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To spread information and knowledge and to promote collaboration in the area of Materials Research, Engineering and Technology amongst the members of MRS-S
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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.

Ms. Eileen So Tsz Ying has joined MRS-S as the 'Project Executive' with effect from June 1, 2010. She holds a Bachelor Degree (with merit) in Business Administration (Marketing) from the NUS Business School. She has good work experience of a few years in companies and educational institutions.

MRS-S has recently instituted a Medal in Physics for the best Ph. D. Thesis in the Physics Department of NTU. It also has instituted the MRS-S Medal and MRS-S Scholarship for the best students of the Diploma in Materials Science (DMIT) at the 'Republic Polytechnic' of Singapore.

The ICMAT 2011 will be held in Singapore during June 26–July 1, 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 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: Feb., 25-27, 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: March, 17-19, 2010. 1 Keynote Talk, 26 Invited Talks; 137 Poster Papers; 7 Best Poster Awards.

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Highlights of Recent Literature

(*Contributed by the Editor*)

Self-Assembled Plasmonic Nanoparticle Clusters

The self-assembly of colloids is an alternative to top-down processing that enables the fabrication of nanostructures. Fan *et al.*, [1] show that self-assembled clusters of metal-dielectric spheres are the basis for nanophotonic structures. By tailoring the number and position of spheres in close-packed clusters, plasmon modes exhibiting strong magnetic and Fano-like resonances emerge. The use of identical spheres simplifies cluster assembly and facilitates the fabrication of highly symmetric structures. Dielectric spacers are used to tailor the interparticle spacing in these clusters to be approximately 2 nm.

The authors state that, 'these types of chemically synthesized nanoparticle clusters can be generalized to other two- and three-dimensional structures and can serve as building blocks for new metamaterials'.

Reference

1. J. A. Fan, C. Wu, K. Bao, J. Bao, R. Bardhan, N. J. Halas, V. N. Manoharan, P. Nordlander, G. Shvets, and F. Capasso, *Science*, **328** (5982), 1135–1138 (2010) (May28 Issue).

Nanoscale Tunable Reduction of Graphene Oxide for Graphene Electronics

The reduced form of graphene oxide (GO) is an attractive alternative to graphene for producing large-scale flexible conductors and for creating devices that require an electronic gap. Here, Wei *et al.*, [1] report on a means to tune the topographical and electrical properties of reduced GO (rGO) with nanoscopic resolution by local thermal reduction of GO with a heated atomic force microscope tip. The rGO regions are up to four orders of magnitude more conductive than pristine GO. No sign of tip wear or sample tearing was observed. Variably conductive nanoribbons with dimensions down to 12 nanometers could be produced in oxidized epitaxial graphene films in a single step that is clean, rapid, and reliable.

Reference

1. Z. Wei, D. Wang, S. Kim, S.-Y. Kim, Y. Hu, M. K. Yakes, A. R. Laracuente, Z. Dai, S. R. Marder, C. Berger, W. P. King, W. A. de Heer, P. E. Sheehan and E. Riedo, *Science*, **328** (5984), 1373–1376 (2010) (11 June Issue).

Hot-Electron Transfer from Semiconductor Nanocrystals

In typical semiconductor solar cells, photons with energies above the semiconductor bandgap generate hot charge carriers that quickly cool before all of their energy can be captured, a process that limits device efficiency. Although fabricating the semiconductor in a nanocrystalline morphology can slow this cooling, the transfer of hot carriers to electron and hole acceptors has not yet been thoroughly demonstrated.

Here, Tisdale *et al.*, [1] used time-resolved optical second harmonic generation to observe hot-electron transfer from colloidal lead selenide (PbSe) nanocrystals to a titanium dioxide (TiO_2) electron acceptor. With appropriate chemical treatment of the nanocrystal surface, this transfer occurred much faster than expected. Moreover, the electric field resulting from sub–50-femtosecond charge separation across the PbSe-TiO_2 interface excited coherent vibrations of the TiO_2 surface atoms, whose motions could be followed in real time.

Reference

1. W. A. Tisdale, K. J. Williams, B. A. Timp, D. J. Norris, E. S. Aydil and X.-Y. Zhu, *Science*, **328** (5985), 1543–1547 (2010) (18 June Issue).

Real-Space Observation of a Two-Dimensional Skyrmion Crystal

Skyrmions are stable topological textures with particle-like properties — a mathematical concept that was originally used to describe nuclear particles but has since turned up at all scales. Last year, the presence of skyrmions in the magnetic compounds MnSi and $(Fe_{1-x}Co_x)Si$ was confirmed with neutron-scattering experiments.

Here, real-space images are presented of a two-dimensional skyrmion lattice in a thin film of the $(Fe_{0.5}Co_{0.5})Si$ using Lorentz transmission electron microscopy by Yu *et al.*, [1]. With a magnetic field of 50–70 mT applied normal to the film, they observed skyrmions in the form of a hexagonal arrangement of swirling spin textures, with a lattice spacing of 90 nm. The authors state that, 'the observed nanometer-scale spin topology might reveal new magneto-transport effects'.

Reference

1. X. Z. Yu, Y. Onose, N. Kanazawa, J. H. Park, J. H. Han, Y. Matsui, N. Nagaosa and Y. Tokura, *Nature*, **465** (7300), 901–904 (2010) (17 June Issue).

Identification of Quaternary Shape Memory Alloys with Near-Zero Thermal Hysteresis and Unprecedented Functional Stability

Improving the functional stability of shape memory alloys (SMAs), which undergo a reversible martensitic transformation, is critical for their applications and remains a central research theme driving advances in shape memory technology.

Here, Zarnetta *et al.*, [1] report that by using a thin-film composition-spread technique and high-throughput characterization methods, the lattice parameters of quaternary Ti-Ni-Cu-Pd SMAs and the thermal hysteresis have been tailored. Novel alloys with near-zero thermal hysteresis, as predicted by the geometric non-linear theory of martensite, are identified. The thin-film results are successfully transferred to bulk materials and near-zero thermal hysteresis is observed for the phase transformation in bulk alloys using the temperature-dependent alternating current potential drop method. A universal behavior of hysteresis versus the middle eigenvalue of the transformation stretch matrix is observed for different alloy systems. Furthermore, significantly improved functional stability, investigated by thermal cycling using differential scanning calorimetry, is found for the quaternary bulk alloy $(Ti_{50.2}Ni_{34.4}Cu_{12.3}Pd_{3.1})$.

Reference

1. R. Zarnetta, R. Takahashi, M. L. Young, A. Savan, Y. Furuya, S. Thienhaus, B. Maass, M. Rahim, J. Frenzel, H. Brunken, Y. S. Chu, V. Srivastava, R. D. James, I. Takeuchi, G. Eggeler and A. Ludwig, *Adv. Funct. Mater.*, **20** (12), 1917–1923 (2010).

MoS_2 and WS_2 Analogues of Graphene

Graphene-like molybdenum disulphide (MoS_2) and tungsten disulphide (WS_2) were prepared by Matte *et al.*, [1] using three different chemical methods and characterized. Examination by microscopic techniques revealed that they consist of one or a few layers, and an atomic-resolution TEM image showed that layered MoS_2 has a hexagonal arrangement of Mo and S atoms. The authors also studied 3D- and 2D- MoS_2 structures and their electronic and phonon properties using the density functional theory.

Reference

1. H. S. S. R. Matte, A. Gomathi, A. K. Manna, D. J. Late, R. Datta, S. K. Pati and C. N. R. Rao, *Angew. Chem. Int. Ed.*, **49** (24), 4059–4062 (2010).

Efficient Quantum Memory for Light

Storing and retrieving a quantum state of light on demand, without corrupting the information it carries, is an important challenge in the field of quantum information processing. Classical measurement and reconstruction strategies for storing light must necessarily destroy quantum information as a consequence of the Heisenberg uncertainty principle. There has been significant effort directed towards the development of devices—so-called quantum memories—capable of avoiding this penalty. So far, successful demonstrations of non-classical storage and on-demand recall have used atomic vapors and have been limited to low efficiencies, of less than 17%, using weak quantum states with an average photon number of around one.

Here, Hedges *et al.*, [1] report a low-noise, highly efficient (up to 69%) quantum memory for light

that uses a solid-state medium, namely Pr^{3+}(0.005%) doped:Y_2SiO_5 single crystal. The device allows the storage and recall of light more faithfully than is possible using a classical memory, for weak coherent states at the single-photon level through to bright states of up to 500 photons. For input coherent states containing on average 30 photons or fewer, the performance exceeded the no-cloning limit. This guaranteed that more information about the inputs was retrieved from the memory than was left behind or destroyed, a feature that will provide security in communications applications.

Reference

1. M. P. Hedges, J. J. Longdell, Y. Li and M. J. Sellars, *Nature*, **465** (7301), 1052–1056 (2010) (24 June Issue).

Femtosecond Electronic Response of Atoms to Ultra-Intense X-rays

An era of exploring the interactions of high-intensity, hard X-rays with matter has begun with the start-up of a hard-X-ray free-electron laser, the Linac Coherent Light Source (LCLS). Understanding how electrons in matter respond to ultra-intense X-ray radiation is essential for all applications.

Here Young *et al.*, [1] reveal the nature of the electronic response in a free atom to unprecedented high-intensity, short-wavelength, high-fluence radiation (respectively $10^{18}\,Wcm^{-2}$, 1.5–0.6 nm, $\sim 10^5$ X-ray photons per $Å^2$). At this fluence, the neon target inevitably changes during the course of a single femtosecond-duration X-ray pulse—by sequentially ejecting electrons—to produce fully-stripped neon through absorption of six photons. Rapid photoejection of inner-shell electrons produces 'hollow' atoms and an intensity-induced X-ray transparency. Such transparency, due to the presence of inner-shell vacancies, can be induced in all atomic, molecular and condensed matter systems at high intensity. Quantitative comparison with theory allowed the authors to extract LCLS fluence and pulse duration. Their successful modeling of X-ray/atom interactions using a straightforward rate equation approach, augurs favorably for extension to complex systems.

Reference

1. L. Young, E. P. Kanter, B. Krässig, Y. Li, A. M. March, S. T. Pratt, R. Santra, S. H. Southworth, N. Rohringer, L. F. DiMauro, G. Doumy, C. A. Roedig, N. Berrah, L. Fang, M. Hoener, P. H. Bucksbaum, J. P. Cryan, S. Ghimire, J. M. Glownia, D. A. Reis, J. D. Bozek, C. Bostedt and M. Messerschmidt, *Nature*, **465** (7302), 56–61 (2010) (1 July Issue).

Quantized Anomalous Hall Effect in Magnetic Topological Insulators

The anomalous Hall effect is a fundamental transport process in solids arising from the spin-orbit coupling. In a quantum anomalous Hall insulator, spontaneous magnetic moments and spin-orbit coupling combine to give rise to a topologically nontrivial electronic structure, leading to the quantized Hall effect without an external magnetic field.

Based on first-principles calculations, Yu *et al.*, [1] predict that the semiconductors Bi_2Te_3, Bi_2Se_3, and Sb_2Te_3 (which have been proved to be 'topological insulators') form magnetically ordered insulators when doped with transition metal elements (Cr or Fe), in contrast to conventional dilute magnetic semiconductors where free carriers are necessary to mediate the magnetic coupling. In two-dimensional thin films, this magnetic order gives rise to a topological electronic structure characterized by a finite Chern number, with the Hall conductance quantized in units of e^2/h (where e is the charge of an electron and h is Planck's constant).

Reference

1. R. Yu, W. Zhang, H.-J. Zhang, S.-C. Zhang, X. Dai and Z. Fang, *Science*, **329** (5987), 61–64 (2010) (2 July Issue).

Polymorphism Control of Superconductivity and Magnetism in Cs_3C_{60} Close to the Mott Transition

Crystals of the spherical molecular C_{60}^{3-} anion support both superconductivity and magnetism but can consist of fundamentally distinct three-dimensional arrangements of the anions. Superconductivity in the A_3C_{60} (A = alkali metal) fullerides has been exclusively associated with face-centered cubic (fcc) packing of

C_{60}^{3-}, but recently the most expanded (and thus having the highest superconducting transition temperature, T_c) composition Cs_3C_{60} has been isolated as a body-centered cubic (bcc) packing, which supports both superconductivity and magnetic order.

Here, Ganin *et al.*, [1] isolate the fcc polymorph of Cs_3C_{60} to show how the spatial arrangement of the electronically active units controls the competing superconducting and magnetic electronic ground states. Unlike all the other fcc A_3C_{60} fullerides, fcc Cs_3C_{60} is not a superconductor but a magnetic insulator at ambient pressure, and becomes superconducting under pressure. The magnetic ordering occurs at an order of magnitude lower temperature in the geometrically frustrated fcc polymorph (Néel temperature, $T_N = 2.2$ K) than in the bcc-based packing ($T_N = 46$ K). The different lattice packings of C_{60}^{3-} change T_c from 38 K in bcc Cs_3C_{60} to 35 K in fcc Cs_3C_{60} (the highest found in the fcc A_3C_{60} family). The existence of two superconducting packings of the same electronically active unit reveals that T_c scales universally in a structure-independent dome-like relationship with proximity to the Mott metal–insulator transition, which is governed by the role of electron correlations characteristic of high-temperature superconducting materials other than fullerides.

Reference

1. A. Y. Ganin, Y. Takabayashi, P. Jeglié, D. Aréon, A. Potoénik, P. J. Baker, Y. Ohishi, M. T. McDonald, M. D. Tzirakis, A. McLennan, G. R. Darling, M. Takata, M. J. Rosseinsky and K. Prassides, *Nature*, **466** (7303), 221–225 (2010) (8 July Issue).

Mesoscopic Percolating Resistance Network in a Strained Manganite Thin Film

Many unusual behaviors in complex oxides are deeply associated with the spontaneous emergence of microscopic phase separation. Depending on the underlying mechanism, the competing phases can form ordered or random patterns at vastly different length scales.

By using a microwave impedance microscope, Lai *et al.*, [1] observed an orientation-ordered percolating network in strained $Nd_{1/2}Sr_{1/2}MnO_3$thin films with a large period of 100 nm. The filamentary metallic domains align preferentially along certain crystal axes of the substrate, suggesting the anisotropic elastic strain as the key interaction in this system. The local impedance maps provide microscopic electrical information of the hysteretic behavior in strained thin film manganites, suggesting close connection between the glassy order and the colossal magnetoresistance effects at low temperatures.

Reference

1. K. Lai, M. Nakamura, W. Kundhikanjana, M. Kawasaki, Y. Tokura, M. A. Kelly and Z.-X. Shen, *Science*, **329** (5988), 190–193 (2010) (9 July Issue).

Step-Growth Polymerization of Inorganic Nanoparticles

Self-organization of nanoparticles (NPs) is an efficient strategy for producing nanostructures with complex, hierarchical architectures. The past decade has witnessed great progress in nanoparticle self-assembly, yet the quantitative prediction of the architecture of nanoparticle ensembles and of the kinetics of their formation remains a challenge.

