



Meeting Scene...

Presented by the Materials Research Society (MRS)
and the European Materials Research Society (E-MRS)

2011 E-MRS Spring Meeting
MRS/E-MRS Bilateral Conference on Energy

A Publication of the
Materials Research Society
Advancing materials. Improving the quality of life.

May 9-13, 2011
Nice, France



[MEETING DAYS 3 and 4, Wednesday and Thursday, May 11 and 12](#)



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Wednesday and Thursday were the busiest days of all at the [E-MRS 2011 Spring Meeting](#) in Nice, France. Meeting attendees were rewarded with three great Plenary Talks, the inaugural EU-40 Materials Prize Lecture, the inaugural Kavli Foundation Lecture at an E-MRS Meeting, another Key Lecture of the [E-MRS/MRS Bilateral Conference on Energy](#), and a Social Reception with awards given to outstanding young scientists, followed by music, drinks, and dancing. Who can possibly look at the the following photo showing researchers in a sea of hats and say that scientists aren't fun?



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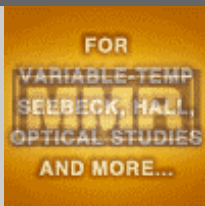
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■ Plenary Talks

Sustainable Development of Human Society
Yuan T. Lee, University of California, Berkeley



In a talk that began with dire visions of the past and present, and ended with a vision of hope for the future, Nobel Prize Winner Yuan T. Lee of the University of California, Berkeley, reviewed the world's energy history and concluded that "it is time for us to wake up and accede to the fact that our world is overdeveloped." But instead of recommending that we retreat, he proposed alternative ways of development that would be sustainable.

Before the industrial revolution started approximately 250 years ago, Lee said, everything we had came from sunshine, including energy. Since that time, almost all energy has come from underground. A world that produced 90.7 percent of its energy from burning wood in 1850 morphed into one that produced 90.4% of its energy from fossil fuels in 1930. The accompanying growth of the human race to the current a population of 6.8 billion people has had a great negative impact on the world's temperature and biodiversity, and has led to an enormous increase in the amount of flooding worldwide. The recent international effort to limit carbon dioxide emissions in order to prevent the world's average

temperature from climbing more than 2°C above the average temperature of the pre-industrial era has fallen short. The restrictions negotiated in Copenhagen exceed the estimated amount of carbon dioxide required to prevent this > 2°C temperature increase by 5 billion tons.

Turning to solutions, Lee said, "the first, and arguably the most important requirement, is that American and European models of development are not to be followed." He suggested that we must re-establish the sun's central role in powering the earth, and restore the planet's ability to absorb carbon dioxide. Materials science can play a major role here, but only if we succeed in educating the next generation of materials scientists to pick up where we leave off. Another priority, according to Lee, is to reorient the development of science and technology for the benefit of the community. This means designing cities along rational lines, so that most things we need are within walking distance of our homes. We must also tap into the diverse cultures and traditions of the people of this planet to learn more sustainable ways of living. Finally, Lee called for a movement from international to global science. "The nation state is still the major source of science funding," he said, "and there is much international competition. But nature does not know these boundaries." To remedy this, Lee proposed the establishment of a global science organization that brings together the best minds in the sciences and humanities to produce an independent, global science agenda. This organization should be funded by 1% of global research and development funds. The International Council for Science (ICSU), with 121 national member

organizations representing 142 countries, might just be the seed for this global science organization, according to Lee.

Light, Metal, and Molecules

Thomas Ebbesen, University of Strasbourg



In the second Plenary Lecture, Thomas Ebbesen of the University of Strasbourg spoke passionately about the interactions of light and metals, beginning with surface plasmons that trap light on a metal surface by interaction with the metal's free electrons. Experimentally, he has spent much of his time making very tiny holes in metals and seeing how they interact with light. From these experiments he has demonstrated that light transmission through a hole can be greater than unity; that is, the amount of light that passes through a hole can be greater than the amount of light falling directly on the hole. Surface interactions "gather in" light nearby, but outside of, the hole to achieve this. Also, the periodicity of hole patterns in metals can change the color of transmitted light from a single source of incident light.

