)-Al(_2)O(_3)(0001)</td>
<td>21</td>
</tr>
<tr>
<td>K Venkataramani, S Helveg, B Hinnemann, M Reichling, F Besenbacher and J V Lauritsen</td>
<td></td>
</tr>
<tr>
<td>Identification of III–N nanowire growth kinetics via a marker technique</td>
<td>22</td>
</tr>
<tr>
<td>R Songmuang, T Ben, B Daudin, D González and E Monroy</td>
<td></td>
</tr>
<tr>
<td>Towards carbon-nanotube integrated devices: optically controlled parallel integration of single-walled carbon nanotubes</td>
<td>22</td>
</tr>
<tr>
<td>Y S Zhou, W Xiong, Y Gao, M Mahjouri-Samani, M Mitchell, L Jiang and Y F Lu</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Formation and electrical transport properties of pentacene nanorod</td>
<td>22</td>
</tr>
<tr>
<td>crystal</td>
<td></td>
</tr>
<tr>
<td>M Akai-Kasaya, C Ohmori, T Kawanishi, M Nashiki, A Saito, M Aono and Y</td>
<td></td>
</tr>
<tr>
<td>Kuwahara</td>
<td></td>
</tr>
<tr>
<td>Self-induced growth of vertical free-standing InAs nanowires on Si(111) by molecular beam epitaxy</td>
<td>23</td>
</tr>
<tr>
<td>G Koblmüller, S Hertenberger, K Vizbaras, M Bichler, F Bao, J-P Zhang</td>
<td></td>
</tr>
<tr>
<td>and G Abstreiter</td>
<td></td>
</tr>
<tr>
<td>Thermal conductivity of multi-walled carbon nanotube sheets: radiation losses and quenching of phonon modes</td>
<td>23</td>
</tr>
<tr>
<td>Ali E Aliev, Marcio H Lima, Edward M Silverman and Ray H Baughman</td>
<td></td>
</tr>
<tr>
<td>Influence of electrode size and geometry on electrochemical experiments with combined SECM–SFM probes</td>
<td>24</td>
</tr>
<tr>
<td>Sascha E Pust, Marc Salomo, Egbert Oesterschulze and Gunther Wittstock</td>
<td></td>
</tr>
<tr>
<td>New insights into the use of magnetic force microscopy to discriminate between magnetic and nonmagnetic nanoparticles</td>
<td>24</td>
</tr>
<tr>
<td>Cristina S Neves, Pedro Quaresma, Pedro V Baptista, Patrícia A Carvalho, João Pedro Araújo, Eulália Pereira and Peter Eaton</td>
<td></td>
</tr>
<tr>
<td>Aligned gold nanoneedle arrays for surface-enhanced Raman scattering</td>
<td>24</td>
</tr>
<tr>
<td>Yong Yang, Masaki Tanemura, Zhengren Huang, Dongliang Jiang, Zhi-Yuan Li, Ying-ping Huang, Go Kawamura, Kohei Yamaguchi and Masayuki Nogami</td>
<td></td>
</tr>
<tr>
<td>Direct observation of the semimetal-to-semiconductor transition of individual single-crystal bismuth nanowires grown by on-film formation of nanowires</td>
<td>25</td>
</tr>
<tr>
<td>Seunghyun Lee, Jinhee Ham, Kyejin Jeon, Jin-Seo Noh and Wooyoung Lee</td>
<td></td>
</tr>
<tr>
<td>Coupling between magnetic and optical properties of stable Au–Fe solid solution nanoparticles</td>
<td>26</td>
</tr>
<tr>
<td>C de Julián Fernández, G Mattei, E Paz, R L Novak, L Cavigli, L Bogani, F J Palomares, P Mazzoldi and A Caneschi</td>
<td></td>
</tr>
<tr>
<td>High-performance supercapacitors using a nanoporous current collector made from super-aligned carbon nanotubes</td>
<td>26</td>
</tr>
<tr>
<td>Ruifeng Zhou, Chuizhou Meng, Feng Zhu, Qunqing Li, Changhong Liu, Shoushan Fan and Kaili Jiang</td>
<td></td>
</tr>
<tr>
<td>Resolution theory, and static and frequency-dependent cross-talk in piezoresponse force microscopy</td>
<td>26</td>
</tr>
<tr>
<td>S Jesse, S Guo, A Kumar, B J Rodriguez, R Proksch and S V Kalinin</td>
<td></td>
</tr>
<tr>
<td>Nanocap arrays of granular CoCrPt:SiO₂ films on silica particles: tailoring of the magnetic properties by Co⁺ irradiation</td>
<td>27</td>
</tr>
<tr>
<td>P Krone, C Brombacher, D Makarov, K Lenz, D Ball, F Springer, H Rohrmann, J Fassbender and M Albrecht</td>
<td></td>
</tr>
<tr>
<td>Nitrogen doping of nanoporous WO₃ layers by NH₃ treatment for increased visible light photoresponse</td>
<td>27</td>
</tr>
<tr>
<td>Yoon-Chae Nah, Indhumati Paramasivam, Robert Hahn, Nabeen K Shrestha and Patrik Schmuki</td>
<td></td>
</tr>
<tr>
<td>Editorial board and journal team</td>
<td>28</td>
</tr>
</tbody>
</table>
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
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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

Platinum nanoparticles: a promising material for future cancer therapy?