Here, Liu *et al.*, [1] report on the marked similarity between the self-assembly of metal NPs and reaction-controlled step-growth polymerization. The NPs act as multifunctional monomer units, which form reversible, noncovalent bonds at specific bond angles and organize themselves into a colloidal polymer. They show that the kinetics and statistics of step-growth polymerization enable a quantitative prediction of the architecture of linear, branched, and cyclic self-assembled nanostructures; their aggregation numbers and size distribution; and the formation of structural isomers.

Reference

1. K. Liu, Z. Nie, N. Zhao, W. Li, M. Rubinstein and E. Kumacheva, *Science*, **329**(5988), 197–200 (2010) (9 July Issue).

Observation of the Magnon Hall Effect

The Hall effect usually occurs in conductors when the Lorentz force acts on a charge current in the presence of a perpendicular magnetic field. Neutral quasiparticles such as phonons and spins can, however, carry heat current and potentially exhibit the thermal Hall effect without resorting to the Lorentz force.

Here, Onose *et al.*, [1] report experimental evidence for the anomalous thermal Hall effect caused by spin excitations (magnons) in an insulating collinear ferromagnet, $Lu_2V_2O_7$ with a pyrochlore lattice structure. Their theoretical analysis indicates that the propagation of the spin waves is influenced by the Dzyaloshinskii-Moriya spin-orbit interaction, which plays the role of the vector potential, much as in the intrinsic anomalous Hall effect in metallic ferromagnets.

Reference

1. Y. Onose, T. Ideue, H. Katsura, Y. Shiomi, N. Nagaosa and Y. Tokura, *Science*, **329**(5989), 297–299 (2010) (16 July Issue).

Meniscus-Confined Three-Dimensional Electrodeposition for Direct Writing of Wire Bonds

Continued progress in the electronics industry depends on downsizing, to a few micrometers (μm), the wire bonds required for wiring integrated chips into circuit boards. Hu and Yu [1] developed an electrodeposition method that exploits the thermodynamic stability of a microscale or nanoscale liquid meniscus to "write" pure copper and platinum three-dimensional (3D) structures of designed shapes and sizes in an ambient air environment. They demonstrated an automated wire-bonding process that enabled wire diameters of less than 1 μm and bond sizes of less than 3 μm, with a breakdown current density of more than 10^{11} A/m^2 for the wire bonds.

The technology was used to fabricate high-density and high-quality interconnects, as well as complex 3D-microscale and even nanoscale metallic structures.

Reference

1. J. Hu and M.-F. Yu, *Science*, **329**(5989), 313–316 (2010) (16 July Issue).

Atomically precise bottom-up fabrication of graphene nanoribbons

Graphene nanoribbons (GNBs)—narrow and straight-edged stripes of graphene, or single-layer graphite—are predicted to exhibit electronic properties that make them attractive for the fabrication of nanoscale electronic devices. In particular, although the two-dimensional parent material graphene exhibits semimetallic behavior, quantum confinement and edge effects should render all GNBs with widths smaller than 10 nm semiconducting. But exploring the potential of GNBs is hampered by their limited availability: although they have been made using chemical, sonochemical and lithographic methods as well as through the unzipping of carbon nanotubes, the reliable production of GNBs smaller than 10nm with chemical precision remains a significant challenge.

Here Cai *et al.*, [1] report a simple method for the production of atomically precise GNBs of different topologies and widths, which uses surface-assisted coupling of molecular precursors into linear polyphenylenes and their subsequent cyclodehydrogenation. The topology, width and edge periphery of the GNB products are defined by the structure of the precursor monomers, which can be designed to give access to a wide range of different GNBs. The authors expect that the bottom-up approach to the atomically precise fabrication of GNBs will enable detailed experimental investigations of the properties of this exciting class of materials.

Reference

1. J. Cai, P. Ruffieux, R. Jaafar, M. Bieri, T. Braun, S. Blankenburg, M. Muoth, A. P. Seitsonen, M. Saleh, X. Feng, K. Müllen and R. Fasel, *Nature*, **466**(7305), 470–473 (2010) (22 July Issue).

Binary Nanocrystal Superlattice Membranes Self-Assembled at the Liquid-Air Interface

The spontaneous organization of multicomponent micrometre-sized colloids or nanocrystals into superlattices is of scientific importance for understanding the assembly process on the nanometre scale and is of great interest for bottom-up fabrication of functional devices. In particular, co-assembly of two types of nanocrystal into binary nanocrystal superlattices (BNSLs) has recently attracted significant attention, as this provides a low-cost, programmable way to design metamaterials with precisely controlled properties that arise from the organization and interactions of the constituent nanocrystal components. Although challenging, the ability to grow and manipulate large-scale BNSLs is critical for extensive exploration of this new

class of material.

Here, Dong *et al.*, [1] report a general method of growing cm-scale, uniform membranes of BNSLs that can readily be transferred to arbitrary substrates. Their method is based on the liquid-air interfacial assembly of multicomponent nanocrystals and circumvents the limitations associated with the current assembly strategies, allowing integration of BNSLs on any substrate for the fabrication of nanocrystal-based devices. The authors demonstrate the construction of magnetoresistive devices by incorporating large-area (1.5 mm $\times$ 2.5 mm) BNSL membranes; their magneto-transport measurements clearly show that device magnetoresistance is dependent on the structure (stoichiometry) of the BNSLs. The ability to transfer BNSLs also allows the construction of free-standing membranes and other complex architectures that have not been accessible previously.

Reference

1. A. Dong, J. Chen, P. M. Vora, J. M. Kikkawa and C. B. Murray, *Nature*, **466**(7305), 474–477 (2010) (22 July Issue).

Ultrahigh Porosity in Metal-Organic Frameworks

Crystalline solids with extended non-interpenetrating three-dimensional crystal structures were synthesized by Furukawa *et al.*, [1] that support well-defined pores with internal diameters of up to 48 Å. The $Zn_4O(CO_2)_6$ unit was joined with either one or two kinds of organic link, 4,4',4"-[benzene-1,3,5-triyl-tris(ethyne-2,1-diyl)]tribenzoate (BTE), 4,4',44"-[benzene-1,3,5-triyl-tris(benzene-4,1-diyl)]tribenzoate (BBC), 4,4',44"-benzene-1,3,5-triyl-tribenzoate (BTB)/2,6-naphthalenedicarboxylate (NDC), and BTE/biphenyl-4,4'-dicarboxylate (BPDC), to give four metal-organic frameworks (MOFs), MOF-180, -200, -205, and -210, respectively.

Members of this series of MOFs showed exceptional porosities and gas (hydrogen, methane, and carbon dioxide) uptake capacities. For example, MOF-210 has Brunauer-Emmett-Teller and Langmuir surface areas of 6240 and 10,400 m^2/g, respectively, and a total carbon dioxide storage capacity of 2870 mg/g. According to the authors, 'the volume-specific internal surface area of MOF-210 (2060 m^2/cm^3) is equivalent to the outer surface of nanoparticles (3-nm cubes) and near the ultimate adsorption limit for solid materials'.

Reference

1. H. Furukawa, N. Ko, Y. B. Go, N. Aratani, S. B. Choi, E. Choi, A. O. Yazaydin, R. Q. Snurr, M. O'Keeffe, J. Kim and O. M. Yaghi, *Science*, **329**(5990), 424–428 (2010) (23 July Issue).

Strain-Induced Pseudo–Magnetic Fields Greater Than 300 Tesla in Graphene Nanobubbles

Recent theoretical proposals suggest that strain can be used to engineer graphene electronic states through the creation of a pseudo–magnetic field. This effect is unique to graphene because of its massless Dirac fermion-like band structure and particular lattice symmetry (C_{3v}).

Here, Levy *et al.*, [1] present experimental spectroscopic measurements by scanning tunneling microscopy of highly strained nanobubbles that form when graphene is grown on a platinum (111) surface. The nanobubbles exhibit Landau levels that form in the presence of strain-induced pseudo–magnetic fields greater than 300 tesla. The authors state that, 'this demonstration of enormous pseudo–magnetic fields opens the door to both the study of charge carriers in previously inaccessible high magnetic field regimes and deliberate mechanical control over electronic structure in graphene or so-called 'strain engineering'.

Reference

1. N. Levy, S. A. Burke, K. L. Meaker, M. Panlasigui, A. Zettl, F. Guinea, A. H. Castro Neto and M. F. Crommie, *Science*, **329**(5991), 544–547 (2010) (30 July Issue).

Ultrathin PbS Sheets by Two-Dimensional Oriented Attachment

Controlling anisotropy is a key concept in the generation of complex functionality in advanced materials. For this concept, oriented attachment of nanocrystal building blocks, a self-assembly of particles into larger single-crystalline objects, is one of the most promising approaches in nanotechnology.

Here, Schliehe *et al.*, [1] report the two-dimensional oriented attachment of lead sulfide (PbS) nanocrystals into ultrathin single-crystal sheets with dimensions on the μm-scale. They found that this process is initiated by co-solvents, which alter nucleation and growth rates during the primary nanocrystal formation, and is finally driven by dense packing of oleic acid ligands on {100} facets of PbS. The authors state that, 'the obtained nanosheets can be readily integrated in a photodetector device without further treatment'.

Reference

1. C. Schliehe, B. H. Juarez, M. Pelletier, S. Jander, D. Greshnykh, M. Nagel, A. Meyer, S. Foerster, A. Kornowski, C. Klinke and H. Weller, *Science*, **329**(5991), 550–553 (2010) (30 July Issue).

Quantum Entanglement Between an Optical Photon and a Solid-State Spin Qubit

Quantum entanglement is among the most fascinating aspects of quantum theory. Entangled optical photons are now widely used for fundamental tests of quantum mechanics and applications such as quantum cryptography. Several recent experiments demonstrated entanglement of optical photons with trapped ions, atoms and atomic ensembles, which are then used to connect remote long-term memory nodes in distributed quantum networks.

Here, Togan *et al.*, [1] realize quantum entanglement between the polarization of a single optical photon and a solid-state quantum bit (qubit) associated with the single electronic spin of a nitrogen vacancy centre in diamond. Their experimental entanglement verification uses the quantum eraser technique, and demonstrates that a high degree of control over interactions between a solid-state qubit and the quantum light field can be achieved. According to the authors, 'the reported entanglement source can be used in studies of fundamental quantum phenomena and provides a key building block for the solid-state realization of quantum optical networks'.

Reference

1. E. Togan, Y. Chu, A. S. Trifonov, L. Jiang, J. Maze, L. Childress, M. V. G. Dutt, A. S. Sørensen, P. R. Hemmer, A. S. Zibrov and M. D. Lukin, *Nature*, **466**(7307), 730–734 (2010) (5 Aug., Issue).

Loss-Free and Active Optical Negative-Index Metamaterials

The recently emerged fields of metamaterials and transformation optics promise a family of exciting applications such as invisibility, optical imaging with deeply subwavelength resolution and nanophotonics with the potential for much faster information processing. The possibility of creating optical negative-index metamaterials (NIMs) using nanostructured metal–dielectric composites has triggered intense basic and applied research over the past several years. However, the performance of all NIM applications is significantly limited by the inherent and strong energy dissipation in metals, especially in the near-infrared and visible wavelength ranges. Generally the losses are orders of magnitude too large for the proposed applications, and the reduction of losses with optimized designs seems to be out of reach. One way of addressing this issue is to incorporate gain media into NIM designs. However, whether NIMs with low loss can be achieved has been the subject of theoretical debate.

Here Xiao *et al.*, [1] experimentally demonstrate that the incorporation of gain material in the high-local-field areas of a metamaterial makes it possible to fabricate an extremely low-loss and active optical NIM. The original loss-limited negative refractive index and the figure of merit (FOM) of the device have been drastically improved with loss compensation in the visible wavelength range between 722 and 738 nm. In this range, the NIM becomes active such that the sum of the light intensities in transmission and reflection exceeds the intensity of the incident beam. At a wavelength of 737 nm, the negative refractive index improves from -0.66 to -1.017 and the FOM increases from 1 to 26. At 738 nm, the FOM is expected to become macroscopically large, of the order of 10^6. The authors state that, 'this study demonstrates the possibility of fabricating an optical negative-index metamaterial that is not limited by the inherent loss in its metal constituent'.

Reference

1. S. Xiao, V. P. Drachev, A. V. Kildishev, X. Ni, U. K. Chettiar, H.-K. Yuan and V. M. Shalaev, *Nature*, **466**(7307), 735–738 (2010) (5 Aug., Issue).

Massive Dirac Fermion on the Surface of a Magnetically Doped Topological Insulator

In addition to a bulk energy gap, topological insulators accommodate a conducting, linearly dispersed Dirac surface state. This state is predicted to become massive if time reversal symmetry is broken, and to become insulating if the Fermi energy is positioned inside both the surface and bulk gaps.

Here, Chen *et al.*, [1] introduced magnetic dopants (Fe- and Mn-ions) into the three-dimensional topological insulator dibismuth triselenide (Bi_2Se_3) to break the time reversal symmetry and further position the Fermi energy inside the gaps by simultaneous magnetic and charge doping. The resulting insulating massive Dirac fermion state, was observed by angle-resolved photoemission. The authors state that, this ' paves the way for studying a range of topological phenomena relevant to both condensed matter and particle physics'.

Reference

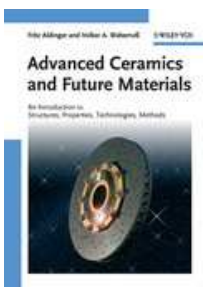
1. Y. L. Chen, J.-H. Chu, J. G. Analytis, Z. K. Liu, K. Igarashi, H.-H. Kuo, X. L. Qi, S. K. Mo, R. G. Moore, D. H. Lu, M. Hashimoto, T. Sasagawa, S. C. Zhang, I. R. Fisher, Z. Hussain and Z. X. Shen, **329**(5992), 659–662 (2010) (6 Aug. Issue).

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

(*Contributed by the Editor*)

Books

- *Advanced Ceramics and Future Materials — An Introduction to Structures, roperties, Technologies, Methods* Edited by Aldinger, Fritz and Weberruss, Volker A. Wiley-VCH, Weinheim 2010, Hardcover, pp. 506, Euro 89, ISBN-10: 3-527-32157-8; ISBN-13: 978-3-527-32157-5 — Wiley-VCH, Weinheim.

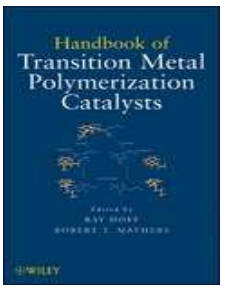


- *Industrial Plasma Technology-Applications from Environmental to Energy Technologies* Edited by Kawai, Yoshinobu/Ikegami, Hideo/Sato, Noriyoshi/Matsuda, Akihisa/Uchino, Kiichiro/Kuzuya, Masayuki/Mizuno, Akira, Wiley-VCH, Weinheim 2010. pp. 434, Hardcover, Euro 149, ISBN-10: 3-527-32544-1; ISBN-13: 978-3-527-32544-3 — Wiley-VCH, Weinheim.

- *Silicon Nanocrystals-Fundamentals, Synthesis and Applications* Edited by Pavesi, Lorenzo/Turan, Rasit, Wiley-VCH, Weinheim 2010. Hardcover, pp. 627, Euro 169, ISBN-10: 3-527-32160-8; ISBN-13: 978-3-527-32160-5 — Wiley-VCH, Weinheim.
- *Surfaces and Interfaces of Electronic Materials* By Brillson, Leonard J. Wiley — IEEE, pp. 570, Euro 109 ISBN-10: 3-527-40915-7; ISBN-13: 978-3-527-40915-0 — Wiley-VCH, Berlin.

