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#### ➤ MRS-S Activities: Past, Present and Future

The Materials Research Society of Singapore (MRS-S) organized five International and four National Conferences in Singapore since 2001. The biennial 'International Conference on Materials for Advanced Technologies (ICMAT)' series were held in 2001, 2003, 2005, 2007 and 2009.

The biennial National Conferences were held in 2004, 2006, 2008 and 2010.

MRS-S also sponsored/supported several other conferences, workshops, symposia and public lectures. It instituted gold medals for the best outgoing students in Materials Science at the National University of Singapore (NUS) and Nanyang Technological University (NTU). It instituted the 'MRS Singapore Student Bursary Fund' at the National University of Singapore. MRS-S also instituted the 'MRS-S Book Prize' at the 'Republic Polytechnic' of Singapore. This yearly Book Prize will be awarded to the top final-year student from the 'Diploma in Materials Science'. MRS-S recently instituted the medal for the best Ph.D. Thesis in the Physics Department of NUS.

To reach out to the public, MRS-S has organized number of public lectures by Nobel Laureates and also an Astronaut.

Prof. B.V.R. Chowdari, President of MRS-S has assumed charge as the President of IUMRS (International Union of Materials Research Societies) w. e. f. Jan., 2011. He will hold the office for two years.

The ICMAT 2011 will be held in Singapore during June, 26-July1, 2011. It will have 37 Symposia, comprising the areas of Nanoscience and Technology, Energy and Environment, Functional Materials, Bio/Soft Materials, Imaging, Crystal Growth and Crystal Technology and Interdisciplinary. There will also be 3 Workshops.

There will be nine Plenary Talks and several Theme Lectures, and Public Lectures by Nobel laureates.

Details of the various Symposia and other relevant information can be found at the website: <http://www.mrs.org.sg/icmat2011/>

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## Highlights of Previous ICMAT Conferences

**Year 2001:** 1–6, July 2001; 16 Symposia; 10 Plenary Lectures; 4 Public Lectures by Nobel Laureates; 1400 delegates; 18 Best Poster Awards; 36 Exhibitors.

**Year 2003:** 7–12, Dec., 2003; 16 Symposia; 9 Plenary Lectures; 2 Public Lectures by Nobel Laureates; 1500 delegates; 19 Best Poster Awards; 29 Exhibitors.

**Year 2005:** 3–8, July 2005; 25 Symposia; 9 Plenary Lectures; 2 Theme Lectures; 3 Public Lectures by Nobel Laureates; 2200 Delegates; 28 Best Poster Awards; 43 Exhibitors.

**Year 2007:** 1–6, July 2007; 18+6 Symposia; 9 Plenary Lectures; 2 Theme Lectures; 2 Public Lectures by Nobel Laureates; 2300 Delegates; 25 Best Poster Awards; 41 Exhibitors.

**Year 2009:** 28 Jun.–3, July 2009; 23 Symposia, 9 Plenary and 3 Theme Lectures, 3 Public Lectures by Nobel Laureates; 2170 Participants; 37 Best Poster Awards; 43 Exhibitors.

## Highlights of Previous National Conferences

**Year 2004:** 6 Aug., 2004; 20 Invited Talks; 130 Poster Papers; 4 Best Poster Awards.

**Year 2006:** 18–20, Jan., 2006; Includes the Symposium on 'Physics and Mechanic of Advanced Materials'; 60 Invited Talks; 200 Poster Papers; 1 Public Lecture; 5 Best Poster Awards.

**Year 2008:** 25–27, Feb. 2008. Incorporated the MRS-I Mumbai (India)-Chapter Joint Indo-Singapore Meeting; 2 Keynote Talks, 60 Invited Talks; 211 Poster Papers; 10 Best Poster Awards.

**Year 2010:** 17–19, March 2010. 1 Keynote Talk, 26 Invited Talks; 137 Poster Papers; 7 Best Poster Awards.

## Highlights of Recent Literature

(Contributed by the Editor)

**Homologous Series of Iron Pnictide Oxide Superconductors  $(\text{Fe}_2\text{As}_2)[\text{Ca}_{n+1}(\text{Sc,Ti})_n\text{O}_y]$  ( $n = 3,4,5$ ) with Extremely Thick Blocking Layers**

Iron pnictide oxide superconductors with extremely thick blocking layers,  $(\text{Fe}_2\text{As}_2)[\text{Ca}_{n+1}(\text{Sc,Ti})_n\text{O}_y]$  ( $n = 3, 4, 5$  and  $y \sim 3n-1$ ) were discovered by Ogino *et al* [1] in the present study. These samples exhibited bulk superconductivity with relatively high  $T_c$  up to 42 K.

The relationship between  $T_c$  and the iron-plane interlayer distance suggested that  $T_c$  of the iron based superconductor is basically determined by the local structure of  $\text{Fe}_2\text{As}_2$  layer. It is thought that there is still considerable room for the development of layered iron pnictides due to the structural and chemical flexibility of the blocking layer.

**Reference**

1. H. Ogino, S. Sato, K. Kishio, J.-I. Shimoyama, T. Tohei and Y. Ikuhara, *Appl. Phys. Lett.*, **97** (7), 072506-1-to-072506-3 (2010).

**Silver Clusters Embedded in Glass as a Perennial High Capacity Optical Recording Medium**

Three-dimensional (3D) optical recording by laser-induced fluorescent silver clusters is demonstrated in glass by Royan *et al* [1]. The fluorescence properties of these stable clusters can be altered, depending on the glass recording exposure conditions. A “Blu-ray”-like drive enables readout of the information inside the glass without cross-talk and photo-bleaching. The authors state that, ‘this original recording medium can provide an answer to the societal problem of long-term high-density data storage’.

**Reference**

1. A. Royon, K. Bourhis, M. Bellec, G. Papon, B. Bousquet, Y. Deshayes, T. Cardinal and L. Canioni, *Adv. Mater.*, **22** (46), 5282–5286 (2010).

**Snapshots of Cooperative Atomic Motions in the Optical Suppression of Charge Density Waves**

Macroscopic quantum phenomena arise from a delicate balance of different interactions among electrons, phonons and spins on the nanoscale. Charge-density-wave (CDW) materials, with their inherent modulation of the electron density and associated periodic lattice distortion, represent ideal model systems for the study of highly cooperative phenomena. With femtosecond time-resolved techniques, it is possible to observe these interactions directly, by abruptly perturbing the electronic distribution while keeping track of energy relaxation pathways and coupling strengths among the different subsystems.

Here, Eichberger *et al* [1] provide direct atomic-level information on the structural dynamics by using femtosecond electron diffraction to study the quasi two-dimensional CDW system 1T-TaS<sub>2</sub>. Effectively, they have directly observed the atomic motions that result from the optically induced change in the electronic spatial distribution. The periodic lattice distortion, which has an amplitude of  $\sim 0.1\text{Å}$ , is suppressed by about 20% on a timescale ( $\sim 250$  femtoseconds) comparable to half the period of the corresponding collective mode. These highly cooperative, electronically driven atomic motions are accompanied by a rapid electron–phonon energy transfer ( $\sim 350$  femtoseconds) and are followed by fast recovery of the CDW ( $\sim 4$  picoseconds). The degree of cooperativity in the observed structural dynamics is remarkable and illustrates the importance of obtaining atomic-level perspectives of the processes directing the physics of strongly correlated systems.

**Reference**

1. M. Eichberger, H. Schäfer, M. Krumova, M. Beyer, J. Demsar, H. Berger, G. Moriena, G. Sciaini and R. J. Dwayne, *Nature*, **468** (7325), 799–802 (2010) (09 Dec. Issue).

### In Situ Observation of the Electrochemical Lithiation of a Single SnO<sub>2</sub> Nanowire Electrode

Huang *et al* [1] report the creation of a nanoscale electrochemical device inside a transmission electron microscope—consisting of a single tin dioxide (SnO<sub>2</sub>) nanowire anode, an ionic liquid electrolyte, and a bulk lithium cobalt dioxide (LiCoO<sub>2</sub>) cathode—and the in situ observation of the lithiation of the SnO<sub>2</sub> nanowire during electrochemical charging. Upon charging, a reaction front propagated progressively along the nanowire, causing the nanowire to swell, elongate, and spiral. The reaction front is a “Medusa zone” containing a high density of mobile dislocations, which are continuously nucleated and absorbed at the moving front. This dislocation cloud indicates large in-plane misfit stresses and is a structural precursor to electrochemically driven solid-state amorphization. Because lithiation-induced volume expansion, plasticity, and pulverization of electrode materials are the major mechanical effects that plague the performance and lifetime of high-capacity anodes in lithium-ion batteries, the authors state that, the above ‘observations provide important mechanistic insight for the design of advanced batteries’.

#### Reference

1. J. Y. Huang, L. Zhong, C. M. Wang, J. P. Sullivan, W. Xu, L. Q. Zhang, S. X. Mao, N. S. Hudak, X. H. Liu, A. Subramanian, H. Fan, L. Qi, A. Kushima and J. Li, *Science*, **330** (6010), 1515–1520 (2010) (10 Dec., Issue).

### Spin Transfer Torques in MnSi at Ultralow Current Densities

Spin manipulation using electric currents is one of the most promising directions in the field of spintronics. Jonietz *et al* [1] used neutron scattering to observe the influence of an electric current on the magnetic structure in a bulk material. In the skyrmion lattice of manganese silicon (MnSi), where the spins form a lattice of magnetic vortices similar to the vortex lattice in type II superconductors, the authors observed the rotation of the diffraction pattern in response to currents that are over five orders of magnitude smaller than those typically applied in experimental studies on current-driven magnetization dynamics in nanostructures. They attribute the observations to an extremely

efficient coupling of inhomogeneous spin currents to topologically stable knots in spin structures.

#### Reference

1. F. Jonietz, S. Mühlbauer, C. Pfleiderer, A. Neubauer, W. Münzer, A. Bauer, T. Adams, R. Georgii, P. Böni, R. A. Duine, K. Everschor, M. Garst and A. Rosch, *Science*, **330** (6011), 1648–1651 (2010) (17 Dec., Issue).

### Electronic Spin Storage in an Electrically Readable Nuclear Spin Memory with a Lifetime >100 Seconds

Electron spins are strong candidates with which to implement spintronics because they are both mobile and able to be manipulated. The relatively short lifetimes of electron spins, however, present a problem for the long-term storage of spin information.

Here, McCamey *et al* [1] demonstrated an ensemble nuclear spin memory in phosphorous-doped silicon, which can be read out electrically and has a lifetime exceeding 100 seconds. The electronic spin information can be mapped onto and stored in the nuclear spin of the phosphorus donors, and the nuclear spins can then be repetitively read out electrically for time periods that exceed the electron spin lifetime. The authors discuss how this memory can be used in conjunction with other silicon spintronic devices.

#### Reference

1. D. R. McCamey, J. Van Tol, G. W. Morley and C. Boehme, *Science*, **330** (6011), 1652–1656 (2010) (17 Dec., Issue).

### Oxygen Doping Modifies Near-Infrared Band Gaps in Fluorescent Single-Walled Carbon Nanotubes

Controlled chemical modifications of single-walled carbon nanotubes (SWCNTs) that tune their useful properties have been sought for multiple applications. Ghosh *et al* [1] found that beneficial optical changes in SWCNTs resulted from introducing low concentrations of oxygen atoms. Stable covalently oxygen-doped nanotubes were prepared by exposure to ozone and then light. Treated samples showed distinct, structure-specific near-infrared fluorescence at wavelengths 10 to 15% longer than displayed by pristine semiconducting SWCNTs. Dopant sites harvest light



However, low conversion efficiencies, particularly with CO<sub>2</sub> reduction, as well as utilization of precious materials have limited the practical generation of solar fuels.

By using a solar cavity-receiver reactor, Chueh *et al* [1] combined the oxygen uptake and release capacity of cerium oxide and facile catalysis at elevated temperatures to thermochemically dissociate CO<sub>2</sub> and H<sub>2</sub>O, yielding CO and H<sub>2</sub>, respectively. Stable and rapid generation of fuel was demonstrated over 500 cycles. Solar-to-fuel efficiencies of 0.7 to 0.8% were achieved and shown to be largely limited by the system scale and design rather than by chemistry.

#### Reference

1. W. C. Chueh, C. Falter, M. Abbott, D. Scipio, P. Furler, S. M. Haile and A. Steinfield, *Science*, **330** (6012), 1797–1801 (2010) (24 Dec., Issue).

### Spin Hall Effect Transistor

The field of semiconductor spintronics explores spin-related quantum relativistic phenomena in solid-state systems. Spin transistors and spin Hall effects have been two separate leading directions of research in this field.

Here, Wunderlich *et al* [1] have combined the two directions by realizing an all-semiconductor spin Hall effect transistor. The device uses diffusive transport and operates without electrical current in the active part of the transistor. The authors demonstrate a spin AND logic function in a semiconductor channel with two gates. The study shows the utility of the spin Hall effect in a microelectronic device geometry, realizes the spin transistor with electrical detection directly along the gated semiconductor channel, and provides an experimental tool for exploring spin Hall and spin precession phenomena in an electrically tunable semiconductor layer.

#### Reference

1. J. Wunderlich, B.-G. Park, A. C. Irvine, L. P. Zárbo, E. Rozkotová, P. Nemeč, V. Novák, J. Sinova and T. Jungwirth, *Science*, **330** (6012), 1801–1804 (2010) (24 Dec., Issue).

### Brownian Motion of Stiff Filaments in a Crowded Environment

The thermal motion of stiff filaments in a crowded environment is highly constrained and anisotropic;

it underlies the behavior of such disparate systems as polymer materials, nano-composites, and the cell cytoskeleton. Despite decades of theoretical study, the fundamental dynamics of such systems remains a mystery.

Using near-infrared video microscopy, Fakhri *et al* [1] studied the thermal diffusion of individual single-walled carbon nanotubes (SWNTs) confined in porous agarose networks. The authors found that even a small bending flexibility of SWNTs strongly enhances their motion: The rotational diffusion constant is proportional to the filament-bending compliance and is independent of the network pore size. The interplay between crowding and thermal bending implies that the notion of a filament's stiffness depends on its confinement. Moreover, the mobility of SWNTs and other inclusions can be controlled by tailoring their stiffness.

#### Reference

1. N. Fakhri, F. C. MacKintosh, B. Lounis, L. Cognet and M. Pasquali, *Science*, **330** (6012), 1804–1807 (2010) (24 Dec., Issue).

### Tunable Field Control Over the Binding Energy of Single Dopants by a Charged Vacancy in GaAs

Local manipulation of electric fields at the atomic scale may enable new methods for quantum transport and creates new opportunities for field control of ferromagnetism and spin-based quantum information processing in semiconductors. Here, Lee and Gupta [1] used a scanning tunneling microscope to position charged arsenic (As) vacancies in the gallium arsenide 110 [GaAs (110)] surface with atomic precision, thereby tuning the local electrostatic field experienced by single manganese (Mn) acceptors. The effects of this field are quantified by measuring the shift of an acceptor state within the band gap of GaAs. Experiments with varying tip-induced band-bending conditions suggest a large binding energy for surface-layer Mn, which is reduced by direct Coulomb repulsion when the As vacancy is moved nearby.

#### Reference

1. D. H. Lee and J. A. Gupta, *Science*, **330** (6012), 1807–1810 (2010) (24 Dec., Issue).

## Dynamics of Magnetic Domain Walls Under Their Own Inertia

The motion of magnetic domain walls induced by spin-polarized current has considerable potential for use in magnetic memory and logic devices. Key to the success of these devices is the precise positioning of individual domain walls along magnetic nanowires, using current pulses.

Here, Thomas *et al* [1] show that domain walls move surprisingly long distances of several micrometers and relax over several tens of nanoseconds, under their own inertia, when the current stimulus is removed. They also show that the net distance traveled by the domain wall is exactly proportional to the current pulse length because of the lag derived from its acceleration at the onset of the pulse. Thus, independent of its inertia, a domain wall can be accurately positioned using properly timed current pulses.

### Reference

1. L. Thomas, R. Moriya, C. Rettner and S. S. P. Parkin, *Science*, **330** (6012), 1810–1813 (2010) (24 Dec., Issue).

## Biscrolling Nanotube Sheets and Functional Guests into Yarns

Multifunctional applications of textiles have been limited by the inability to spin important materials into yarns. Generically-applicable methods are demonstrated by Lima *et al* [1] for producing weavable yarns comprising up to 95 wt. % of otherwise un-spinnable particulate or nanofiber powders that remain highly functional. Scrolled 50-nm-thick carbon nanotube (CNT) sheets confine these powders in the galleries of irregular scroll sacks whose observed complex structures are related to twist-dependent extension of Archimedean spirals, Fermat spirals, or spiral pairs into scrolls. The strength and electronic connectivity of a small weight fraction of scrolled CNT sheet enables yarn weaving, sewing, knotting, braiding, and charge collection.

This technology is used to make yarns of superconductors, lithium-ion battery materials, graphene ribbons, catalytic nanofibers for fuel cells, and titanium dioxide for photocatalysis.

### Reference

1. M. D. Lima, S. Fang, X. Lepró, C. Lewis, R. Ovalle-Robles, J. Carretero-González, E. Castillo-Martínez, M. E. Kozlov, J. Oh, N. Rawat, C. S. Haines, M. H. Haque, V. Aare, S. Stoughton, A. A. Zakhidov and R. H. Baughman, *Science*, **331** (6013), 51–55 (2011) (7 Jan., Issue).

## Two-dimensional Electron Gas with Universal Subbands at the Surface of SrTiO<sub>3</sub>

As silicon is the basis of conventional electronics, so strontium titanate (SrTiO<sub>3</sub>) is the foundation of the emerging field of oxide electronics. SrTiO<sub>3</sub> is the preferred template for the creation of exotic, two-dimensional (2D) phases of electron matter at oxide interfaces that have metal–insulator transitions, superconductivity or large negative magnetoresistance. However, the physical nature of the electronic structure underlying these 2D electron gases (2DEGs), which is crucial to understanding their remarkable properties, remains elusive.

Here, Santander-Syro *et al* [1] show, using angle-resolved photoemission spectroscopy, that there is a highly metallic universal 2DEG at the vacuum-cleaved surface of SrTiO<sub>3</sub> (including the non-doped insulating material) independently of bulk carrier densities over more than seven decades. This 2DEG is confined within a region of about five unit cells and has a sheet carrier density of  $\sim 0.33$  electrons per square lattice parameter. The electronic structure consists of multiple subbands of heavy and light electrons. The similarity of this 2DEG to those reported in SrTiO<sub>3</sub>-based heterostructures, and field-effect transistors suggests that different forms of electron confinement at the surface of SrTiO<sub>3</sub> lead to essentially the same 2DEG. The authors state that, ‘our discovery provides a model system for the study of the electronic structure of 2DEGs in SrTiO<sub>3</sub>-based devices and a novel means of generating 2DEGs at the surfaces of transition-metal oxides’.

### Reference

1. J. A. F. Santander-Syro, O. Copie, T. Kondo, F. Fortuna, S. Pailhès, R. Weht, X. G. Qiu, F. Bertran, A. Nicolaou, A. Taleb-Ibrahimi, P. Le Fèvre, G. Herranz, M. Bibes, N. Reyren, Y. Apertet, P. Lecoeur, A. Barthélémy and M. J. Rozenberg, *Nature*, **469**(7329), 189–193 (2011) (13 Jan., Issue).

### Nanoscale Chemical Tomography of Buried Organic–Inorganic Interfaces in the Chiton Tooth

Biological organisms possess an unparalleled ability to control the structure and properties of mineralized tissues. They are able, for example, to guide the formation of smoothly curving single crystals or tough, lightweight, self-repairing skeletal elements. In many biominerals, an organic matrix interacts with the mineral as it forms, controls its morphology and polymorph, and is occluded during mineralization. The remarkable functional properties of the resulting composites—such as outstanding fracture toughness and wear resistance—can be attributed to buried organic–inorganic interfaces at multiple hierarchical levels. Analyzing and controlling such interfaces at the nanometer (nm) length scale is critical also in emerging organic electronic and photovoltaic hybrid materials. However, elucidating the structural and chemical complexity of buried organic–inorganic interfaces presents a challenge to state-of-the-art imaging techniques.

Here, Gordon and Joester [1] show that pulsed-laser atom-probe tomography reveals three-dimensional (3D) chemical maps of organic fibres with a diameter of 5–10 nm in the surrounding nanocrystalline magnetite ( $\text{Fe}_3\text{O}_4$ ) mineral in the tooth of a marine mollusc, the chiton *Chaetopleura apiculata*. Remarkably, most fibres co-localize with either sodium or magnesium. Furthermore, clustering of these cations in the fibre indicates a structural level of hierarchy previously undetected. Their results demonstrate that in the chiton tooth, individual organic fibres have different chemical compositions, and therefore probably different functional roles in controlling fibre formation and matrix–mineral interactions. Atom-probe tomography is able to detect this chemical/structural heterogeneity by virtue of its high 3D-spatial resolution and sensitivity across the periodic table. The authors ‘anticipate that the quantitative analysis and visualization of nm-scale interfaces by laser-pulsed atom-probe tomography will contribute greatly to our understanding not only of biominerals (such as bone, dentine and enamel), but also of synthetic organic–inorganic composites’.

