ICMAT 2005–IUMRS-ICAM 2005 Covered Frontiers of Materials Science, Engineering, and Technology

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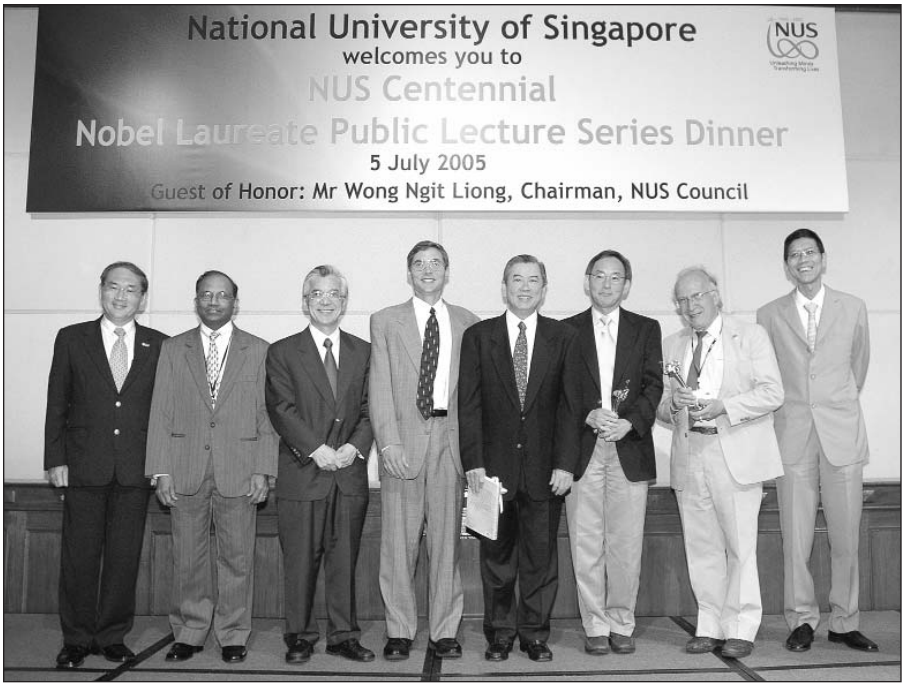
The 3rd International Conference on Materials for Advanced Technologies (ICMAT 2005), combined with the International Union of Materials Research Societies 9th International Conference on Advanced Materials (IUMRS-ICAM 2005), was held July 3–8, 2005, in Singapore. The conference was organized by MRS–Singapore in association with the National University of Singapore (NUS), the Institute of Materials Research and Engineering (IMRE), and Nanyang Technological University (NTU). NUS furthermore celebrated its centennial year at this conference.

The conference hosted plenary lectures delivered by Nobel Laureates Steven Chu (Lawrence Berkeley National Laboratory, USA) on "Miniaturization in Biology," Carl E. Wieman (Univ. of Colorado, USA) on "Dilute Gas BEC: A Very Novel Quantum Material," and Roald Hoffmann (Cornell Univ., USA) on "Waiting to be Made." In honor of the centennial celebration of NUS, the Nobel Laureates also presented lectures for conference participants and the general public, including students from universities, junior colleges, and polytechnic institutes (see sidebar on page 880).

In addition, the conference featured five additional plenary lectures and four theme lectures (see sidebar) as well as 25 technical symposia, a banquet, and a three-day exhibition by 50 vendors and equipment manufacturers. The conference saw 2250 delegates from 56 countries, who presented more than 2000 papers. Singapore, Japan, China, India, Korea, and the United States had the largest contingents. More than 800 posters were presented during three days of the conference. One poster from each symposium was selected for a Best Poster award. Among the theme lectures was an award presentation delivered by Zenji Horita (Kyushu Univ., Fukuoka, Japan), who received the IUMRS Sōmiya Award with Terence G. Langdon (Univ. of Southern California, Los Angeles, USA) for their collaboration on severe plastic deformation as a means of processing materials. Following are highlights of the research presented in the technical symposia.