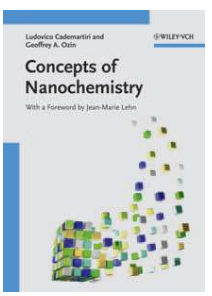
- *Ideas in Chemistry and Molecular Sciences-Advances in Nanotechnology, Materials and Devices* Edited by Pignataro, Bruno, Wiley-VCH, Weinheim 2010. Hardcover, pp. 410, Euro 99, ISBN-10: 3-527-32543-3; ISBN-13: 978-3-527-32543-6 — Wiley-VCH, Weinheim.

- Handbook of Transition Metal Polymerization Catalysts Edited by Hoff, Ray/Mathers, Robert T. Wiley-VCH, Weinheim 2010. Hardcover, pp. 576, Euro 125 ISBN-10: 0-470-13798-3; ISBN-13: 978-0-470-13798-7 — John Wiley & Sons.



- *Introductory Quantum Mechanics for Semiconductor Nanotechnology* By Kim, Dae Mann, Wiley-VCH, Weinheim 2010. Hardcover, pp. 448 Euro 139, ISBN-10: 3-527-40975-0; ISBN-13: 978-3-527-40975-4 — Wiley-VCH, Berlin.

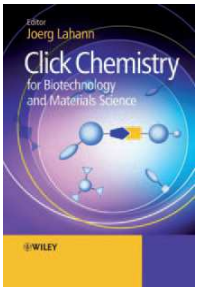
- *The Big Ideas of Nanoscale Science and Engineering-A Guidebook for Secondary Teachers* By Shawn Y. Stevens, LeeAnn M. Sutherland and Joseph S. Krajcik. NSTA Press, Arlington, VA, 2010, Paperback: pp. 219, illus. $27.95, ISBN 978-1935155072.
- *Introduction to Functional Magnetic Resonance Imaging-Principles and Techniques* By Richard B. Buxton, 2nd (ed), Cambridge University Press, New York, 2010. Hardback, pp. 469, illus. $200, ISBN 978-0521899956.
- *Concepts of Nanochemistry* By Ludovico Cademartiri and Geoffrey A. Ozin. Wiley-VCH, Weinheim 2009. pp. 262, softcover, Euro 39.00, ISBN 978-3527325979.



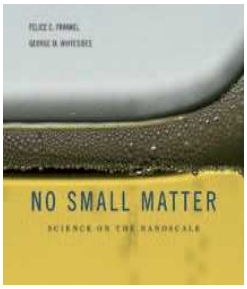
For a review, see, *Angew. Chem. Int. Ed.*, **49** (20), 3409–3410 (2010).

- *Click Chemistry for Biotechnology and Materials Science* Edited by Joerg Lahann. John. Wiley & Sons, Hoboken, 2009. pp. 432, hardcover, Euro 125.00. ISBN 978-0470699706.

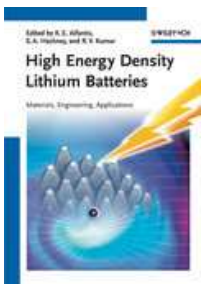
For a review, see, *Angew. Chem. Int. Ed.*, **49**(20), 3410–3411 (2010).



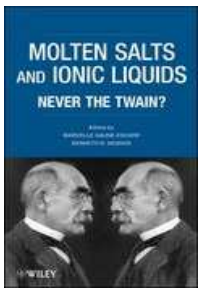
- *No Small Matter. Science on the Nanoscale* By Felice C. Frankel and George M. Whitesides. Harvard University Press 2009. pp. 192, hardcover, Euro 27.95. ISBN 978-0674035669.
  For a review, see, *Angew. Chem. Int. Ed.*, **49** (21), 3410–3411 (2010).



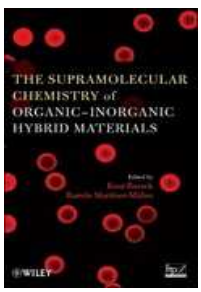
- *Stochastic Processes for Physicists - Understanding Noisy Systems* By Kurt Jacobs. Cambridge University Press, New York, 2010. Hardback, pp. 202, $45, ISBN 978-0521765428.
- *High Energy Density Lithium Batteries-Materials, Engineering, Applications* Edited by Aifantis, Katerina E. Hackney, Stephen A. Kumar, R. Vasant. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 266, Euro 109. ISBN-10: 3-527-32407-0. ISBN-13: 978-3-527-32407-1 — Wiley-VCH, Weinheim.



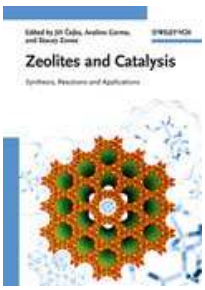
- *Molten Salts and Ionic Liquids-Never the Twain?* Edited by Gaune-Escard, Marcelle/Seddon, Kenneth R. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 442, Euro 105. ISBN-10: 0-471-77392-1; ISBN-13: 978-0-471-77392-4 — John Wiley & Sons.



- *The Supramolecular Chemistry of Organic-Inorganic Hybrid Materials* Edited by Rurack, Knut/Martinez-Manez, Ramon. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 766, Euro 125, ISBN-10: 0-470-37621-X; ISBN-13: 978-0-470-37621-8 — John Wiley & Sons.



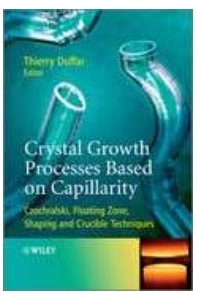
- *Zeolites and Catalysis-Synthesis, Reactions and Applications* Edited by Cejka, Jiri/Corma, Avelino/Zones, Stacey. Wiley-VCH, Weinheim. 2010. Hardcover, pp. 882, vol. 2, Euro 299. ISBN-10: 3-527-32514-X; ISBN-13: 978-3-527-32514-6 — Wiley-VCH, Weinheim.



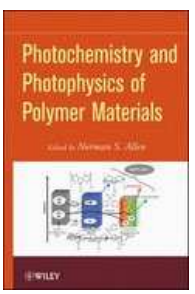
- *Ceramics Science and Technology. Volume 2: Materials and Properties* Edited by Riedel, Ralf/Chen,

I-Wei. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 862, Euro 249. ISBN-10: 3-527-31156-4; ISBN-13: 978-3-527-31156-9 — Wiley-VCH, Weinheim.

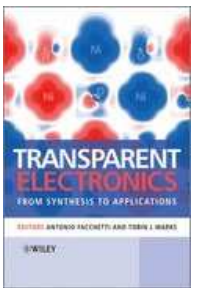
- *Crystal Growth Processes Based on Capillarity–Czochralski, Floating Zone, Shaping and Crucible Techniques* Edited by Duffar, Thierry. Wiley-VCH, Weinheim, 2010. Hardcover, pp 566, Euro 159. ISBN-10: 0-470-71244-9; ISBN-13: 978-0-470-71244-3 — John Wiley & Sons.



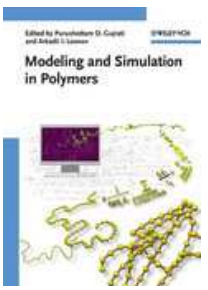
- *Handbook of Photochemistry and Photophysics of Polymeric Materials* By Allen, N. S. Wiley-VCH, Weinheim, 2010. Hardcover, pp 690, Euro 125, ISBN-10: 0-470-13796-7; ISBN-13: 978-0-470-13796-3 — John Wiley & Sons.



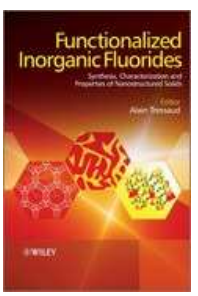
- *Transparent Electronics-From Synthesis to Applications* Edited by Facchetti, Antonio/Marks, Tobin. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 470, Euro 135, ISBN-10: 0-470-99077-5; ISBN-13: 978-0-470-99077-3 — John Wiley & Sons.



- *Modeling and Simulation in Polymers* Edited by Gujrati, Purushottam D./Leonov, Arkady I. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 542, Euro 149, ISBN-10: 3-527-32415-1; ISBN-13: 978-3-527-32415-6 — Wiley-VCH, Weinheim.

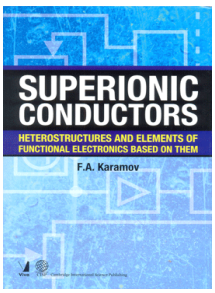


- *Functionalized Inorganic Fluorides-Synthesis, Characterization and Properties of Nanostructured Solids* Edited by Tressaud, Alain. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 614, Euro 149, ISBN-10: 0-470-74050-7; ISBN-13: 978-0-470-74050-7 — John Wiley & Sons.

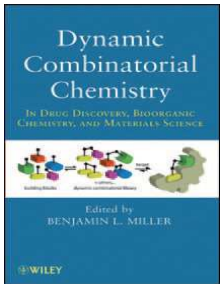


- *Superionic Conductors-Heterostructures and Elements of Functional Electronics Based on Them*

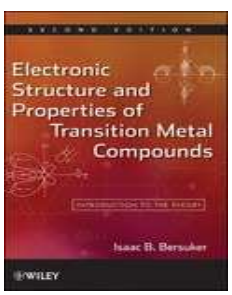
By F. A. Karamov, Viva Books, India, 2010. Hardcover, pp. 230, Price Indian Rs. 1095, ISBN-978-8130909462.



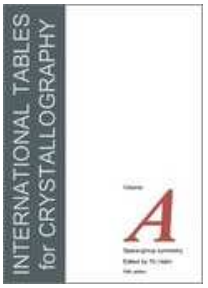
- *CMOS Analog Design Using All-Region MOSFET Modeling* By Márcio Cherem Schneider and Carols Galup-Montoro. Cambridge University Press, Cambridge, 2010. Hardback, pp. 504, illus. $99, ISBN 978-0521110365.
- *A Designer's Guide to Asynchronous VLSI* By Peter A. Beerel, Recep O. Ozdag, and Marcos Ferretti. Cambridge University Press, Cambridge, 2010. Hardback, pp. 351, illus. $120, ISBN 978-0521872447.
- *Nanotechnologies for Future Mobile Devices* By Tapani Ryhänen *et al.*,. Cambridge University Press, Cambridge, 2010. Hardback, pp. 282, illus. $70, ISBN 978-0521112161.
- *Organometallics in Environment and Toxicology* Edited by Astrid Sigel, Helmut Sigel and Roland K. O. Sigel. RSC Publishing, Cambridge, 2010. Hardback, pp. 605, illus. £150, ISBN 978-1847551771.
- *Understanding Modern Transistors and Diodes* By David L. Pulfrey. Cambridge University Press, Cambridge, 2010. Hardback, pp. 353, illus. $80, ISBN 978-0521514606.
- *Dynamic Combinatorial Chemistry. In Drug Discovery, Bioorganic Chemistry, and Materials Science.* Edited by Benjamin L. Miller. John Wiley & Sons, Hoboken 2009. pp. 266, hardcover Euro 64.90, ISBN 978-0470096031. For a review, see, *Angew. Chem. Int. Ed.*, **49**(24), 4011 (2010).



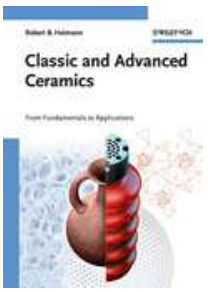
- *Carbon Nanotubes–Methods and Protocols* Edited by Kannan Balasubramanian and Marko Burghard, Humana (Springer), New York, 2010. Hardback, pp. 266, illus. $119, ISBN 978-1607615774.
- *Molecular Forces and Self Assembly — In Colloid, Nano Sciences and Biology* By Barry W. Ninham and Pierandrea Lo Nostro. Cambridge University Press, New York, 2010. Hardback, pp. 381, illus. $78, ISBN 978-0521896009.
- *Condensed Matter Field Theory* By Alexander Altland and Ben Simons, 2nd ed. Cambridge University Press, Cambridge, 2010. Hardback, pp. 784, illus. $90, £50, ISBN 978-0521769754.
- *Electronic Structure and Properties of Transition Metal Compounds-Introduction to the Theory* By Bersuker, Isaac B. Wiley-VCH, Weinheim 2010. 2nd ed. pp. 760, Hardcover, Euro 125, ISBN-10: 0-470-18023-4; ISBN-13: 978-0-470-18023-5 — John Wiley & Sons.



- *International Tables for Crystallography* By Fuess, H. Hahn, Th. Wondratschek, H. Müller, U. Shmueli, U. Authier, A. Kopsky, V. Litvin, D. B. Rossmann, M. G. Arnold, E. Hall and S. R. McMahon, B.8 Volume Set. 2nd Edition. Wiley-VCH, Weinheim 2010. Hardcover, pp. 5980, Euro 1650, ISBN-10: 0-470-66163-1; ISBN-13: 978-0-470-66163-5 — John Wiley & Sons.

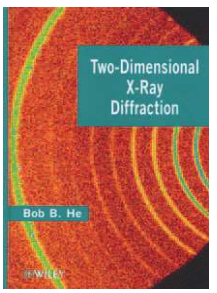


- *Classic and Advanced Ceramics-From Fundamentals to Applications* By Heimann, Robert B. Wiley-VCH, Weinheim 2010, Hardcover, pp. 553, Euro 149, ISBN-10: 3-527-32517-4; ISBN-13: 978-3-527-32517-7 — Wiley-VCH, Weinheim.

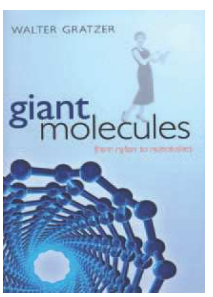


- *Materials Science and Engineering* By Callister, William D. International Student Version. 8th ed Wiley-VCH, Weinheim 2010. Softcover, pp. 1000, Euro 57.90, ISBN-10: 0-470-50586-9; ISBN-13: 978-0-470-50586-1 — John Wiley & Sons.

- *Atomic Force Microscopy* By Peter Eaton and Paul West. Oxford University Press, Oxford, 2010. Hardback, pp. 256, $99, £55, ISBN 978-0199570454.
- *Cancer Nanotechnology-Methods and Protocols* Edited by Stephen R. Grobmyer and Brij M. Moudgil. Humana (Springer), New York, 2010. Hardback, pp. 410, $139, ISBN 978-1607616085.
- *Introduction to Optical Quantum Information Processing* By Pieter Kok and Brendon W. Lovett, Cambridge University Press, Cambridge, 2010. Hardback, pp. 500, $78, £45, ISBN 978-0521519144.
- *Surface Plasmon Resonance-Methods and Protocols* Edited by Nico J. de Mol and Marcel J. E. Fischer. Humana (Springer), New York, 2010. Hardback, pp. 296, $119. ISBN 978-1607616696.
- *Two-Dimensional X-Ray Diffraction* By Bob B. He. John Wiley & Sons, Hoboken 2009. Hardcover pp. 426, Euro 97.90, ISBN 978-0470227220.
  For a review, see, *Angew. Chem. Int. Ed.*, **49**(29), 4858–4859 (2010).