### Reference

1. L. M. Gordon and D. Joester, *Nature*, **469** (7329), 194–197 (2011) (13 Jan., Issue).

### Directed Self-assembly of a Colloidal Kagome Lattice

A challenging goal in materials chemistry and physics is spontaneously to form intended superstructures from designed building blocks. In fields such as crystal engineering and the design of porous materials, this typically involves building blocks of organic molecules, sometimes operating together with metallic ions or clusters. The translation of such ideas to nanoparticles and colloidal-sized building blocks would potentially open doors to new materials and new properties, but the pathways to achieve this goal are still undetermined.

Here Chen *et al* [1] show how colloidal spheres can be induced to self-assemble into a complex predetermined colloidal crystal—in this case a colloidal kagome lattice—through decoration of their surfaces with a simple pattern of hydrophobic domains. The building blocks are simple micrometre-sized spheres with interactions (electrostatic repulsion in the middle, hydrophobic attraction at the poles, which the authors call ‘triblock Janus’) that are also simple, but the self-assembly of the spheres into an open kagome structure contrasts with previously known close-packed periodic arrangements of spheres. With a view to possible enhanced functionality, the resulting lattice structure possesses two families of pores, one that is hydrophobic on the rims of the pores and another that is hydrophilic. This strategy of ‘convergent’ self-assembly from easily fabricated colloidal building blocks encodes the target supracolloidal architecture, not in localized attractive spots but instead in large redundantly attractive regions, and can be extended to form other supracolloidal networks.

### Reference

1. Q. Chen, S. C. Bae and S. Granick, *Nature*, **469** (7330), 381–384 (2011) (20 Jan., Issue).

### Quantum Criticality Without Tuning in the Mixed Valence Compound $\beta\text{-YbAlB}_4$

Fermi liquid theory, the standard theory of metals, has been challenged by a number of observations of

anomalous metallic behavior found in the vicinity of a quantum phase transition. The breakdown of the Fermi liquid is accomplished by fine-tuning the material to a quantum critical point by using a control parameter such as the magnetic field, pressure, or chemical composition.

The high-precision magnetization measurements, by Matsumoto *et al* [1], of the ultrapure *f*-electron-based superconductor  $\beta$ -YbAlB<sub>4</sub> demonstrate a scaling of its free energy that is indicative of zero-field quantum criticality without tuning in a metal. The breakdown of Fermi liquid behavior takes place in a mixed-valence state, which is in sharp contrast with other known examples of quantum critical *f*-electron systems that are magnetic Kondo lattice systems with integral valence.

### Reference

1. Y. Matsumoto, S. Nakatsuji, K. Kuga, Y. Karaki, N. Horie, Y. Shimura, T. Sakakibara, A. H. Nevidomskyy and P. Coleman, *Science*, **331** (6015), 316–319 (2011) (21 Jan., Issue).

### A Magnetically Focused Molecular Beam of Ortho-Water

Like dihydrogen, water exists as two spin isomers, ortho and para, with the nuclear magnetic moments of the hydrogen atoms either parallel or antiparallel. The ratio of the two spin isomers and their physical properties play an important role in a wide variety of research fields, ranging from astrophysics to nuclear magnetic resonance (NMR). Unlike ortho and para H<sub>2</sub>, however, the two water isomers remain challenging to separate, and as a consequence, very little is currently known about their different physical properties.

Here, Kravchuk *et al* [1] report the formation of a magnetically focused molecular beam of ortho-water. The beam formed also had a particular spin projection. Thus, in the presence of holding magnetic fields, the water molecules are hyperpolarized, laying the foundation for ultrasensitive NMR experiments in the future.

### Reference

1. T. Kravchuk, M. Reznikov, P. Tichonov, N. Avidor, Y. Meir, A. Bekkerman and G. Alexandrowicz, *Science*, **331** (6015), 319–321 (2011) (21 Jan., Issue).

### Hard-tip, Soft-spring Lithography

Nanofabrication strategies are becoming increasingly expensive and equipment-intensive, and consequently less accessible to researchers. As an alternative, scanning probe lithography has become a popular means of preparing nanoscale structures, in part owing to its relatively low cost and high resolution, and a registration accuracy that exceeds most existing technologies. However, increasing the throughput of cantilever-based scanning probe systems while maintaining their resolution and registration advantages has from the outset been a significant challenge. Even with impressive recent advances in cantilever array design, such arrays tend to be highly specialized for a given application, expensive, and often difficult to implement. It is therefore difficult to imagine commercially viable production methods based on scanning probe systems that rely on conventional cantilevers.

Here, Shim *et al* [1] describe a low-cost and scalable cantilever-free tip-based nanopatterning method that uses an array of hard silicon tips mounted onto an elastomeric backing. This method—which the authors call, ‘hard-tip, soft-spring lithography’—overcomes the throughput problems of cantilever-based scanning probe systems and the resolution limits imposed by the use of elastomeric stamps and tips: it is capable of delivering materials or energy to a surface to create arbitrary patterns of features with sub-50-nm resolution over cm-scale areas. The authors state that, ‘hard-tip, soft-spring lithography is a versatile nanolithography strategy that should be widely adopted by academic and industrial researchers for rapid prototyping applications’.

### Reference

1. W. Shim, A. B. Braunschweig, X. Liao, J. Chai, J. K. Lim, G. Zheng and C. A. Mirkin, *Nature*, **469** (7331), 516–520 (2011) (27 Jan., Issue).

### Rotational Symmetry Breaking in the Hidden-Order Phase of URu<sub>2</sub>Si<sub>2</sub>

A second-order phase transition is characterized by spontaneous symmetry breaking. The nature of the broken symmetry in the so-called “hidden-order” phase transition in the heavy-fermion compound URu<sub>2</sub>Si<sub>2</sub>, at transition temperature  $T_H = 17.5$  K, has posed a long-standing mystery.

Here, Okazaki *et al* [1] report the emergence of an in-plane anisotropy of the magnetic susceptibility below  $T_h$ , which breaks the four-fold rotational symmetry of the tetragonal URu<sub>2</sub>Si<sub>2</sub>. Two-fold oscillations in the magnetic torque under in-plane field rotation were sensitively detected in small pure crystals. Their findings suggest that the hidden-order phase is an electronic “nematic” phase, a translationally invariant metallic phase with spontaneous breaking of rotational symmetry.

#### Reference

1. R. Okazaki, T. Shibauchi, H. J. Shi, Y. Haga, T. D. Matsuda, E. Yamamoto, Y. Onuki, H. Ikeda and Y. Matsuda, *Science*, **331** (6016), 439–442 (2011) (28 Jan., Issue).

### Magnetic Bistability of Molecules in Homogeneous Solution at Room Temperature

Magnetic bistability, as manifested in the magnetization of ferromagnetic materials or spin crossover in transition metal complexes, has essentially been restricted to either bulk materials or to very low temperatures. Venkataramani *et al* [1] present a molecular spin switch that is bistable at room temperature in homogeneous solution.

Irradiation of a carefully designed nickel complex (azopyridine-functionalized Ni-porphyrin 1) with blue-green light (500 nm) induces coordination of a tethered pyridine ligand and concomitant electronic rearrangement from a diamagnetic to a paramagnetic state in up to 75% of the ensemble. The process is fully reversible on irradiation with violet-blue light (435 nm). No fatigue or degradation is observed after several thousand cycles at room temperature under air. Preliminary data show promise for applications in magnetic resonance imaging.

#### Reference

1. S. Venkataramani, U. Jana, M. Dommaschk, F. D. Sönnichsen, F. Tuczek and R. Herges, *Science*, **331** (6016), 445–448 (2011) (28 Jan., Issue).

### Ultralong-Range Polaron-Induced Quenching of Excitons in Isolated Conjugated Polymers

In conjugated polymers, radiative recombination of excitons (electron-hole pairs) competes with nonradiative thermal relaxation pathways. Bolinger *et al* [1]

visualized exciton quenching induced by hole polarons in single-polymer chains in a device geometry. The distance-scale for quenching was measured by means of a new sub-diffraction, single-molecule technique—bias-modulated intensity centroid spectroscopy—which allowed the extraction of a mean centroid shift of 14 nm for highly ordered, single-polymer nanodomains. This shift requires energy transfer over distances an order of magnitude greater than previously reported for bulk conjugated polymers and is far greater than predicted by the standard mechanism for exciton quenching, the unbiased diffusion of free excitons to quenching sites. Instead, multistep “energy funneling” to trapped, localized polarons is the probable mechanism for polaron-induced exciton quenching.

#### Reference

1. J. C. Bolinger, M. C. Traub, T. Adachi and P. F. Barbara, *Science*, **331** (6017), 565–567 (2011) (4 Feb., Issue).

### Two-Dimensional Nanosheets Produced by Liquid Exfoliation of Layered Materials

Here, Coleman *et al* [1] show that layered compounds such as MoS<sub>2</sub>, WS<sub>2</sub>, MoSe<sub>2</sub>, MoTe<sub>2</sub>, TaSe<sub>2</sub>, NbSe<sub>2</sub>, NiTe<sub>2</sub>, BN, and Bi<sub>2</sub>Te<sub>3</sub> can be efficiently dispersed in common solvents and can be deposited as individual flakes or formed into films. Electron microscopy strongly suggests that the material is exfoliated into individual layers. By blending this material with suspensions of other nanomaterials or polymer solutions, the authors prepared hybrid dispersions or composites, which can be cast into films. They show that WS<sub>2</sub> and MoS<sub>2</sub> effectively reinforce polymers, whereas WS<sub>2</sub>/carbon nanotube hybrid films have high conductivity, leading to promising thermoelectric properties.

#### Reference

1. J. N. Coleman, M. Lotya, A. O’Neill, S. D. Bergin, P. J. King, U. Khan, K. Young, A. Gaucher, S. De, R. J. Smith, I. V. Shvets, S. K. Arora, G. Stanton, H.-Y. Kim, K. Lee, G. T. Kim, G. S. Duesberg, T. Hallam, J. J. Boland, J. J. Wang, J. F. Donegan, J. C. Grunlan, G. Moriarty, A. Shmeliov, R. J. Nicholls, J. M. Perkins, E. M. Grievson, K. Theuwissen, D. W. McComb, P. D. Nellist and V. Nicolosi, *Science*, **331** (6017), 568–571(2011) (4 Feb., Issue).

## Programmable Nanowire Circuits for Nanoprocessors

A nanoprocessor constructed from intrinsically nanometre-scale building blocks is an essential component for controlling memory, nanosensors and other functions proposed for nanosystems assembled from the bottom up.

Here, Yan *et al* [1] describe the design, fabrication and use of programmable and scalable logic tiles for nanoprocessors. The tiles were built from programmable, non-volatile nanowire transistor arrays. Ge/Si core/shell nanowires coupled to designed dielectric shells yielded single-nanowire, non-volatile field-effect transistors (FETs) with uniform, programmable threshold voltages and the capability to drive cascaded elements. The authors developed an architecture to integrate the programmable nanowire FETs and define a logic tile consisting of two interconnected arrays with 496 functional configurable FET nodes in an area of  $960 \mu\text{m}^2$ . The logic tile was programmed and operated first as a full adder with a maximal voltage gain of ten and input–output voltage matching. Then they showed that the same logic tile can be reprogrammed and used to demonstrate full-subtractor, multiplexer, demultiplexer and clocked D-latch functions. These results represent a significant advance in the complexity and functionality of nanoelectronic circuits built from the bottom up with a tiled architecture that could be cascaded to realize fully integrated nanoprocessors with computing, memory and addressing capabilities.

### Reference

1. H. Yan, H. S. Choe, S. W. Nam, Y. Hu, S. Das, J. F. Klemic, J. C. Ellenbogen and C. M. Lieber, *Nature*, **470** (7333), 240–244 (2011) (10 Feb. Issue).

## Negative Linear Compressibility and Massive Anisotropic Thermal Expansion in Methanol Monohydrate

The vast majority of materials shrink in all directions when hydrostatically compressed; exceptions include certain metallic or polymer foam structures, which may exhibit negative linear compressibility (NLC) (that is, they expand in one or more directions under hydrostatic compression). Materials that exhibit this property at the molecular level—crystalline solids with intrinsic NLC—are extremely uncommon.

With the use of neutron powder diffraction, Fortes *et al* [1] have discovered and characterized both NLC and extremely anisotropic thermal expansion, including negative thermal expansion (NTE) along the NLC axis, in a simple molecular crystal (the deuterated 1:1 compound of methanol and water). Apically linked rhombuses, which are formed by the bridging of hydroxyl-water chains with methyl groups, extend along the axis of NLC/NTE and lead to the observed behavior.

### Reference

1. A. D. Fortes, E. Suard and K. S. Knight, *Science*, **331** (6018), 742–746 (2011) (11 Feb., Issue).

## Increasing Solar Absorption for Photocatalysis with Black Hydrogenated Titanium Dioxide Nanocrystals

When used as a photocatalyst, titanium dioxide ( $\text{TiO}_2$ ) absorbs only ultraviolet light, and several approaches, including the use of dopants such as nitrogen, have been taken to narrow the band gap of  $\text{TiO}_2$ .

Chen *et al* [1] demonstrated a conceptually different approach to enhancing solar absorption by introducing disorder in the surface layers of nanophase  $\text{TiO}_2$  through hydrogenation. They showed that disorder-engineered  $\text{TiO}_2$  nanocrystals exhibit substantial solar-driven photocatalytic activities, including the photo-oxidation of organic molecules in water and the production of hydrogen with the use of a sacrificial reagent.

### Reference

1. X. Chen, L. Liu, P. Y. Yu and S. S. Mao, *Science*, **331** (6018), 746–750 (2011) (11 Feb., Issue).

## A Terahertz Metamaterial with Unnaturally High Refractive Index

Controlling the electromagnetic properties of materials, going beyond the limit that is attainable with naturally existing substances, has become a reality with the advent of metamaterials. The range of various structured artificial ‘atoms’ has promised a vast variety of otherwise unexpected physical phenomena, among which the experimental realization of a negative refractive index has been one of the main foci thus far.

Here, Choi *et al* [1] demonstrate that a broadband, extremely high index of refraction can be realized from large-area, free-standing, flexible terahertz metamaterials composed of strongly coupled unit cells. By drastically increasing the effective permittivity through strong capacitive coupling and decreasing the diamagnetic response with a thin metallic structure in the unit cell, a peak refractive index of 38.6 along with a low-frequency quasi-static value of over 20 were experimentally realized for a single-layer terahertz metamaterial, while maintaining low losses. As a natural extension of these single-layer metamaterials, the authors fabricated quasi-three-dimensional high-refractive-index metamaterials, and obtained a maximum bulk refractive index of 33.2 along with a value of around 8 at the quasi-static limit.

#### Reference

1. M. Choi, S. H. Lee, Y. Kim, S. B. Kang, J. Shin, M. H. Kwak, K.-Y. Kang, Y.-H. Lee, N. Park and B. Min, *Nature*, **470** (7334), 369–373 (2011) (17 Feb. Issue).

### Three-Dimensional Atomic Imaging of Crystalline Nanoparticles

Determining the three-dimensional (3D) arrangement of atoms in crystalline nanoparticles is important for nanometre-scale device engineering and also for applications involving nanoparticles, such as optoelectronics or catalysis. A nanoparticle's physical and chemical properties are controlled by its exact 3D morphology, structure and composition. Although atomic-resolution electron microscopy has been feasible for nearly four decades, neither electron tomography nor any other experimental technique has yet demonstrated atomic resolution in three dimensions.

Here, Van Aert *et al* [1] report the 3D reconstruction of a complex crystalline nanoparticle at atomic resolution. To achieve this, they combined aberration-corrected scanning transmission electron microscopy, statistical parameter estimation theory and discrete tomography. Unlike conventional electron tomography, only two images of the target—a silver nanoparticle embedded in an aluminium matrix—are sufficient for the reconstruction when combined with available knowledge about the particle's crystallographic structure. Additional projections confirm the reliability of the result. The authors state that, 'the results

presented help close the gap between the atomic resolution achievable in two-dimensional electron micrographs and the coarser resolution that has hitherto been obtained by conventional electron tomography'.

#### Reference

1. S. Van Aert, K. J. Batenburg, M. D. Rossell, R. Erni and G. Van Tendeloo, *Nature*, **470** (7334), 374–377 (2011) (17 Feb. Issue).

### Metallic and Insulating Oxide Interfaces Controlled by Electronic Correlations.

The formation of two-dimensional electron gases (2DEGs) at complex oxide interfaces is directly influenced by the oxide electronic properties. Jang *et al* [1] investigated how local electron correlations control the 2DEG by inserting a single atomic layer of a rare-earth oxide (RO), (R = La, Pr, Nd, Sm, or Y) into an epitaxial strontium titanate oxide (SrTiO<sub>3</sub>) matrix using pulsed-laser deposition with atomic layer control. They find that structures with La, Pr, and Nd ions result in conducting 2DEGs at the inserted layer, whereas the structures with Sm or Y ions are insulating. The local-spectroscopic and theoretical results indicate that the interfacial conductivity is dependent on electronic correlations that decay spatially into the SrTiO<sub>3</sub> matrix. The authors state that, 'such correlation effects can lead to new functionalities in designed heterostructures'.

#### Reference

1. H. W. Jang, D. A. Felker, C. W. Bark, Y. Wang, M. K. Niranjan, C. T. Nelson, Y. Zhang, D. Su, C. M. Folkman, S. H. Baek, S. Lee, K. Janicka, Y. Zhu, X. Q. Pan, D. D. Fong, E. Y. Tsymbal, M. S. Rzchowski, and C. B. Eom, *Science*, **331** (6019), 886–889 (2011) (18 Feb., Issue).

### Spin Selectivity in Electron Transmission Through Self-Assembled Monolayers of Double-Stranded DNA

In electron-transfer processes, spin effects normally are seen either in magnetic materials or in systems containing heavy atoms that facilitate spin-orbit coupling.

Here, Göhler *et al* [1] report spin-selective transmission of electrons through self-assembled monolayers of double-stranded DNA on gold. Double-stranded DNA (dsDNA) is chiral both because of its primary

structure and because of its secondary, double helix, structure. By directly measuring the spin of the transmitted electrons with a Mott polarimeter, they found spin polarizations exceeding 60% at room temperature (RT). The spin-polarized photoelectrons were observed even when the photoelectrons were generated with unpolarized light. The observed spin selectivity at RT was extremely high as compared with other known spin filters. The spin filtration efficiency depended on the length of the DNA in the monolayer and its organization.

#### Reference

1. B. Göhler, V. Hamelbeck, T. Z. Markus, M. Kettner, G. F. Hanne, Z. Vager, R. Naaman, and H. Zacharias, *Science*, **331** (6019), 894–897 (2011) (18 Feb., Issue).

### Geometric Frustration in Compositionally Modulated Ferroelectrics

Geometric frustration gives rise to new fundamental phenomena and is known to yield intriguing effects such as the formation of exotic states like spin ice, spin liquids and spin glasses, and has also led to interesting findings of fractional charge quantization and magnetic monopoles. Mechanisms related to geometric frustration have been proposed to understand the origins of relaxor and multiferroic behaviour, colossal magnetocapacitive coupling, and unusual and novel mechanisms of high-transition-temperature superconductivity.

Here, Choudhury *et al* [1] show, using a technique based on first principles, that compositionally graded ferroelectrics, (Ba,Sr)TiO<sub>3</sub> (BST) possess the characteristic ‘fingerprints’ associated with geometric frustration. These systems have a highly degenerate energy surface and display critical phenomena. They further reveal exotic orderings with novel stripe phases involving complex spatial organization. These stripes display

spiral states, topological defects and curvature. Compositionally graded ferroelectrics can thus be considered the ‘missing link’ that brings ferroelectrics into the broad category of materials able to exhibit geometric frustration. The authors’ *ab initio* calculations allow deep microscopic insight into this novel geometrically frustrated system.

#### Reference

1. N. Choudhury, L. Walizer, S. Lisenkov and L. Bellaiche, *Nature*, **470** (7335), 513–517 (2011) (24 Feb. Issue).

### Synthesis, Structure, and Reactivity of an Iron(V) Nitride

Despite being implicated as important intermediates, iron(V) compounds have proven very challenging to isolate and characterize. Here, Scepaniak *et al* [1], report the preparation of the iron(V) nitrido complex, [PhB(<sup>t</sup>BuIm)<sub>3</sub>Fe<sup>V</sup>≡N]BAR<sub>F4</sub> (PhB(<sup>t</sup>BuIm)<sub>3</sub><sup>−</sup> = phenyltris(3-*tert*-butylimidazol-2-ylidene) borato, BAR<sub>F4</sub> = B(3,5-(CF<sub>3</sub>)<sub>2</sub>C<sub>6</sub>H<sub>3</sub>)<sub>4</sub><sup>−</sup>), by one electron oxidation of the iron(IV) nitrido precursor.

Single-crystal x-ray diffraction of the iron(V) complex reveals a four-coordinate metal ion with a terminal nitrido ligand. Mossbauer and electron paramagnetic resonance spectroscopic characterization, supported by electronic structure calculations, provide evidence for a d<sup>3</sup>-iron(V) metal center in a low spin (*S* = 1/2) electron configuration. Low-temperature reaction of the iron(V) nitrido complex with water under reducing conditions, leads to high yields of ammonia with concomitant formation of an iron(II) species.