Ebbesen elucidated the major role that interactions of light and metals play in some of our favorite devices, such as PlayStations and digital cameras. A PlayStation has four CPUs working in parallel, and each requires a light sensor for synchronization. The solution is a plasmonic antenna on a tiny piece of Si, which qualifies as the fastest Si photodetector known to date. Overlapping surface plasmons have also been used as color filter arrays in digital cameras. The plasmons, arranged in the form of three overlapping bullseyes, act as three gratings extracting a different color of light from the same area.

On a more fundamental scientific level, Ebbesen discussed the difference between weak and strong coupling of molecules and surface plasmons, confessing that "strong coupling is what I'm most excited about." In weak coupling, the material keeps its surface properties, and plasmons can enhance the absorption of visible light by a factor of ten. In strong coupling, the surface of the material is altered by Rabi splitting into new states called "hybrid polaritons," which can result in ultra-strong coupling in a metal cavity. To date, Ebbesen has achieved a record 700 meV splitting energy at room temperature. He proposes that chemical reaction kinetics might be altered in a strong coupling regime when new states appear in the cavity where a reaction is taking place.

Ebbesen concluded his lecture by stunning the audience with the proclamation that, in reality, no light is needed for these coupling processes: "The observed coupling involves vacuum (electromagnetic) fluctuations, so no light is necessary," he said. "Just harvest the vacuum fluctuations!"

Semiconductor Nanowires: A Platform for Nanoscience and Nanotechnology

Charles Lieber, Harvard University

In what might be the first-ever use of the phrase "cyborg tissue" in an E-MRS Plenary Lecture, Charles Lieber of Harvard University vastly expanded the unsuspecting audience's understanding of the virtually unlimited possibilities of semiconductor nanowires in a single instant.

But that came at the end of the presentation. It started out on a more prosaic note, with Lieber defining nanowire technology as one based on well defined, tunable building blocks that could be



used in the bottom-up assembly of hybrid, multicomponent functional nanomaterials in novel environments. He reviewed the key advances in nanowire structures over the years—from straight, single material nanowires to coaxial ones made of two materials, and from branching nanowires to kinked structures resulting from topological changes. His research team’s approach to photovoltaics is to focus on single nanowires to define the limits of what can be achieved with novel nanostructures. They synthesized highly crystalline nanowires to improve the open cell voltage (V_{oc}), which is one key to increased efficiency of photovoltaics, and achieved a V_{oc} measurement of approximately 0.5 V in a 200-nm-diameter nanowire for the first time. Furthermore, their measurements of the absolute photocurrent in a device of known structure showed nanostructure-tunable resonances and external quantum efficiencies greater than 1,

which could lead to improved efficiencies in ultrathin photovoltaics. In another experiment, assembly of five-nanowire-high vertical stacks demonstrated a scalable increase in J_{sc} .

But Lieber’s true interest seems to be in nano-electronic/biological interfaces. Nanowire dimensions are on the same scale as nerve synapses (sub-100-nm) and ion channels in cells (several nm), making nanoelectronic transducers perfect for interfacing with the brain and other tissues. To date, his group has demonstrated a bio-nanowire FET device capable of detecting the binding and unbinding of a single molecule; a system capable of detecting disease-marker proteins in a multiplexed, real-time manner; and selective, real-time detection of a single virus particle. Remarkably, they have also developed a nanowire-biological FET capable of a 100-billion-fold increase in the discrimination of components of blood serum.

Now Lieber and his group are on the verge of being able to record the output of chemical and biological signals of a single cell using high density nanowire FET arrays with sub-micron spatial resolution and 10 microsecond temporal resolution. Not satisfied with recording signals leaving a cell, they are also synthesizing nano-FETs with tip diameters < 50 nm and kinked 3D nanowire probes for intracellular signal recording. At this level, Lieber said that they are creating new materials that might be called “cyborg tissue.” “We are trying to blur the distinction,” Lieber concluded, “between electronic devices, living cells, and tissues.”