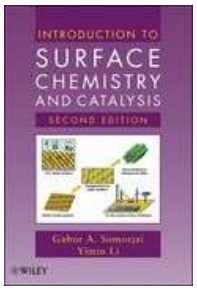
- *Giant Molecules- From Nylon to Nanotubes* By Walter Gratzer. Oxford University Press, Oxford 2009. Hardcover, pp. 254, Euro 14.99, ISBN 978-0199550029.
  For a review, see, *Angew. Chem. Int. Ed.*, **49**(29), 4859 (2010).



- *Diamond Nanotechnology — Syntheses and Applications* By James C. Sung and Jianping Lin, Pan Stanford, Singapore, 2010. Hardback, pp. 260, illus $149, C$179, ISBN 978-9814241410.
- *Excitonic and Vibrational Dynamics in Nanotechnology — Quantum Dots vs. Nanotubes* By Svetlana

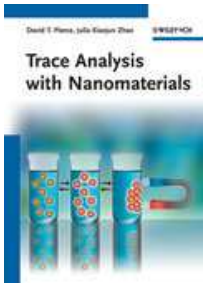
V. Kilina and Bradley F. Habenicht, Pan Stanford, Singapore, 2010. Hardback, pp. 200, illus. $129, C$155, ISBN 978-9814241304.

- *Introduction to Surface Chemistry and Catalysis* By Somorjai, Gabor A. Li, Yimin, Wiley-VCH, Weinheim, 2nd ed, 2010. Hardcover, pp. 772, Euro 125, ISBN-10: 0-470-50823-X; ISBN-13: 978-0-470-50823-7 — John Wiley & Sons.

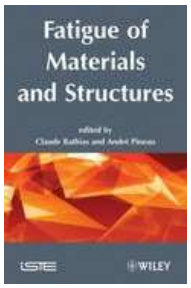


- *Kinetic Processes-Crystal Growth, Diffusion, and Phase Transitions in Materials* By Jackson, Kenneth A. 2. completely revised and enlarged Edition. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 433, Euro 99, ISBN 978-3-527-32736-2.

- *Trace Analysis with nanomaterials* Edited by Pierce, David T. Zhao, Julia Xiaojun, Wiley-VCH, Weinheim, 2010. Hardcover, pp. 396, Euro 139, ISBN 978-3-527-32350-0.



- *Fatigue of Materials and Structures* Edited by Bathias, Claude/Pineau, André. Wiley-VCH, Weinheim, 2010. Hardcover, pp. 512, Euro 185 ISBN-10: 1-84821-051-5; ISBN-13: 978-1-84821-051-6 — John Wiley & Sons.



- *Solid State Ionics- Fundamental Researches and Technological Applications* (Proceedings of the 12th Asian Conf. on Solid State Ionics, 2-6 May, 2010). Edited by B.V.R. Chowdari, H. Liu, W. Chen, Q. Xu and Z. Yu, Wuhan Univ. Technol. Press, Wuhan, China. 2010. Hardcover. 1182 pages. Price: Chinese RMB 200. ISBN- 978-7-5629-3159-1.

Review Articles

- Applications of Ultrasound to the Synthesis of Nanostructured Materials. By J. H. Bang and K. S. Suslick, *Adv. Mater.*, **22**(10), 1039–1059 (2010).

Abstract

Recent advances in nanostructured materials have been led by the development of new synthetic methods that provide control over size, morphology, and nano/microstructure. The utilization of high intensity ultrasound offers a facile, versatile synthetic tool for nanostructured materials that are often unavailable by conventional methods. The primary physical phenomena associated with ultrasound that are relevant to materials synthesis are cavitation and nebulization. Acoustic cavitation (the formation, growth, and implosive collapse of bubbles in a liquid) creates extreme conditions inside the collapsing bubble and serves as the origin of most sonochemical phenomena in liquids or liquid-solid slurries. Nebulization (the creation of mist from ultrasound passing through a liquid and impinging on a liquid-gas interface) is the basis for ultrasonic spray pyrolysis (USP) with subsequent reactions occurring in the heated droplets of the mist. In both cases, we have examples of phase-separated attoliter microreactors: for sonochemistry, it is a hot gas inside bubbles isolated from one another in a liquid, while for USP it is hot droplets isolated from one another in a gas. Cavitation-induced sonochemistry provides a unique interaction between energy and matter, with hot spots inside the bubbles of $\sim$5000 K, pressures of $\sim$ 1 kbar, heating and cooling rates of $> 10^{10}$ K.s^{-1}; these extraordinary conditions permit access to a range of chemical reaction space normally not accessible, which allows for the synthesis of a wide variety of unusual nanostructured materials. Complementary to cavitational chemistry, the microdroplet reactors created by USP facilitate the formation of a wide range of nanocomposites.

In this review, Bang and Suslick summarize the fundamental principles of both synthetic methods and recent development in the applications of ultrasound in nanostructured materials synthesis. 210 References.

- Multidimensional Architectures for Functional Optical Devices. By K. A. Arpin, A. Mihi, H. T. Johnson, A. J. Baca, J. A. Rogers, J. A. Lewis and P. V. Braun, *Adv. Mater.*, **22**(10), 1084–1101 (2010).

Abstract

Materials exhibiting multidimensional structure with characteristic lengths ranging from the nanometer to the micrometer scale have extraordinary potential for emerging optical applications based on the regulation of light-matter interactions via the mesoscale organization of matter. As the structural dimensionality increases, the opportunities for controlling light-matter interactions become increasingly diverse and powerful. Recent advances in multidimensional structures have been demonstrated that serve as the basis for three-dimensional photonic-bandgap materials, metamaterials, optical cloaks, highly efficient low-cost solar cells, and chemical and biological sensors.

In this Review, the state-of-the-art design and fabrication of multidimensional architectures for functional optical devices are covered and the next steps for this important field are described. 156 References.

- New Frontiers in Materials Science Opened by Ionic Liquids. By T. Torimoto, T. Tsuda, K. Okazaki and S. Kuwabata, *Adv. Mater.*, **22**(11), 1196–1221 (2010).

Abstract

Ionic liquids (ILs) including ambient-temperature molten salts, which exist in the liquid state even at room temperature, have a long research history. However, their applications were once limited because ILs were considered as highly moisture-sensitive solvents that should be handled in a glove box. After the first synthesis of moisture-stable ILs in 1992, their unique physicochemical properties became known in

all scientific fields. ILs are composed solely of ions and exhibit several specific liquid-like properties, e.g., some ILs enable dissolution of insoluble bio-related materials and the use as tailor-made lubricants in industrial applications under extreme physicochemical conditions. Hybridization of ILs and other materials provides quasi-solid materials, which can be used to fabricate highly functional devices. ILs are also used as reaction media for electrochemical and chemical synthesis of nanomaterials. In addition, the negligible vapor pressure of ILs allows the fabrication of electrochemical devices that are operated under ambient conditions, and many liquid-vacuum technologies, such as X-ray photoelectron spectroscopy (XPS) analysis of liquids, electron microscopy of liquids, and sputtering and physical vapor deposition onto liquids.

In this article, Torimoto *et al.*, review recent studies on ILs that are employed as functional advanced materials, advanced mediums for materials production, and components for preparing highly functional materials. 299 References.

- Vertically Aligned Single-Walled Carbon Nanotubes by Chemical Assembly — Methodology, Properties, and Applications. By P. Diao and Z. Liu, *Adv. Mater.*, **22**(13), 1430–1449 (2010).

Abstract

Single-walled carbon nanotubes (SWNTs), as one of the most promising one-dimension nanomaterials due to its unique structure, peculiar chemical, mechanical, thermal, and electronic properties, have long been considered as an important building block to construct ordered alignments. Vertically aligned SWNTs (v-SWNTs) have been successfully prepared by using direct growth and chemical assembly strategies.

In this review, Diao and Liu focus explicitly on the v-SWNTs fabricated via chemical assembly strategy. They provide a full and systematic summary covering the advances in all aspects of this area, including various approaches for the preparation of v-SWNTs using chemical assembly techniques, characterization, assembly kinetics, and electrochemical properties of v-SWNTs. The authors also review the applications of v-SWNTs in electrochemical and bioelectrochemical sensors, photoelectric conversion, and scanning probe microscopy. 134 References.

- Plasma-Assisted Approaches in Inorganic Nanostructure Fabrication. BY J. Zheng, R. Yang, L. Xie, J. Qu, Y. Liu and X. Li, *Adv. Mater.*, **22**(13), 1451–1473 (2010).

Abstract

Plasma is a unique medium for chemical reactions and materials preparations, which also finds its application in the current tide of nanostructure fabrication. Although plasma-assisted approaches have been long used in thin-film deposition and the top-down scheme of micro-/nanofabrication, fabrication of zero- and one-dimensional inorganic nanostructures through the bottom-up scheme is a relatively new focus of plasma application.

In this article, recent plasma-assisted techniques in inorganic zero- and one-dimensional nanostructure fabrication are reviewed, which includes four categories of plasma-assisted approaches: plasma-enhanced chemical vapor deposition, thermal plasma sintering with liquid/solid feeding, thermal plasma evaporation and condensation, and plasma treatment of solids. The special effects and the advantages of plasmas on nanostructure fabrication are illustrated with examples, emphasizing on the understandings and ideas for controlling the growth, structure, and properties during plasma-assisted fabrications. The review provides insight into the utilization of the special properties of plasmas in nanostructure fabrication. 227 References.

- Three-Dimensional Nanostructures for Photonics. By G. von Freymann, A. Ledermann, M. Thiel, I. Staude, S. Essig, K. Buschand and M. Wegener, *Adv. Funct. Mater.*, **20**(7), 1038–1052 (2010).

Abstract

Recent progress in direct laser writing of three-dimensional (3D) polymer nanostructures for photonics is reviewed. This technology has reached a level of maturity at which it can be considered as the 3D analogue of planar electron-beam lithography. Combined with atomic-layer deposition and/or chemical-vapor deposition of dielectrics-the 3D analogues of planar evaporation technologies, the 3D polymer templates can be converted or inverted into 3D high-refractive-index-contrast nanostructures.

Examples discussed in this review include positive and inverse 3D silicon-based woodpile photonic crystals possessing complete photonic bandgaps, novel optical resonator designs within these structures, 3D chiral photonic crystals for polarization-state manipulation, and 3D icosahedral photonic quasicrystals. The latter represent a particularly complex 3D nanostructure. 105 References.

- Lithium batteries: Status, prospects and future. By B. Scrosati and J. Garche, *J. Power Sources*, **195**(9), 2419–2430 (2010).

Abstract

Lithium batteries are characterized by high specific energy, high efficiency and long life. These unique properties have made lithium batteries the power sources of choice for the consumer electronics market with a production of the order of billions of units per year. These batteries are also expected to find a prominent role as ideal electrochemical storage systems in renewable energy plants, as well as power systems for sustainable vehicles, such as hybrid and electric vehicles. However, scaling up the lithium battery technology for these applications is still problematic since issues such as safety, costs, wide operational temperature and materials availability, are still to be resolved.

This review focuses first on the present status of lithium battery technology, then on its near future development and finally it examines important new directions aimed at achieving quantum jumps in energy and power content. 76 References.

- Advanced Materials for Sodium-Beta Alumina Batteries: Status, Challenges and Perspectives. By X. Lu, G. Xia, J. P. Lemmon and Z. Yang, *J. Power Sources*, **195**(9), 2431–2442 (2010).

Abstract

The increasing penetration of renewable energy and the trend toward clean, efficient transportation have spurred growing interests in sodium-beta alumina batteries that store electrical energy via sodium ion transport across a β"-Al_2O_3 solid electrolyte at elevated temperatures (typically 300–350°C). Currently, the negative electrode or anode is metallic sodium in molten state during battery operation; the positive electrode or cathode can be molten sulfur (Na–S battery) or solid transition metal halides plus a liquid phase secondary electrolyte (e.g., ZEBRA battery). Since the groundbreaking works in the sodium-beta alumina batteries a few decades ago, encouraging progress has been achieved in improving battery performance, along with cost reduction. However, there remain issues that hinder broad applications and market penetration of the technologies. To better the Na-beta alumina technologies require further advancement in materials along with component and system design and engineering.

This paper offers a comprehensive review on materials of electrodes and electrolytes for the Na-beta alumina batteries and discusses the challenges ahead for further technology improvement. 105 References.

- Four-Dimensional Electron Microscopy. By A. H. Zewail, *Science*, **328**(5975), 187–193 (2010) (9 April Issue).

Abstract

The discovery of the electron over a century ago and the realization of its dual character have given birth to one of the two most powerful imaging instruments: the electron microscope. The electron microscope's ability to resolve three-dimensional (3D) structures on the atomic scale is continuing to affect different fields, including materials science and biology. In this Review, Ahmed highlights recent developments and inventions made by introducing the fourth dimension of time in electron microscopy.

Today, ultrafast electron microscopy (4D UEM) enables a resolution that is 10 orders of magnitude better than that of conventional microscopes, which are limited by the video-camera rate of recording. After presenting the central concept involved, that of single-electron stroboscopic imaging, he discusses prototypical applications, which include the visualization of complex structures when unfolding on different length and time scales. The developed UEM variant techniques are several, and here he illucidates convergent-beam and near-field imaging, as well as tomography and scanning-pulse microscopy. The review concludes with current explorations in imaging of nanomaterials and biostructures and an outlook on possible future directions in space-time, 4D electron microscopy. 56 References.

- The Chemistry of Graphene. By K. P. Loh, Q. Bao, P. K. Ang and J, Yang, *J. Mater. Chem.*, **20**(12), 2277–2289 (2010).

Abstract

A review on the latest developments on graphene, written from the perspective of a chemist, is presented. The role of chemistry in bringing graphene research to the next level is discussed. 153 References.

- Surface Engineering for High Performance Organic Electronic Devices: the Chemical Approach. By L. Miozzo, A. Yassar and G. Horowitz, *J. Mater. Chem.*, **20**(13), 2513–2538 (2010).

Abstract

Self-assembled monolayers (SAMs) are rapidly becoming an essential part of organic electronics such as light emitting diodes (LEDs), organic field-effect transistors (OFETs), and complementary circuits, where they are employed to control the morphology and energetics of the interfaces. This review focuses on interface engineering and its influence on such devices.

The authors describe the growth of SAMs of organic molecules on various surfaces of interest for this purpose (mainly metals and oxides). For the growth of SAMs on metal electrodes, the most common approach makes use of thiols to modify the metal surface, but the preparation of SAMs on dielectrics requires other reactive groups such as carboxylic or phosphonic acids. They also review the control of the interfacial properties by appropriate molecular design of the SAMs and their effect on device performance. SAMs can modify the morphology of the organic semiconductor, the dielectric properties of the insulator, the electronic states at the dielectric interface and the level alignment at the electrode interfaces. All these factors can influence current transport mainly by modifying the charge mobility, the contact resistance and the trap density at the interfaces. 143 References.

- Designing Biomaterials Based on Biomineralization of Bone. By N. M. Alves, I. B. Leonor, H. S. Azevedo, R. L. Reis and J. F. Mano, *J. Mater. Chem.*, **20**(15), 2911–2921 (2010).