#### Reference

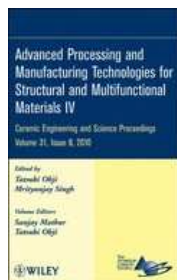
1. J. J. Scepaniak, C. S. Vogel, M. M. Khusniyarov, F. W. Heinemann, K. Meyer and J. M. Smith, *Science*, **331** (6020), 1049–1052 (2011) (25 Feb., Issue).

## Recent Books and Review Articles in the Area of Materials Science, Engineering and Technology

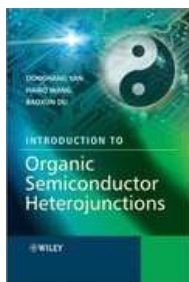
(Contributed by the Editor)

### Books

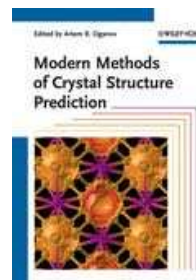
- *Ceramic Engineering and Science Proceedings. Volume 31, Issue 8.* By ACerS. Wiley-VCH, Weinheim. 2010. 260 Pages. Hardcover. Euro 65.90. ISBN-10: 0-470-59473-X. ISBN-13: 978-0-470-59473-5 – John Wiley & Sons.



- *Ceramic Engineering and Science Proceedings: Volume 31, Issue 9.* By ACerS. Wiley-VCH, Weinheim. 2010. 150 Pages. Hardcover. Euro 65.90. ISBN-10: 0-470-59474-8. ISBN-13: 978-0-470-59474-2 — John Wiley & Sons.
- *Introduction to Organic Semiconductor Heterojunctions* By Yan, Donghang/Wang, Haibo/Du, Baoxun. Wiley-VCH, Weinheim. 2010. 256 Pages. Hardcover. Euro 119. ISBN-10: 0-470-82594-4. ISBN-13: 978-0-470-82594-5 – John Wiley & Sons.



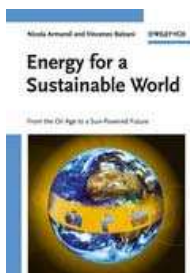
- *Modern Methods of Crystal Structure Prediction.* By Oganov, Artem R. Wiley-VCH, Weinheim. 2010. 252 Pages. Hardcover. Euro 119. ISBN-10: 3-527-40939-4. ISBN-13: 978-3-527-40939-6 – Wiley-VCH, Berlin.



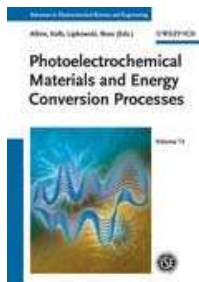
- *50 Years of Anderson Localization.* By Elihu Abrahams. World Scientific, Hackensack, NJ, 2010. Hardback: 609 pp., illus. \$128, £84. ISBN: 9789814299060. Paperback: 609 pp., illus. \$48, £32. ISBN: 9789814299077.
- *Advanced RF MEMS.* By Stepan Lucyszyn. Cambridge University Press, Cambridge, 2010. Hardback: 440 pp., illus. \$99, £70. ISBN: 9780521897716.
- *Condensed Matter Physics* By Michael P. Marder. 2nd ed. Wiley, Hoboken, NJ, 2010. Hardback: 980 pp., illus. \$125. ISBN: 9780470617984.
- *Emission Detectors.* By Alexander I. Bolozdynya. World Scientific, Hackensack, NJ, 2010. Hardback: 223 pp., illus. \$60, £37. ISBN: 9789812834058.
- *Fundamentals and New Frontiers of Bose-Einstein Condensation.* By Masahito Ueda. World Scientific, Hackensack, NJ, 2010. Hardback: 367 pp., illus. \$85, £58. ISBN 9789812839596.
- *Lectures on Advanced Mathematical Methods for Physicists.* By Sunil Mukhi and N. Mukunda. World Scientific, Hackensack, NJ, 2010. Hardback: 286 pp., illus. \$88, £61. ISBN: 9789814299732. Co-published with Hindustan Book Agency.
- *Modern Atomic and Nuclear Physics-Problems and Solutions Manual.* By Fujia Yang and Joseph Hamilton. 2nd ed. World Scientific, Hackensack,

- NJ, 2010. Paperback: 104 pp., illus. \$19, £13. ISBN: 9789814307680.
- *Optical Interactions in Solids*. By Baldassare Di Bartolo. 2nd ed. World Scientific, Hackensack, NJ, 2010. Hardback: 630 pp., illus. \$95, £59. ISBN: 9789814295741.
  - *Properties of Perovskites and Other Oxides*. By K. Alex Müller and Tom W. Kool. World Scientific, Hackensack, NJ, 2010. Hardback: 582 pp., illus. \$138, £86. ISBN: 9789814293358. Paperback: 582 pp., illus. \$69, £43. ISBN: 9789814317696.
  - *Thermodynamics*. By H. J. Kreuzer and Isaac Tamblyn. World Scientific, Hackensack, NJ, 2010. Hardback: 237 pp., illus. \$58, £36. ISBN: 9789814327527.
  - *Characterization of Nanoparticles Intended for Drug Delivery*. By Scott E. McNeil. Humana (Springer), New York, 2011. Hardback: 281 pp., illus. \$119. ISBN: 9781603271974.
  - *Molecular Driving Forces*. Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience. 2nd ed. By Ken A. Dill and Sarina Bromberg. Garland Science (Taylor and Francis), New York, 2010. Paperback: 776 pp., \$140. ISBN: 9780815344308.
  - *Fundamentals of Quantum Information*. By Hiroyuki Sagawa and Nobuaki Yoshida. World Scientific, Hackensack, NJ, 2010. Hardback: 266 pp., \$58, £36. ISBN: 9789814324236.
  - *Introductory Quantum Physics and Relativity*. By Jacob Dunningham and Vlatko Vedral. Imperial College Press, London, 2011. Hardback: 237 pp., illus. \$80, £50. ISBN: 9781848165144. Paperback: 237 pp., illus. \$42, £26. ISBN: 9781848165151.
  - *Light Microscopy -Methods and Protocols*. By Hélio Chiarini-Garcia and Rossana C. N. Melo. Humana (Springer), New York, 2011. Hardback: 254 pp., illus. \$119. ISBN: 9781607619499.
  - *Mechanical Properties of Complex Intermetallics*. By Esther Belin-Ferré. World Scientific, Hackensack, NJ, 2010. Hardback: 465 pp., illus. \$150, £93. ISBN: 9789814322164.
  - *Modern Aspects of Superconductivity*. By Sergei Kruchinin, Hidemi Nagao, and Shigeyuki Aono. World Scientific, Hackensack, NJ, 2010. Hardback: 231 pp., illus. \$90, £62. ISBN: 9789814261609.
  - *Molecular Imaging-Methods and Protocols*. By Khalid Shah. Humana (Springer), New York, 2011. Hardback: 262 pp., illus. \$119. ISBN: 9781607619000.
  - *Optical Processes in Microparticles and Nanostructures*. A Festschrift Dedicated to Richard Kounai Chang on His Retirement from Yale University. By Ali Serpengüzel and Andrew W. Poon. World Scientific, Hackensack, NJ, 2011. Hardback: 485 pp., illus. \$140, £87. ISBN: 9789814295772.
  - *Polymer Viscoelasticity Basics*. Molecular Theories, Experiments and Simulations. 2nd ed. By Yn-Hwang Lin. World Scientific, Hackensack, NJ, 2011. Hardback: 440 pp., illus. \$110, £68. ISBN: 9789814313032.
  - *Six Quantum Pieces*. A First Course in Quantum Physics. By Valerio Scarani, with Chua Lynn and Liu Shi Yang. World Scientific, Hackensack, NJ, 2011. Hardback: 158 pp., illus. \$48, £30. ISBN 9789814327534. Paperback: 158 pp., illus. \$24, £15. ISBN 9789814327541.
  - *Supersymmetric Quantum Mechanics — An Introduction*. By Asim Gangopadhyaya, Jeffrey V. Malloy, and Constantin Rasinariu. World Scientific, Hackensack, NJ, 2011. Hardback: 291 pp., illus. \$80, £50. ISBN 9789814313087. Paperback: 291 pp., illus. \$40, £25. ISBN 9789814313094.
  - *Energy for a Sustainable World*. From the Oil Age to a Sun-Powered Future By Armaroli, Nicola/Balzani, Vincenzo. Wiley-VCH, Weinheim. 2010. 368 Pages. Softcover. Euro 29.90. ISBN-10: 3-527-32540-9,

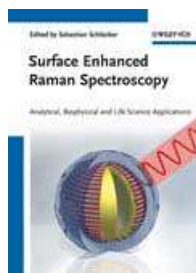
ISBN-13: 978-3-527-32540-5 – Wiley-VCH, Weinheim.



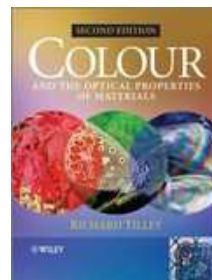
- *Photoelectrochemical Materials and Energy Conversion Processes*. Advances in Electrochemical Sciences and Engineering (Volume 12). By Alkire, Richard C./Kolb, Dieter M./Lipkowski, Jacek/Ross, Phil. Wiley-VCH, Weinheim. 2010. 360 Pages. Hardcover. Euro 139. ISBN-10: 3-527-32859-9, ISBN-13: 978-3-527-32859-8 – Wiley-VCH, Weinheim.



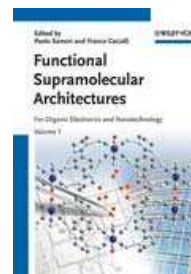
- *Surface Enhanced Raman Spectroscopy — Analytical, Biophysical and Life Science Applications*. By Schlücker, Sebastian. Wiley-VCH, Weinheim. 2010. 332 Pages. Hardcover. Euro 119. ISBN-10: 3-527-32567-0. ISBN-13: 978-3-527-32567-2 – Wiley-VCH, Weinheim.



- *Colour and The Optical Properties of Materials — An Exploration of the Relationship Between Light, the Optical Properties of Materials and Colour*. By Tilley, Richard J. D. 2<sup>nd</sup> Edition. Wiley-VCH, Weinheim. 2010. 526 Pages. Softcover. Euro 61.90. ISBN-10: 0-470-74695-5; ISBN-13: 978-0-470-74695-0 – John Wiley & Sons; 526 Pages. Hardcover. Euro 162. ISBN 978-0-470-74696-7.



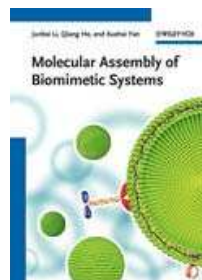
- *Functional Supramolecular Architectures-for Organic Electronics and Nanotechnology*. By Samori, Paolo / Cacialli, Franco. Wiley-VCH, Weinheim. 2010. 994 Pages. Hardcover. Two Volumes. Euro 299. ISBN-10: 3-527-32611-1. ISBN-13: 978-3-527-32611-2 – Wiley-VCH, Weinheim.



- *Artificial Receptors for Chemical Sensors*. By Mirsky, Vladimir M. / Yatsimirsky, Anatoly. Wiley-VCH, Weinheim. 2010. 470 Pages. Hardcover. Euro 139. ISBN-10: 3-527-32357-0, ISBN-13: 978-3-527-32357-9 – Wiley-VCH, Weinheim.



- *Molecular Assembly of Biomimetic Systems*. By Li, Junbai/He, Qiang/Yan, Xuehai. Wiley-VCH, Weinheim. 2010. 192 Pages. Softcover. Euro 109. ISBN-10: 3-527-32542-5. ISBN-13: 978-3-527-32542-9 – Wiley-VCH, Weinheim.



- *Handbook of Materials for Nanomedicine*. By Vladimir Torchilin and Mansoor M. Amiji. Pan Stanford, Singapore, 2010. Hardback: 865 pp., illus. \$399. ISBN: 9789814267557.

- *Handbook of Nanoindentation with Biological Applications*. By Michelle L. Oyen. Pan Stanford, Singapore, 2010. Hardback: 366 pp., illus. \$149. ISBN: 9789814241892.

- *Power for the World — The Emergence of Electricity from the Sun*. By Wolfgang Palz. Pan Stanford, Singapore, 2010. Hardback: 605 pp., illus. \$79. ISBN 9789814303378.

- *Green Chemistry and Engineering-A Practical Design Approach* By Jiménez-González, Concepción / Constable, David J. C. Wiley-VCH, Weinheim. 2011. 680 Pages. Hardcover. Euro 87.90. ISBN-10: 0-470-17087-5. ISBN-13: 978-0-470-17087-8 – John Wiley & Sons.



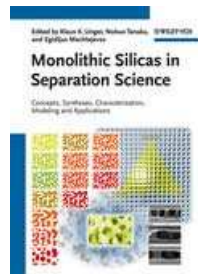
- *Handbook of Fluorescence Spectroscopy and Imaging — From Single Molecules to Ensembles*. By Sauer, Markus/Hofkens, Johan/Enderlein, Jörg. Wiley-VCH, Weinheim. 2011. 282 Pages. Hardcover. Euro 109. ISBN-10: 3-527-31669-8. ISBN-13: 978-3-527-31669-4 – Wiley-VCH, Weinheim.



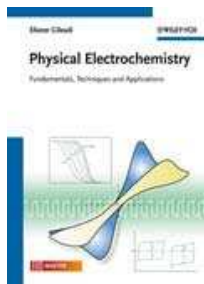
- *Microgel Suspensions — Fundamentals and Applications*. By Fernandez-Nieves, Alberto/Wyss, Hans/Mattsson, Johan/Weitz, David A. Wiley-VCH, Weinheim. 2011. 462 Pages. Hardcover. Euro 139. ISBN-10: 3-527-32158-6. ISBN-13: 978-3-527-32158-2 — Wiley-VCH, Weinheim.



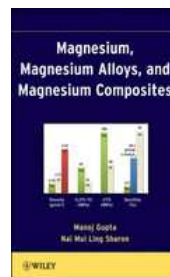
- *Monolithic Silicas in Separation Science — Concepts, Syntheses, Characterization, Modeling and Applications* By Unger, Klaus K./Tanaka, Nobuo/Machtejevas, Egidijus. Wiley-VCH, Weinheim. 2011. 344 Pages. Hardcover. Euro 109. ISBN-10: 3-527-32575-1. ISBN-13: 978-3-527-32575-7 – Wiley-VCH, Weinheim.



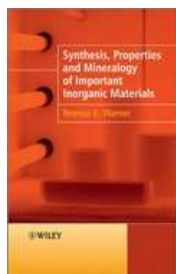
- *Physical Electrochemistry — Fundamentals, Techniques and Applications*. By Gileadi, Eliezer. Wiley-VCH, Weinheim. 2011. 374 Pages. Softcover. Euro 69. ISBN-10: 3-527-31970-0. ISBN-13: 978-3-527-31970-1 – Wiley-VCH, Weinheim.



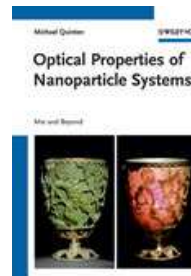
- *Magnesium, Magnesium Alloys, and Magnesium Composites*. By Gupta, Manoj/Sharon, Nai Mui Ling. Wiley-VCH, Weinheim. 2011. 258 Pages. Hardcover. Euro 109. ISBN-10: 0-470-49417-4. ISBN-13: 978-0-470-49417-2 – John Wiley & Sons.



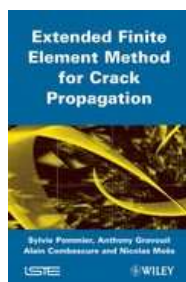
- *Synthesis, Properties and Mineralogy of Important Inorganic Materials*. By Warner, Terence E. Wiley-VCH, Weinheim. 2011. 288 Pages. Hardcover. Euro 119. ISBN-10: 0-470-74612-2. ISBN-13: 978-0-470-74612-7 – John Wiley & Sons. Softcover. 288 Pages. Euro 4.190. ISBN 978-0-470-74611-0.



- *Optical Properties of Nanoparticle Systems*. By Quinten, Michael. Wiley-VCH, Weinheim. 2011. 488 Pages. Hardcover. Euro 129. ISBN-10: 3-527-41043-0. ISBN-13: 978-3-527-41043-9 – Wiley-VCH, Berlin.



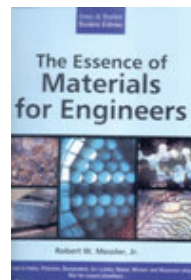
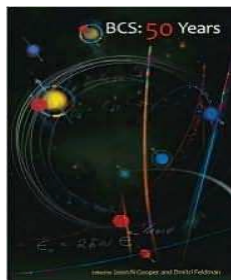
- *Extended Finite Element Method for Crack Propagation*. By Pommier, Sylvie/Gravouil, Anthony/Moes, Nicolas/Combesure, Alain. Wiley-VCH, Weinheim. 2011. 256 Pages. Hardcover. Euro 81.9. ISBN-10: 1-84821-209-7. ISBN-13: 978-1-84821-209-1 – John Wiley & Sons.



- *Fatigue of Materials and Structures-Application to Damage and Design*. By Bathias, Claude / Pineau, André. Volume 2. . Wiley-VCH, Weinheim. 2011. 512 Pages. Hardcover. Euro 125. ISBN-10: 1-84821-267-4. ISBN-13: 978-1-84821-267-1 – John Wiley & Sons.



- *BCS-50 Years*. By Leon N. Cooper and Dmitri Feldman. World Scientific, Hackensack, NJ, 2010. Hardback: 585 pp., illus. \$135, £84. ISBN: 9789814304641. Paperback: 585 pp., illus. \$65, £40. ISBN: 9789814304658.
- *The Essence of Materials For Engineers*. By Robert W. Messler, Jr. Jones & Bartlett India Pvt. Ltd., 2011. 570 pp. Original Price: \$107.95. Special Indian Price: Rs 595.



- *The Handy Physics Answer Book*. 2nd ed. By Paul W. Zitzewitz. Visible Ink (Gale Research), Detroit, 2011. Paperback: 383 pp., illus. \$21.95, C\$24.95.

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**Review Articles**

- A ten-year perspective on dilute magnetic semiconductors and oxides. By T. Dietl, *Nature Mater.*, **9**(12), 965–974 (2010).

**Abstract**

Over the past ten years, the search for compounds combining the properties of semiconductors and ferromagnets has evolved into an important field of materials science. This endeavor has been fuelled by many demonstrations of remarkable low-temperature functionalities in the ferromagnetic structures (Ga,Mn)As and p-(Cd,Mn)Te, and related compounds, and by the theoretical prediction that magnetically doped, p-type nitride and oxide semiconductors might support ferromagnetism, mediated by valence-band holes to above room temperature. Indeed, ferromagnetic signatures persisting at high temperatures have been detected in a number of non-metallic systems, even under conditions in which the presence of spin ordering was not originally anticipated.

Here, Dietl reviews the recent experimental and theoretical developments, emphasizing that they not only disentangle many controversies and puzzles accumulated over the past decade, but also offer new research prospects. 112 References.

- Nanosheets of Oxides and Hydroxides: Ultimate 2D Charge-Bearing Functional Crystallites. By R. Ma and T. Sasaki, *Adv. Mater.*, **22** (45), 5082–5104 (2010).

**Abstract**

A wide variety of cation-exchangeable layered transition metal oxides and their relatively rare counterparts, anion-exchangeable layered hydroxides, have been exfoliated into individual host layers, i.e., nanosheets. Exfoliation is generally achieved via a high degree of swelling, typically driven either by intercalation of bulky organic ions (quaternary ammonium cations, propylammonium cations, etc.) for the layered oxides or by solvation with organic solvents (formamide, butanol, etc.) for the hydroxides. Ultimate two-dimensional (2D) anisotropy for the nanosheets, with thickness of around one nanometer versus lateral size ranging from submicrometer to several tens

of micrometers, allows them to serve either as an ideal quantum system for fundamental study or as a basic building block for functional assembly. The charge-bearing inorganic macromolecule-like nanosheets can be assembled or organized through various solution-based processing techniques (e.g., flocculation, electrostatic sequential deposition, or the Langmuir–Blodgett method) to produce a range of nanocomposites, multilayer nanofilms, and core–shell nanoarchitectures, which have great potential for electronic, magnetic, optical, photochemical, and catalytic applications. 131 References.

- Recent Developments in Top-Emitting Organic Light-Emitting Diodes. By S. Chen, L. Deng, J. Xie, L. Peng, L. Xie, Q. Fan and W. Huang, *Adv. Mater.*, **22** (46), 5227–5239 (2010).

**Abstract**

Organic light-emitting diodes (OLEDs) have rapidly progressed in recent years due to their unique characteristics and potential applications in flat panel displays. Significant advancements in top-emitting OLEDs have driven the development of large-size screens and microdisplays with high resolution and large aperture ratio.

After a brief introduction to the architecture and types of top-emitting OLEDs, the microcavity theory typically used in top-emitting OLEDs is described in detail here. Then, methods for producing and understanding monochromatic (red, green, and blue) and white top-emitting OLEDs are summarized and discussed. Finally, the status of display development based on top-emitting OLEDs is briefly addressed. 111 References.