■ EU-40 Materials Prize

Carbon Nanotechnology

Andrea C. Ferrari, Cambridge University

The final plenary talk in this special session was given by Andrea C. Ferrari of Cambridge University. Ferrari is the recipient of the first EU-40 Materials Prize, awarded to young researchers. Ferrari, who is 38, has already published over 180 papers and has over ~10,000 citations. His fast-paced talk titled “Carbon Nanotechnology” described work by him and collaborators on various forms of carbon over his short career span. He started by describing commercial applications of diamond-like carbon (DLC) films, including as a protective overcoat for vascular stents, razor blades, PET bottles and hard drives. DLC has been successfully used in MEMS devices as well. Ferrari described the use of field emission displays using carbon film triodes.



Turning to carbon nanotubes (CNTs), he discussed how CNTs can now be produced in large quantities commercially. Patterning is possible using catalytic CNTs as well as precise control of CNT growth including arrays. CNTs can be used for field emission and Ferrari described the development of ultrafast mode locked lasers using this material. Wide spectral coverage is possible using different diameters of the CNTs and the laser can be tuned. Ferrari next discussed graphene, which has received considerable recent attention. Because of its superlative properties, a wide range of applications is envisaged for graphene. He described ways to form graphene on a large industrial scale by liquid phase exfoliation of graphite. In fact, this method can be used to exfoliate any layered compound such as boron nitride and

metal chalcogenides. Graphene is being used to form transparent conductors to replace ITO to form touch screens and electro-tactile displays, and Nokia for one is working on such commercial applications that are expected to reach the consumer market soon. The potential of graphene thus appears to be limitless.

■ Kavli Award Talk: Third Key Lecture in Bilateral Energy Conference

Perovskite-type Materials for Future Energy Technologies

Anke Weidenkaff, EMPA and the University of Bern



Anke Weidenkaff of EMPA and the University of Bern was chosen to receive the inaugural Kavli Foundation Lecture Award at an E-MRS Meeting. The Kavli Foundation supports scientific research, honors scientific achievement, and promotes public understanding of scientists and their work. Its particular focus areas include astrophysics, nanoscience, and neuroscience.

Weidenkaff is enthusiastic about the prospects of thermoelectric power to convert the heat of the sun directly into electricity, but she faces many challenges, including energy density, energy storage,

and scarcity of the elements used in the technology. Her research team is approaching the challenges by investigating the chemical stability of materials at the high temperatures needed to achieve high efficiencies; exploring the means to achieve large thermopower in good conditions through correlated electronic systems; and achieving low thermal conductivity by hindering phonon transport.

The materials used in the solar concentrator she is experimenting with must be stable in the open air at high temperatures, and be able to withstand high temperature gradients. Weidenkaff is investigating very stable perovskite-type oxides with their strongly correlated electrons for this application. Her team is synthesizing a wide variety of perovskite oxides in powder and thin film forms by “soft chemistry” (micelles, sol gel, etc.) methods. Strontium titanate with the formula $\text{SrTi}_{1-x}\text{Nb}_x\text{O}_{3+\delta}$ proved to be too electrically resistive, but they discovered that exchanging oxygen with nitrogen increased the conductivity; the same method was also used for europium titanate. To reduce the thermal conductivity of perovskite oxides, they increased the phonon scattering at grain boundaries by reducing the particle size. $\text{PrCo}_{0.5}\text{Ni}_{0.5}\text{O}_3$ made using this approach proved to be temperature stable to 1000°C. They also experimented with twin domains, and substituted heavy atoms like bismuth in perovskites such as $\text{Ca}_{3-x}\text{Bi}_x\text{Co}_4\text{O}_{9+\delta}$ to increase phonon scattering.

Besides materials for thermoelectric power devices, Weidenkaff is also interested in solar production of hydrogen by photoelectrochemistry, using perovskite oxides as photocatalysts. They found that by nitriding $\text{LaTiO}_{3.5}$ to LaTiO_2N , the catalyst captured more sunlight by shifting the absorption edge into the visible light range. Nitridation also changed the bandgap in perovskite-type oxy-nitride niobates such as $\text{SrTi}_{1-x}\text{Nb}_x(\text{O},\text{N})_3$, which again increased visible light absorption.



■ Bilateral Energy Conference Technical Talks (Symposia Q to ZZ)

Symposium U. Nano-energy: Energy Transduction at the Nanoscale for Energy Conversion Devices.