Abstract

In nature, organisms control crystal nucleation and growth using organic interfaces as templates. Scientists, in the last decades, have tried to learn from nature how to design biomimetic biomaterials inspired by the hierarchical complex structure of bone and other natural mineralised tissues or to control the biomineralization process onto biomaterials substrates to promote the osteoconductive properties of implantable devices. The design of synthetic bone analogues, i.e., with a structure and properties similar to bone, would certainly constitute a major breakthrough in bone tissue engineering. Moreover, many strategies have been proposed in the literature to develop bioactive bone-like materials, for instance using bioactive glasses. Fundamental aspects of biomineralization may be also important in order to propose new methodologies to improve calcification onto the surface of biomaterials or to develop bioactive tridimensional templates that could be used in regenerative medicine. In particular, it has been shown that some chemical groups and proteins, as well as the tridimensional matrix in which calcification would occur, play a fundamental role on the nucleation and growth of hydroxyapatite. All these distinct aspects are reviewed and discussed in this paper. 98 References.

- Intercalation and Superconductivity in Ternary Layer Structured Metal Nitride Halides (MNX: M = Ti, Zr, Hf; X = Cl, Br, I). By S. Yamanaka, *J. Mater. Chem.*, **20**(15), 2922–2933 (2010).

Abstract

The ternary metal nitride halides MNX (M = Ti, Zr, Hf; X = Cl, Br, I) contain two types of layer structured polymorphs having different types of two-dimensional metal nitride networks. Both are band insulators, and changed into superconductors with moderately high transition temperatures T_cs up to 25.5 K upon electron-doping by means of intercalation through the interlayer space. The structural characteristics, electron doping

by intercalation, and the unconventional superconductivity are reviewed. 84 References.

- Organic Electronics from Perylene to Organic Photovoltaics: Painting a Brief History with a Broad Brush. By F. G. Brunetti, R. Kumar and F. Wudl, *J. Mater. Chem.*, **20**(15), 2934–2948 (2010).

Abstract

The past ten years have witnessed the development of bulk-heterojunction (BHJ) solar cells, which have emerged as an attractive renewable energy source in response to rising energy costs and environmental pollution. In such a solar cell, charge transfer at the donor–acceptor interface is a crucial aspect that significantly affects overall device efficiency. Therefore, the choice of these two components and their design are important factors for the optimization of plastic solar cells (PSCs).

This article correlates the performance of the device to the active layer composites, analyzing the motivations behind specific BHJ designs. Several low-bandgap polymers are described based on their different donor–acceptor units and their influence on both the optical absorption and the electrochemical properties. As for the accepting materials, the authors examine the effect of chemical functionalization in a series of fullerene derivatives, carbon nanotubes and non-fullerene based compounds on their performances in PSCs. The understanding of film-morphology control is also briefly discussed. 154 References.

- Metal–Organic Frameworks as Semiconductors. By C. G. Silva, A. Corma and H. García, *J. Mater. Chem.*, **20**(16), 3141–3156 (2010).

Abstract

The aim of the present article is to present the current evidence in support of considering some Metal–organic frameworks (MOFs) as semiconductors. While MOFs and zeolites share common structural properties derived from the microporous crystal structure, zeolites are insulating materials and most of the attempts to exploit them in optoelectronics have met with failure. In contrast, some MOFs may have interesting photochemical properties that derive from the fundamental event of charge separation in electrons and holes upon light absorption. Photoinduced charge separation is the hallmark of a semiconductor that can behave simultaneously as an oxidizing or reducing agent. Considering the novelty of this field, most of the available data about MOFs as semiconductor have been obtained from MOF-5, a case that is complicated due to its low structural stability. Therefore, the authors point out that further studies showing the semiconducting properties of other MOFs are still welcome. The purpose of this article is to trigger intense research in this area including the synthesis of semiconducting MOFs by design and development of applications. 82 References.

- A Survey on Piezoelectric Ceramics for Generator Applications. By T. Rödig, A. Schönecker and G. Gerlach, *J. Amer. Ceram. Soc.*, **93**(4), 901–912 (2010).

Abstract

Piezoelectric generators enable maintenance-free power supply for integrated electronics in smart system applications. The majority of publications consider the aspect of power transfer electronics; however, the influence of the transducer materials was rarely described. Recently, material characteristics received increased attention from the ceramics community.

The authors set the focus of the present paper to commercially available piezoelectric ceramics. Different figures of merit are derived from system analysis using electromechanical modeling. They allow for the description of typical load scenarios and commercial piezoceramics. Derived rules are expected to be helpful for guiding ceramic engineers and system designers to succeed in improved generator solutions. 53 References.

- Extra-Large-Pore Zeolites: Bridging the Gap between Micro and Mesoporous Structures. By J. Jiang, J. Yu and A. Corma, *Angew. Chem. Int. Ed.*, **49**(18), 3120–3145 (2010).

Abstract

The conditions required to produce zeolites with low framework density and extra-large pores are discussed. Correlations between framework stability and geometrical and topological descriptors are presented. An attempt has been made to rationalize the synthesis

of extra-large-pore zeolites in terms of the synthesis mechanism, the directing effect of the organic structure directing agent (OSDA), the framework atoms, and the gel concentration. Extra-large-pore zeolites, including the recently discovered chiral mesoporous ITQ-37, are described and their catalytic and adsorption properties discussed. Finally, strategies are presented for the preparation of extra-large-pore zeolites with different pore topologies that can fulfill pre-established catalytic and adsorption targets. 203 References.

- Electroreduction of Dioxygen for Fuel-Cell Applications: Materials and Challenges. By A. A. Gewirth and M. S. Thorum, *Inorg. Chem.*, **49**(8), 3557–3566 (2010).

Abstract

A review of the oxygen reduction reaction (ORR) and its use in fuel-cell applications is presented. Discussed are mechanisms of the ORR and implementations of catalysts for this reaction. Specific catalysts discussed include nanoparticles, macrocycles and pyrolysis products, carbons, chalcogenides, enzymes, and coordination complexes. A prospectus for future efforts is provided. 160 References.

- Microwave Versus Conventional Sintering: A Review of Fundamentals, Advantages and Applications. By M. Oghbaei and O. Mirzaee, *J. Alloys Compds.*, **194**(1-2), 175–189 (2010).

Abstract

Microwave sintering has emerged in recent years as a new method for sintering a variety of materials that has shown significant advantages against conventional sintering procedures. This review first provides a summary of fundamental theoretical aspects of microwave and microwave hybrid sintering, and then advantages of microwave sintering against conventional methods are described. At the end, some applications of microwave sintering are mentioned which so far have manifested the advantages of this novel method. 48 References.

- Gold Nanoparticles for Biology and Medicine. By D. A. Giljohann, D. S. Seferos, W. L. Daniel, M. D. Massich, P. C. Patel and C. A. Mirkin, *Angew. Chem. Int. Ed.*, **49**(19), 3280–3294 (2010).

Abstract

Gold colloids have fascinated scientists for over a century and are now heavily utilized in chemistry, biology, engineering, and medicine. Today these materials can be synthesized reproducibly, modified with seemingly limitless chemical functional groups, and, in certain cases, characterized with atomic-level precision. This review highlights recent advances in the synthesis, bioconjugation, and cellular uses of gold nanoconjugates. There are now many examples of highly sensitive and selective assays based upon gold nanoconjugates. In recent years, focus has turned to therapeutic possibilities for such materials. Structures which behave as gene-regulating agents, drug carriers, imaging agents, and photoresponsive therapeutics have been developed and studied in the context of cells and many debilitating diseases. These structures are not simply chosen as alternatives to molecule-based systems, but rather for their new physical and chemical properties, which confer substantive advantages in cellular and medical applications. 127 References.

- Micrometer and Nanometer-Scale Parallel Patterning of Ceramic and Organic–Inorganic Hybrid Materials. By J. E. ten Elshof, S. U. Khan and O. F. Göbel, *J. European Ceram. Soc.*, **30**(7), 1555–1577 (2010).

Abstract

This review gives an overview of the progress made in recent years in the development of low-cost parallel patterning techniques for ceramic materials, silica, and organic–inorganic silsesquioxane-based hybrids from wet-chemical solutions and suspensions on the micrometer and nanometer-scale. The emphasis of the discussion is placed on the application of soft-lithographic methods, but photolithography-aided patterning methods for oxide film growth are also discussed. In general, moulding-based patterning approaches and surface modification-based patterning approaches can be distinguished. Lateral resolutions well below 100 nm have been accomplished with some

of these methods, but the fabrication of high-aspect ratio patterns remains a challenge.197 References.

- Magnetically Separable Nanocatalysts: Bridges between Homogeneous and Heterogeneous Catalysis. By S. Shylesh, V. Schünemann and W. R. Thiel, *Angew. Chem. Int. Ed.*, **49**(20), 3428–3459 (2010).

Abstract

Recovery and reuse of expensive catalysts after catalytic reactions are important factors for sustainable process management. The aim of this review is to highlight the progress in the formation and catalytic applications of magnetic nanoparticles and magnetic nanocomposites. Directed functionalization of the surfaces of nanosized magnetic materials is an elegant way to bridge the gap between heterogeneous and homogeneous catalysis. The introduction of magnetic nanoparticles in a variety of solid matrices allows the combination of well-known procedures for catalyst heterogenization with techniques for magnetic separation. 223 References.

- Processing of Bulk Metallic Glass. By J. Schroers, *Adv. Mater.*, **22**(14), 1566–1597 (2010).

Abstract

Bulk metallic glass (BMG) formers are multicomponent alloys that vitrify with remarkable ease during solidification. Technological interest in these materials has been generated by their unique properties, which often surpass those of conventional structural materials. The metastable nature of BMGs, however, has imposed a barrier to broad commercial adoption, particularly where the processing requirements of these alloys conflict with conventional metal processing methods. Research on the crystallization of BMG formers has uncovered novel thermoplastic forming (TPF)-based processing opportunities. Unique among metal processing methods, TPF utilizes the dramatic softening exhibited by a BMG as it approaches its glass-transition temperature and decouples the rapid cooling required to form a glass from the forming step.

This article reviews crystallization processes in BMG former and summarizes and compares TPF-based processing methods. Finally, an assessment of scientific and technological advancements required for broader commercial utilization of BMGs will be made. 422 References.

- Single-Molecule Spectroscopy for Plastic Electronics: Materials Analysis from the Bottom-Up. By J. M. Lupton, *Adv. Mater.*, **22**(15), 1689–1721 (2010).

Abstract

Pi (π)-conjugated polymers find a range of applications in electronic devices. These materials are generally highly disordered in terms of chain length and chain conformation, besides being influenced by a variety of chemical and physical defects. Although this characteristic can be of benefit in certain device applications, disorder severely complicates materials analysis. Accurate analytical techniques are, however, crucial to optimizing synthetic procedures and assessing overall material purity. Fortunately, single-molecule spectroscopic techniques have emerged as an unlikely but uniquely powerful approach to unraveling intrinsic material properties from the bottom up. Building on the success of such techniques in the life sciences, single-molecule spectroscopy is finding increasing applicability in materials science, effectively enabling the dissection of the bulk down to the level of the individual molecular constituent.

This article reviews recent progress in single molecule spectroscopy of conjugated polymers as used in organic electronics. 264 References.

- Nonspherical Noble Metal Nanoparticles: Colloid-Chemical Synthesis and Morphology Control. By T. K. Sau and A. L. Rogach, *Adv. Mater.*, **22**(16), 1781–1804 (2010).

Abstract

Metal nanoparticles have been the subject of widespread research over the past two decades. In recent years, noble metals have been the focus of numerous studies involving synthesis, characterization, and applications. Synthesis of an impressive range of noble metal nanoparticles with varied morphologies has been reported. Researchers have made a great progress in learning how to engineer materials on a nanometer length scale that has led to the

understanding of the fundamental size- and shape-dependent properties of matter and to devising of new applications.

In this article, the authors review the recent progress in the colloid-chemical synthesis of nonspherical nanoparticles of a few important noble metals (mainly Ag, Au, Pd, and Pt), highlighting the factors that influence the particle morphology and discussing the mechanisms behind the nonspherical shape evolution. The article attempts to present a thorough discussion of the basic principles as well as state-of-the-art morphology control in noble metal nanoparticles. 320 References.

- Chemical Vapor Deposition of Conformal, Functional, and Responsive Polymer Films. By M. E. Alf, A. Asatekin, M. C. Barr, S. H. Baxamusa, H. Chelawat, G. Ozaydin-Ince, C. D. Petruczok, R. Sreenivasan, W. E. Tenhaeff, N. J. Trujillo, S. Vaddiraju, J. Xu and K. K. Gleason, *Adv. Mater.*, **22**(18), 1993–2027 (2010).

Abstract

Chemical vapor deposition (CVD) polymerization utilizes the delivery of vapor-phase monomers to form chemically well-defined polymeric films directly on the surface of a substrate. CVD polymers are desirable as conformal surface modification layers exhibiting strong retention of organic functional groups, and, in some cases, are responsive to external stimuli. Traditional wet-chemical chain- and step-growth mechanisms guide the development of new heterogeneous CVD polymerization techniques. Commonality with inorganic CVD methods facilitates the fabrication of hybrid devices. CVD polymers bridge microfabrication technology with chemical, biological, and nanoparticle systems and assembly. Robust interfaces can be achieved through covalent grafting enabling high-resolution (60 nm) patterning, even on flexible substrates. Utilizing only low-energy input to drive selective chemistry, modest vacuum, and room-temperature substrates, CVD polymerization is compatible with thermally sensitive substrates, such as paper, textiles, and plastics. CVD methods are particularly valuable for insoluble and infusible films, including fluoropolymers, electrically conductive polymers, and controllably crosslinked networks and for the potential to reduce environmental, health, and safety impacts associated with solvents. Quantitative models aid the development of large-area and roll-to-roll CVD polymer reactors. Relevant background, fundamental principles, and selected applications are reviewed. 506 References.

- Recent Development of Active Nanoparticle Catalysts for Fuel Cell Reactions. By V. Mazumder, Y. Lee and S. Sun, *Adv. Funct. Mater.*, **20**(8), 1224–1231 (2010).

Abstract

This review focuses on the recent advances in the synthesis of nanoparticle (NP) catalysts of Pt-, Pd- and Au-based NPs as well as composite NPs. First, new developments in the synthesis of single-component Pt, Pd and Au NPs are summarized. Then the chemistry used to make alloy and composite NP catalysts aiming to enhance their activity and durability for fuel cell reactions is outlined. The review next introduces the research push in developing CoN/C and FeN/C as non-Pt catalysts. Examples of size-, shape- and composition-dependent catalyses for oxygen reduction at cathode and formic acid oxidation at anode are highlighted to illustrate the potentials of the newly developed NP catalysts for fuel cell applications. 50 References.

- Interface Engineering for Organic Electronics. By H. Ma, H.-L. Yip, F. Huang and A. K.-Y. Jen, *Adv. Funct. Mater.*, **20**(9), 1371–1388 (2010).