(From left to right): Liew Ah Choy (director, International Relations Office, National University of Singapore), B.V.R. Chowdari (organizing chair and president of MRS-Singapore), Shih Choon Fong (president, NUS), Carl Wieman (Nobel Laureate in physics, University of Colorado, USA), Wong Ngit Liong (chair, NUS Council), Steven Chu (Nobel Laureate in physics, Lawrence Berkeley National Laboratory, USA), Roald Hoffmann (Nobel Laureate in chemistry, Cornell University, USA), and Tan Chorh Chuan (provost, NUS)

D.F. Williams (editor in chief, *Biomaterials*) opened Symposium A on "Advanced Biomaterials" with the keynote address on the issue of biocompatibility of biomaterials; A. Hoffman (Univ. of Washington, USA), known as the "grandfather of polymeric biomaterials," spoke on new smart polymers for microfluidic devices that could selectively conjugate proteins by simply changing the temperature; and T. Okano (Tokyo Women's Medical Univ., Japan), known as the "champion" of cell sheet technology, gave an outstanding theme lecture and inspired the audience with reports of the many clinical successes, especially in corneal tissue engineering. A. Mikos (co-editor, *Tissue Engineering*) gave further insights into new trends in scaffolds for tissue engineering; and K.W. Leong (Johns Hopkins Univ. School of Medicine, USA) described the vast opportunities in nanofiber technology. Y. Tabata (Kyoto Univ., Japan) addressed growth factors and drug-delivery systems; S. Best (Univ. of Cambridge, UK) addressed bioceramics; and T.C. Lim (NUS, Singapore) described the clinical success of a scaffold platform technology for cranium bone regeneration that has benefited more than 20 patients. The symposium also featured presentations on surface modifications and nanobiotechnology.

In Symposium B, interfacial interactions at the molecular and nanometer scale were discussed. In the area of surface science, S.F. Bent (Stanford Univ., USA), F. Rochet (Univ. Pierre et Marie Curie, France), and J. Yoshinobu (Univ. of Tokyo, Japan) presented their recent studies on interfacial interactions between organic molecules and semiconductor substrates. X. Peng (Univ. of Arkansas, USA) discussed the vital role of ligand monolayer on the surfaces of nanocrystals where interface chemistry meets nanoscience; X.Y. Zhu (Univ. of Minnesota, USA) described recent efforts in the understanding of molecule–metal interfaces in assembly structures; and J. Hrbek (Brookhaven National Laboratory, USA) discussed the manipulation of nanoparticle growth on surfaces. In the area of bionanotechnology, biologically functionalized surfaces were introduced, ranging from the immobilizing technique of protein microarrays to recent developments in surface biochemistry for genomics, proteomics, and personalized medicine.

Symposium C on "Biomedical Devices and Instrumentations" covered frontier areas of materials research, device design, and processing technologies for biomedical applications. It brought together medical device designers, manufacturers, researchers, and representatives from the practicing medical community under one banner to discuss current and future technology needs to promote the biomedical industry around the globe. Most of the scientific presentations stressed the importance of simple, cost-effective, portable/disposable, and reliable microdevices and targeted immediate applications in the life sciences. The journal *Biomedical Microdevices: BioMEMS and Biomedical Nanotechnology* has agreed to publish the papers from this symposium.

Symposium D covered various aspects of magnetic materials and devices. Recent progress in the field of dilute magnetic materials, such as current-induced domain wall switching, were reported. Magnetic characterization techniques at the nanometer scale, ranging from scanning probe microscopy to atomic probe and transmission electron microscopy, were discussed. The talks on novel magnetic materials focused on magnetism of carbon and extremely soft magnetic alloys.

Frontier topics of research in various aspects of mechanical behavior of nano- and microscale systems and advanced materials were explored in Symposium E. Presentations covered issues related to advanced materials such as single-crystal silicon, metallic alloys, carbon nanotubes, polymeric composites, thin films or multilayers, microelectronic materials such as lead-free solder materials, metallic glass, micro- and nanoelectromechanical systems, and bio- and nanostructured materials. In mechanical aspects, the topics of contact mechanics, finite element simulation, molecular dynamics simulation, fracture and deformation, fatigue, viscoelasticity, and the strength of nanostructured materials were addressed. Recent developments and applications of instrumented indentation to various industrial areas were also discussed. Applications of carbon nanotubes were also presented. Papers will be published as a special issue of *Materials Science and Engineering A*.