Quantum-Rod-Based Heterostructures for Solar Hydrogen Generation

Invited speaker Lionel Vayssieres from the National Institute for Materials Science, Japan, spoke about novel functional nanomaterials with high performance and improved stability in the design and development of metal oxide semiconductors using quantum dots. He gave a plethora of examples of quantum-based nanorods from zinc oxide, multilayered materials, and iron oxide. He presented SEM images showing anisotropic properties, with intermediate bands and a highly quantized band structure, indicated the presence of quantum rods and quantum dots. The structures can enable high efficiency absorption in the visible range, and can tune bandgaps and band edges by quantum confinement effects. This unique characterization provides a platform for investigating and modeling structures at the nanoscale, especially for semiconductors and solar photovoltaics.



Nanostructured Materials for Rechargeable Lithium Batteries

Nanostructured materials have been extensively considered as electrode materials for lithium batteries owing to the high demand of increasingly efficient electric battery storage capabilities. Invited speaker Palani Balaya from the National University of Singapore gave an overview of different nanostructured materials based on LiFePO_4 , TiO_2 , and LiFePO_4/C . Balaya and his team compared the morphology, rate of storage capability, and storage performance with the meso-structures based on these materials. The observations showed that mesostructured LiFePO_4 exhibits superior storage performance with significantly less polarization and clear plateaus for the storage process at high rates. Such an enhanced storage performance in meso- LiFePO_4 is attributed to the 2-D diffusion of both lithium ions and electrons, consistent with reports on single crystal LiFePO_4 and ab-initio simulations, according to Balaya. Mesoporous- TiO_2 with high surface area exhibits superior reversible storage capacity. LiFePO_4 nanoplates exhibit high polarization at high rates, dissipating the energy in the form of heat. However, the tap density of meso- TiO_2 is found to be about 6.6 times higher than commercial TiO_2 nanopowder. Mesopores favor facile lithium ion insertion/extraction, while the intimate contacts across the nanograins (15-20 nm) within micron sized meso- TiO_2 provides continuous wiring for electronic transport. Lithium storage at low rates is observed even in the absence of additive carbon.



■ Technical Talks from Other Symposia

Symposium A. MACAN11: Reconciling Atomistic and Continuum Approaches to Interfaces

Atomic structure and reactivity of ferromagnetic Fe deposited on Si(001)

The growth of ferromagnetic thin layers on semiconductor surfaces has recently received increased attention due to the potential application of magnetoelectronic devices in silicon technology and for the study of fundamental magnetic properties. Nicoleta G. Gheorgh from the National Institute of Materials Physics, Nanoscale Condensed Matter Physics, Romania, presented new studies concerning synthesis of ferromagnetic Fe layers on Si(001), and quantified the structural properties, interface reactivity, and magnetism. Gheorgh and his team characterized the interface reactivity by Auger electron spectroscopy, the surface structure by low electron energy diffraction spectroscopy (LEEDS), the local order of Fe atoms by X-ray absorption fine structure (XAFS), and the magnetism by the magneto-optical Kerr effect (MOKE). They observed a higher deposition of ferromagnetic Fe at room temperature, which not only stabilizes better surface ordering, but also enhances Fe and Si interdiffusion and therefore decreases the magnetism. They also observed a much lower magnetization at high temperature with saturation magnetization of about 10 % of the value obtained for room temperature deposition. The combined MOKE and EXAFS studies showed consistent values for the range of Fe thicknesses where the reaction takes place. These observations could prove to be of importance in the semi-conductor industry where temperatures

can vary widely.



Symposium C: Size-dependent Properties of Nanomaterials

Optical Absorption in Thin Epitaxial Layers of GaN

Gallium nitride (GaN) is gaining ground in the PV market as a viable and tunable device for optical absorption. By varying the composition of the material, its bandgap can be shifted. Dimiter Alexandrov of Lakehead University in Ontario, Canada, and coworkers investigated the optical epitaxial layers of GaN grown on sapphire substrates (0001) by plasma-based migration enhanced afterglow (MEAglow). Their results show a variation of the optical absorption edge in the range of 1.6 - 3.3 eV, which is below the known energy band gap of GaN.