Abstract

The field of organic electronics has been developed vastly in the past two decades due to its promise for low cost, lightweight, mechanical flexibility, versatility of chemical design and synthesis, and ease of processing. The performance and lifetime of these devices, such as organic light-emitting diodes (OLEDs), photovoltaics (OPVs), and field-effect transistors (OFETs), are critically dependent on the properties of both active materials and their interfaces. Interfacial properties can be controlled ranging from simple wettability or adhesion between different materials to direct modifications of the electronic structure of the materials.

In this Article, the strategies of utilizing surfactant-modified cathodes, hole-transporting buffer layers, and self-assembled monolayer (SAM)-modified anodes are highlighted. In addition to enabling the production of high-efficiency OLEDs, control of interfaces in both conventional and inverted polymer solar cells is shown to enhance their efficiency and stability; and the tailoring of source-drain electrode-semiconductor interfaces, dielectric-semiconductor interfaces, and ultrathin dielectrics is shown to allow for high-performance OFETs. 199 References.

- Biomedical Applications of Thermally Activated Shape Memory Polymers. By W. Small, P. Singhal, T. S. Wilson and D. J. Maitland, *J. Mater. Chem.*, **20**(17), 3356–3366 (2010).

Abstract

Shape memory polymers (SMPs) are smart materials that can remember a primary shape and can return to this primary shape from a deformed secondary shape when given an appropriate stimulus. This property allows them to be delivered in a compact form via minimally invasive surgeries in humans, and deployed to achieve complex final shapes.

Here the authors review the various biomedical applications of SMPs and the challenges they face with respect to actuation and biocompatibility. While shape memory behavior has been demonstrated with heat, light and chemical environment, here they focus the discussion on thermally stimulated SMPs. 140 References.

- Thermo-Moisture Responsive Polyurethane Shape-Memory Polymer and Composites: A Review. By W. M. Huang, B. Yang, Y. Zhao and Z. Ding, *J. Mater. Chem.*, **20**(17), 3367–3381 (2010).

Abstract

The polyurethane shape-memory polymer (SMP) developed by Mitsubishi Heavy Industry, Japan is not only thermo-responsive, but also moisture-responsive as recently found. The moisture-responsive ability atop the well-known thermo-responsive feature could open a new dimension for applications of this material.

This paper presents a concise review of the thermo- and moisture-responsive properties and thermomechanical behaviors of this SMP and its composites, and potential applications utilizing these features, in particular in biomedical engineering. 68 References.

- Advances in Layered Oxide Cathodes for Intermediate Temperature Solid Oxide Fuel Cells. By A. Tarancón, M. Burriel, J. Santiso, S. J. Skinner and J. A. Kilner, *J. Mater. Chem.*, **20**(19), 3799–3813 (2010).

Abstract

In the context of solid oxide fuel cells (SOFCs) applications, mixed-ionic electronic conductors offer significant advantages over conventional cathodes especially in the intermediate-to-low range of temperatures where the performance of the cathode is of fundamental importance. An increasing number of layered oxide materials have been found to present excellent properties as mixed ionic-electronic conductors. Therefore, considerable efforts have been recently devoted to better understand and evaluate layered ordered structures. This article highlights the most important advances in this topic concentrating on both structural aspects and impact in cathode performance for SOFCs applications. 125 References.

- Photoluminescent ZnO Nanoparticles Modified by Polymers. By H.-M. Xiong, *J. Mater. Chem.*, **20**(20), 4251–4262 (2010).

Abstract

Photoluminescent ZnO nanoparticles, due to nontoxicity and cheapness, are promising materials applied in UV laser devices and biological labels. ZnO photoluminescence is usually composed of two parts: UV emission arising from the typical band gap transition and visible emission due to the oxygen vacancies. In order to protect ZnO nanoparticles and improve their optical properties, polymers are mixed with ZnO or modified on ZnO surfaces to produce various nanocomposites. In the meantime, some new luminescent phenomena are found when polymers and ZnO nanoparticles together participate in the luminescent process. This review will focus on the synthetic methods, structural features and photoluminescent properties of the polymer–ZnO nanocomposites.

72 References.

- Stretchable, Curvilinear Electronics Based on Inorganic Materials. By D.-H. Kim, J. Xiao, J. Song, Y. Huang and J. A. Rogers, *Adv. Mater.*, **22**(19), 2108–2124 (2010).

Abstract

All commercial forms of electronic/optoelectronic technologies use planar, rigid substrates. Device possibilities that exploit bio-inspired designs or require intimate integration with the human body demand curvilinear shapes and/or elastic responses to large strain deformations. This article reviews progress in research designed to accomplish these outcomes with established, high-performance inorganic electronic materials and modest modifications to conventional, planar processing techniques.

The authors outline the most well developed strategies and illustrate their use in demonstrator devices that exploit unique combinations of shape, mechanical properties and electronic performance. They conclude with an outlook on the challenges and opportunities for this emerging area of materials science and engineering. 102 References.

- Gecko-Inspired Surfaces: A Path to Strong and Reversible Dry Adhesives. By L. F. Boesel, C. Greiner, E. Arzt and A. de Campo, *Adv. Mater.*, **22**(19), 2125–2137 (2010).

Abstract

The amazing adhesion of gecko pads to almost any kind of surfaces has inspired a very active research direction over the last decade: the investigation of how geckos achieve this feat and how this knowledge can be turned into new strategies to reversibly join surfaces. This article reviews the fabrication approaches used so far for the creation of micro- and nanostructured fibrillar surfaces with adhesive properties. In the light of the pertinent contact mechanics, the adhesive properties are presented and discussed. The decisive design parameters are fiber radius and aspect ratio, tilt angle, hierarchical arrangement and the effect of the backing layer. Also, first responsive systems that allow thermal switching between nonadhesive and adhesive states are described. These structures show a high potential of application, providing the remaining issues of robustness, reliability, and large-area manufacture can be solved. 129 References.

- Exploring Structures and Phase Relationships of Ceramics from First Principles. By A. Seko, *J. Amer. Ceram. Soc.*, **93** (5), 1201–1214 (2010).

Abstract

Statistical thermodynamics plays a crucial role in modern materials science. The free energy of compounds is indispensable for discussing the phase stability. In general, a number of phenomena contribute to the temperature dependence of the free energy. In multicomponent systems, an important contribution to the free energy arises from the atomic configuration. The configurational effects have been estimated by density functional theory (DFT) calculations and the cluster expansion (CE) method.

In this article, methodologies for computing the configurational properties based on DFT calculations and the CE method are reviewed. Several applications of the methodologies to the configurational behaviors in ceramic systems are then discussed. We have constructed a phase diagram for a pseudobinary ZnO–MgO system using a combination of the CE method and the cluster variation method (CVM). Instead of the CVM, Monte Carlo (MC) simulations can be adopted to take account of the configurational contribution. Using a combination of DFT calculations and the canonical MC simulations via the CE method, we have investigated the temperature dependence of the cation distribution in $MgAl_2O_4$ spinel. A similar combined approach has been applied to elucidate the stable cation ordering in spinel oxides and the structure and phase stability of a series of nonstoichiometric SnO_{2-x} compounds. 118 References.

- Overview on Fabrication of Three-Dimensional Structures in Multi-Layer Ceramic Substrate. By L. E. Khoong, M. Tan and Y. C. Lam, *J. European Ceram. Soc.*, **30**(10), 1973–1987 (2010).

Abstract

Three-dimensional (3D) structures in a multi-layer ceramic substrate are important in realizing ceramic-based meso- and micro-systems. During lamination

and/or co-firing, three-dimensional structures, especially those with suspended structures, tend to deform and sag due to the intrinsic nature of the green (un-fired) ceramic material. Fabrication of 3D structures with well-controlled dimensional stability and mechanical integrity remains a challenge.

This review discusses the challenges in fabricating structures in a multi-layer ceramic substrate. An overview is provided of the current state of the art in patterning and lamination techniques for the fabrication of these 3D structures. 58 References.

- Colloidal Hybrid Nanostructures: A New Type of Functional Materials. By R. Costi, A. E. Saunders and U. Banin, Angew. *Chem. Int. Ed.*, **49**(29), 4878–4897 (2010).

Abstract

One key goal of nanocrystal research is the development of experimental methods to selectively control the composition and shape of nanocrystals over a wide range of material combinations. The ability to selectively arrange nanosized domains of metallic, semiconducting, and magnetic materials into a single hybrid nanoparticle offers an intriguing route to engineer nanomaterials with multiple functionalities or the enhanced properties of one domain.

In this Review, the authors focus on recent strategies used to create semiconductor-metal hybrid nanoparticles, present the emergent properties of these multicomponent materials, and discuss their potential applicability in different technologies.182 References.

- Testing Metal-Oxide Nanomaterials for Human Safety. By R. Landsiedel, L. Ma-Hock, A. Kroll, D. Hahn, J. Schnekenburger, K. Wiench and W. Wohlleben, *Adv. Mater.*, **22**(24), 2601–2627 (2010).

Abstract

Nanomaterials can display distinct biological effects compared with bulk materials of the same chemical composition. The physico-chemical characterization of nanomaterials and their interaction with biological media are essential for reliable studies and are reviewed here with a focus on widely used metal oxide and carbon nanomaterials. Available rat inhalation and cell culture studies compared to original results suggest that hazard potential is not determined by a single physico-chemical property but instead depends on a combination of material properties. Reactive oxygen species generation, fiber shape, size, solubility and crystalline phase are known indicators of nanomaterials biological impact.

According to these properties the summarized hazard potential decreases in the order multi-walled carbon nanotubes $>>$ CeO_2, ZnO $>$ TiO_2 $>$ functionalized SiO_2 $>$ SiO_2, ZrO_2, carbon black. Enhanced understanding of biophysical properties and cellular effects results in improved testing strategies and enables the selection and production of safe materials. 194 References.

- A Critical Review of Two-Phase Flow in Gas Flow Channels of Proton Exchange Membrane Fuel Cells. By R. Anderson, L. Zhang, Y. Ding, M. Blanco, X. Bi and D. P. Wilkinson, *J. Power Sources*, **195**(15), 4531–4553 (2010).

Abstract

Water management in proton exchange membrane (PEM) fuel cells has received extensive attention due to its key role in fuel cell performance. The unavoidable water, from humidified gas streams and electrochemical reaction, leads to gas–liquid two-phase flow in the flow channels of fuel cells. The presence of two-phase flow increases the complexity in water management in PEM fuel cells, which remains a challenging hurdle in the commercialization of this technology. Unique water emergence from the gas diffusion layer, which is different from conventional gas–liquid two-phase flow where water is introduced from the inlet together with the gas, leads to different gas–liquid flow behaviors, including pressure drop, flow pattern, and liquid holdup along flow field channels. These parameters are critical in flow field design and fuel cell operation and therefore two-phase flow has received increasing attention in recent years.

This review emphasizes gas–liquid two-phase flow in minichannels or microchannels related to PEM fuel cell applications. In situ and ex situ experimental setups have been utilized to visualize and quantify two-phase flow phenomena in terms of flow regime

maps, flow mal-distribution, and pressure-drop measurements. Work should continue to make the results more relevant for operating PEM fuel cells. Numerical simulations have progressed greatly, but conditions relevant to the length scales and time scales experienced by an operating fuel cell have not been realized. Several mitigation strategies exist to deal with two-phase flow, but often at the expense of overall cell performance due to parasitic power losses. Thus, experimentation and simulation must continue to progress in order to develop a full understanding of two-phase flow phenomena so that meaningful mitigation strategies can be implemented. 189 References.

- Ceramic and Polymeric Solid Electrolytes for Lithium-ion Batteries. By J. W. Fergus, *J. Power Sources*, **195**(15), 4554–4569 (2010).

Abstract

Lithium-ion batteries (LIBs) are important for energy storage in a wide variety of applications including consumer electronics, transportation and large-scale energy production. The performance of LIBs depends on the materials used. One critical component is the electrolyte, which is the focus of this paper. In particular, inorganic ceramic and organic polymer solid-electrolyte materials are reviewed. Solid electrolytes provide advantages in terms of simplicity of design and operational safety, but typically have conductivities that are lower than those of organic liquid electrolytes. This paper provides a comparison of the conductivities of solid-electrolyte materials being used or developed for use in LIBs. 230 References.

- Progress in Metal-supported Solid Oxide Fuel Cells: A Review. By M. C. Tucker, *J. Power Sources*, **195**(15), 4570–4582 (2010).

Abstract

Metal-supported solid oxide fuel cells provide significant advantages over conventional ceramic cells, including low materials cost, ruggedness, and tolerance to rapid thermal cycling and redox cycling. Various metal-supported cell designs have been developed, utilizing a range of electrolyte, electrode, and support materials prepared by various fabrication and deposition techniques.

This paper reviews the current state of metal-supported cell technology and suggests opportunities for further development. 70 References.

- Research Progress in High Voltage Spinel $LiNi_{0.5}Mn_{1.5}O_4$ Material. By R. Santhanam and B. Rambabu, *J. Power Sources*, **195**(17), 5442–5451 (2010).

Abstract

Lithium-ion batteries (LIBs) are now considered to be the technology of choice for future hybrid electric and full electric vehicles to address global warming. $LiCoO_2$ has been the most widely used cathode material in commercial lithium-ion batteries. Since $LiCoO_2$ has economic and environmental issues, intensive research has been directed towards the development of alternative low cost, environmentally friendly cathode materials as possible replacement of $LiCoO_2$. Among them, spinel $LiNi_{0.5}Mn_{1.5}O_4$ material is one of the promising and attractive cathode materials for next generation LIBs because of its high voltage (4.7 V), acceptable stability, and good cycling performance.

Research advances in high voltage spinel $LiNi_{0.5}Mn_{1.5}O_4$ are reviewed in this paper. Developments in synthesis, structural characterization, effect of doping, and effect of coating are presented. In addition to conventional synthesis methods, several alternative synthesis methods are also summarized. Apart from battery performance, the application of spinel $LiNi_{0.5}Mn_{1.5}O_4$ material in asymmetric supercapacitors is also discussed. 112 References.

- Silicon Nitride for High-Temperature Applications. By H. Klemm, *J. Amer. Ceram. Soc.*, **93**(6), 1501–1522 (2010).

Abstract

In this review, a summary of the development of high-temperature silicon nitride ($T>1200°C$) is provided. The high-temperature capacity of various advanced commercial silicon nitrides and materials under development was analyzed in comparison with a silicon nitride without sintering additives produced by hot isostatic pressing. Based on this model Si_3N_4 composed of only crystalline Si_3N_4 grains and amorphous silica in the grain boundaries the influence of various sintering additive systems will be evaluated

with focus on the high-temperature potential of the resulting materials. The specific design of the amorphous grain-boundary films is the key factor determining the properties at elevated temperatures. Advanced Si_3N_4 with Lu_2O_3 or Sc_2O_3 as sintering additive are characterized by a superior elevated temperature resistance caused by effective crystallization of the grain-boundary phase. Nearly clean amorphous films between the Si_3N_4 grains comparable to that of Si_3N_4 without sintering additives were found to be the reason of this behavior. Benefit in the long-term stability of Si_3N_4 at elevated temperatures was observed in composites with SiC and $MoSi_2$ caused by a modified oxidation mechanism. The insufficient corrosion stability in hot gas environments at elevated temperatures was found to be the main problem of Si_3N_4 for application in advanced gas turbines.