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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

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

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2 College of BioNano Technology, Kyungwon University, Gyeonggi-Do 461-701, Korea

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

S Chung et al 2010 Nanotechnology 21 125104

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

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Researchers have made extensive efforts to mimic or reverse-engineer in vivo neural circuits using micropatteming 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

Immobilization of motile bacterial cells via dip-pen nanolithography

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

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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 metabolomes 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, α- and ρ-HPA, PAG, nicotinate and hippurate accompanied by decreases in the levels of urinary α-ketoglutatarate, succinate, citrate, N-methylcotinamide, 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, glutamate and glutamine 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

Nonvolatile memory devices based on few-layer graphene films

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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) (PVDF/TrFE), FLG/ferroelectric devices exhibited nonvolatile resistance changes due to a polarization switching of the PVDF/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
Flexible organic light-emitting diodes with transparent carbon nanotube electrodes: problems and solutions

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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

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

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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 cm² 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

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

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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 $\Omega/\square$ 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 $\mu$A.

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

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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 complex dyes and infiltrated with the solid-state hole transporter medium $\text{2, 2', 7, 7'-tetrakis-(N, N-di-p-methoxyphenylamine)-9, 9'-spirobifluorene (spiro-OMeTAD)}$. 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

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

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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
Tunable-white-light-emitting materials are developed by combining two single-crystal oxide nanowire materials—ZnO and SnO₂—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 SnO₂ nanowires. Combined ZnO:SnO₂ 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

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

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

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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

Tunable-white-light-emitting nanowire sources

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Tunable-white-light-emitting materials are developed by combining two single-crystal oxide nanowire materials—ZnO and SnO₂—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 SnO₂ nanowires. Combined ZnO:SnO₂ 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

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

Field-emission scanning electron microscopy images of ZnO nanowires (D ~ 70 nm) and SnO₂ nanowires (D ~ 40 nm). The images in the inset show EDS data for ZnO and SnO₂.

Nanotechnology special issues in 2010

- Quantum science and technology at the nanoscale
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Customizable *in situ* TEM devices fabricated in freestanding membranes by focused ion beam milling

Anders Lei1, Dirch Hjorth Petersen1, Timothy John Booth2, Lasse Vinther Homann1, Christian Kallesoe1, Ozlem Sardan Sukas1, Yvonne Gyrsing2, Kristian Molhave1 and Peter Boggild1

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Nanotechnology Highlights 2010

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 silicon nanoparticles 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 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

Site-directed delivery of ferritin-encapsulated gold nanoparticles

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Newly designed porter proteins, which catch gold nanoparticles and deliver the nanoparticles selectively to a silicon dioxide (SiO2) 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 SiO2 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

Fullerene monolayer formation by spray coating

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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 C60 dissolved in toluene and carbon disulfide. Monolayer thick C60 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 C60 films on Au(111) have been found comparable to thermally evaporated C60. We attribute the monolayer formation in spray coating to a crystallization process mediated by an ultrathin solution film on a sample surface.
Y Chen et al 2010 Nanotechnology 21 185303

Synthesis of TiO2 nanoframe and the prototype of a nanoframe solar cell

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Nanoframes containing 20 nm diameter TiO2 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 TiO2. 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 I3− 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

Biofabrication methods for the patterned assembly and synthesis of viral nanotemplates

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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

Multi-layer TiO2 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.)

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

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Fabrication of isolated noble metal nanoparticles embedded in transparent substrates is the fastest 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

Ultrafast direct imprinting of nanostructures in metals by pulsed laser melting

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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

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

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

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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

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

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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 $4 \times 10^{13}$ 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

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

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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 $(ΔpH/ΔR)/pH = 2.6%/pH$ and a rise time of 8 s. A small pH level difference $(ΔpH = 0.2)$ 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
L-cysteine functionalized gold nanoparticles for the colorimetric detection of Hg\textsuperscript{2+} induced by ultraviolet light

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A simple, cost-effective yet rapid and sensitive colorimetric sensor for the detection of Hg\textsuperscript{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\textsuperscript{2+}, especially with the assistance of ultraviolet radiation. The presence of Hg\textsuperscript{2+} can be monitored by the colorimetric response of gold nanoparticles. The detection of Hg\textsuperscript{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\textsuperscript{2+} detection.