Symposium F on "Nano-Optics and Microsystems" covered a large and diverse field of key technologies from advanced microelectromechanical system (MEMS) technologies, nanophotonic-bandgap integrated circuits, and biophotonic medical devices to bio-MEMS. Highlights of the invited talks included molecular/cellular bionanotechnology for future molecular medicine, multifunctional microsystems in plastics, very high-aspect-ratio micro- and nanostructures, and lab-on-a-chip microfluidic systems for DNA/RNA extraction. Notably, invited talks on the challenges facing MEMS commercialization and rf MEMS without moving parts were well-received by the participants and provoked much discussion, since the marketability of MEMS products is one of the ultimate aims and rf MEMS without moving parts were unthinkable years ago. The symposium also drew a huge following of participants in technical sessions that hosted advanced topics such as microfluidic chips for protein arrays and malaria diagnosis, scanning probe microscopy probes using NEMS (nanoelectromechanical systems) technology and high-aspect-ratio through-wafer copper vertical interconnects for MEMS packaging. Selected papers of this symposium will be published in a special journal issue of *Sensors and Actuators A: Physical*.

Presentations in Symposium G on "Nanodevices and Nanofabrication" included electronic devices on the nano- and molecular scales, nanomechanics and NEMS, synthesis and characterization of nanostructures, fabrication technologies for nanodevices and nanostructures, manipulation and aligning processes at nanometer/molecular scales, quantum phenomena, and modeling of nanodevices and nanostructures. Papers presented at the symposium will be published as a special issue of the *International Journal of Nanoscience*.

The theme of Symposium H on "Si Microelectronics: Processing to Packaging" reflected major areas of research in the fields of microelectronics ranging from nanodevices to nanosystems packaging. D.L. Kwong (Inst. of Microelectronics, Singapore) gave the keynote address, followed by presentations on nanodevices and complementary metal oxide semiconductor processes, Cu interconnect materials and processes, and advanced packaging technologies that would play a crucial role in the realization of the requirements set forth by the International Technology Roadmap for Semiconductors (ITRS).

The nanodevices and materials fields witnessed excellent presentations in the areas of materials for sub-90-nm node devices, Si/SiGe on insulator technologies, strained Si, high-dielectric-constant materials and processes as well as novel nanoscale devices. Presentations on Cu interconnect technologies focused on Cu plating processes, low-κ dielectric materials and integration, barrier materials, adhesion properties, surface cleaning methodologies, electromigration, dielectric breakdown, and related reliability considerations. The packaging sessions covered topics ranging from wafer-level packaging, Cu wire bonding, Au wire bonding and reliability phenomena, and electromigration in solder joints, to fatigue, creep, mechanical shock and vibration phenomena in solder joints, and relevant aspects of optoelectronics packaging. Selected papers presented at this symposium will be published as a special issue of *Thin Solid Films*.

A highlight of Symposium K on current research and development efforts in SiC and related materials was the report of a bulk crystal growth technique involving repeated *a*-face growth followed by *c*-face growth to produce wafers with a dislocation density of <75 cm^{-2}. This suggests that the prospect for obtaining dislocation-free 4H-SiC wafers may not be too far in the future. Other highlights included presentations on a high-temperature chemical vapor deposition (CVD) technique that could produce 2–3 in. epitaxial 4H-SiC wafers with micropipe densities of <0.5 cm^{-2} and the production of free-standing 3C-SiC wafers grown on undulant Si wafers designed to reduce stacking faults and eliminate antiphase boundaries. The symposium also saw an informative discussion of defect levels at both oxide–SiC interfaces and in bulk SiC to explain the electronic properties of SiO_2-SiC structure, semi-insulating and degenerately doped 4H-SiC.