Progress has been achieved in the development of potential material systems for environmental barrier coatings (EBC) for Si_3N_4; however, the long-term stability of the whole system EBC-base Si_3N_4 has to be subject of comprehensive future studies. Besides the superior high-temperature properties, the whole application process from cost-effective industrial production, reliability and failure probability, industrial handling up to specific conditions during the application have to be focused in order to bring advanced Si_3N_4 currently available to industrial application. 195 References.

- Application of Nanostructured Porous Silicon in the Field of Optics. A review. By V. Torres-Costa and R. J. Martín-Palma, *J. Mater. Sci.*, **45**(11), 2823–2838 (2010).

Abstract

Porous silicon nanostructures have attracted a great deal of interest during the past few years, due to their many remarkable properties. The high-efficiency visible photo- and electro-luminescence of this material opened the way to the development of silicon-based optoelectronic devices fully compatible with standard industry processes. In addition to these luminescent properties, nanostructured porous silicon shows a variety of other interesting properties, including tunable refractive index, low light absorption in the visible, high internal surface, variable surface chemistry, or high chemical reactivity. All these properties, along with its ease of fabrication and the possibility of producing precisely controlled layered structures make this material adequate for its use in a wide range of fields, such as optics, micro- and optoelectronics, chemical sensing or biomedical applications, for example.

This article reviews the applications of nanostructured porous silicon that exploit its unique optical properties, as in the case of light emitting devices, filtered photodetectors, optical sensors, and others. 72 References.

- Materials and Manufacturing Technologies for Solid Oxide Fuel Cells. By N. H. Menzler, F. Tietz, S. Uhlenbruck, H. P. Buchkremer and D. Stöver, *J. Mater. Sci.*, **45** (12), 3109–3135 (2010).

Abstract

This article summarizes recent developments in solid oxide fuel cell (SOFC) research regarding materials, processing and microstructure–property relationships. In the materials section, the various cell and stack materials are briefly described, i.e., electrolytes, electrodes, contact and protective layers, interconnects and sealing materials. The section on processing gives an overview of manufacturing technologies for cells including a view of different substrate materials and designs. Besides the widely used planar cell designs, the technologies for tubular designs are also described. In addition, the technologies are grouped with respect to the support, e.g., metal- or ceramic–metal (cermet anode substrate)-supported SOFCs. Finally, special emphasis is laid on the microstructure of functional layers which primarily govern the power output of the SOFC. 207 References.

- Structural Fabrication and Functional Modulation of Nanoparticle-Polymer Composites. By H. Zhang, J. Han and B. Yang, *Adv. Funct. Mater.*, **20** (10), 1533–1550 (2010).

Abstract

This review summarizes recent progress in the fabrication methodologies and functional modulations of nanoparticle (NP)-polymer composites. On the basis of the techniques of NP synthesis and surface modification, the fabrication methods of nanocomposites

are highlighted; these include surface-initiated polymerization on NPs, in situ formation of NPs in polymer media, and the incorporation through covalent linkages and supramolecular assemblies. In these examples, polymers are foremost hypothesized as inert hosts that stabilize and integrate the functionalities of NPs, thus improving the macroscopic performance of NPs. Furthermore, due to the unique physicochemical properties of polymers, polymer chains are also dynamic under heating, swelling, and stretching. This creates an opportunity for modulating NP functionalities within the preformed nanocomposites, which will undoubtedly promote the developments of optoelectronic devices, optical materials, and intelligent materials. 190 References.

- Design of Multiresponsive Hydrogel Particles and Assemblies. By G. R. Hendrickson, M. H. Smith, A. B. South and L. A. Lyon, *Adv. Funct. Mater.*, **20**(11), 1697–1712 (2010).

Abstract

In the realm of soft nanotechnology, hydrogel micro- and nanoparticles represent a versatile class of responsive materials. Over the last decade, our group has investigated the synthesis and physicochemical properties of a variety of synthetic hydrogel particles. From these efforts, several particle types have emerged with potentially enabling features for biological applications, including nanogels for targeted drug delivery, microlenses for biosensing, and coatings for biomedical devices. For example, core/shell nanogels have been used to encapsulate and deliver small interfering RNA to ovarian cancer cells; nanogels used in this fashion may improve therapeutic outcomes for a variety of macromolecular therapeutics. Microgels arranged as multilayers on implantable biomaterials greatly minimize the host inflammatory response to the material. Furthermore, the triggered release of drugs (i.e., insulin) has been demonstrated from similar assemblies.

The goal of this article is to highlight developments in the design of responsive microgels and nanogels in the context of our recent efforts and in relation to the community that has grown up around this fascinating class of materials. 136 References.

- Stretchable, Large-Area Organic Electronics. By T. Sekitani and T. Someya, *Adv. Mater.*, **22**(20), 2228–2246 (2010).

Abstract

Stretchability will significantly expand the application scope of electronics, particularly large-area electronics-displays, sensors, and actuators. If arbitrary surfaces and movable parts could be covered with stretchable electronics, which is impossible with conventional electronics, new classes of applications are expected to emerge. A large hurdle is manufacturing electrical wiring with high conductivity, high stretchability, and large-area compatibility.

This Review describes stretchable, large-area electronics based on organic field-effect transistors for applications to sensors and displays. First, novel net-shaped organic transistors are employed to realize stretchable, large-area sensor networks that detect distributions of pressure and temperature simultaneously. The whole system is functional even when it is stretched by 25%. In order to further improve stretchability, printable elastic conductors are developed by dispersing single-walled carbon nanotubes (SWNTs) as dopants uniformly in rubbers. Further, the authors describe integration of printable elastic conductors with organic transistors to construct a rubber-like stretchable active matrix for large-area sensor and display applications. Finally, they discuss the future prospects of stretchable, large-area electronics with delineating a picture of the next-generation human/machine interfaces from the aspect of materials science and electronic engineering. 69 References.

- Hydrogen Storage in Metal-Organic Frameworks. By Y. H. Hu and L. Zhang, *Adv. Mater.*, **22**(20), E117–E130 (2010).

Abstract

Metal organic frameworks (MOFs) are highly attractive materials because of their ultra-high surface areas, simple preparation approaches, designable structures, and potential applications. In the past several years, MOFs have attracted worldwide attention in the area of hydrogen energy, particularly for hydrogen storage.

In this review, the recent progress of hydrogen storage in MOFs is presented. The relationships between

hydrogen capacities and structures of MOFs are evaluated, with emphasis on the roles of surface area and pore size. The interaction mechanism between H_2 and MOFs is discussed. The challenges to obtain a high hydrogen capacity at ambient temperature are explored. 118 References.

- Aligned, Ultralong Single-Walled Carbon Nanotubes: From Synthesis, Sorting, to Electronic Devices. By Z. Liu , L. Jiao, Y. Yao, X. Xian and J. Zhang, *Adv. Mater.*, **22**(21), 2285–2310 (2010).

Abstract

Aligned, ultralong single-walled carbon nanotubes (SWNTs) represent attractive building blocks for nanoelectronics. The structural uniformity along their tube axis and well-ordered two-dimensional architectures on wafer surfaces may provide a straightforward platform for fabricating high-performance SWNT-based integrated circuits. On the way towards future nanoelectronic devices, many challenges for such a specific system also exist.

This Review summarizes the recent advances in the synthesis, identification and sorting, transfer printing and manipulation, device fabrication and integration of aligned, ultralong SWNTs in detail together with discussion on their major challenges and opportunities for their practical application. 162 References.

- Chemically Derived Graphene Oxide: Towards Large-Area Thin-Film Electronics and Optoelectronics. By G. Eda and M. Chhowalla, *Adv. Mater.*, **22**(22) 2392–2415 (2010).

Abstract

Chemically derived graphene oxide (GO) possesses a unique set of properties arising from oxygen functional groups that are introduced during chemical exfoliation of graphite. Large-area thin-film deposition of GO, enabled by its solubility in a variety of solvents, offers a route towards GO-based thin-film electronics and optoelectronics. The electrical and optical properties of GO are strongly dependent on its chemical and atomic structure and are tunable over a wide range via chemical engineering.

In this Review, the fundamental structure and properties of GO-based thin films are discussed in relation to their potential applications in electronics and optoelectronics. 270 References.

- Nanostructured Thermoelectrics.
  By P. Pichanusakorn and P. Bandaru, *Mater. Sci. & Engg.*, R **67**(2–4), 19–63 (2010).

Abstract

Thermal to electrical energy conversion, through thermoelectric and thermionic materials, has been proposed to be much more efficient in lower dimensional materials at the nanoscale. In this paper, the authors review the underlying materials physics of nanostructured thermoelectrics which gives rise to such enhanced efficiency. They first describe the basic phenomenology of the contributing terms to the power factor in the thermoelectric figure of merit, i.e., the Seebeck coefficient (S) and the electrical conductivity (σ), which are analyzed through the Boltzmann transport formalism and then thoroughly compared to recent experiments in nanostructures. Additional factors, hitherto not given much consideration, such as carrier scattering time approximations vis-à-vis dimensionality and the density of states (DOS) are also studied. Through such a study, the authors postulate that it is the sheer magnitude and not the specific shape of the DOS that is important in enhancing the thermoelectric power factor. It is clear that most of the understood increase in the figure of merit of nanostructured thermoelectrics has been accomplished through a drastic reduction of the lattice thermal conductivity (κ)—by two orders of magnitude from the bulk values through the introduction of scattering at different length scales. Such a reduction has provided a large impetus for the use of nanostructures and these are reviewed. Also considered are the solid state implementations of thermionic structures, which seem to be converging towards thermoelectric devices and hence can be described by a similar figure of merit. Approaches for energy filtering and further increasing efficiencies are also described. 269 References.

- Glass-Based Seals for Solid Oxide Fuel and Electrolyzer Cells — A Review. By M. K. Mahapatra and K. Lu, *Mater. Sci. & Engg.*, R **67**(5-6), 65–85 (2010).

Abstract

High temperature hermetic seal is essential for utilizing the full potentials of planar solid oxide fuel/electrolyzer cells. A seal glass needs to have excellent thermal and chemical stabilities, mechanical integrity, and sealing ability in stringent oxidizing and reducing environments and for hundreds of thermal cycles. Comprehensive analysis and understanding are needed in the design of a seal glass in order to meet the demanding requirements.

In this review, seal requirements and the advantages of glass-based seals are first discussed. Different glass compositions are reviewed from thermal, chemical, mechanical, and electrical property point of view. Based on these considerations, glass composition design approaches are provided that aid in search of the best seal glass that can offer all the desired properties and stabilities. Required thermal properties such as thermal expansion coefficient, glass transition temperature, and softening temperature have been achieved in several alkaline earth borosilicate glass systems. Interfacial compatibility with other cell components has also been obtained for several alkaline earth borosilicate glass systems. However, long-term thermal and chemical stabilities are yet to be achieved. Among all the glass systems studied, a boron-free $SrO–La_2O_3–Al_2O_3–SiO_2$ seal glass has been specifically discussed because it has met al.,l the thermal and chemical properties along with high thermal and chemical stabilities. For future endeavors, the relationships between seal glass constituents, glass network structures, required thermal, chemical, mechanical, and electrical properties need to be established in order to improve sealing performance while maintaining design flexibility and low fabrication cost. 190 References.

- Surface Analytical Studies of Interfaces in Organic Semiconductor Devices. By Y. Gao, *Mater. Sci. & Engg.*, R **68**(3), 39–87 (2010).

Abstract

Surface and interface analytical studies have generated critical insight of the fundamental processes at interfaces involving organic semiconductors. This article reviews surface analytical studies of interface formation of organic semiconductors with different materials. Metal/organic interface is a focus of both device engineering and basic science, since it is a key factor in nearly all important aspects of device performances, including operation voltages, degradation, and efficiency. Metal–organic interface dipole formation, charge transfer, chemical reaction, energy level alignment, in-diffusion, quenching of luminescence and possible recovery of it, are discussed. The effect of the insertion of ultra-thin interlayers such as LiF and doping by alkali metals are also discussed.

In organic/organic interface, the energy offset between the two dissimilar organic materials is vitally important to efficient device operation of organic light emitting diodes (OLED), as well as charge separation at donor–acceptor interface in organic photovoltaic devices (OPV). The interface energy level alignment, band bending, Debye screening, and charge separation dynamics as observed in surface analytical studies, and the implications to OLED and OPV are discussed. The interfaces of organic semiconductor (OSCs) with other inorganic materials are also important. For organic thin film transistors (OTFT), the electronic properties of the interface formed between the organic and the dielectric strongly influences the current–voltage characteristics, as the electronic activity has been shown to occur primarily at the interface between the dielectric and the organic materials. Also described are the interface formation of OSCs with dielectric materials and with indium-tin-oxide (ITO), a material whose transparency and conductivity make it indispensable for a number of opto-electronic applications and whose electronic properties and energy level alignment with organics have proven dramatically altered by surface treatments. 613 References.

- Advances in the Growth and Characterization of Magnetic, Ferroelectric, and Multiferroic Oxide Thin Films. By L. W. Martin, Y.-H. Chu and R. Ramesh, *Mater. Sci. & Engg.*, R **68**(4–6), 89–133 (2010).

Abstract

The growth and characterization of functional oxide

thin films that are ferroelectric, magnetic, or both at the same time are reviewed.

The evolution of synthesis techniques and how advances in in-situ characterization have enabled significant acceleration in improvements to these materials are described. Methods for enhancing the properties of functional materials or creating entirely new functionality at interfaces are described, including strain engineering and layering control at the atomic-layer level. Emerging applications of these functional oxides such as achieving electrical control of ferromagnetism and the future of these complex functional oxides are discussed. 448 References.

- Perovskite Oxide Nanotubes: Synthesis, Structural Characterization, Properties and Applications. By X. Zhu, Z. Liu and N. Ming, *J. Mater. Chem.*, **20**(20), 4015–4030 (2010).

Abstract

Perovskite oxides exhibit a wide range of functional properties, such as ferroelectricity, piezoelectricity, pyroelectricity, non-linear dielectric behavior, as well as multiferroic property. These properties are indispensable for applications in microelectronic devices. Recent advances in science and technology of perovskite oxides have resulted in the feature sizes of microelectronic devices down-scaling into nanoscale dimensions. At the nanoscale, perovskite oxides display novel physical properties that are different from their bulk and film counterparts. Understanding these size effects of perovskite oxides at the nanoscale is of importance for the developing a new generation of revolutionary electronic nanodevices. Due to these effects being dependent on the structure and finite size, considerable efforts have been made in the controllable synthesis of low-dimensional perovskite nanostructures such as perovskite oxide nanotubes (PONTs). PONTs can not only be used as building blocks for miniaturized microelectronic devices, but also offer fundamental scientific opportunities for investigating the intrinsic size effects of physical properties.

This review article describes the recent progress made in the field of PONTs, which covers their synthesis, structural characterization, properties and applications. The authors begin with a comprehensive survey on the research activities on PONTs, and then focus on their synthesis strategies. Structural characterization and multifunctional properties of the PONTs prepared by the template synthesis are also summarized. Their potential applications in 3D memory devices, nanoscale fluidic control systems, nanoscale power generators and terahertz generators, are discussed. Finally, the authors conclude by providing their perspectives to the future directions of PONTs. 110 References.