F Chai \textit{et al} 2010 \textit{Nanotechnology} \textbf{21} 025501

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

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

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Beijing National Laboratory for Molecular Science, Institute of Chemistry, Chinese Academy of Sciences, Beijing 100190, 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(\(\Delta f\)) 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 \textit{et al} 2010 \textit{Nanotechnology} \textbf{21} 055502

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

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

Xianfeng Wang\textsuperscript{1,2,3}, Bin Ding\textsuperscript{1,2}, Jianyong Yu\textsuperscript{4}, Moran Wang\textsuperscript{4} and Fukui Pan\textsuperscript{5}

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Y Xia \textit{et al} 2010 \textit{Nanotechnology} \textbf{21} 085501

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Y Xia \textit{et al} 2010 \textit{Nanotechnology} \textbf{21} 085501
Transmission electron microscopy image showing gold shell growth using LPS@C18N3@Au seed.

Transmission electron microscopy image of CdTe QDs.

High-resolution transmission electron microscopy image of CdTe QDs.

Calibration of optically trapped nanotools

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, \( \langle x_{\text{tool}}, y_{\text{tool}}, \theta_{\text{tool}} \rangle = (0, 0, 0) \). 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. \( \theta_{\text{tool}} \) is the angle of the tool, relative to the x-axis.

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

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

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

Y Chen et al 2010 Nanotechnology 21 125502

Batch-processed carbon nanotube wall as pressure and flow sensor

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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 \( 3 \times 10^{-3} \) 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

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 single molecule immunoassay by localized surface plasmon resonance

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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

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

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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 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 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

Scanning electron microscopy image showing gold bipyramid structure.

Did you know?

Nanotechnology received more than 16 000 citations in 2009.

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 HfO₂/SiO/HfO₂ multilayer structures

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3 nMat Group, CEMES-CNRS, rue J. Marvig 29, Toulouse FR-31055, France

The synthesis of two-dimensional arrays of Si nanocrystals in an HfO₂ matrix has been achieved by deposition of HfO₂/SiO/HfO₂ multilayer structures followed by high temperature (1100 °C) thermal treatment in nitrogen atmosphere. Silicon out-diffusion from the SiO layer through the HfO₂ 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

Ordering of monodisperse Ni nanoclusters by templating on high-temperature reconstructed α-Al₂O₃(0001)

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3 Fachbereich Physik, Universität Osnabrück, 49076 Osnabrück, Germany

We demonstrate that the characteristic √31 × √31 R9° reconstructed surface of α-alumina (Al₂O₃) 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-Al₂O₃ are supported by density functional theory (DFT) calculations. The ability of α-Al₂O₃(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 ×R9° reconstructed surface formed by high-temperature annealing. The insulating template, demonstrated for Al₂O₃, may be a generally attractive system for the study of nanostructures which need to be isolated from a conducting bulk.

K Venkataramani et al 2010 Nanotechnology 21 265602

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

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

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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
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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 \( T_{\text{sub}} = 740 \) °C and R2D measured at \( T_{\text{sub}} = 745 \) °C as a function of \( T_{\text{Ga}} \). The grey shading represents the regime where the impinging Ga flux is higher than the active N flux at \( T_{\text{sub}} = 745 \) °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

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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

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

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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 SiOx mask on Si(111) facilitated epitaxial InAs nanowire growth, as confirmed by high-resolution x-ray diffraction θ–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

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

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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 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 (κ_{MWNT} = 600 ± 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 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.
Influence of electrode size and geometry on electrochemical experiments with combined SECM–SFM probes

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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

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

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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

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That over 1.3 million Nanotechnology articles were downloaded in 2009.

Aligned gold nanoneedle arrays for surface-enhanced Raman scattering
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 10⁸, 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

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 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

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

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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 SiO2 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

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

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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, Co₃O₄ or Mn₂O₃ 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

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

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Hysteresis loops measured at 3 K of the Au₉Fe₄, Au₉Fe₉ and Fe₉ as-implanted samples, and of the Au₉Fe₄ sample after 1 h thermal treatment at 600 °C.
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 105703

Nanocap arrays of granular CoCrPt:SiO₂ films on silica particles: tailoring of the magnetic properties by Co⁺ irradiation

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An approach for tailoring the magnetic properties by ion irradiation of granular perpendicular CoCrPt:SiO₂ 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 \(0.5 \times 10^{14} \text{ cm}^{-2}\) 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:SiO₂ film initiated by Co⁺ irradiation resulting in a modified reversal behavior. Further increase of the irradiation fluence beyond \(1.6 \times 10^{14} \text{ ions cm}^{-2}\) 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 SiO₂ particle.

Nitrogen doping of nanoporous WO₃ layers by NH₃ treatment for increased visible light photoresponse

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Nanoporous WO₃ layers were grown by electrochemical anodization of W in a fluoride containing electrolyte. These layers were exposed to a thermal treatment in NH₃ to achieve nitrogen doping of the material. The morphology, crystal structure, composition and photoresponse of pure and nitrogen doped WO₃ 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 WO₃ layers can be achieved by controlling the temperature and time during the NH₃ treatment. Most importantly, it is demonstrated that for the nitrogen doped WO₃ 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 WO₃ layers after annealing at 450 °C in air for 1 h followed by a NH₃ 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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