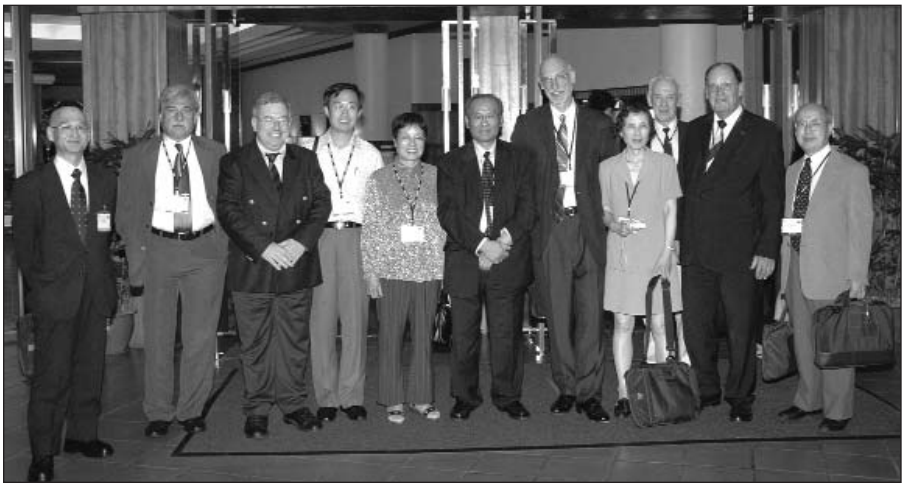
Symposium M on "Photonic Materials and Devices" covered a broad range of materials including III–V and dilute nitride semiconductors, quantum dots and nanocrystals, oxides and silicon, polymers, and organics. J.H. Marsh (Intense Photonics, UK) spoke on the use of quantum-well intermixing (QWI) for passivating the facets required to improve the reliability of high-power laser diode arrays. One application is in digital printing. O. Acher (CEA Le Ripault, France) described significant advances in laser cutting of paper for desktop applications, using a 1 W laser diode and a specially formulated ink that absorbs in the near-infrared. QWI has also been extended to modify selectively the properties of quantum dot (QD) materials. C. Jagadish (Australian National University) discussed advances in growing QDs on pre-patterned substrates for integrated optoelectronics. M. Hopkinson (Sheffield Univ., UK) discussed the use of a unique molecular-beam epitaxy technique to grow dot-in-well (DWELL) structure to realize InAs/InGaAs quantum dot lasers at 1310 nm with a low threshold current density of 17 A/cm^{-2} and an output power as high as 100 mW.

C. Tu (University of Calif., San Diego) presented a detailed material study of dilute nitride III–V compound semiconductors, which have garnered much recent interest because a small amount of nitrogen can result in a large change in bandgap and band structure. In particular, incorporating 0.5% nitrogen in GaP results in a change in the band structure from indirect to direct, making it possible to fabricate a red LED on a transparent GaP substrate. On the other hand, GaInNP grown on GaAs has a very small conduction band offset; thus, GaInNP doped with Si could be an ideal emitter and collector material for GaAs-based *n-p-n* heterojunction bipolar transistors (HBTs).

Epitaxy of III–V photonics on silicon can be used to create a platform capable not only of higher electron and hole mobilities in one material, but also of integrating optical devices to increase functionality and improve material performance. This heterogeneous integration was the subject discussed by E. Fitzgerald (Massachusetts Institute of Technology, USA) and S. Ringel (Ohio State Univ., USA). Fitzgerald presented the materials challenges and innovations achieved to bring III–V materials and Si together on a common substrate to achieve a Si-chip that can support electrical and optical interconnects. Ringel discussed the growth of GaAs on Si using step-graded SiGe interlayers to accommodate the 4% mismatch in lattice constants between GaAs and Si. Advances in photovoltaics are also enabled by the introduction of metamorphic multijunction solar cells. Ringel's group also announced its room-temperature electrically pumped red laser diodes grown on Si.

The field of organic electronics and light-emitting diodes (LEDs) also received significant attention. Th. Birendra Singh and colleagues at Johannes Kepler University in Austria reported on the interfacial effects of trapped charges at the polymeric dielectric–organic semiconductor interface in organic field-effect transistors (OFETs). They demonstrated a fullerene-based *n*-channel OFET exhibiting an electron mobility of 2.5 cm^2/Vs with an on/off ratio in excess of 10^5, as well as a photoactive OFET using a donor–acceptor blend, that is, conjugated polymer/fullerene solid-state mixtures, showing a very high ratio of photocurrent to dark current.

In Symposium N on "ZnO and Related Materials," M. Kawasaki (Tohoku Univ., Japan) gave an invited talk on *p*-type doping and LEDs based on ZnO. His group announced its ZnO homojunction LED with ultraviolet emission using a repeated temperature modulation technique. This novel technique may lead to ZnO-based UV lasers in the near future. Ferromagnetism in transition-metal-doped ZnO remained controversial. K.V. Rao (Royal Inst. of Technology, Sweden) reported a novel Cu-doped ZnO system that exhibited ferromagnetism with a Curie temperature (T_C) above 450°C. Such a phenomenon observed in ZnO:Cu, which contains no magnetic transition elements, is unusual. The proceedings of the symposium will be published as a special issue of the *Journal of Crystal Growth*.