- Switchable Adhesion on Liquid/Solid Interfaces. By M. Liu and L. Jiang, *Adv. Funct. Mater.*, **20** (21), 3753–3764 (2010).

**Abstract**

Construction and application of surfaces with switchable liquid–solid adhesion have generated worldwide interest during the past a few years. These surfaces are of great importance not only for fundamental research but for various practical applications in smart and fluid-controllable devices.

This Article reviews several techniques that have been developed to switch the adhesion on liquid/solid interfaces, including tuning the surface chemical composition, tailoring the surface morphology, and applying external stimuli. Particular attention is paid to superhydrophobic surfaces with reversible switching between low- and high-adhesion to water droplets in response to external stimuli. The dynamic behavior of water droplets on such surfaces can be controlled ranging from rolling to pinning state, while maintaining superhydrophobic states. In addition, smart adhesion in oil/water/solid system and platelet/water/solid system are also discussed, which is of importance for application in designing novel anti-bioadhesion materials. 108 References.

- The electro-oxidation of carbon monoxide, hydrogen/carbon monoxide and methanol in acid medium on Pt-Sn catalysts for low-temperature fuel cells: A comparative review of the effect of Pt-Sn structural characteristics. By E. Antolini, E.R. Gonzalez, *Electrochim. Acta*, **56** (1), 1–14 (2010).

### Abstract

The electrocatalytic activity for CO, H<sub>2</sub>/CO and CH<sub>3</sub>OH oxidation of Pt-Sn catalysts has been extensively investigated for a possible use as anode materials for low-temperature fuel cells. This paper presents an overview of the relationship between the structural characteristics of the catalysts (catalyst composition, degree of alloying, presence of oxides) and their electrocatalytic activity for the oxidation of the different fuels. 84 References.

- Tailoring Material Properties through Defect Engineering. By H. L. Tuller and S. R. Bishop, *Chem. Lett.*, **39** (12), 1226–1231 (2010).

### Abstract

Many advanced materials today derive their function from precise control of point defects. Through manipulation of point defects, the electrical, optical, mechanical, and other properties of materials can be systematically modified and optimized.

This paper illustrates the type of progress that has been made in understanding the often complex equilibria exhibited by many materials and shows, by use

of examples, how this knowledge can be applied to tailor materials' properties through defect engineering. Examples which highlight key points of defect engineering include: dark conductivity of radiation detectors, chemomechanics and nanoionics of solid oxide fuel cell materials, sensitivity of high frequency resonators for high-temperature mass measurements, and emission lifetime and luminescence intensity of phosphor materials. 37 References.

- Activatable nanomaterials at the forefront of biomedical sciences. By T. Kim, Y.-M. Huh, S. Haam and K. Lee, *J. Mater. Chem.*, **20** (38), 8194–8206 (2010).

### Abstract

This article reviews the emerging applications of activatable nanomaterials in the bio- and medical fields, namely, molecular imaging, theragnostics, cancer therapy, tissue engineering, and biosensors. Nanomaterials, with an ideal size to interact with biological systems replete with nanoscopic biomolecules, are now finding applications in previously inconceivable tasks of affecting biological systems at the sub-cellular level, revolutionizing the technological developments of the bio- and medical fields.

This article places special emphasis on the nanomaterial designs, the activation mechanism of the prepared materials and the nanoscopically localized effect of the resulting nanomaterial-originated events, which are designed to manipulate the behavior of biological systems or obtain critical biological information. 82 References.

- Novel properties of graphene nanoribbons: a review. By S. Dutta and S. K. Pati, *J. Mater. Chem.*, **20** (38), 8207–8223 (2010).

### Abstract

Low-dimensional materials are of great interest to both theorists and experimentalists, owing to their novel electronic properties which arise mainly because of a host of quantum confinement effects. Recent experimental findings of graphene have provided a new platform to explore the interesting electronic properties in strictly two dimensions.

In this article, the authors review the novel properties of an interesting class of quasi one dimensional materials, known as graphene nanoribbons, which can be obtained by finite termination of graphene sheet with smooth edges. Recent experimental sophistications provide various physical and chemical ways to materialize these systems. Two different edge geometries, namely zigzag and armchair, arising from the finite termination of graphene, control the electronic properties of graphene nanoribbons. The authors attempt to give an overview of their interesting electronic, magnetic, optical, conduction properties and explore possible ways of enhancing their device applicability by a number of ways including external perturbations, doping and chemical modifications. 260 References.

- Surface modification of colloidal CdX-based quantum dots for biomedical applications. By J. K. Oh, *J. Mater. Chem.*, **20** (39), 8433–8445 (2010).

### Abstract

Colloidal CdX (X = Se, S, and Te) and their core/shell quantum dots (QDs) have narrow and size-dependent emission spectra, multicolor excitation with large extinction coefficients, and excellent photostability against photobleaching. Because of these unique photoluminescence properties of QDs over conventional fluorescent organic dyes and fluorescent proteins, QDs are useful for various applications such as biological labeling, biosensing and detection, light emitting diodes (LED), and solar cells (photovoltaics). Toward successful biological applications, control of the surface chemistry of QDs is required, enabling the preparation of QDs with water-solubility (or colloidal stability), biocompatibility, nonspecific adsorption to cells, efficient fluorescence, and active targeting.

This review describes recent strategies developed for the modification of the surface of CdX-based QDs for biological applications. 174 References.

- Printed electronics: the challenges involved in printing devices, interconnects, and contacts based on inorganic materials. By J. Perelaer, P. J. Smith, D. Mager, D. Soltman, S. K. Volkman, V. Subramanian, J. G. Korvink and U. S. Schubert, *J. Mater. Chem.*, **20** (39), 8446–8453 (2010).

### Abstract

Printed electronics represent an emerging area of research that promises large markets due to the ability to bypass traditional expensive and inflexible silicon-based electronics to fabricate a variety of devices on flexible substrates using high-throughput printing approaches. This article presents a summary of work to date in the field of printed electronics and the materials chemistry involved. In particular, the focus is upon the use of metal- and metal oxide-containing inks in the preparation of contacts and interconnects. The review discusses the challenges associated with processing these types of inks and ways to successfully obtain the desired features. 83 References.

- Microscale synthesis of quantum dots. By A. M. Nightingale and J. C. de Mello, *J. Mater. Chem.*, **20** (39), 8454–8463 (2010).

### Abstract

Microfluidic reactors are emerging as a highly promising technology for quantum dot synthesis due to the unparalleled control they provide over particle properties. In this article, the authors review recent developments in the microfluidic synthesis of quantum dots, and discuss some of the advantages and challenges of preparing nanocrystalline materials in microscale fluidic channels. The relative merits of continuous-flow and segmented-flow reactors are considered, together with a number of outstanding issues that must be successfully addressed for microfluidics to become a truly viable technology for quantum dot synthesis. 78 References.

- Biomaterials and their potential applications for dental tissue engineering. By K. M. Galler, R. N. D'Souza and J. D. Hartgerink, *J. Mater. Chem.*, **20** (40), 8730–8746 (2010).

### Abstract

Engineering oral tissues as a multidisciplinary approach to build complex structures such as bone, teeth or soft dental tissues remains a challenging endeavor which will also require significant additional development of materials chemistry before it will be successful. The authors highlight areas of recent success and describe major challenges which the materials

chemistry community, in collaboration with clinicians, must still overcome. The isolation of stem cell populations from various sources in the oral cavity and advances in utilizing their differentiation potential has been driving the field forward.

So far, bio-inert materials have mainly been used as carriers and delivery vehicles, relying on the intrinsic cellular competence to form tissues. As this may not suffice to induce regeneration, there is a need for novel biomimetic scaffolds capable of providing chemical and mechanical cues to promote multiple specific interactions between cells and matrix. These signals can orchestrate processes such as cell adhesion, migration, differentiation, matrix synthesis, mineralization, and/or vasculogenesis.

In this review, the authors give a brief description of oral anatomy and pathology, state-of-the-art treatment methods and their shortcomings. They provide an overview of current strategies to fabricate bioactive matrices, with an emphasis on nanostructured materials, and suggest design principles for scaffolding systems specifically tailored towards dental tissue regeneration. In this review, they also envision future approaches based on these emerging areas that rely on recent developments in tissue engineering and stem cell research. At the interface between material science and biology, cellular response can be controlled by materials chemistry, and potential applications for regenerative strategies are evolving. 176 References.

- Development of bone substitute materials: from ‘biocompatible’ to ‘instructive’. By M. Bongio, J. J. J. P. van den Beucken, S. C. G. Leeuwenburgh and J. A. Jansen, *J. Mater. Chem.*, **20** (40), 8747–8759 (2010).

### Abstract

Progress made in basic research in the last decades led to a tremendous increase in quality of clinically applied bone substitute materials (polymers, ceramics and composites). The desired biological performance of these materials has consequently shifted from a passive role where materials were merely accepted by the body to an active role in which materials instruct their biological surroundings. Bone substitute materials were traditionally based on bioceramics, that can be optimized in terms of composition, structure

and porosity. Now, polymers are increasingly gaining importance for use in medical applications due to their high versatility.

This review provides an overview of the evolution from 1st generation biotolerant and bioinert materials *via* 2nd generation bioresponsive bone substitutes towards 3rd generation bioinstructive bone substitute materials that possess inherent biological cues for bone regeneration. 148 References.

- Magnetic nanoparticles: biomedical applications and challenges. By N. Tran and T. J. Webster, *J. Mater. Chem.*, **20** (40), 8760–8767 (2010).

### Abstract

The progress in the development of magnetic nanoparticle based therapies for various biomedical applications is reviewed here. Most significantly, magnetic nanoparticles have been widely used in drug delivery and hyperthermia treatment for cancer. However, recent applications of magnetic nanoparticles demonstrate their promise towards decreasing implant infection and increasing tissue growth. To build the most effective magnetic nanoparticle systems for various biomedical applications, particle characteristics including size, surface chemistry, magnetic properties and toxicity have to be fully investigated.

In this review, several new applications of magnetic nanoparticles in the medical arena as well as remaining challenges for such clinical use are discussed. 123 References.

- The high functionalization of temperature-responsive culture dishes for establishing advanced cell sheet engineering. By K. Itoga and T. Okano, *J. Mater. Chem.*, **20** (40), 8768–8775 (2010).

### Abstract

The authors’ laboratory developed “cell sheet engineering”, which has been applied to regenerative medicine. However, the applications are restricted to the transplants of single-, double-, and triple-layered cell sheets, because of the poor supplies of nutrients and oxygen. To fabricate thicker and dense tissues *in vitro*, multi-layered cell sheets need to have capillary networks. Additionally, individual tissues found in animal bodies have individual specific micropatterns of cells for expressing their specific functions

and characteristics. Therefore, authors' laboratory has developed various kinds of micropatterned surfaces which could align cells in the shape of micropatterns.

In this review, the authors summarize and discuss patterned surfaces that allow us to perform the high functionalization of temperature-responsive culture dishes for establishing advanced cell sheet engineering. 61 References.

- Fiber-reinforced scaffolds for tissue engineering and regenerative medicine: use of traditional textile substrates to nanofibrous arrays. By S. D. McCullen, C. M. Haslauer and E. G. Lobo, *J. Mater. Chem.*, **20** (40), 8776–8788 (2010).

### Abstract

Regenerative medicine is a promising therapeutic strategy for the repair and replacement of diseased or injured tissues and organs. The main approach for this method is the fabrication and use of scaffold materials to act as a surrogate framework and promote cell-seeded populations to develop into a mature and functional tissue. Scaffold based strategies for regenerative medicine have focused on the use of three dimensional, biocompatible, biodegradable structures to provide an adequate template for *ex vivo* cell expansion and maturation, native tissue in-growth, and restoration of the original tissue qualities with respect to the tissue's biochemical constituents, morphology, form, and function. To achieve this, the use of fiber and/or textile substrates have been used as either the underlying skeleton or reinforcing agents with or without three-dimensional matrices to provide scaffolds that exhibit suitable mechanical properties, high cellularity, and better mimicry of the natural tissue organization and its resulting composition.

In this article the authors discuss, (1) fiber reinforcement in natural tissues, (2) literature examples of fiber reinforcement in engineered tissues, and (3) strategies and next steps to expand this field. Fiber reinforcement continues to be an ideal strategy for tissue scaffolds that require mechanical reinforcement while providing high surface volume in a compliant form. 73 References.

- Sugars: burden or biomaterials of the future? By I. Pashkuleva and R. L. Reis, *J. Mater. Chem.*, **20** (40), 8803–8818 (2010).

### Abstract

During the past few years, the field of tissue engineering (TE) has been shifting from replacement to regenerative strategies. Following this tendency, the requirements for biomaterials to be used in TE have been also changing. While a few decades ago bio-inert materials that do not provoke undesired body responses were in the focus of material sciences, nowadays third generation biomaterials mimicking the nanoscale mechanisms of the interactions between cells and their *in vivo* environment are the target of material design. Although these mechanisms involve different bioactive molecules, until now mainly strategies involving small peptide epitopes that copycat specific sequences of complex proteins have been exploited. The breakthroughs that such approaches brought to biomaterials and TE fields are undeniable. Nevertheless, the important role that carbohydrates play in tissue structuring and function is still poorly explored and exploited in this context and the authors believe that this is one of the missing pieces in the TE puzzle.

Carbohydrates are an integral part of our life. We are literally covered by them: from bacteria to mammalian cells, the molecular landscape of the cell surface is coated with sugars forming the so-called glycocalyx. This strategic placement of the sugars makes them crucial for the development, growth, function and/or survival of an organism. It is believed that the structural diversity of carbohydrates is the key for understanding and controlling those processes because of the huge number of ligand structures, which sugars can display in molecular recognition systems. However, their main advantages: the intricacy and the large natural diversity have turned against the scientists and have hampered their study. As a result, the field of glycomics is much less developed compared to its counterparts genomics and proteomics within TE. Recent advances in carbohydrate synthesis, sensing technologies and processing methodologies are inducing rapid changes in this field and are discussed in this review. The use of carbohydrates as an interrogation and modulation tool for better understanding of the complexity and dynamics of the natural three-dimensional environment of the cells are also focussed. 100 References.

- Multimodal biomaterial strategies for regeneration of infarcted myocardium. By S. Mukherjee, J. R. Venugopal, R. Ravichandran, S. Ramakrishna and M. Raghunath, *J. Mater. Chem.*, **20** (40), 8819–8831 (2010).

### Abstract

Myocardial tissue engineering (MTE) is an exciting front of research which is both highly competitive and extremely challenging for researchers. MTE aims to attenuate the functional set back in terms of cardiac output faced by the heart undergoing myocardial infarction (MI). MI results in substantial death of cardiomyocytes in the infarct zone followed by a strong inflammatory response and heart transplantation is the most common corrective measure for cardiac tissue engineering. Researchers are continuously striving to develop a better alternative to this highly invasive technique. Although numerous cell-based and cell-free strategies have been employed to bring about the repair of myocardium in recent times, the quest for optimal biomaterial still continues, owing to hurdles in design and fabrication of fully functional and efficiently engineered construct. In order to fabricate the constructs for myocardial repair, several biodegradable and non-biodegradable polymeric biomaterials have been analyzed over the years for their mechanical properties, biocompatibility with various cell types and functionality upon implantation. A hallmark of functional myocardium is its ability to propagate electrical impulses and respond to these impulses by synchronized contractions that generate forces for pumping blood for all metabolic activities of the body. For biomaterials to influence the myocardium microenvironment, suitable designs for cell recruitment and formation of functional conductive bundles are expected. The unique tissue structure and functioning of heart have prevented constructs from being proficient enough to be taken to clinical trials. Nonetheless, various tissue engineering strategies have evolved such as 3D implants, 2D patches and injectables, whose positive indications render optimism to investigators, that the tissue engineered regimen, would bring new treatments for patients who have suffered from agonizing MI.

Focusing on biomaterials, this review provides an insight into such multi-modal research strategies, major advances and promising paradigm shifts in the field of myocardial tissue engineering. 211 References.

- Biomaterials for stem cell differentiation. By A. Singh and J. Elisseeff, *J. Mater. Chem.*, **20** (40), 8832–8847 (2010).

### Abstract

Stem cell-based therapeutic treatments hold great promise in treating diseases by replacement of body parts and organs through the generation of new tissues. Directing the controlled differentiation of stem cells into a lineage-specific manner requires a controlled biophysical and biochemical microenvironment and signals. Biomaterials may act as artificial microenvironments and therefore, can deliver stem cell regulatory signals in a precise and near-physiological fashion. A variety of biomaterials are being developed that support cellular attachment, proliferation and most importantly lineage-specific differentiation. Development of new intelligent biomaterials in synergy with cell biology will advance stem cell-based clinical therapeutics.

This review discusses the various biomaterials, in particular polymers, applied towards the goal of lineage-specific differentiation of stem cells. 247 References.

- Input of atomic layer deposition for solid oxide fuel cell applications. By M. Cassir, A. Ringuedé and L. Niinistö, *J. Mater. Chem.*, **20** (41), 8987–8993 (2010).

### Abstract

The development of a new generation of solid oxide fuel cells (SOFCs) operating at lower temperatures with competitive performances requires the use of high-quality thin layers, either as electrolytes, electrodes or interlayers, such as catalysts, diffusion barriers, bond or protective layers. Atomic layer deposition (ALD) is a sequential chemical vapour deposition (CVD) technique allowing processing of one mono-atomic layer after another, conformal, adherent and homogeneous nano-scaled films which are often crystalline as-deposited without the need of

high-temperature annealing treatments. Moreover, the scalability of ALD offers an important prospect for industrial applications.

In this article, the literature dealing with ALD applied to SOFCs is thoroughly analyzed, showing the present achievements as well as the numerous advantages of this technique. New developments for the future are currently in progress extending the potential use of ALD to other high-temperature devices such as proton electrolyte fuel cells, high-temperature water electrolysis, HTWE (with reversed SOFC-type systems) and molten carbonate fuel cells (MCFCs). 70 References.

- Product integration of compact roll-to-roll processed *polymer solar cell* modules: methods and manufacture using flexographic printing, slot-die coating and rotary screen printing. By F. C. Krebs, J. Fyenbo and M. Jørgensen, *J. Mater. Chem.*, **20** (41), 8994–9001 (2010).

#### Abstract

The improvement of the performance of roll-to-roll processed polymer solar cell modules through miniaturization of the device outline is described. The final modules comprised 16 serially connected cells. A total of 1960 modules were prepared for each run and the best power conversion reached was 2.75% for devices based on P3HT:[70]PCBM.

The solar cell modules were used to demonstrate the complete manufacture of a small lamp entirely using techniques of flexible electronics. The solar cell module was used to charge a polymer lithium ion battery through a blocking diode. The entire process was fully automated and demonstrates the capacity of polymer solar cells in the context of flexible and printed electronics. Finally a comparison was made between the learning curve for OPV (organic photovoltaic cells) and crystalline silicon solar cells in terms of the cost per watt peak and the cumulative watt peak. OPV as a technology was found to have a significantly steeper learning curve. 36 References.

- Wastewater treatment with heterogeneous Fenton-type catalysts based on porous materials. By M. Hartmann, S. Kullmann and H. Keller, *J. Mater. Chem.*, **20** (41), 9002–9017 (2010).

#### Abstract

The Fenton reagent which was discovered by H. J. H. Fenton over 100 years ago is still of special interest for wastewater treatment in the present time. The main objective of heterogeneous Fentoncatalysts is the combination of high activity, low ironleaching and the possibility of employing the system at pH environments near neutrality. This review discusses the use of iron-containing pillared clays as well as micro- and mesoporous (alumino-) silicatecatalysts prepared by ion-exchange, impregnation or direct synthesis for the degradation of organic compounds like phenol and organic dyes including Orange II. Moreover, the treatment of more complex waste streams is reviewed. After a general introduction into the chemistry of the Fenton and the photo-Fenton reaction as well as the catalysts employed, specific examples are discussed with respect to the active species present, the stability of the catalyst and the influence of reaction conditions such as pH, temperature and the presence of impurities. References.

- Recent Progress in Nanostructured Cathode Materials for Lithium Secondary Batteries. By H.-K. Song, K. T. Lee, M. G. Kim, L. F. Nazar and J. Cho, *Adv. Funct. Mater.*, **20** (22), 3818–3834 (2010).

#### Abstract

Diversified and extended applications of lithium-ion batteries demand the development of more enhanced materials that can be achieved by sophisticated synthetic methods. Combination of novel materials with strategic design of their shape on the nanometer scale enables a breakthrough to overcome problems experienced by present technologies. In this feature article, an overview is given of Mn-based and polyanion-based cathode materials with nanoscale features for lithium-ion batteries as materials to replace conventional bulk cathode materials. Various synthetic methods coupled with nanostructuring as well as the benefits obtained from the nanostructure are described. 146 References.

- EXAFS as Powerful Analytical Tool for the Investigation of Organic–Inorganic Hybrid Materials. By S. Gross and M. Bauer, *Adv. Funct. Mater.*, **20** (23), 4026–4047 (2010).