In a different study, a theoretical investigation attempted to understand this peculiar shift variation of the absorption edge using LCAO electron band structure calculations. A variation of the lattice constant of the first deposited layers of GaN was found to be caused by the influence of the sapphire substrate. The LCAO electron band structures were calculated using only interactions between nearest-neighbor orbitals. Electron energy pockets were found in both the conduction and the valence bands at the Γ point of the electron band structures. These pockets have overlapping electron wave functions describing localized states, so tunnel optical absorption can occur.

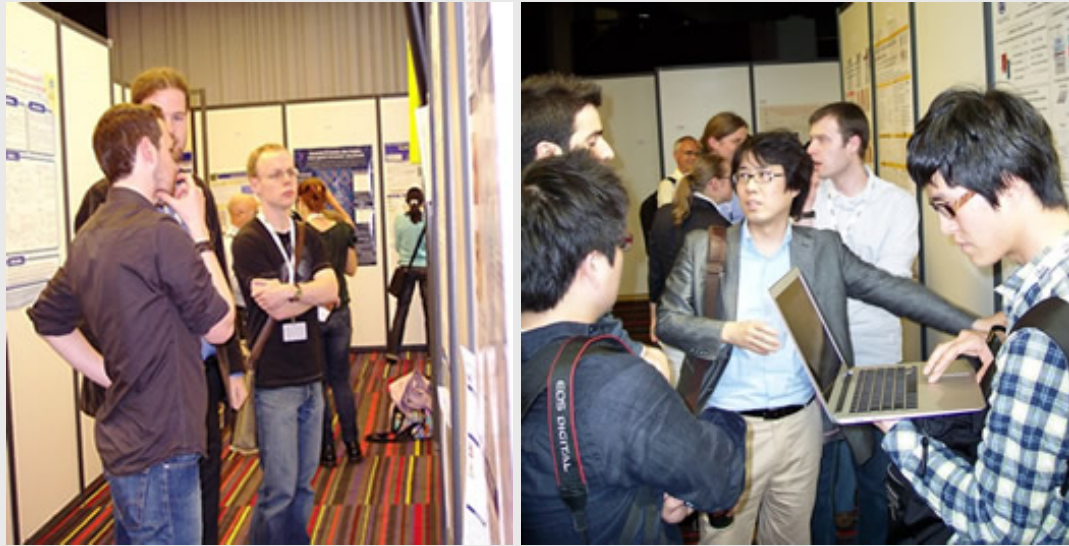


Symposium D: Synthesis & Characterization of Nanoscale Multifunctional Oxide Films

Crucial Impact of Oxygen Vacancy Defects on the Ferroelectric Characteristics of Epitaxial BaTiO₃ Thin Films

Bulk and thin film properties are often found to be quite different when measured. This may be due to a number of factors, including strain state, stoichiometry, and defects attributable to the growth process. Oxygen vacancies are easy to accommodate and can have profound impacts on electrical characteristics. The severity of the impact of oxygen vacancies on BaTiO₃ was highlighted in Guang Niu's talk this morning. At the Institut des Nanotechnologies de Lyon, Ecole Centrale de Lyon, Niu deposited 50 nm films of BaTiO₃ on Nb-doped SrTiO₃ substrates by molecular-beam epitaxy (MBE), both in an O₂ background and in the presence of activated oxygen. These films were found to start relaxing under the 2.2% epitaxial compressive strain at roughly 6 nm. Electrical measurements showed significant differences for activated O and O₂-grown films, with

activated O films having the expected hysteresis behavior similar to bulk BaTiO₃. The BaTiO₃ films were also domain patterned using Piezoresponse Force Microscopy. Results showed that only the films deposited with activated oxygen or post-deposition annealed had stable poling regions and had behavior similar to bulk BaTiO₃, stressing the important role of oxygen defects on material properties in oxides.