(From left to right): Representatives of some of the adhering bodies of the International Union of Materials Research Societies: Hiroshi Yamamoto (MRS-Japan), H.-U. Habermeier (European-MRS), Gabriel M. Crean (European-MRS/IUMRS), Guoqing Zhang (Chinese-MRS/IUMRS), Mrs. Zhou Lian, Zhou Lian (Chinese-MRS/IUMRS), Robert J. Nemanich (MRS/IUMRS), Ya-Fang Han (Chinese-MRS), John E. Baglin (MRS/IUMRS), Peter A. Glasow (European-MRS/IUMRS), and Masahiro Yoshimura (MRS-Japan)

The importance of alternative energy sources and the so-called hydrogen economy was evident in Symposium P on "Materials for Rechargeable Batteries, Hydrogen Storage and Fuel Cells" as the level of participation necessitated parallel sessions, PA and PB. Lithium-ion batteries (LIBs) received great emphasis in Session PA. Recent developments in understanding the behavior of second-generation, positive electrode (cathode) materials such as $Li(Ni_xMn_xCo_{1-2x})O_2$ ($0 < x \leq 0.5$), modified $LiMn_2O_4$, and $LiFePO_4$ were discussed. Aspects of negative electrode materials including graphite, thin-film silicon, metal nitrides, phosphides, antimonides, and silicides were presented. In addition to recent advances in liquid electrolytes for use in LIBs, considerable attention was given to the Li-ion solid electrolytes based on crystalline, amorphous, and glass ceramics. The highlights were the description of fabrication and performance testing of all-solid bulk and micro-LIBs for a variety of applications including smart cards.

Session PB focused on hydrogen-energy-related technologies, with emphasis given to hydrogen storage and fuel cells. The technical challenges in the utilization of hydrogen-based energy, especially in terms of the development of novel solid-state hydrogen storage materials and higher-operating-temperature proton-exchange-membrane fuel cells (PEMFCs) were addressed.

Meta-materials or left-handed materials—which are composite structures made of metallic inclusions properly arranged in space in order to achieve negative values of permeability and permittivity—featured strongly as a hot topic of research interest in Symposium R on "Electromagnetic Materials," since this class of materials exhibits novel and unusual electromagnetic properties that could serve in a range of possible future applications. Other topics that generated great interest among participants were microwave magnetic materials, electronically tunable dielectric materials, and the up and coming area of nanocomposites.

In Symposium S on "Science and Technology of Hybrid Materials," T. Tsakalakos (Rutgers Univ., USA) delivered an invited talk on multifunctional hybrid materials for biomedical applications, illustrating the promising potential and challenges of this field.

F.F. Lange (University of Calif., Santa Barbara) gave an invited talk on poly (dimethylsiloxane) channel stamping/patterning films and ceramics. L. Ren (Xiamen Univ., China) discussed bioactive gelatin–siloxane hybrids as a tissue engineering scaffold for osteoblast growth and differentiated function. Researchers also discussed the current state of the art of hybrid materials. The proceedings of Symposium S will be published in *Solid State Phenomena*.

Presentations in Symposium T on "Novel Porous Materials for Emerging Applications" emphasized the cutting edge of the science and technology of fabricating novel organic, inorganic, and organic–inorganic hybrid porous materials with hierarchical nanoporous architectures, tailoring pore sizes and surface functionalities for matching the requirements of emerging applications. Discussions focused on new design-synthesis strategies for making functional porous materials with prescribed structural, chemical, and morphological properties for applications in energy storage (e.g., hydrogen storage, supercapacitors, fuel cells, and rechargeable batteries), bioengineering (e.g., drug delivery, immobilization of biocatalysts, and tissue engineering), photonics and electronics, and nanotechnology. Porous materials of various compositions such as silicate, organosilica, silicon, alumina, metal, metal oxide, carbon, polymer, and metal-organic frameworks (MOF) as powders, monoliths, thin films, membranes, and nanoparticles were covered. The papers presented in the symposium will be published in a special issue of the *Journal of Materials Chemistry* and the *Journal of Porous Materials*.