### Abstract

The potential and application of X-ray absorption spectroscopy (XAS) for structural investigations of organic–inorganic hybrid materials, with a special emphasis on systems consisting of inorganic building blocks (clusters) embedded into polymer backbones, is extensively reviewed. In the first part of the paper, the main features of organic–inorganic hybrid materials, their classification, the synthetic approaches for their preparation, and their applications are concisely presented, whereas the particular issues related to their characterization are discussed in more detail. In the second section of the paper, the principles and the theoretical background of the XAS method, including experimental design, data reduction, evaluation, analysis, and interpretation are described and discussed. Examples of potentialities of the method for the short-range structural investigation of inorganic nanostructures in hybrids are provided, and the state-of-the-art in the field of hybrid materials is reviewed. In the third part, six different case studies belonging to our past and present experience in this field are presented and discussed, with a particular focus on their XAS investigation. 132 References.

- Direct Physical Imaging and Chemical Probing of LiFePO<sub>4</sub> for Lithium-Ion Batteries. By S.-Y. Chung, Y.-M. Kim and S.-Y. Choi, *Adv. Funct. Mater.*, **20** (24), 4219–4232 (2010).

### Abstract

The control of unexpectedly rapid Li intercalation reactions without structural instability in olivine-type LiFePO<sub>4</sub> nanocrystals is one of the notable scientific advances and new findings attained in materials physics and chemistry during the past decade. A variety of scientific studies and technological investigations have been carried out with LiFePO<sub>4</sub> to elucidate the origins of many peculiar physical aspects as well as to develop more effective synthetic processing techniques for better electrochemical performances.

Among the several features of LiFePO<sub>4</sub> that have

attracted much interest, in this article the authors address four important issues—regarding doping of aliovalent cations, distribution of Fe-rich secondary metallic phases, nanoparticle formation during crystallization, and anti-site Li/Fe partitioning—by means of straightforward atomic-scale imaging and chemical probing. The direct observations in the present study provide significant insight into alternative efficient approaches to obtain conductive LiFePO<sub>4</sub> nanocrystals with controlled defect structures. 70 References.

- Recent Developments in One-Dimensional Inorganic Nanostructures for Photodetectors. By T. Zhai, L. Li, X. Wang, X. Fang, Y. Bando and D. Golberg, *Adv. Funct. Mater.*, **20** (24), 4233–4248 (2010).

### Abstract

With large surface-to-volume ratios and Debye length comparable to their small sizes, one-dimensional (1D) inorganic nanostructures have extensively been investigated and widely used to fabricate high-performance nanoscale electronic and optoelectronic devices.

This article reviews the state-of-the-art research activities that focus on the one-dimensional inorganic nanostructures and their photodetector applications. It begins with a survey of 1D-inorganic nanostructures and the fundamentals of photodetectors. Some remarkable photoresponse characteristics are then presented, which are organized into sections covering several kinds of important nanostructures, such as ZnO, V<sub>2</sub>O<sub>5</sub>, ZnS, In<sub>2</sub>Se<sub>3</sub>, InSe, CdS, CdSe, ZnSe, Sb<sub>2</sub>Se<sub>3</sub>, ZrS<sub>2</sub>, Ag<sub>2</sub>S, and Zn<sub>x</sub>Cd<sub>1-x</sub>Se. Each section describes the corresponding photodetective properties in detail. Finally, the article concludes with some perspectives and outlook on the future developments in the field. 149 References.

- Recent Progress on ZnO-Based Metal-Semiconductor Field-Effect Transistors and Their Application in Transparent Integrated Circuits. By H. Frenzel, A. Lajn, H. von Wenckstern, M. Lorenz, F. Schein, Z. Zhang and M. Grundmann, *Adv. Mater.*, **22**(47), 5332–5349 (2010).

### Abstract

Metal-semiconductor field-effect transistors (MES-FETs) are widely known from opaque high-speed

GaAs or high-power SiC and GaN technology. For the emerging field of transparent electronics, only metal-insulator-semiconductor field-effect transistors (MIS-FETs) were considered so far.

This article reviews the progress of high-performance MESFETs in oxide electronics and reflects the recent advances of this technique towards transparent MESFET circuitry. The authors discuss design prospects as well as limitations regarding device performance, reliability and stability. The presented ZnO-based MESFETs and inverters have superior properties compared to MISFETs, i.e., high channel mobilities and on/off-ratios, high gain, and low uncertainty level at comparatively low operating voltages. This makes them a promising approach for future low-cost transparent electronics. 52 References.

- Self-Healing Materials. By M. D. Hager, P. Greil, C. Leyens, S. van der Zwaag and U. S. Schubert, *Adv. Mater.*, **22**(47), 5424–5430 (2010).

### Abstract

Self-healing materials are able to partially or completely heal damage inflicted on them, e.g., crack formation; it is anticipated that the original functionality can be restored.

This article covers the design and generic principles of self-healing materials through a wide range of different material classes including metals, ceramics, concrete, and polymers. Recent key developments and future challenges in the field of self-healing materials are summarized, and generic, fundamental material-independent principles and mechanism are discussed and evaluated. 96 References.

- Engineering the Extracellular Environment: Strategies for Building 2D and 3D Cellular Structures. By O. G. -Gentil, O. Semenov, A. S. Roca, T. Groth, R. Zahn, J. Vörös and M. Z.-Wong, *Adv. Mater.*, **22**(48), 5443–5462 (2010).

### Abstract

Cell fate is regulated by extracellular environmental signals. Receptor specific interaction of the cell with proteins, glycans, soluble factors as well as neighboring cells can steer cells towards proliferation, differentiation, apoptosis or migration.

In this review, approaches to build cellular structures by engineering aspects of the extracellular environment are described. These methods include non-specific modifications to control the wettability and stiffness of surfaces using self-assembled monolayers (SAMs) and polyelectrolyte multilayers (PEMs) as well as methods where the temporal activation and spatial distribution of adhesion ligands is controlled. Building on these techniques, construction of two-dimensional cell sheets using temperature sensitive polymers or electrochemical dissolution is described together with current applications of these grafts in the clinical arena. Finally, methods to pattern cells in three-dimensions as well as to functionalize the 3D environment with biologic motifs take us one step closer to being able to engineer multicellular tissues and organs. 267 References.

- Semiconductor Gas Sensors: Dry Synthesis and Application. By A. Tricoli, M. Righettoni and A. Teleki, *Angew. Chem. Int. Ed.*, **49** (42), 7632–7659 (2010).

### Abstract

Since the development of the first chemoresistive metal oxide based gas sensors, transducers with innovative properties have been prepared by a variety of wet- and dry-deposition methods. Among these, direct assembly of nanostructured films from the gas phase promises simple fabrication and control and with the appropriate synthesis and deposition methods nm to  $\mu\text{m}$  thick films, can be prepared. Dense structures are achieved by tuning chemical or vapor deposition methods whereas particulate films are obtained by deposition of airborne, mono- or polydisperse, aggregated or agglomerated nanoparticles. Innovative materials in non-equilibrium or sub-stoichiometric states are captured by rapid cooling during their synthesis.

This review presents some of the most common chemical and vapor-deposition methods for the synthesis of semiconductor metal oxide based detectors for chemical gas sensors. In addition, the synthesis of highly porous films by novel aerosol methods is discussed. A direct comparison of structural and chemical properties with sensing performance is given. 280 References.

- The Growth and Properties of Relaxor-Based Ferroelectric Single Crystals. By X. Li and H. Luo, *J. Amer. Ceram. Soc.*, **93** (10), 2915–2928 (2010).

### Abstract

Much attention is drawn to the fundamental research and the applications of the relaxor-based ferroelectrics for the next generation of piezoelectric devices. Mass production of  $\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3-x\text{PbTiO}_3$  (PMNT) and ternary  $x\text{Pb}(\text{In}_{1/2}\text{Nb}_{1/2})\text{O}_3-y\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3-z\text{PbTiO}_3$  (PIMNT) single crystals with a Bridgman method was reported. The piezoelectric, pyroelectric, and electric–optical performances of PMNT single crystals are much more excellent than traditional ceramics with the composition near morphotropic phase boundaries. Compared with PMNT crystal, PIMNT crystals can be used in a more broad range of device applications due to their high Curie temperature  $T_c$  and large coercive fields  $E_c$ . A relaxor-based  $\text{Na}_{0.5}\text{Bi}_{0.5}\text{TiO}_3-x\text{BaTiO}_3$  (NBBT) crystal grown by the top seeded solution growth method was also investigated to find a lead-free material with better piezoelectric performance.

The properties of these relaxor-based single crystals were summarized. The mechanism of the enhanced piezoelectric response is discussed, based on the phase transitions induced by the variations of the temperature, pressure, composition, and electric field. 103 References.

- Processing Technologies for High-Permittivity Thin Films in Capacitor Applications. By G. L. Brennecke, J. F. Ihlefeld, J.-P. Maria, B. A. Tuttle and P. G. Clem, *J. Amer. Ceram. Soc.*, **93** (12), 3935–3954 (2010).

### Abstract

Capacitor technologies are as varied as the applications that they enable, but one of the common themes in advanced capacitors for consumer electronics is a desire for increased capacitance in smaller areas/volumes. The heroic advances of discrete capacitor manufacturers have kept pace with the increasing demands of miniaturization, but a time is quickly approaching when it appears that powder-based fabrication techniques simply will not be able to achieve desired layer thicknesses and capacitance densities.

Here, the authors review the current state of the art and recent advances in the processing science and technology of high-permittivity thin films with a focus on industrially scalable solution-based fabrication processes of perovskite ferroelectric systems that appear to offer the greatest promise for the fabrication of future nanoscale capacitors. 159 References.

- An Update on Nanomaterials-Based Textiles for Protection and Decontamination. By S. Sundarrajan, A. R. Chandrasekaran and S. Ramakrishna, *J. Amer. Ceram. Soc.*, **93** (12), 3955–3975 (2010).

### Abstract

Protective clothing currently used against chemical and biological warfare (CBW) agents use activated charcoal impregnated with metal ions, which serve to physically adsorb nerve and blister agents thereby creating disposal hazards after its usage. Nanotechnology is booming in an unprecedented way in creating its impact in various applications such as in catalysis. Metal oxide nanoparticles (MONPs) such as  $\text{TiO}_2$  and  $\text{MgO}$  are currently used as potential catalysts for the decontamination of CBW agents.

Various synthetic routes adopted for the preparation of MONPs are highlighted in this review. When compared with conventionally-prepared samples, aerogel-prepared samples are more reactive toward toxic chemicals and their ability to degrade CBW is presented here.  $\text{TiO}_2$  photocatalysts in the presence of UV light and mixed metal oxides are found to be efficient catalysts when compared with individual oxides. The recent trend of exploiting nanoparticles and the high aspect ratio ceramic oxide nanofibers for use in protective clothing, wipe materials, and textiles has been presented. Some of the issues concerning integration of metal oxides into fabrics for sensors are also reviewed in this article. 196 References.

- Review of Fe Chalcogenides as the Simplest Fe-Based Superconductor. By Y. Mizuguchi and Y. Takano, *J. Phys. Soc. Jpn.* **79** (10), 102001-1 to -18 (2010).

### Abstract

The physical properties of the newly discovered Fe-chalcogenide superconductors are summarized. They

are of great interest because they are the simplest Fe-based superconductors. Furthermore, Fe-chalcogenides show a huge pressure effect on their superconducting properties. The origin of the high transition temperature was discussed with change in both the crystal structure and magnetism. Advances in the thin-film and superconducting-wire fabrication are also described. 70 References.

- Electronic Structure Calculation by First Principles for Strongly Correlated Electron Systems. By M. Imada and T. Miyake, *J. Phys. Soc. Jpn.* **79** (11), 112001-1- to -42 (2010).

### Abstract

Recent trends of *ab initio* studies and progress in methodologies for electronic structure calculations of strongly correlated electron systems are discussed. The interest for developing efficient methods is motivated by recent discoveries and characterizations of strongly correlated electron materials and by requirements for understanding mechanisms of intriguing phenomena beyond a single-particle picture.

A three-stage scheme is developed as renormalized multi-scale solvers (RMS) utilizing the hierarchical electronic structure in the energy space. It provides us with an *ab initio* downfolding of the global band structure into low-energy effective models followed by low-energy solvers for the models. The RMS method is illustrated with examples of several materials. In particular, the authors overview cases such as dynamics of semiconductors, transition metals and their compounds including iron-based superconductors and perovskite oxides, and organic conductors of  $\kappa$ -ET type. 291 References.

- Self-assembly of layered functionalized hybrid materials. A good opportunity for extractive chemistry. By A. Mehdi, *J. Mater. Chem.*, **20** (42), 9281–9286 (2010).

### Abstract

This paper is devoted to layered hybrid organic-inorganic materials obtained by self-assembly of organosilica precursors during the hydrolytic sol-gel process. The self-assembly is induced by lipophilic van der Waals interactions between alkylene chains.

The introduction of functional groups such as –SS– gives rise to –SH or –SO<sub>3</sub>H functionalized materials after chemical modifications. This methodology has been extended to the formation of lamellar hybrid materials containing amino groups thanks to CO<sub>2</sub> as bridging groups as well as the formation of lamellar hybrid materials containing carboxylic groups. In this last case, the material was elaborated thanks to *in situ* hydrogen bond formation between carboxylic acid groups. An easy preparation of bis-zwitterionic lamellar material from only 3-aminopropyltriethoxysilane, succinic anhydride, and ethylene diamine is also presented. All these functional materials exhibit a very high chelating capability towards transition metal and lanthanide ions and can be used for environmental remediation. 24 References.

- Chemical modification of aluminium alkoxides for sol-gel processing. By R. Lichtenberger and U. Schubert, *J. Mater. Chem.*, **20** (42), 9287–9296 (2010).

### Abstract

The chemistry of aluminium alkoxides and chemical modifications thereof by a variety of organic compounds, such as pyridine, aminoalcohols,  $\beta$ -diketonic compounds or carboxylic acids, are reviewed. Special focus is put on structural aspects.

Modification of aluminium alkoxides by organic ligands is of great importance for materials syntheses by sol-gel processing, because this allows adjusting the reactivity towards hydrolysis and condensation reactions and renders alumina-based inorganic-organic hybrid materials possible. Coordination, solvation and oligomerization have important influences on the structure and chemistry of the modified aluminium alkoxides, and organic side reactions, e.g., transesterification, have to be taken into account. 94 References.

- POSS-based hybrids by melt/reactive blending. By A. Fina, O. Monticelli and G. Camino, *J. Mater. Chem.*, **20** (42), 9297–9305 (2010).

### Abstract

Organic-inorganic polyhedral oligomeric silsesquioxane (POSS)-polymer hybrids have gained a wide research interest in the last decade, thanks to the great

versatility of POSS synthesis and availability of different chemical structures, aimed at modifications of physical/chemical properties of polymers or at delivering new functional properties. Traditionally, *in situ* co-polymerisation of POSS to produce hybrid organic–inorganic polymers with pendent POSS groups has been used both for thermoplastics and thermosets. In recent years, attention has been also given to the possibility of preparing POSS–polymer systems by melt blending techniques, taking advantage of (i) miscibility of POSS into polymers thanks to physical interactions, or (ii) chemical reaction between POSS and the polymer. These two methods, usually referred to respectively as melt blending and reactive blending, represent very appealing, inexpensive and environmentally friendly processes for industrial development of POSS technology.

This paper reviews the present state of the art on both melt blending and reactive blending of POSS into thermoplastic *polymers*, discussing present achievements and limitations from both methods. 85 References.

- Hybrid materials based on clays for environmental and biomedical applications. By E. Ruiz-Hitzky, P. Aranda, M. Darder and G. Rytwo, *J. Mater. Chem.*, **20** (42), 9306–9321 (2010).

### Abstract

Nanostructured hybrids derived from clays are materials of increasing interest based on both structural characteristics and functional applications, including environmental and biomedical uses. This review introduces some recent examples of nanostructured clay derivatives (organoclays) useful as adsorbents or photocatalysts for environmental applications such as the removal of pollutants or development of environmentally oriented pesticide formulations. The second group of nanostructured materials considered here are related to the so-called bio-nanohybrids, formed by combination of an inorganic solid (clay mineral) with organic entities from biological origin at the nanometric scale.

Bio-nanocomposites are an emerging group of nanomaterials resulting from the assembly of different clay minerals and biopolymers. Among the proposed applications, the development of novel hybrid materials for scaffolds and regenerative medicine, as well as

new substrates to immobilize biological species from enzymes to viruses, is notable. Hybrid materials based on layered double hydroxides are receiving special attention in view of the possible applications as drug delivery systems. References.

- Hybrid materials: versatile matrices for supporting homogeneous catalysts. By A. Zamboulis, N. Moitra, J. J. E. Moreau, X. Cattoën and M. W. C. Man, *J. Mater. Chem.*, **20** (42), 9322–9338 (2010).

### Abstract

Hybrid materials are increasingly used for supporting homogeneous catalysts. This review describes the various methodologies used to synthesize such hybrid materials or to graft catalysts on inorganic or hybrid supports. Applications of these materials for reactions mediated by supported organometallic or organic catalysts are presented. 139 References.

- Recent developments in nanostructured materials for high-performance thermoelectrics. By P. Vaquero and A. V. Powell, *J. Mater. Chem.*, **20** (43), 9577–9584 (2010).

### Abstract

This highlight discusses recent trends in the search for new high-efficiency thermoelectric materials. Thermoelectric materials offer considerable attractions in the pursuit of a more efficient use of existing energy resources, as they may be used to construct power-generation devices that allow useful electrical power to be extracted from otherwise waste heat. Here, we focus on the significant enhancements in thermoelectric performance that have been achieved through nanostructuring. The principal factor behind the improved performance appears to be increased phonon scattering at interfaces. This results in a substantial reduction in the lattice contribution to thermal conductivity, a low value of which is a key requirement for improved thermoelectric performance. 61 References.

- Metal-oxide films for electrochromic applications: present technology and future directions. By D. T. Gillaspie, R. C. Tenent and A. C. Dillon, *J. Mater. Chem.*, **20** (43), 9585–9592 (2010).

**Abstract**

Many transition metal-oxide films exhibit an electrochromic (EC) effect as they change their optical transmittance upon charge insertion or extraction. These materials may be integrated into multilayer devices, and the optical modulation is then produced by application of a small electrical voltage. Electrochromic films are therefore being developed for application in dynamic or “smart” windows that are at the forefront of emerging energy-saving advances in building technologies. Here we will describe the state-of-the-art technology that is being implemented in commercial applications. It predominantly relies on the use of tungsten oxide-based films (coloring with ion insertion) and nickel oxide-based films (coloring with ion extraction). We also suggest future research directions that are motivated by the need to reduce the production costs of large-area EC windows. Specifically, we describe the possibility of alternative less expensive manufacturing processes, as well as the development of flexible EC devices that allow for an inexpensive “retrofit” installation to existing structures. 53 References.

- About the interactions between nanoparticles and imidazolium moieties: emergence of original hybrid materials. By M.-A. Neouze, *J. Mater. Chem.*, **20** (43), 9593–9607 (2010).

**Abstract**

In the parallel dramatic development of both nanoparticles and ionic liquids for materials chemistry, remarkable synergy was observed when combining nanoparticles and one type of ionic liquid, namely imidazolium moieties. This feature article highlights the main steps in the use and understanding of such combinations. It starts with a presentation of the use of imidazolium based ionic liquids as synthesis media for the preparation of nanoparticles, under various classical and non-classical processes. Then, the interactions taking place between the nanoparticle surfaces and functionalized or non-functionalized imidazoliums are reviewed. A step-by-step description of the way to new hybrid materials, based on this combination of imidazolium units and nanoparticles, follows. The multiple role of the imidazolium moiety is evidenced. Finally,

the main fields of application for the new hybrid materials will be presented. 261 References.

- Advances in Li–S batteries. By X. Ji and L. F. Nazar, *J. Mater. Chem.*, **20** (44), 9821–9826 (2010).

**Abstract**

Rechargeable Li–S batteries have received ever-increasing attention recently due to their high theoretical specific energy density, which is 3 to 5 times higher than that of Li ion batteries based on intercalation reactions. Li–S batteries may represent a next-generation energy storage system, particularly for large scale applications. The obstacles to realize this high energy density mainly include high internal resistance, self-discharge and rapid capacity fading on cycling. These challenges can be met to a large degree by designing novel sulfur electrodes with “smart” nanostructures.

This article provides an overview of major developments of positive electrodes based on this concept. 64 References.

- Dynamic color in stimuli-responsive cholesteric liquid crystals. By T. J. White, M. E. McConney and T. J. Bunning, *J. Mater. Chem.*, **20** (44), 9832–9847 (2010).

**Abstract**

Color surrounds us and the ability to change color by external stimuli (heat, force, light exposure, magnetic or electric field) continues to be leveraged for many present day applications. This review focuses on the state of the art in the use of cholesteric liquid crystals (CLCs) as color changing optical materials. After a brief summary of thermal and electrically induced color changes, the bulk of the article describes recent efforts in photoresponsive CLCs, materials in which light is used to control the color output. 184 References.

- Novel anisotropic materials from functionalised colloidal cellulose and cellulose derivatives. By B. L. Holt, S. D. Stoyanov, E. Pelan and V. N. Paunov, *J. Mater. Chem.*, **20** (45), 10058–10070 (2010).