Symposium K: Protective Coatings and Thin Films

Single-chamber Deposition of Multilayer Barriers by Plasma Enhanced and Initiated CVD of Organosilicon

Many materials, such as those used in organic photovoltaic devices, are highly sensitive to environmental degradation. Applying protective coatings is necessary to extend device lifetime. Effective barrier coatings often consist of alternating organic and inorganic layers in order to create a coating with minimal water permeable defects. Anna Coclite from the Massachusetts Institute of Technology presented research on how a single-chamber system can be used to simplify the deposition process of these coatings. The process uses a single precursor, hexavinylidisiloxane (HVDSO), in both a coupling-initiated chemical vapor deposition (iCVD) and plasma enhanced chemical vapor deposition (PECVD) process to deposit the organic (>70% carbon) and inorganic (<10% carbon) layers, respectively. By successively growing silica and organosilicon layers in a hexalayer, a barrier improvement by a factor of 100 was realized over a carbon-depleted silica layer of the same thickness. The organic layers successfully separated the permeable defects in the inorganic layers.



Symposium L: Basic Research on Ionic - Covalent Materials for Nuclear Applications

Damage Formation Mechanisms in CdTe under Ion Irradiation

CdTe, a material useful for radiation detectors, infrared lenses, and solar cells, has an unusually high resistance to amorphization under ion irradiation. When subjected to ion-beam-induced damage, CdTe retains a high degree of crystallinity while developing defects that extend much

deeper into the crystal than the implanted ions. Claudia Schnohr from Friedrich-Schiller-Universitat Jena reported on research investigating the origin of this extended defect development and amorphization resistance in CdTe. The ion-beam-induced damage was analyzed in-situ by Rutherford backscattering spectrometry in a channeling configuration. Defect profiles differed significantly between low- and room-temperature irradiation, with defects being concentrated more at the surface at low temperature. Regardless of temperature, CdTe maintains significant crystallinity despite prolonged radiation exposure. The proposed explanation attributes the high resistance to amorphization to the ionicity of the bonds, and the extended defects to recombination-enhanced diffusion and not to a thermally activated process.



Symposium P: Bio-Inspired and Bio-Integrated Materials as New Frontiers Nanomaterials

Optical Biomimetics--Structural Color In Nature And Early Attempts To Copy It

Andrew Parker, an evolutionary biologist from the Natural History Museum in London, has done extensive work on biomimetics. He talked about how he seeks inspiration from evolution, nature's way of "trial and error," and the need to mimic nature in the design of optical devices. His study attempts to understand the interactions between proteins and surfaces, which are of significant importance in understanding the end use properties of proteins. Understanding these interactions is essential in biomaterial applications such as coatings for biomedical devices, because the functionality and conformation of the adsorbed proteins control the subsequent cell adhesion on the surfaces. He and his coworkers employed fibrinogen, a blood plasma protein that plays an important role in thrombus formation; its adsorption on various surfaces is used as a key factor in determining their haemocompatibility. Parker used spectroscopic ellipsometry and atomic force microscopy to study the structural and optical properties, and found that properties of the adsorbed protein layers are correlated with the conditions of the fibrinogen solution, as well as with the surface properties of the thin films used.



Elastic Mapping of Epithelial Cells Treated with Nanomaterials

Carbon nanotubes (CNTs) have been explored for applications in fiber optics, conductive plastics, and molecular electronics due to their novel properties, and can be found in different forms (tubes, buckyballs, sheets, etc.). More recently, their “bottom-up” functionalization with proteins, carbohydrates, or nucleic acids opened up exciting research directions in biolabeling, biodetection, biomolecule delivery, bioseparation and regenerative medicine and tissue engineering. Cerasela Zoica Dinu of West Virginia University discussed how CNTs can be modified into potential therapeutic platforms. Dinu also addressed the need to develop a sensitive method to compare the toxicity of nanotubes because of their urgent need in the bio-nano-technology industry. To gain a conceptual understanding of the cellular factors and mechanisms responsible for the uptake and distribution of the nanotubes inside the cells and ultimately for the nanotube effect on the cell fate, they used atomic force microscopy to provide a systematic analysis of the elastic mapping of a single cell and to unravel the biological complexity of cell-nanotube interaction. There was a change in elasticity after incubation of CNTs, and a shift in Young’s modulus. Also there were lots of tiny holes around the cells containing CNTs. Dinu concluded by emphasizing the need to understand the mechanisms involved in cell-CNT interaction, as well as in-vivo-response.



Scanning the Meeting



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