Symposium U was the "13th Annual POLYCHAR World Forum on Advanced Materials" (see Web site www.unt.edu/POLYCHAR). In his invited talk, R. Hoffmann (Cornell Univ., USA) discussed the compartmentalization of materials science. Among other materials, he and his team work on carbides. He mentioned that many ceramists work on traditional ceramics, cements, and concretes, and most of them avoid carbides since the latter form chains and networks. Polymer scientists—who have the tools to deal with chains and networks—also stay away from studying carbides, believing these are inorganic non-polymeric materials. Many relevant topics on advanced materials were also discussed.

The POLYCHAR-13 Prize Committee awarded, among others, the following prizes: the Paul J. Flory Polymer Research Award (*ex aequo*) to Jung-Il Jin, Univ. of Korea, Seoul, and R.P. Singh, Univ. of Lucknow, India; the Carl Klason Award for a Young Investigator to Dhanjay Jhurry, Univ. of Mauritius; and the Bruce Hartmann Award for the Best Student Paper to Ayping Yang, Univ. of Tokyo, Japan, and Shandong Univ., China, for two papers, a poster and an oral presentation.

Recent developments in the preparation, processing, characterization, and applications of polymer nanostructured materials were highlighted in Symposium V. Invited lectures were given by R. Vaia (U.S. Air Force Mater. Res. Lab.) on polymer carbon nanotube composites, W. Knoll (Max Planck Inst. for Polymer Research, Germany) on functional nanoscopic hybrid architectures, J. Vancso (Univ. of Twente, the Netherlands) on chemistry and template fabrication on the nanoscale, D.G.. Kurth (Max Planck Inst. for Colloids and Interfaces, Germany) on functional materials based on metallo-supramolecular modules, D.H. Kim (Max Planck Inst. for Colloids and Interfaces, Germany) on nanostructured materials templated by thin films of block copolymers, and W. Jingshen (Hong Kong Univ. of Science and Technology, China) on polypropylene/$CaCO_3$ nanocomposites. Selected papers will be published in the *Journal of Nanoscience and Nanotechnology*.

Symposium W on "Advanced Materials and Polymers for Defense and Aerospace Applications" attracted the participation of delegates from institutions across the globe—ranging from the armed forces and defense research laboratories in the United States and contractors in Europe to representatives from institutions in India, China, and Singapore. Sponsored by the U.S. Office of Naval Research (ONR) and the Asian Office of Aerospace Research and Development (AOARD-Tokyo), the symposium was filled with excellent keynote and invited lectures on the state of the art in materials research over a wide spectrum of areas. A common theme in many of the presentations was the realization that composite and hybrid systems—at scales ranging from macro to nano—would be the way of the future, providing advantages over many currently used technologies. The pervasiveness of nanotechnology was evident from the number of speakers who specialized in this area. Overall, the presentations sparked animated discussions among members of the audience. The keynote speakers presented synopses of the materials of the future in the context of evolving and future defense/security requirements. B. Rath (Naval Res. Lab., USA) spoke on defense materials for the

ICMAT 2005–IUMRS-ICAM 2005 Special Lectures

Plenary Lectures

- Subra Suresh (Massachusetts Institute of Technology, USA) on "Materials Science Approaches for Cell Biology and Human Disease State"
- C.N.R. Rao (Jawaharlal Nehru Centre for Advanced Scientific Research, India) on "Chemical Routes to Nanomaterials"
- Bernard Raveau (ENSICAEN, France) on "The Future of Oxides as Functional Materials"
- Masuo Aizawa (Tokyo Inst. of Technology, Japan) on "Bio-Nanotechnology/Nano-Biotechnology Challenges for Intelligent Materials and Systems"
- Chenming Calvin Hu (Univ. of Calif., Berkeley, USA) on "The Roles of New Materials in Future CMOS Technology"

Theme Lectures

- Paul C.W. Chu (Hong Kong Univ. of Sci. & Technology, China) on "What Does Nanotechnology have Any Thing to Do with High-Temperature Superconductivity Science and Technology?"
- Denis Fichou (CEA–Saclay, France) on "Building-Up Supramolecular Self-Assemblies on Surfaces: Towards Molecular Nanoelectronics"
- Teruo Okano (Tokyo Women's Medical Univ., Japan) on "Cell Sheet Technology—A New Revolutionary Tool for Tissue Engineering"
- Zenji Horita (Kyushu Univ., Fukuoka, Japan), IUMRS Sōmiya Award lecture