**Abstract**

This article describes selected examples of the properties and the methods of preparation of cellulose micro and nano crystallites (whiskers) and derivatives, with aspects related to fabrication of various anisotropic materials.

Nanometre sized cellulose crystallites have a variety of novel anisotropic properties markedly different from those of common forms of cellulose. They can be obtained from a variety of native cellulose sources through partial hydrolysis with strong acids or *via* mechanical defibrillation. The authors discuss different fabrication techniques and surface modifications of cellulose whiskers which determine their wettability, surface charge and range of applications. Concentrated suspensions of cellulose whiskers of high aspect ratio can form chiral nematic liquid crystalline phases which retain their structure upon evaporation, producing iridescent films. At present, the bulk of the research on cellulose whiskers is focused on creation of composite materials in which they enhance mechanical properties and improve their biodegradability. The high strength of the cellulose nanocrystals has also been utilized in the fabrication of reinforced composite films with applications for anisotropic microcapsule preparation. Microrods and multifunctional microampules from hydrophobised cellulose have recently been recognised as being able to produce super-stable foams with long shelf life and allow the foam structural elements to encapsulate a range of liquid and solid additives. 157 References.

- Chromonic review. By J. Lydon, *J. Mater. Chem.*, **20** (45), 10071–10099 (2010).

**Abstract**

Chromonic systems are lyotropic liquid crystal phases formed by soluble aromatic compounds. They occur as the result of the face-to-face aggregation of the molecules into columns. There are two principal chromonic phases; the N phase which consists of a nematic array of columns and at higher concentrations, the M phase, in which the columns lie in a hexagonal array. Chromonic phases are formed by a range of multi-ring aromatic compounds including drugs, dyes and nucleic acids. They have characteristic multi-peritectic phase diagrams and distinctive optical textures.

The exploitation of the unique properties of chromonic systems has scarcely started. Recent promising studies show that the combination of self-ordering, ease of alignment, sensitivity to changing conditions and additives, coupled with their optical properties and electro-optical properties, makes possible a range of sophisticated devices, including polarizers, optical compensators, light-harvesting devices and micro-patterned materials—and the fact that they are water-based, suggests a future role in biosensors for medical diagnosis. 114 References.

- Models of organometallic complexes for optoelectronic applications. By A. C. Jacko, R. H. McKenzie and B. J. Powell, *J. Mater. Chem.*, **20** (46), 10301–10307 (2010).

**Abstract**

Organometallic complexes have potential applications as the optically active components of organic light emitting diodes (OLEDs) and organic photovoltaics (OPV). Development of more effective complexes may be aided by understanding their excited state properties.

Here, the authors discuss two key theoretical approaches to investigate these complexes: first principles atomistic models and effective Hamiltonian models. They review applications of these methods, such as, determining the nature of the emitting state, predicting the fraction of injected charges that form triplet excitations, and explaining the sensitivity of device performance to small changes in the molecular structure of the organometallic complexes. 58 References.

- Understanding gas separation in metal–organic frameworks using computer modeling. By D. Liu and C. Zhong, *J. Mater. Chem.*, **20** (46), 10308–10318 (2010).

**Abstract**

Metal–organic frameworks (MOFs) are a new family of nanoporous materials that combine the advantages of both inorganic and organic materials with great variety in functionality, pore size and topology. Gas separation is one of the fields that the first practical application of MOFs may be applied to; however, the study of MOFs as adsorbents in gas separation is still in its

early stage, and their separation characteristics are not quite clear.

Here, the authors summarize the recent advances on gas separation in MOFs using computer modeling, and show how computer modeling can help to understand the separation characteristics of MOFs. In addition, several strategies are proposed to improve the separation efficiency of MOFs, which are expected to be useful for designing new MOFs with improved separation performance for targeted properties. 108 References.

- Titania-water interactions: a review of theoretical studies. By C. Sun, L.-M. Liu, A. Selloni, G. Q. (Max) Lu and S. C. Smith, *J. Mater. Chem.*, **20** (46), 10319–10334 (2010).

### Abstract

The interaction between water (H<sub>2</sub>O) and titanium dioxide (TiO<sub>2</sub>) has a central role in many environment- and energy-related applications, such as the photodecomposition of organic pollutants, solar cells, and solar-hydrogen production. The importance of these applications has motivated strong interest and intensive experimental and theoretical studies of H<sub>2</sub>O adsorption on TiO<sub>2</sub> surfaces for decades.

This review attempts to summarize the major theoretical outcomes on this topic in the last twenty years, ranging from low coverages of adsorbed water molecules up to water multilayers on various TiO<sub>2</sub> surfaces. Theoretical/computational methods as well as structural models are discussed and a detailed comparison of the results from various computational settings is presented. The interaction of water with photoexcited TiO<sub>2</sub> surfaces is a challenging but very interesting subject for future studies. 159 References.

- Thermodynamics and structures of oxide crystals by a systematic set of first principles calculations. By I. Tanaka, A. Togo, A. Seko, F. Oba, Y. Koyama and A. Kuwabara, *J. Mater. Chem.*, **20** (46), 10335–10344 (2010).

### Abstract

When first principles calculations are systematically made with high numerical accuracy, they can be successfully combined with statistical thermodynamics in

order not only to “reproduce” the experimental data but also to “predict” as-yet-unknown structures and properties. Lattice dynamics calculations can be used to compute the temperature dependence of thermodynamical quantities such as free energy. The products and pathways of phase transitions can also be analyzed on the basis of the information of imaginary phonon modes. Cluster expansion technique can be used to take account the statistical thermodynamics of crystalline solutions. Ground state structures within a given lattice model as well as the thermostistical information of crystalline solutions or disordered compounds with temperature can be investigated. Such approaches require a large set of first principles calculations, which has become possible only recently.

In this article, a few examples using the combined methods are given. They include ZrO<sub>2</sub>, Ga<sub>2</sub>O<sub>3</sub>, Bi<sub>2</sub>O<sub>3</sub>, CO<sub>2</sub>, spinel oxides, and SnO<sub>2x</sub>. 76 References.

- Thermodynamics of solid electrolytes and related oxide ceramics based on the fluorite structure. By A. Navrotsky, *J. Mater. Chem.*, **20** (47), 10577–10587 (2010).

### Abstract

Oxides based on the fluorite structure are important as electrolytes in solid oxide fuel cells, thermal barrier coatings, gate dielectrics, catalysts, and nuclear materials. Though the parent fluorite structure is simple, the substitution of trivalent for tetravalent cations, coupled with the presence of charge-balancing oxygen vacancies, leads to a wealth of short-range and long-range ordered structures and complex thermodynamic properties. The location of vacancies and the nature of clusters affect the energetics of mixing in rare earth doped zirconia, hafnia, ceria, urania, and thoria, with systematic trends in energetics as a function of cation radius. High temperature oxide melt solution calorimetry has provided direct measurement of formation enthalpies of these refractory materials. Surface and interfacial energies have also been measured in yttria stabilized zirconia (YSZ) nanomaterials. Other ionic conductors having perovskite, apatite, and mellilite structures are discussed briefly. 46 References.

- Nanoporous molecular crystals. By N. B. McKeown, *J. Mater. Chem.*, **20** (47), 10588–10597 (2010).

### Abstract

Nanoporous Molecular Crystals (NMCs) are nanoporous materials composed of discrete molecules between which there are only non-covalent interactions—that is, they do not possess an extended framework composed of covalent or coordination bonds. They are formed from removing guest molecules from inclusion compounds (ICs), a process that for most ICs usually results in the collapse of the open structure of the crystals but in the case of NMCs the packing of the host molecules is retained and nanoporosity is obtained.

In recent years a number of NMCs have been confirmed by the technique of gas adsorption and these materials are surveyed in this article. In addition, the reasons for stability of these crystals are discussed. It is the author's belief that many more ICs, the structures of which are readily obtainable from the Cambridge Structural Database (CSD), may act as precursors to NMCs. 180 References.

- Fulfilling thermoelectric promises:  $\beta$ -Zn<sub>4</sub>Sb<sub>3</sub> from materials research to power generation. By B. B. Iversen, *J. Mater. Chem.*, **20** (48), 10778–10787 (2010).

### Abstract

The  $\beta$ -phase of Zn<sub>4</sub>Sb<sub>3</sub> was re-discovered as a very promising thermoelectric material in the mid-nineties. The material seemed to have it all: a very high thermoelectric figure of merit in the technologically important mid-temperature region (200–400°C), potential for further optimization through doping and best of all, it was made of cheap, 'non-toxic' and abundant elements. A vast amount of waste heat is present in the mid-temperature region, which is likely to be the optimal region for power generation applications. Furthermore, few other attractive thermoelectric materials are known with good performance in this temperature region. Almost 15 years have passed and Zn<sub>4</sub>Sb<sub>3</sub> has still not been built into commercial thermoelectric devices. However, this may change as intensive research appears to have solved some of the significant problematic issues that were unravelled in the last

decade.

This article presents the Zn<sub>4</sub>Sb<sub>3</sub> story, which touches upon all the major aspects of materials chemistry: synthesis, structural characterization, measurement of properties, materials optimization, device fabrication and commercialization. 43 References.

- Donor–acceptor block copolymers for photovoltaic applications. By M. Sommer, S. Huettner and M. Thelakkat, *J. Mater. Chem.*, **20** (48), 10788–10797 (2010).

### Abstract

Extensive research activities in polymer synthesis and device engineering have been devoted to the development of donor–acceptor (D–A) bulk heterojunction solar cells in the last years. In such devices, several photophysical processes occur all of which have to be optimized for efficient operation. First, excitons created upon light absorption need to reach the D/A interface within their exciton diffusion length (10–20 nm), where they may dissociate into holes and electrons. Subsequent charge transport and finally charge collection at the electrodes can occur, given that continuous pathways of donor and acceptor domains are provided. Owing to the small exciton diffusion lengths and the required optical absorption length of 100–200 nm, vertically aligned pathways with a high aspect ratio of either phase should percolate through the film. The morphologies resulting from this ideal situation resemble those of vertically oriented microphase separated block copolymer thin films, and hence suggest the importance of D–A block copolymers for organic photovoltaics. Furthermore, the covalent bond between the donor and acceptor blocks is not only desired to improve morphology control, but also to enhance long term stability of the device. The potential of block copolymers with electronic functionality to microphase separate into well-defined microstructures with several tens of nanometers in size thus addresses the morphological requirements mentioned above. This article gives an overview of donor–acceptor block copolymers and summarizes recent developments of this field. 84 References.

- Conducting-polymer-based supercapacitor devices and electrodes. By G. A. Snook, P. Kao and A. S. Best, *J. Power Sources*, **196** (1), 1–12 (2011).

#### Abstract

Supercapacitor electrodes and devices that utilise conducting polymers are envisaged to bridge the gap between existing carbon-based supercapacitors and batteries to form units of intermediate specific energy. This review looks at the major conducting polymer materials, namely, polyaniline, polypyrrole, polythiophene and derivatives of polythiophene, as well as composites of these materials with carbon nanotubes and inorganic battery materials. Various treatments of the conducting polymer materials to improve their properties are considered and comparisons are made with other supercapacitor materials such as carbon and with inorganic battery materials. Conducting polymers are pseudo-capacitive materials, which means that the bulk of the material undergoes a fast redox reaction to provide the capacitive response and they exhibit superior specific energies to the carbon-based supercapacitors (double-layer capacitors). In general conducting polymers are more conductive than the inorganic battery materials and consequently have greater power capability. On the downside, conducting polymers swell and contract substantially on charge and discharge, respectively. Consequently, cycle-life is poor compared with carbon-based supercapacitors which generally only charge via adsorption and desorption of ions (giving typically a few thousand cycles for conducting polymers compared with >500 000 cycles for carbon-based devices). 128 References.

- A review of the electrochemical performance of alloy anodes for lithium-ion batteries. By W.-J. Zhang, *J. Power Sources*, **196** (1), 13–24 (2011).

#### Abstract

Alloy anodes are promising anode materials for lithium-ion batteries due to their high-energy capacity and safety characteristics. However, the commercial use of alloy anodes has been hindered to date by their low cycle life and high initial capacity loss. This review highlights the recent progress in improving and understanding the electrochemical performance of various alloy anodes. The approaches used

for performance improvement are summarized, and the causes of first-cycle irreversible capacity loss are discussed. The capacity retentions and irreversible capacity losses of various alloy anodes are compared. Several alloy anodes exhibited excellent cycle life (up to 300 cycles) with high initial coulombic efficiency (80–90%) and large reversible capacity (500–700 mAh g<sup>-1</sup>). 203 References.

- Internal steam reforming in solid oxide fuel cells: Status and opportunities of kinetic studies and their impact on modeling. By D. Mogensen, J.-D. Grunwaldt, P.V. Hendriksen, K. D. -Johansen and J. U. Nielsen, *J. Power Sources*, **196** (1), 25–38 (2011).

#### Abstract

Solid oxide fuel cells (SOFC) systems with internal steam reforming have the potential to become an economically competitive technology for cogeneration power plants, exploiting its significantly higher electrical efficiency compared to existing technologies. Optimal design and operation of such a system require SOFC models that include accurate description of the steam reforming rate. The objective of this article is to review the reported kinetic expressions for the steam reforming reaction. Extensive work has been performed on traditional catalysts for steam reforming. Because of differences in operating conditions, catalyst support material and structure it is critical to transfer this knowledge directly to internal reforming in SOFCs, which is discussed in further detail in this article. There are big differences in the reported kinetic expression for steam reforming over both industrial Ni catalysts and SOFC anode materials. Surprisingly, there is a good agreement between measured rates and the geometric anode areas at high operating temperatures, even for very different anodes. Detailed experimental data on the intrinsic steam reforming kinetics of Ni-YSZ are necessary for micro structure SOFC modeling, such expression are however lacking, but it may be viable to use measurements on industrial steam reforming catalysts instead. Nevertheless there is a further need for experimental studies on determining the exact steam reforming kinetics for SOFC anodes. 183 References.

- A review of polymer electrolyte membrane fuel cell stack testing. By M. Miller and A. Bazylak, *J. Power Sources*, **196** (2), 601–613 (2011).

### Abstract

This paper presents an overview of polymer electrolyte membrane fuel cell (PEMFC) stack testing. Stack testing is critical for evaluating and demonstrating the viability and durability required for commercial applications. Single cell performance cannot be employed alone to fully derive the expected performance of PEMFC stacks, due to the non-uniformity in potential, temperature, and reactant and product flow distributions observed in stacks.

The authors provide a comprehensive review of the state-of-the art in PEMFC testing. They discuss the main topics of investigation, including single cell vs. stack-level performance, cell voltage uniformity, influence of operating conditions, durability and degradation, dynamic operation, and stack demonstrations. They also present opportunities for future work, including the need to verify the impact of stack size and cell voltage uniformity on performance, determine operating conditions for achieving a balance between electrical efficiency and flooding/dry-out, meet lifetime requirements through endurance testing, and develop a stronger understanding of degradation. 181 References.

- Lithium insertion/extraction mechanism in alloy anodes for lithium-ion batteries. By Y.-J. Zhang, *J. Power Sources*, **196** (3), 877–885 (2011).

### Abstract

The electrochemical performance of alloy anodes has been reviewed in a previous paper. In this work, the fundamental understanding of lithium-insertion/extraction mechanism in alloy anodes is discussed. The article summarizes the different types of lithium-reaction processes observed in Si, Sn, Sb, Al, Mg and their alloys, with particular emphasis on the characteristics unique to alloy anodes, including the sloping voltage profiles, lithiation amorphization, cycling hysteresis and reaction-potential depression. These unique characteristics are discussed with respect to the effect of interface and surface energies on the

phase transformation and thermodynamic stability of fine alloy particles. 85 References.

- Review on Li–air batteries—Opportunities, limitations and perspective. By A. Kraytsberg and Y. Ein-Eli, *J. Power Sources*, **196** (3), 886–893 (2011).

### Abstract

Li–air batteries are potentially viable ultrahigh energy density chemical power sources, which could potentially offer specific energies up to ~3000Wh/kg and being rechargeable. The modern state of art and the challenges in the field of Li–air batteries are considered. Although their implementation holds the greatest promise in a number of applications ranging from portable electronics to electric vehicles, there are also impressive challenges in development of cathode materials and electrolyte systems of these batteries. 74 References.

- Micro-tubular solid oxide fuel cells and stacks. By K. S. Howe, G. J. Thompson and K. Kendall, *J. Power Sources*, **196** (4), 1677–1686 (2011).

### Abstract

The properties and performance of micro-tubular solid oxide fuel cells are compared and the differentiating factors discussed. The best recorded power density for a single cell in the literature to date is 1.1 W/cm<sup>2</sup>, with anode microstructure and current collection technique emerging as two key factors influencing electrical performance. The use of hydrocarbon fuels instead of pure hydrogen and methods for reducing the resultant carbon deposition are briefly discussed. Performance on thermal and reduction–oxidation (RedOx) cycling is also a critical issue for cell durability. Combining these individual cells into stacks is necessary to obtain useful power outputs. As such, issues of fluid and heat transfer within such stacks become critical, and computational modelling can therefore be a useful design tool.

Experimentally tested stacks and stack models are discussed and the findings summarized. New results for a simple stack manufactured at the University of Birmingham are also given. 106 References.

- Infrared Colloidal Quantum Dots for Photovoltaics: Fundamentals and Recent Progress. By J. Tang and E. H. Sargent, *Adv. Mater.*, **23** (1), 12–29 (2011).

**Abstract**

Colloidal quantum dots (CQDs) are solution-processed semiconductors of interest in low-cost photovoltaics. Tuning of the bandgap of CQD films via the quantum size effect enables customization of solar cells' absorption profile to match the sun's broad visible- and infrared-containing spectrum reaching the earth.

Here the authors review recent progress in the realization of low-cost, efficient solar cells based on CQDs. They focus in particular on CQD materials and approaches that provide both infrared and visible-wavelength solar power conversion CQD photovoltaics now exceed 5% solar power conversion efficiency, achieved by the introduction of a new architecture, the depleted-heterojunction CQD solar cell, that jointly maximizes current, voltage, and fill factor. CQD solar cells have also seen major progress in materials processing for stability, recently achieving extended operating lifetimes in an air ambient. The authors summarize progress both in device operation and also in gaining new insights into materials properties and processing – including new electrical contact materials and deposition techniques, as well as CQD synthesis, surface treatments, film-forming technologies – that underpin these rapid advances. 91 References.

- Self-Assembled Photonic Structures. By J. F. Galisteo-López, M. Ibisate, R. Sapienza, L. S. Froufe-Pérez, Á. Blanco and C. López, *Adv. Mater.*, **23** (1), 30–69 (2011).

**Abstract**

Photonic crystals have proven their potential and are nowadays a familiar concept. They have been approached from many scientific and technological flanks. Among the many techniques devised to implement this technology, self-assembly has always been one of great popularity surely due to its ease of access and the richness of results offered. Self-assembly is also probably the approach entailing more materials aspects owing to the fact that they lend themselves to be fabricated by a great many, very different methods on a vast variety of materials and to multiple purposes. To these well-known material systems a new sibling has been born (photonic glass) expanding the paradigm of optical materials inspired by solid state physics crystal concept. It is expected that they may become an

important player in the near future not only because they complement the properties of photonic crystals but because they entice the researchers' curiosity.

In this review, a panorama is presented of the state of the art in this field with the view to serve a broad community concerned with materials aspects of photonic structures and more so those interested in self-assembly. 553 References.

- Nanostructures and Functional Materials Fabricated by Interferometric Lithography. By D. Xia, Z. Ku, S. C. Lee and S. R. J. Brueck, *Adv. Mater.*, **23** (2), 147–179 (2011).

**Abstract**

Interferometric lithography (IL) is a powerful technique for the definition of large-area, nanometer-scale, periodically patterned structures. Patterns are recorded in a light-sensitive medium, such as a photoresist, that responds nonlinearly to the intensity distribution associated with the interference of two or more coherent beams of light. The photoresist patterns produced with IL are a platform for further fabrication of nanostructures and growth of functional materials and are building blocks for devices.

This article provides a brief review of IL technologies and focuses on various applications for nanostructures and functional materials based on IL including directed self-assembly of colloidal nanoparticles, nanophotonics, semiconductor materials growth, and nanofluidic devices. Perspectives on future directions for IL and emerging applications in other fields are presented. 201 References.

- Emergent Properties Resulting from Type-II Band Alignment in Semiconductor Nanoheterostructures. By S. S. Lo, T. Mirkovic, C.-H. Chuang, C. Burda and G. D. Scholes, *Adv. Mater.*, **23** (2), 180–197 (2011).

**Abstract**

The development of elegant synthetic methodologies for the preparation of monocomponent nanocrystalline particles has opened many possibilities for the preparation of heterostructured semiconductor nanostructures. Each of the integrated nanodomains is characterized by its individual physical properties, surface

chemistry, and morphology, yet, these multicomponent hybrid particles present ideal systems for the investigation of the synergetic properties that arise from the material combination in a non-additive fashion. Of particular interest are type-II heterostructures, where the relative band alignment of their constituent semiconductor materials promotes a spatial separation of the electron and hole following photoexcitation, a highly desirable property for photovoltaic applications.