- Chemical Routes to Chalcogenide Materials as Thin Films or Particles with Critical Dimensions with the Order of Nanometers. By M. Afzaal, M. A. Malik and P. O'Brien, *J. Mater. Chem.*, **20**(20), 4031–4040 (2010).

Abstract

Chalcogenides, namely compounds containing S, Se and Te, are an important class of semiconducting materials with applications and potential for application in many areas of technology. The availability of materials often depends on the processing methodologies available. The present article focuses on methods from single molecule precursors for binary chalcogenides of the first transition series together with those of zinc or cadmium. 116 References.

- Photoluminescent ZnO Nanoparticles Modified by Polymers. By H.-M. Xiong, *J. Mater. Chem.*, **20**(21), 4251–4262 (2010).

Abstract

Photoluminescent ZnO nanoparticles, due to nontoxicity and cheapness, are promising materials applied in UV laser devices and biological labels. ZnO photoluminescence is usually composed of two parts: UV emission arising from the typical band gap transition and visible emission due to the oxygen vacancies. In order to protect ZnO nanoparticles and improve their optical properties, polymers are mixed with ZnO or modified on ZnO surfaces to produce various nanocomposites. In the meantime, some new luminescent phenomena are found when polymers and ZnO nanoparticles together participate in the luminescent process.

This review focuses on the synthetic methods, structural features and photoluminescent properties of the polymer–ZnO nanocomposites. 72 References.

- Porous Photocatalysts for Advanced Water Purifications. By J. H. Pan, H. Dou, Z. Xiong, C. Xu, J. Ma and X. S. Zhao, *J. Mater. Chem.*, **20**(22), 4512–4528 (2010).

Abstract

Semiconductor-mediated heterogeneous photocatalysis is a promising technology for water purifications without generating harmful by-products. The photocatalyst with designed physicochemical properties is the key in the process. Utilization of particulate photocatalysts will create some technological problems, such as difficulty in recycling and management. Thus, cost-effective methods for mass production of highly active photocatalysts that can be operated in an industrial photoreactor with less energy consumption and harmless subsequent consequences are increasingly attracting research attention. Photocatalysts with controllable morphologies at a wide range of scales shall be taken into account in designing the photocatalyst.

This review article features recent research progress towards the design and preparation of porous photocatalysts with prescribed structural, compositional, and morphological properties suitable for use in a photocatalytic reactor for water treatment via advanced oxidation processes. With a brief introduction of the important features of a porous photocatalyst in industrial reactors, the review highlights various synthetic strategies for fabricating porous photocatalysts with well-defined microscopic morphologies and nano/meso-scopic active nanobuilding blocks. The synthesis–component–structure–property relationship working in photocatalyst design is discussed. Immobilization of photocatalysts on different porous substrates is highlighted. The perspectives of designing photocatalysts for industrial applications are suggested. 256 References.

Conference Report

The 12 th Asian Conference on Solid State Ionics, 2nd–6th, May, 2010, Wuhan, China

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Solid State Ionics is a growing inter-disciplinary branch of science and technology. It is concerned with ionic motion in a wide spectrum of materials covering inorganic solids, ceramics, glasses, polymers, composites and nano-scale materials with applications in solid state devices such as solid state and polymer batteries, fuel cells, electrochromic displays, solar cells and sensors.

The Asian Conference on Solid State Ionics (ACSSI) is the 12th in a series of meetings held every two years since 1988, with the purpose of providing a forum for the presentation and discussion of the latest advanced research from Asia and other countries on solid state ionic materials, devices and related topics. The Chinese Conference on Solid State Ionics (CCSSI), is the 15thbiennial conference organized by the Chinese Society for Solid State Ionics, with the purpose of providing a platform for the presentation and discussion of the latest research results in the field of solid state ionics from China and other countries.

The 12th ACSSI and 15th CCSSI conferences were organized together by Wuhan University of Technology, Wuhan, China during 2nd–6th May 2010 under the conference chairmanship of Prof. Hanxing Liu, Dean of School of Materials Science and Engineering.

On 2nd May, during the opening ceremony, the president of Wuhan University of Technology, Prof. Qingjie Zhang welcomed the delegates from all over the world and emphasized the importance of ACSSI and CCSSI at DongHu Hotel, the conference venue. The vice-president of the Asian Society of Solid State Ionics (ASSSI), Prof.

12th ACSSI Conference Venue, DongHu Hotel, Wuhan, China.

Prof. Qingjie Zhang

Prof. Yoo Han-Ill

Delegates at the opening ceremony

Yoo Han-Ill (S. Korea), the general secretary of Chinese Ceramic Society, Prof. Zhanping Jin, and the chairman of the Chinese Institute of Solid State Ionics, Prof. Zhaoyin Wen also delivered their welcome addresses and expressed their enthusiasm about the twin conferences. They briefly mentioned about the history of the ACSSI and CCSSI, and hoped that the conferences will help to develop mutual friendship and a fruitful exchange of ideas and discussions between scientists for the five days of talks and presentations. Prof. Yoo Han-Ill regretted that the president of ASSSI, Prof. B.V.R. Chowdari, from Singapore could not attend the conference due to unforeseen circumstances.

After the opening ceremony, all the delegates assembled for the group photo. Academician, Prof. Liquan Chen, of the Chinese Academy of Engineering, Beijing, Prof. M. Martin from Germany and Prof. Shu Yamaguchi from Japan gave invited Talks on the topics, “Efforts of solid state ionists for low carbon energy”, “Ionic transport in complex oxides” and “Nanoionics – Present status and future prospect”, respectively. Those plenary talks marked the official start of the conference technical sessions.

The conference received more than 260 abstracts and more than 150 contributed papers to the “Proceedings of the 12*th* Asian Conference on Solid State Ionics – Fundamental Researches and Technological Applications”, which is published by Wuhan University of Technology Press as a book and CD. The proceedings were edited by B.V.R. Chowdari, Hanxing Liu, Wen Chen, Qing Xu and Zhiyong Yu.

Prof. Liquan Chen

Prof. M. Martin

Prof. Shu Yamaguchi

Group Photo.

More then 220 delegates from China, USA, UK, Germany, Poland, Japan, Korea, India, Malaysia, Indonesia, Sri Lanka, Brazil, Russia and Singapore attended the conference. There were 32 invited talks, 62 oral presentations, and 93 poster presentations discussing about the latest research results on Theory, Experimental and Applications in Solid State Ionics field, which improved the communication and co-operation between the delegates from the countries mentioned above. Finally, five posters from China, Japan, Korea and India were awarded the best posters in the conference. Details of the Poster Award winners are listed below. They were given away on the last day of the conference.

The conference organizers arranged a Wuhan City Tour for all the delegates followed by a special dinner on a ship on the famous Yangzi River in China. Besides, all the delegates were also invited to attend two more banquets at Hongyi Hotel and LiYuan Hotel in Wuhan. Special food arrangements on request by Indians, Malaysians, and Indonesians were done to accommodate their taste and habit. All the delegates deeply appreciated and satisfied with the food and the organization of the conference.

On 6^{th} May, the last day of the conference, vice-president of the ASSSI, Prof. Yoo Han-Ill, gave a plenary talk entitled, “Experimental Verification of the Onsager Reciprocity in Flow of Charged Particles in Solids” which was well-received by the audience. He also thanked every participant for their contribution to the success of the conference. Prof. Krok from Poland, presented the details of the forthcoming 18^{th} Solid State Ionics Conference (SSI-18) in July,2011 in Poland. Prof. Kawamura from Japan announced that the 13^{th} ACSSI will be held at Sendai in Japan 2012. Prof. Stefan Adams from Singapore gave details of the forthcoming ICMAT2011 (International Conference on Materials for Advanced Technologies) to be held in Singapore in June–July, 2011.

Best Poster Awards

S. No	Poster No.	Title of the Poster	Authors (Country)
1.	P-I-09	Study of PVP: NH_4Cl polymer electrolyte.	N. Vijaya *et al.*, (India)
2.	P-I-41	Dislocation associated incubational domain formation in lightly gadolinium-doped Ceria.	Zhipeng Li *et al.*, (Japan)
3.	P-I-43	Enhanced lithium ionic conductivity in $LiBH_4$ by anion substitution	R. Miyazaki *et al.*, (Japan)
4.	P-II-26	Nanostructured molybdenum oxides as anode materials for lithium-ion batteries.	Yongsheng Hu *et al.*, (China)
5.	P-II-52	Research on tubular solid oxide fuel cells (SOFC) in SICCAS.	Chunhua Zhao *et al.*, (China)

Forthcoming Conferences

6th International Symposium on Novel Materials and their Synthesis 11–14 October, 2010, Wuhan, China

Yu-Ping Wu

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International Conference on Materials Science and Technology 2010 (ICMST 2010) 19–22 October, 2010, Serpong, Indonesia

The International Conference on Materials Science and Technology 2010 (ICMST 2010) will be held in Serpong, Indonesia, during October 19 to 22, 2010, in conjunction with the Asian Workshop on Solid State Ionics.

The main theme of ICMST 2010 is “Research and Development of Advanced Materials for Better Future”. The conference is organized by the Center for Technology of Nuclear Industry Materials, National Nuclear Energy Agency (BATAN) with the aim to provide International forum for presenting research papers and depth discussion by scientists from Indonesia, Asia and other countries on the state of the art in materials science research. This will be accomplished by the presence of invited world-class speakers for the scientific programme.

There will be Plenary, Key Note, Invited and Oral Talks, along with Poster presentations

Scope

Topics which will be discussed at the Conference include

(i) R&D of Materials Science and Technology,

(i) Fundamental properties of materials and their characterizations
(ii) Materials for specific application in energy-storage; pharmaceutical; biotechnology
(iii) Theoretical modelling
(iv) Fundamental properties of nanomaterials, and their characterizations.

(v) Use of nanotechnology and nanomaterials for commercial purposes

(ii) Nuclear technology for materials research,

(i) Use of neutron scattering for characterization of materials
(ii) Non destructive testing of materials
(iii) Use of nuclear technique for improving materials properties

(iii) Solid State Ionic (Materials for Energy Sources and devices):

(a) Synthesis, and characterization of ionically conducting materials
(b) Ionically transport mechanisms and theoretical modeling
(c) Cathode/anode materials and interfaces
(d) Electronically conducting polymers, polymer devices
(e) Ion conducting biological systems and biomaterials
(f) Application technologies of batteries, fuel cells, sensors, solar cells, supercapacitors, molecular electronic devices.

Website: http://icmst.batan.go.id
Contact person: Dr.rer.nat. Evvy Kartini, Chair of ICMST 2010.
e-mail: icmst@batan.go.id; kartini@batan.go.id

AsiaNANO2010
1–3, November, 2010, Tokyo, Japan

The AsiaNANO2010 (Asian Conference on Nanoscience and Nanotechnology 2010) will be held at Miraikan, Tokyo, Japan, for 1–3 November, 2010.
The main topics:

(1) Nanomaterials
(2) Nanofabrication
(3) Application of nanostructures
(4) Nanocharacterization
(5) Self-organizing systems
(6) Fusion Nano
(7) Post Nano

Important Dates:
Abstract submission deadline (registration required): July 31st, 2010.
Notice of acceptance: August 31st, 2010.
Manuscript submission for conference Proceedings: November, 3rd, 2010

Please check the details of *Second announcement*, List of Invited Speakers, Abstract Submission, Conference Proceedings, Awards, etc., in the conference web site: *http://asianano2010.org*

15th International Metallurgy & Materials Congress (IMMC15), 11–13, November, 2010, Istanbul, Turkey

The 15th International Metallurgy & Materials Congress (IMMC15) is going to be held by UCEAT Chamber of Metallurgical Engineers in Istanbul, Turkey, between 11–13 November, 2010.

Starting from the first congress hold in 1975, this traditional congress together with the trade fair is the largest event of Turkey and the region in this field. The program will be composed of oral and poster sessions covering all aspects of metallurgy, materials science and engineering.

Informative notes: Invited Talks:

- Micro-Nano Scale: Basic Science to Practical Systems and Commercial Applications, Meyya Meyyappan, J Li, C Nguyen, J Lee, NASA Ames Research Center, USA.
- Recent Development of High Mechanical Bio-functional Metallic Biomaterials, Mitsuo Niinomi, T Akahori, M Nakai, H Tsutsumi, Dept. of Biomaterials Science, Institute for Materials Research, Tohoku University, Japan.
- Study of Precipitation in Next Generation HSLA Steels, Peter Hodgson, S Mukherjee, I B Timokhina, Institute for Technology Research and Innovation, Deakin University, Australia.
- Heat Treatment: State-of-the Art, Future Trends, George E. Totten, Dept. of Mechanical Engineering, Texas A&M University, USA.

The following events will also take place simultaneously:

- ANKIROS 2010, 10th International Iron-Steel and Foundry Technology, Machinery and Products Trade Fair
- ANNOFER 2010, 9th International Non-Ferrous Metals Technology, Machinery and Products Trade Fair
- TURKCAST 2010, 4th Foundry Products Trade Fair organised by Hannover-Messe Ankiros Fair Organisation, and
- 5th International Ankiros Foundry Congress organised by Foundrymen's Association of Turkey

For detailed information please visit: http://www.metalurji.org.tr/congress

Chairman of the Organization Committee: Prof. Dr. C. Hakan Gür.

Nineteenth International Symposium on Processing and Fabrication of Advanced Materials (PFAM XIX) Conference January 14–17, 2011, Auckland, New Zealand

The events will include technical sessions, keynote addresses and social networking events.

Abstracts are due by 30th June 2010. Please use the Online Submission System powered by EasyChair to submit abstract. Abstracts are limited to 200 words and should be written in English and uploaded using PDF file.

Website: www.pfam-19.auckland.ac.nz

Conference Chair: Prof. Debes Bhattacharyya
e-mail: d.bhattacharyya@auckland.ac.nz

Conference Secretary: Dr. Richard Lin
e-mail: rj.lin@auckland.ac.nz

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

Nanyang Technological University: www.ntu.edu.sg

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

Institute of Microelectronics (IME): www.ime.a-star.edu.sg

Data Storage Institute: www.dsi.a-star.edu.sg

Institute of Chemical & Engineering Sciences: www.ices.a-star.edu.sg

Institute of High Performance Computing: www.ihpc.a-star.edu.sg

Singapore Institute of Manufacturing Technology: www.SIMTech.a-star.edu.sg

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

MRS-S Membership

Readers are invited to become members of the Materials Research Society of Singapore (MRS-S).

Professional Membership is open to any person engaged in activities associated with materials science, engineering and technology.

Student Membership is open to any bonafide student of a tertiary institution genuinely interested in the practice of materials science, engineering and technology.

Corporate Membership is open to any organisation, government or private, commercial or otherwise, that is in any way engaged in any activities that deal with any aspect of material science, engineering and technology. A Corporate Membership is entitled to nominate two of its employees as its official representatives and to change its nominees from time to time provided the Committee has no objection to any such nomination.

Annual Subscription Fee:
Professional Membership: S$50
Student Membership: S$5
Corporate Membership: S$500

For details and application form, please visit: www.mrs.org.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 last 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

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

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