Nobel Laureate Public Lectures
(National University of Singapore Cultural Center)

- Steven Chu (Lawrence Berkeley National Laboratory, USA) on "Molecular Biology and Nanotechnology"
- Carl E. Wieman (Univ. of Colorado, USA) on "Bose–Einstein Condensation: Quantum Weirdness at the Lowest Temperature in the Universe"
- Roald Hoffmann (Cornell Univ., USA) on "Chemistry's Essential Tension: The Same and Not The Same"

future; S. Sivaram (Natl. Chem. Lab., India) highlighted the importance of organic–inorganic hybrids; and H. Carlson and C. Lee, both from the Air Force Office of Scientific Research, USA, presented overviews of the research programs and research on polymeric materials, respectively, at their institution.

Symposium X, the "Third Vacuum & Surface Science Conference of Asia and Australia, VASSCAA-3," was organized to create a forum in Asia and Australia to discuss vacuum, surface, and related sciences, techniques, and applications. The conference was endorsed by the International Union for Vacuum Science, Technique, and Application (IUVSTA). The keynote and invited talks highlighted the latest results in surface, interface, and nanoscale science. E.W. Plummer (Univ. of Tennessee, USA) presented the novel surface phases of correlated electron materials, and K.H. Ploog (Paul Drude Inst., Germany) showed the latest results of *in situ* studies of epitaxial growth by synchrotron x-ray diffraction. S. Rusponi (EPFL, Switzerland) talked about magnetism at the nanoscale, and Z.Q. Qiu (University of Calif., Berkeley, USA) explained the quantum size effect in ultrathin films grown on ferromagnetic substrates. E.G. Wang (Chinese Acad. of Sci., China) addressed adatom diffusion in nanoscale growth, and S.G. Louie (Univ. of Calif., Berkeley and Lawrence Berkeley Natl. Lab., USA) discussed the theory and computation of optical, transport, and mechanical properties of nanostructures.

Symposium Y on "Optical Spectroscopic Techniques" covered a wide range of frontier scientific research and advanced technologies that utilize spectroscopic characterizations. The electronic properties of semiconductor quantum structures were reviewed. These two-, one-, and zero-dimensional structures are vitally important to optoelectronic, photonic, and biological applications. The use of optical spectroscopic methods as noninvasive diagnostic techniques were presented as well as probing molecular structures using femtosecond time-resolved spectroscopy. Near-field scanning optical microscopy that combines chemical-specific information with nanometer spatial resolution, surface-enhanced Raman spectroscopy using noble and rare-earth metal nanoparticles that allows single-molecule detection, and the latest developments in optical instrumentation were among the topics discussed. The presented papers will be published in a special on-line conference issue of the *Journal of Physics: Condensed Matter*.

Symposium Z on "Education in Materials Science, Engineering and Technology" featured dynamic and innovative programs in materials education at all levels and included in-depth discussions of the many challenges in sustaining effective programs to meet the fast-changing needs of the global community. In breakout groups on the final day, highlights for the future were discussed in the categories of "Global Perspectives," "E-Resources for the Future," "Keeping Programs Current and Compelling," and "Effective Outreach." One recurring topic was the question of how to effectively handle the exciting but relentless evolution of new topics such as biomaterials, green processing, nanotechnology, and soft materials within the academic structure and time constraints. Following are key questions that were addressed during the conference: Are our programs directed toward graduates headed for research careers, or industrial careers? Do we aim to develop science comprehension/literacy in the nontechnical population? Do we focus on preparing the "Renaissance engineer" (the Harvard view, impressively articulated by V. Narayanamurti of Harvard Univ., USA)? Should academic degree programs extend for enough years to accommodate the new topics? Should there be a new emphasis on "integrated science" curricula (as strongly advocated in the presentation by C.N.R. Rao of the Jawaharlal Nehru Centre for Advanced Scientific Research, India)? The opinions expressed by other participants on these and a variety of other key topics will be reviewed in a "Forum Report," to be published as part of the complete symposium proceedings in a special issue of the *Journal of Materials Education*.

Organization of the conference was made possible with generous sponsorship from NUS, IMRE, NTU, Singapore Agency for Science, Technology, and Research (A*STAR), Singapore Defence Science and Technology Agency (DSTA), and the French Embassy in Singapore.

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