This article highlights recent progress in both synthetic strategies, which allow for material and architectural modulation of novel nano-heterostructures, as well as the experimental work that provides insight into the photophysical properties of type-II heterostructures. The effects of external factors, such as electric fields, temperature, and solvent are explored in conjunction with exciton and multi-exciton dynamics and charge transfer processes typical for type-II semiconductor heterostructures. 111 References.

- Silicon Nanowires for Photovoltaic Solar Energy Conversion. By K.-Q. Peng and S.-T. Lee, *Adv. Mater.*, **23** (2), 198–215 (2011).

### Abstract

Semiconductor nanowires are attracting intense interest as a promising material for solar energy conversion for the new-generation photovoltaic (PV) technology. In particular, silicon nanowires (SiNWs) are under active investigation for PV applications because they offer novel approaches for solar-to-electric energy conversion leading to high-efficiency devices via simple manufacturing.

This article reviews the recent developments in the utilization of SiNWs for PV applications, the relationship between SiNW-based PV device structure and performance, and the challenges to obtaining high-performance cost-effective solar cells. 227 References.

- Size Effects on Magnetic Actuation in Ni-Mn-Ga Shape-Memory Alloys. By D. C. Dunand and P. Müllner, *Adv. Mater.*, **23** (2), 216–232 (2011).

### Abstract

The off-stoichiometric Ni<sub>2</sub>MnGa Heusler alloy is a magnetic shape-memory alloy capable of reversible

magnetic-field-induced strains (MFIS). These are generated by twin boundaries moving under the influence of an internal stress produced by a magnetic field through the magnetocrystalline anisotropy. While MFIS are very large (up to 10%) for monocrystalline Ni-Mn-Ga, they are near zero (<0.01%) in fine-grained polycrystals due to incompatibilities during twinning of neighboring grains and the resulting internal geometrical constraints. By growing the grains and/or shrinking the sample, the grain size becomes comparable to one or more characteristic sample sizes (film thickness, wire or strut diameter, ribbon width, particle diameter, etc), and the grains become surrounded by free space. This reduces the incompatibilities between neighboring grains and can favor twinning and thus increase the MFIS. This approach was validated recently with very large MFIS (0.2–8%) measured in Ni-Mn-Ga fibers and foams with bamboo grains with dimensions similar to the fiber or strut diameters and in thin plates where grain diameters are comparable to plate thickness.

Here, the authors review the processing, micro- and macrostructure, and magneto-mechanical properties of (i) Ni-Mn-Ga powders, fibers, ribbons and films with one or more small dimension, which are amenable to the growth of bamboo grains leading to large MFIS, and (ii) “constructs” from these structural elements (e.g., mats, laminates, textiles, foams and composites). Various strategies are proposed to accentuate this geometric effect which enables large MFIS in polycrystalline Ni-Mn-Ga by matching grain and sample sizes. 199 References.

- White Organic Light-Emitting Diodes. By M. C. Gather, A. Köhnen and K. Meerholz, *Adv. Mater.*, **23** (2), 233–248 (2011).

### Abstract

White organic light-emitting diodes (WOLEDs) offer a range of attractive characteristics and are in several ways conceptually different from most currently used light sources. From an application perspective, their advantages include a high power efficiency that rivals the performance of fluorescent lamps and inorganic LEDs and the potential for a very low cost of manufacturing. As flat-panel light sources they are intrinsically glare-free and generate light over a large area.

WOLEDs are constantly improving in terms of performance, durability, and manufacturability, but these improvements require joint research efforts in chemistry and the materials sciences to design better materials as well as in physics and engineering to invent new device concepts and design suitable fabrication schemes, a process that has generated many exciting scientific questions and answers.

This article reviews current developments in the field of WOLEDs and puts a special focus on new device concepts and on approaches to reliable and cost-efficient WOLED manufacturing. 122 References.

- Metal-Organic Frameworks: A Rapidly Growing Class of Versatile Nanoporous Materials. By S. T. Meek, J. A. Greathouse and M. D. Allendorf, *Adv. Mater.*, **23** (2), 249–267 (2011).

### Abstract

Metal-organic frameworks (MOFs) represent a new class of hybrid organic-inorganic supramolecular materials comprised of ordered networks formed from organic electron donor linkers and metal cations. They can exhibit extremely high surface areas, as well as tunable pore size and functionality, and can act as hosts for a variety of guest molecules. Since their discovery, MOFs have enjoyed extensive exploration, with applications ranging from gas storage to drug delivery to sensing.

This review covers advances in the MOF field from the past three years, focusing on applications, including gas separation, catalysis, drug delivery, optical and electronic applications, and sensing. The authors also summarize recent work on methods for MOF synthesis and computational modeling. 168 References.

- Rylene and Related Diimides for Organic Electronics. By X. Zhan, A. Facchetti, S. Barlow, T. J. Marks, M. A. Ratner, M. R. Wasielewski and S. R. Marder, *Adv. Mater.*, **23** (2), 268–284 (2011).

### Abstract

Organic electron-transporting materials are essential for the fabrication of organic p-n junctions, photovoltaic cells, n-channel field-effect transistors, and complementary logic circuits. Rylene diimides are a

robust, versatile class of polycyclic aromatic electron-transport materials with excellent thermal and oxidative stability, high electron affinities, and, in many cases, high electron mobilities; they are, therefore, promising candidates for a variety of organic electronics applications.

In this review, recent developments in the area of high-electron-mobility diimides based on rylenes and related aromatic cores, particularly perylene- and naphthalene-diimide-based small molecules and polymers, for application in high-performance organic field-effect transistors and photovoltaic cells are summarized and analyzed. 85 References.

- Metal-Assisted Chemical Etching of Silicon: A Review. — In memory of Prof. Ulrich Gösele. By Z. Huang, N. Geyer, P. Werner, J. de Boor and U. Gösele, *Adv. Mater.*, **23** (2), 285–308 (2011).

### Abstract

This article presents an overview of the essential aspects in the fabrication of silicon and some silicon/germanium nanostructures by metal-assisted chemical etching. First, the basic process and mechanism of metal-assisted chemical etching is introduced. Then, the various influences of the noble metal, the etchant, temperature, illumination, and intrinsic properties of the silicon substrate (e.g., orientation, doping type, doping level) are presented. The anisotropic and the isotropic etching behaviors of silicon under various conditions are presented. Template-based metal-assisted chemical etching methods are introduced, including templates based on nanosphere lithography, anodic aluminum oxide masks, interference lithography, and block-copolymer masks. The metal-assisted chemical etching of other semiconductors is also introduced.

A brief introduction to the application of Si nanostructures obtained by metal-assisted chemical etching is given, demonstrating the promising potential applications of metal-assisted chemical etching. Finally, some open questions in the understanding of metal-assisted chemical etching are compiled. 121 References.

- Molecular Characterization of Organic Electronic Films. By D. M. DeLongchamp, R. J. Kline, D. A. Fischer, L. J. Richter and M. F. Toney, *Adv. Mater.*, **23** (3), 319–337 (2011).

### Abstract

Organic electronics have emerged as a viable competitor to amorphous silicon for the active layer in low-cost electronics. The critical performance of organic electronic materials is closely related to their morphology and molecular packing. Unlike their inorganic counterparts, polymers combine complex repeat unit structure and crystalline disorder. This combination prevents any single technique from being able to uniquely solve the packing arrangement of the molecules.

Here, a general methodology for combining multiple, complementary techniques that provide accurate unit cell dimensions and molecular orientation is described. The combination of measurements results in a nearly complete picture of the organic film morphology. 102 References.

- Carbon Nanotubes: Measuring Dispersion and Length. By J. A. Fagan, B. J. Bauer, E. K. Hobbie, M. L. Becker, A. R. H. Walker, J. R. Simpson, J. Chun, J. Obrzut, V. Bajpai, F. R. Phelan, D. Simien, J. Y. Huh and K. B. Migler, *Adv. Mater.*, **23** (3), 338–348 (2011).

### Abstract

Advanced technological uses of single-walled carbon nanotubes (SWCNTs) rely on the production of single length and chirality populations that are currently only available through liquid-phase post processing. The foundation of all of these processing steps is the attainment of individualized nanotube dispersions in solution. An understanding of the colloidal properties of the dispersed SWCNTs can then be used to design appropriate conditions for separations. In many instances nanotube size, particularly length, is especially active in determining the properties achievable in a given population, and, thus, there is a critical need for measurement technologies for both length distribution and effective separation techniques.

In this Review, the current state of the art for measuring dispersion and length populations, including separations, is documented, and examples are used to

demonstrate the desirability of addressing these parameters. 56 References.

- Surface Wrinkling: A Versatile Platform for Measuring Thin-Film Properties. By J. Y. Chung, A. J. Nolte and C. M. Stafford, *Adv. Mater.*, **23** (3), 349–368 (2011).

### Abstract

Surface instabilities in soft matter have been the subject of increasingly innovative research aimed at better understanding the physics of their formation and their utility in patterning, organizing, and measuring materials properties on the micro and nanoscale.

The focus of this Review is on a type of instability pattern known as surface wrinkling, covering the general concepts of this phenomenon and several recent applications involving the measurement of thin-film properties. The ability of surface wrinkling to yield new insights into particularly challenging materials systems such as ultrathin films, polymer brushes, polyelectrolyte multilayer assemblies, ultrasoft materials, and nanoscale structured materials is highlighted. A perspective on the future directions of this maturing field, including the prospects for advanced thin-film metrology methods, facile surface patterning, and the control of topology-sensitive phenomena, such as wetting and adhesion, is also presented. 127 References.

- Combinatorial and High-Throughput Screening of Biomaterials. By C. G. Simon Jr. and S. Lin-Gibson, *Adv. Mater.*, **23** (3), 369–387 (2011).

### Abstract

Combinatorial and high-throughput methods have been increasingly used to accelerate research and development of new biomaterials. These methods involve creating miniaturized libraries that contain many specimens in one sample in the form of gradients or arrays, followed by automated data collection and analysis.

This article reviews recent advances in utilizing combinatorial and high-throughput methods to better understand cell–material interactions, particularly highlighting the authors' efforts at the NIST Polymers Division. Specifically, fabrication techniques to generate controlled surfaces (2D) and 3D cell environments (tissue engineering scaffolds) as well as

methods to characterize and analyze material properties and cell–material interactions are described. In conclusion, additional opportunities for combinatorial methods for biomaterials research are noted, including streamlined sample fabrication and characterization, appropriate and automated bioassays, and data analysis. 93 References.

- Photoresist Latent and Developer Images as Probed by Neutron Reflectivity Methods. By V. M. Prabhu, S. Kang, D. L. Van der Hart, S. K. Satija, E. K. Lin and W. Wu, *Adv. Mater.*, **23** (3), 388–408 (2011).

### Abstract

Photoresist materials enable the fabrication of advanced integrated circuits with ever-decreasing feature sizes. As next-generation light sources are developed, using extreme ultraviolet light of wavelength 13.5 nm, these highly tuned formulations must meet strict image-fidelity criteria to maintain the expected performance gains from decreases in feature size. However, polymer photoresists appear to be reaching resolution limits and advancements in measurements of the in situ formed solid/solid and solid/liquid interface is necessary.

This Review focuses on the chemical and physical structure of chemically amplified photoresists at the lithographic feature edge at length scales between 1 nm and 100 nm. Neutron reflectivity measurements provide insight into the nanometer-scale composition profiling of the chemical latent image at an ideal lithographic line-edge that separates optical resolution effects from materials processing effects. Four generations of advanced photoresist formulations were examined over the course of seven years to quantify photoresist/photoacid and photoresist/developer interactions on the fidelity of lithographic features. The outcome of these measurements complement traditional resist design criteria by providing the effects of the impacts of the photoresist and processing on the feature fidelity. These physical relations are also described in the context of novel resist architectures under consideration for next-generation photolithography with extreme-ultraviolet radiation. 99 References.

- Topochemical Manipulation of Perovskites: Low-Temperature Reaction Strategies for Directing Structure and Properties. By K. G. S. Ranmohotti, E. Josepha, J. Choi, J. Zhang and J. B. Wiley, *Adv. Mater.*, **23** (4), 442–460 (2011).

### Abstract

Topochemical reaction strategies offer an important low-temperature (<500°C) approach to the conscious manipulation of various inorganic host materials, allowing access to compounds that cannot be prepared by standard high-temperature methods. As the utility of these strategies continues to expand, researchers will be able to more effectively target materials with technologically significant properties.

This review presents recent advances in topochemical reaction strategies as applied to perovskite and perovskite-related compounds. Emphasis is placed on structural modifications and corresponding variations in properties. Additionally, the future prospects of this approach to the rational design of intricate target compounds are discussed. 180 References.

- Bulk Metallic Glass: The Smaller the Better. By G. Kumar, A. Desai and J. Schroers, *Adv. Mater.*, **23** (4), 461–476 (2011).

### Abstract

Bulk metallic glasses (BMGs) are strong, highly elastic, and resistant to wear but still find limited utility due to their macroscopic brittle nature, high costs, and difficulty of processing, particularly when complex shapes are desired. These drawbacks can be mitigated when BMGs are used in miniature parts (<1 cm), an application which takes advantage of BMGs' enhanced plasticity at small length scales as well the insignificant material cost associated with such parts. As an alternative to traditional metal processing techniques, thermo-plastic forming (TPF)-based microfabrication methods have been developed which can process some BMGs like plastics.

In this article, the authors discuss the properties and fabrication of BMGs on miniscule length scales to explore their prospective application in small-scale devices. 113 References.

- Recent Trends in Surface Characterization and Chemistry with High-Resolution Scanning Force Methods. By C. Barth, A. S. Foster, C. R. Henry and A. L. Shluger, *Adv. Mater.*, **23** (4), 477–501 (2011).

### Abstract

The current status and future prospects of non-contact atomic force microscopy (nc-AFM) and Kelvin probe force microscopy (KPFM) for studying insulating surfaces and thin insulating films in high resolution are discussed. The rapid development of these techniques and their use in combination with other scanning probe microscopy methods over the last few years has made them increasingly relevant for studying, controlling, and functionalizing the surfaces of many key materials.

After introducing the instruments and the basic terminology associated with them, state-of-the-art experimental and theoretical studies of insulating surfaces and thin films are discussed, with specific focus on defects, atomic and molecular adsorbates, doping, and metallic nanoclusters. The latest achievements in atomic site-specific force spectroscopy and the identification of defects by crystal doping, work function, and surface charge imaging are reviewed and recent progress being made in high-resolution imaging in air and liquids is detailed. Finally, some of the key challenges for the future development of the considered fields are identified. 381 References.

- Ordered Materials for Organic Electronics and Photonics. By M. O'Neill and S. M. Kelly, *Adv. Mater.*, **23** (5), 566–584 (2011).

### Abstract

The authors present a critical review of semiconductor/light emitting, liquid crystalline materials and their use in electronic and photonic devices such as transistors, photovoltaics, OLEDs and lasers.

They report that annealing from the mesophase improves the order and packing of organic semiconductors to produce state-of-the-art transistors. They discuss theoretical models which predict how charge transport and light emission is affected by the liquid crystalline phase. Organic photovoltaics and OLEDs require optimization of both charge transport and optical properties and the authors identify the various

trade-offs involved for ordered materials. They report the crosslinking of reactive mesogens to give pixelated full-colour OLEDs and distributed bi-layer photovoltaics, and show how the molecular organization inherent to the mesophase can control the polarization of light-emitting devices and the gain in organic, thin-film lasers and can also provide distributed feedback in chiral nematic mirrorless lasers. The progress on the surface alignment of liquid crystalline semiconductors to obtain monodomain devices without defects or devices with spatially varying properties, is presented. Finally the significance of all of these developments is assessed. 168 References.

- ZnS Nanostructure Arrays: A Developing Material Star. By X. Fang, L. Wu and L. Hu, *Adv. Mater.*, **23** (5), 585–598 (2011).

### Abstract

Semiconductor nanostructure arrays are of great scientific and technical interest because of the strong non-linear and electro-optic effects that occur due to carrier confinement in three dimensions. The use of such nanostructure arrays with tailored geometry, array density, and length-diameter-ratio as building blocks are expected to play a crucial role in future nanoscale devices. With the unique properties of a direct wide-bandgap semiconductor, such as the presence of polar surfaces, excellent transport properties, good thermal stability, and high electronic mobility, ZnS nanostructure arrays has been a developing material star. The research on ZnS nanostructure arrays has seen remarkable progress over the last five years due to the unique properties and important potential applications of nanostructure arrays, which are summarized here.

Firstly, a survey of various methods to the synthesis of ZnS nanostructure arrays are introduced. Next recent efforts on exploiting the unique properties and applications of ZnS nanostructure arrays are discussed. Potential future directions of this research field are also highlighted. 133 References.

- Aerosol Route to Functional Nanostructured Inorganic and Hybrid Porous Materials. By C. Boissiere, D. Grosso, A. Chaumonot, L. Nicole and C. Sanchez, *Adv. Mater.*, **23** (5), 599–623 (2011).

**Abstract**

The major advances in the field of the designed construction of hierarchically structured porous inorganic or hybrid materials wherein multiscale texturation is obtained via the combination of aerosol or spray processing with sol–gel chemistry, self-assembly and multiple templating are the topic of this review.

The available materials span a very large set of structures and chemical compositions (silicates, aluminates, transition metal oxides, nanocomposites including metallic or chalcogenides nanoparticles, hybrid organic–inorganic, biohybrids). The resulting materials are manifested as powders or smart coatings via aerosol-directed writing combine the intrinsic physical and chemical properties of the inorganic or hybrid matrices with defined multiscale porous networks having a tunable pore size and connectivity, high surface area and accessibility. Indeed the combination of soft chemical routes and spray processing provides “a wind of change” in the field of “advanced materials”. These strategies give birth to a promising family of innovative materials with many actual and future potential applications in various domains such as catalysis, sensing, photonic and microelectronic devices, nano-ionics and energy, functional coatings, biomaterials, multifunctional therapeutic carriers, and microfluidics, among others. 198 References.

- Antifouling Coatings: Recent Developments in the Design of Surfaces That Prevent Fouling by Proteins, Bacteria, and Marine Organisms. By I. Banerjee, R. C. Pangule and R. S. Kane, *Adv. Mater.*, **23** (6), 690–718 (2011).

**Abstract**

The major strategies for designing surfaces that prevent fouling due to proteins, bacteria, and marine organisms are reviewed.

Biofouling is of great concern in numerous applications ranging from biosensors to biomedical implants and devices, and from food packaging to industrial and marine equipment. The two major approaches to combat surface fouling are based on either preventing biofoulants from attaching or degrading them. One of the key strategies for imparting adhesion resistance involves the functionalization of surfaces with poly(ethylene glycol) (PEG) or oligo(ethylene glycol).

Several alternatives to PEG-based coatings have also been designed over the past decade. While protein-resistant coatings may also resist bacterial attachment and subsequent biofilm formation, in order to overcome the fouling-mediated risk of bacterial infection it is highly desirable to design coatings that are bactericidal. Traditional techniques involve the design of coatings that release biocidal agents, including antibiotics, quaternary ammonium salts (QAS), and silver, into the surrounding aqueous environment. However, the emergence of antibiotic- and silver-resistant pathogenic strains has necessitated the development of alternative strategies. Therefore, other techniques based on the use of polycations, enzymes, nanomaterials, and photoactive agents are being investigated. With regard to marine antifouling coatings, restrictions on the use of biocide-releasing coatings have made the generation of nontoxic antifouling surfaces more important. While considerable progress has been made in the design of antifouling coatings, ongoing research in this area should result in the development of even better antifouling materials in the future. 365 References.

- Applications of Bio-Inspired Special Wettable Surfaces. By X. Yao, Y. Song and L. Jiang, *Adv. Mater.*, **23** (6), 719–734 (2011).

**Abstract**

In this review, the authors focus on recent developments in applications of bio-inspired special wettable surfaces. They highlight surface materials that in recent years have shown to be the most promising in their respective fields for use in future applications.

The selected topics are divided into three groups, applications of superhydrophobic surfaces, surfaces of patterned wettability and integrated multifunctional surfaces and devices. The discuss how the bio-inspired wettability has been integrated into traditional materials or devices to improve their performances and to extend their practical applications by developing new functionalities. 166 References.

- A Critical Look at Multilayered Polymer Capsules in Biomedicine: Drug Carriers, Artificial Organelles, and Cell Mimics. B. Städler, A. D. Price and A. N. Zelikin, *Adv. Funct. Mater.*, **21** (1), 14–28 (2011).

**Abstract**

This Article discusses utility of multilayered polymer capsules in biomedicine, specifically in drug delivery and in design of artificial organelles and cells. The authors provide a critical view on recent successes and identified shortcomings of these capsules in delivery of therapeutic cargo and outline plausible further developments of capsules as candidate drug carriers. A special emphasis is placed on poly(methacrylic acid) hydrogel capsules as successful carriers used in delivery of anti-cancer drugs and protein and peptide vaccines. They further present a novel biomedical approach whereby the same vessel acts first as a microreactor and then as a carrier for de-novo synthesized therapeutic cargo. Finally, utility of polymer capsules in design of cell mimics is discussed with an emphasis on assembly and performance of capsosomes, polymer capsules with liposomal subcompartments.

This presentation of capsules in biomedicine aims to provide an overview of past achievements and existing challenges associated with these candidate vessels and to stimulate further research interest from a broad scientific audience. 106 References.

- Materials for Printable, Transparent, and Low-Voltage Transistors. By J. Sun, B. Zhang and H. E. Katz, *Adv. Funct. Mater.*, **21** (1), 29–45 (2011).

**Abstract**

Since the 1990s, printable, transparent, and low-voltage transistors have attracted great attention from academia and industry due to the demand for specialized circuitry such as in radio-frequency identification (RFID) tags, medical sensors, and electronically active textiles. Some flexible and portable devices have been available commercially; however, the challenge to convert more conceptual devices into real-life applications is still the materials. This article starts with a brief summary of some examples from silicon electronics, to place the other materials in context, followed by the topics including high-capacitance dielectrics, transparent conductors and semiconductors, and printability of recently developed electronic materials. The recent progress about these topics is reviewed, and discussions of each topic suggest future science and engineering research opportunities. 149 References.

- Functional Porous Polymers by Emulsion Templating: Recent Advances. By S. D. Kimmins and N. R. Cameron, *Adv. Funct. Mater.*, **21** (2), 211–225 (2011).

**Abstract**

Porous materials are currently of great scientific as well as technological interest. A strategy that is increasingly employed to prepare highly porous and well defined macroporous polymers is emulsion templating, whereby the droplets of a high internal phase emulsion are used to create pores in a solid material by curing or polymerization of the emulsion continuous phase.

This Article covers recent work in this area, focusing on: the preparation of such materials from new precursors and via novel approaches; the chemical modification of existing materials; and the application of the resulting porous structures in diverse areas of science and technology. 122 References.

- Organic–Organic Heterojunction Interfaces: Effect of Molecular Orientation. By W. Chen, D.-C. Qi, H. Huang, X. Gao and A. T. S. Wee, *Adv. Funct. Mater.*, **21** (3), 410–424 (2011).

**Abstract**

Organic–organic heterojunctions (OOHs) are critical features in organic light-emitting diodes, ambipolar organic field-effect transistors and organic solar cells, which are fundamental building blocks in low-cost, large-scale, and flexible electronics. Due to the highly anisotropic nature of  $\pi$ -conjugated molecules, the molecular orientation of organic thin films can significantly affect the device performance, such as light absorption and charge-carrier transport, as well as the energy level alignment at OOH interfaces.

This Article highlights recent progress in the understanding of interface energetics at small molecule OOH interfaces, focusing on the characterization and fabrication of OOH with well-defined molecular orientations using a combination of in situ low-temperature scanning tunneling microscopy, synchrotron-based high-resolution ultraviolet photoelectron spectroscopy and near-edge X-ray absorption fine structure measurements. The orientation dependent energy level alignments at the OOH interfaces are discussed in detail. 130 References.

- Electric Current Activation of Sintering: A Review of the Pulsed Electric Current Sintering Process. By Z. A. Munir, D. V. Quach and M. Ohyanagi, *J. Amer. Ceram. Soc.*, **94** (1), 1–19 (2011).

#### Abstract

The phenomenal increase during the past decade in research utilizing pulsed electric current to activate sintering is attributed generally to the intrinsic advantages of the method relative to conventional sintering methods and to the observations of the enhanced properties of materials consolidated by this method.

This review focuses on the fundamental aspects of the process, discussing the reported observations and simulation studies in terms of the basic aspects of the process and identifying the intrinsic benefits of the use of the parameters of current (and pulsing), pressure, and heating rate. 153 References.

- Origins of Electro-Mechanical Coupling in Polycrystalline Ferroelectrics During Subcoercive Electrical Loading. By A. Pramanick, D. Damjanovic, J. E. Daniels, J. C. Nino and J. L. Jones, *J. Amer. Ceram. Soc.*, **94** (1), 293–309 (2011).

#### Abstract

The electromechanical coupling in ferroelectric materials is controlled by several coexisting structural phenomena which can include piezoelectric lattice strain, 180° and non-180° domain wall motion, and inter-phase boundary motion. The structural mechanisms that contribute to electromechanical coupling have not been readily measured in the past, particularly under the low-to-medium driving electric field amplitudes at which many piezoelectric materials are used.

In this article, results from *in situ*, high-energy, and time-resolved X-ray diffraction experiments are interpreted together with macroscopic piezoelectric coefficient measurements in order to better understand the contribution of these mechanisms to the electromechanical coupling of polycrystalline ferroelectric materials. The compositions investigated include 2 mol% each of La-doped-  $\text{PbZr}_{0.60}\text{Ti}_{0.40}\text{O}_3$ , - $\text{PbZr}_{0.52}\text{Ti}_{0.48}\text{O}_3$ , - $\text{PbZr}_{0.40}\text{Ti}_{0.60}\text{O}_3$ , un-doped  $\text{PbZr}_{0.52}\text{Ti}_{0.48}\text{O}_3$ , and 2 mol% Fe-doped  $\text{PbZr}_{0.47}\text{Ti}_{0.53}\text{O}_3$ . In all compositions, a strong correlation is found between the field-amplitude-dependence

of the macroscopic piezoelectric coefficient and the contribution of non-180° domain wall motion determined from the diffraction data. The results show directly that the Rayleigh-like behavior of  $d_3$  piezoelectric coefficient is predominantly due to a Rayleigh-like behavior of non-180° domain wall motion. Furthermore, after separating contributions from lattice (atomic level) and domain wall motion (nanoscale level) to the measured macroscopic piezoelectric properties, the authors show that previously ignored intergranular interactions (microscopic level) account for a surprisingly large portion of the electromechanical coupling. These results demonstrate that electromechanical coupling in polycrystalline aggregates is substantially different from that observed in single crystalline materials. The construct of emergence is used to describe how averaged macro-level phenomena are different from the material response observed in an isolated subcomponent of the material. Consequently, and due to its size-scale complexity, the description of grain-to-grain interactions is presently inaccessible in most *ab initio* and phenomenological approaches.

Results presented here demonstrate the need to account for these interactions in order to completely describe macroscopic electromechanical properties of polycrystalline materials. 81 References.

- Organic Radical Battery Approaching Practical Use. By K. Nakahara, K. Oyaizu and H. Nishide, *Chemistry Lett.*, **40** (3), 222–227 (2011).

#### Abstract

The electrochemical redox reactions of organic polymers bearing robust unpaired electrons were investigated to determine the applicability of these polymers to rechargeable batteries. Such an “organic radical battery” would be environmentally friendly and have high-power characteristics. This highlight review describes the performance of a battery using a nitroxyl radical polymer as the cathode active material. The electron-transfer mechanism and recent developments that should lead to the practical application of the organic radical battery are also described. 45 References.

- Hydrogen-bonded Supramolecular  $\pi$ -Functional Materials. By D. Gonzalez-Rodriguez and A. P. H. J. Schenning, *Chem. Mater.*, **23** (3), 310–325 (2011).

#### Abstract

Recent developments in the area of H-bonded supramolecular assemblies of  $\pi$ -conjugated systems, that is, oligomers and polymers, are described. The state-of-the-art summary of the recent developments in the design of discrete systems and functional materials is presented. 114 References.

- Materials and Devices Toward Fully Solution Processable Organic Light-emitting Diodes. By C. Zhong, C. Duan, F. Huang, H. Wu and Y. Cao, *Chem. Mater.*, **23** (3), 326–340 (2011).

#### Abstract

Organic light-emitting diodes (OLEDs) have been successfully developed and have now entered the commercial marketplace. Besides the impressive performance as displays, one of the key advantages of OLEDs is that they can potentially be made entirely by solution process and thus are more suitable for low cost, large area flexible displays and white lighting panels. To realize this, many efforts have been devoted on the development of solution processable light-emitting materials and charge transporting materials as well as electrode materials, which have resulted in the successful demonstration of high performance fully solution processed OLEDs and have opened a way to achieve all printable roll-to-roll organic optoelectronic devices. 141 References.

- Enhancing photocatalytic activity of titania materials by using porous structures and the addition of gold nanoparticles. By X. Wang and R. A. Caruso, *J. Mater. Chem.*, **21** (1) 20–28 (2011).

#### Abstract

Titanium dioxide ( $\text{TiO}_2$ ) is a photocatalyst that has attracted considerable attention for tackling pollution in liquid or gaseous environments.  $\text{TiO}_2$  has the benefits of high stability and low toxicity, it is abundant and therefore is relatively cheap. However, intrinsic issues in the material, in particular the recombination

between the photon induced electron and hole pair, the wide band gap ( $\sim 3.2$  eV), and the associated issues of nanoparticle separation (generally nanoparticle samples are required to achieve high surface areas) have hampered the full potential of this photocatalytic (PC) material.

Here, recent progress in producing porous titania materials, the addition of gold nanoparticles (Au-NPs) to the  $\text{TiO}_2$  and the coupling of these two approaches to improve the PC properties are reviewed. Incorporating porosity within the  $\text{TiO}_2$  material affords large surface areas without associated nanoparticulate separation issues, and increased accessibility for the organic pollutant to the active sites on the  $\text{TiO}_2$ , thereby enhancing PC activity. Au-NPs act as electron sinks to enhance the charge separation between the  $e^-/h^+$  produced on photon absorption, hence improving the quantum yield of superoxide radicals, resulting in improved PC activity. Further enhancement can be achieved by coupling the porous structure of the  $\text{TiO}_2$  and the addition of Au NPs. 79 References.

- A “tool box” for rational design of degradable controlled release formulations. By S. N. Rothstein and S. R. Little, *J. Mater. Chem.*, **21** (1) 29–39 (2011).

#### Abstract

Controlled release technology could provide a universal solution to the problems of patient compliance and sub-optimal dosing that often plague modern pharmaceuticals. Yet, harnessing this potential requires the ability to design drug delivery formulations which satisfy specific dosing schedules.

This review intends to portray how material properties, processing methods and mathematical models can serve as effective tools for rationally tuning the duration and rate of drug release from biodegradable polymer matrices. 109 References.

- Polystyrene sphere-assisted one-dimensional nanostructure arrays: synthesis and applications. By L. Li, T. Zhai, H. Zeng, X. Fang, Y. Bando and D. Golberg, *J. Mater. Chem.*, **21** (1) 40–56 (2011).

#### Abstract

Polystyrene (PS) spheres can self-assemble into colloidal crystal monolayers that are currently employed

for template-assisted synthesis of one-dimensional (nanopillars, nanorods, nanowires and nanotubes) nanostructure arrays. Compared to other classes of templates, PS-sphere monolayers can be easily formed and adjusted on substrates, and further manipulated using subsequent growth methods. Recently, several synthetic techniques have been developed and resulted in increased number of publications. Many applications including field-emitters, antireflection, light-emitting diodes (LEDs), photonic crystals, surface wetting, and photocatalysis have been reported utilizing these PS-sphere mediated nanoarrays.

In this article, these synthetic strategies are highlighted along with a review of the applications emerging from current PS-sphere assisted nanoarrays and future challenges are analyzed. 185 References.

- Environmentally friendly approaches toward the mass production of processable graphene from graphite oxide. By J. I. Paredes, S. Villar-Rodil, M. J. Fernández-Merino, L. Guardia, A. Martínez-Alonso and J. M. D. Tascón, *J. Mater. Chem.*, **21** (2) 298–306 (2011).

### Abstract

Graphene has attracted a great deal of scientific interest in latter years owing to its unique properties, with many prospective applications being actively investigated at present. However, the actual implementation of graphene in technological uses will depend critically on the development of appropriate methodologies for its mass production. In this regard, one of the most promising approaches is based on the exfoliation and reduction of graphite oxide. Graphenes derived from graphite oxide can be prepared at low cost and high throughput, can be further processed in a number

of solvents, and are chemically versatile, among other attractive features. In an environment-conscious world, the availability of green approaches toward graphene production would also constitute an added advantage.

During the last year, different environmentally friendly methods for the production of graphene from graphite oxide have emerged, which are highlight here. These are based on solvothermal and electrochemical processes, as well as on the use of green reductants. Several open questions and possible future directions for this research topic are also discussed. 55 References.

- Recent progress in the synthesis and applications of nanoporous carbon films. By Y. Tao, M. Endo, M. Inagaki and K. Kaneko, *J. Mater. Chem.*, **21** (2) 313–323 (2011).

### Abstract

The synthesis and applications of thin nanoporous carbon films or membranes (NPCFs) are outlined with a focus on recent literature examples.

NPCFs have large specific surface area, high electrical and thermal conductivity and both chemical and mechanical stability properties that facilitate increasing conventional uses in purification and separation, adsorption, and catalysis. They have potential applications in nanodevices, supercapacitors, lithium ion batteries, and chemical and bio-sensors. The authors summarize the various NPCF fabrication techniques, including solid- or soft-templating, direct pyrolysis on porous organic polymer precursors, chemical or physical vapor deposition and electrochemical deposition, and highlight the future design trends in the fabrication of NPCFs with ordered nanopore structures. 149 References.

## Forthcoming Conferences

### **11<sup>th</sup> UNESCO/IUPAC Workshop and Conference on Functional Polymeric Materials and Composites, 26–29, April, 2011, Stellenbosch, South Africa**

Contact: Prof. Harold Pasch, Dept. of Chemical & Physical Sci., Univ. of Stellenbosch, Matieland 7602, South Africa. E-mail: hpasch@sun.ac.za

### **11<sup>th</sup> International Conference on Frontiers of Polymers and Advanced Materials, 23–27, May, 2011, Pretoria, South Africa**

Contact: Prof. Walter W. Focke, Dept. of Chemical Engg., Univ. of Pretoria, Menlo Park, Pretoria, 0102, South Africa. E-mail: walter.focke@up.ac.za

### **18<sup>th</sup> International Conference on Solid State Ionics, July 3–8, 2011, Warsaw, Poland**

#### **Topics**

Theory, modelling and kinetics- Techniques- Oxide Ion Conductors- Mixed Conductors- New Materials- Fuel Cells- Electrocatalysis- Sensors- Proton Conductors- Nanoionics- Glasses- Lithium Batteries- Polymer Electrolytes- Energy Storage- Ionic Liquids.

Workshop for young scientist will be organized at Faculty of Physics, Warsaw University of Tech.

Workshop for young scientist will be organized at the Faculty of Physics, Warsaw University of Tech., Warsaw.

#### **Confirmed Invited Speakers**

Maria Forsyth (Australia), Clare Grey (USA/UK), Saiful Islam (UK), Rainer Waser (Germany), Harumi Yokokawa (Japan) and Christian Masquelier (Amiens, France).

Website: <http://ssi-18.net/>

### **19<sup>th</sup> Annual International Conference on Composites or Nano Engineering (ICCE-19), July 24–30, 2011, Shanghai, China**

#### **Major Topics of ICCE-19**

Aging, Flammability; Bio-Composites; Mathematical Modeling; Chemistry of Materials; Coatings and Wear; Metal Matrix Composites; Ceramics Composites; Micromechanics; Packaging Barrier; Electronic/Magnetic Materials; Particulate Composites; Engineering Science and Structures; Powder Metallurgy; Textile Composites; Functionally Graded Materials; Impact Engineering; Vibration; Infrastructures; Composites; Computational Materials; Durability; Natural Fibers; Processing; Biology; Physics of Materials.

#### **Major Symposia of ICCE-19**

Metals Research; Nano Bio Materials; Nano Devices and Actuators; Inorganic Nanowires; Nano-Fabrication; NanoLithography; Nanosensor; Magnetic Materials; Thin Films; Surface-Coating; Processing/Characterization; Durability of Composites.

Deadline for Submission of Short Paper: March, 24, 2011;

Deadline for Full Length Paper: July, 17, 2011

Website: <http://www.icce-nano.org/>

**The 6th Conference of the Asian Consortium on Computational Materials Science (ACCMS-6),  
6–9 Sept., 2011, Singapore**

The 6th Conference of the Asian Consortium on Computational Materials Science (ACCMS-6), will be held in Singapore, from 6 to 9 September 2011. The conference is jointly organized by the National University of Singapore, Institute of Advanced Studies at the Nanyang Technological University, and Materials Research Society of Singapore.

The ACCMS was established in 2000 in order to nurture and promote research and development activities in computational materials in Asian countries. The biennial ACCMS conference has become an international event for exchanging and archiving knowledge on the development of advanced computational methodology and its strong link to material science and engineering applications. The previous ACCMS conferences were successfully held in India (Bangalore 2001), Russia (Novosibirsk, 2004), China (Beijing, 2005), Korea (Seoul, 2007) and Vietnam (Hanoi, 2009).

Computational Materials Science (CMS) has emerged as a distinct multidisciplinary branch of science and computer modeling and simulation is playing an increasingly important role in materials science research. ACCMS-6 will provide a platform for computational materials scientists in Asian and world to present their recent results on research and development in CMS. The scope of the conference ranges from fundamental computational methodology (density functional theory and beyond, quantum mechanical based interatomic potentials, molecular dynamic and Monte-Carlo simulation of thermodynamic and kinetic properties at large length and time scales, phase field method of micro-structural simulation, etc.) to its industrial applications of different materials properties.

All computational materials scientists, including graduate students, from Asia as well as in other parts of the world are invited to participate in this conference. In addition to the three-day conference (7–9 September) which consists of plenary sessions, invited talks, contributed talks and poster presentation, pre-conference short courses will be held on 6 September to introduce new computational methods and/or emerging computational trends to beginners and those who may be interested in exploring new methods in their research.

Website: <http://www.mrs.org.sg/accms6/>

For further information, please contact, Prof. Yuan Ping Feng, Co-Chair of ACCMS-6

Tel: (65) 6516 2960; E-mail: [phyfyp@nus.edu.sg](mailto:phyfyp@nus.edu.sg)

or Miss Eileen So, Secretariat of ACCMS-6, DID: (65) 6874 1176; HP: (65) 8223 9845

Email: [accms6@mrs.org.sg](mailto:accms6@mrs.org.sg)

**The 7th International Conference on Porous Metals and Metallic Foams [MetFoam2011],  
Sep., 18–21, 2011, Busan, Korea**

For details, see the Website: [www.metfoam2011.org](http://www.metfoam2011.org)

**The 7th International Symposium on ‘Novel Materials and their Synthesis’,  
11–14, October 2011, Shanghai, China**

For further information, please contact, Prof. Yuping Wu, Chemistry Dept.,

New energy and Mater. Lab., Fudan Univ., Shanghai, 200 433, China.

E-mail: [wuyp@fudan.edu.cn](mailto:wuyp@fudan.edu.cn)

**Materials Education & Research in Singapore**

There are two Universities and several Research Institutes in Singapore involved in teaching, research and development in the broad area of Materials Science, Engineering and Technology. These are listed below along with the Websites and provide information on the available courses and opportunities for undergraduate, graduate and post doctoral research. They also entertain queries regarding openings for Research Scientists and Faculty positions.

National University of Singapore: [www.nus.edu.sg](http://www.nus.edu.sg)

Nanyang Technological University: [www.ntu.edu.sg](http://www.ntu.edu.sg)

Institute of Materials Research and Engineering (IMRE): [www.imre.a-star.edu.sg](http://www.imre.a-star.edu.sg)

Institute of Microelectronics (IME): [www.ime.a-star.edu.sg](http://www.ime.a-star.edu.sg)

Data Storage Institute: [www.dsi.a-star.edu.sg](http://www.dsi.a-star.edu.sg)

Institute of Chemical & Engineering Sciences: [www.ices.a-star.edu.sg](http://www.ices.a-star.edu.sg)

Institute of High Performance Computing: [www.ihpc.a-star.edu.sg](http://www.ihpc.a-star.edu.sg)

Singapore Institute of Manufacturing Technology: [www.SIMTech.a-star.edu.sg](http://www.SIMTech.a-star.edu.sg)

Institute of Bioengineering and Nanotechnology (IBN): [www.ibn.a-star.edu.sg](http://www.ibn.a-star.edu.sg)

## INVITATION

## MRS-S members are welcome to contribute to ‘MRS-S OUTLOOK’

- To suggest topics and prospective author(s) for ‘thematic’ articles pertaining to the areas of materials science, engineering and technology. These will be of general interest to the students, teachers as well as active researchers. These can be 10–15 pages (A4-size, single spaced) with figures, tables and select references.
- To contribute reports on the recently held conferences and information on the forthcoming conferences.
- To contribute ‘Highlights from Recent Literature’ in the areas of materials science, engineering and technology. These must pertain to the past two years, and be of general interest to non-specialists, students, teachers as well as active researchers. Each ‘Highlight’ must not exceed 250–300 words, including reference(s). Contributing author(s) and e-mail address(es) will be included under each ‘Highlight’.
- To contribute information about the recent awards and distinctions conferred on the MRS-S members.
- To contribute ‘Letters to the Editor’. They may be edited for brevity, clarity and available space, and the author(s) will be informed.

*Information on the above aspects may be communicated to the Editor.*

Dr. G.V. Subba Rao

E-mail: [phyvsg@nus.edu.sg](mailto:phyvsg@nus.edu.sg)

*The Editorial Board of ‘MRS-S OUTLOOK’ reserves the right to include or not any of the submitted contributions.*

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