The scientific symposium "Materials Challenges for Clean Energy in the New Millennium"

The global energy problem is rapidly intensifying due to escalating competition for resources from emerging, populous countries such as China, India, and Brazil and compelling evidence pointing towards the imperative need for controlling greenhouse gas and carbon emissions.

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A topical symposium of current global interest entitled "Materials Challenges for Clean Energy in the New Millennium" was held on April 29 at Northeastern University and inaugurated by the former President of India, Dr. A. P. J. Abdul Kalam, a visionary engineer. The event was co-sponsored by Harvard School of Engineering and Applied Sciences. The symposium aimed to formulate cutting edge solutions for challenges facing the next generation clean energy technologies.

As the bio-nano interface holds most promise for benign technologies, the program featured distinguished visionaries working at this scientific frontier in terms of materials design and manipulation at the atomic scale. The common goal was to develop novel materials and techniques capable of satisfying the demands for clean energy in the new millennium. Exciting solutions based on improved catalysts, green membranes, superconductivity, hybrid technology for batteries, polymers and photosensitive proteins for robust solar cells were considered by the speakers. With these in mind, Professor George Whitesides (Harvard) and Mildred Dresselhaus (MIT) provided overarching views of the clean energy generation landscape. While Professor Whitesides listed advancements in solar conversion and improvements in catalysis as the keys for the future and discussed the need to explore new chemical pathways for CO2 conversion to "clean" hydrocarbon fuel. Professor Dresselhaus' illustrated the engineering of materials for clean energy using bottom up approaches; For instance, nano-building blocks can be used to optimize thermo-electric devices, solar cells, fuel cells and batteries.

Solar energy was a particular focus of the symposium, as it has long been an attractive source of clean and abundantly renewable energy, despite only representing a tiny fraction of the produced energy mostly due to economical reasons. Fortunately, the advent of new nanomaterials is expected to significantly reduce the costs of solar energy production. It was also noted that, atomic level engineering can be used effectively on surfaces for catalysis or in bulk materials for H or Li intercalation. As far as transportation is concerned, recent progress in superconductivity was noted to provide solutions both for mitigating transmission losses for more compact engines. These breakthroughs in tandem with progress in Li intercalated materials are pushing the cutting edge of plug-in hybrid technology in transportation.

Professor Sanjeev Mukerjee (Northeastern University) discussed ways to design new materials for hybrid flow through batteries enabling safer storage devices with greater energy densities and rate capability. Based upon advances in nanotechnology, special materials could be tailored for a transition to non-noble metal electro catalysis in conventional low and medium temperature acid and alkaline exchange membrane fuel cells. The need for nanofabricated electrochemical interfaces was also emphasized for improving transport and charge transfer efficiencies.

Professor Charlie Lieber (Harvard) showed how advances in the synthesis and the doping of semiconductor nanowires make this class of nanostructures a powerful platform for testing fundamental concepts and limits of photovoltaics down to the level of single nanowires. His investigations have demonstrated very high short-

Partial list of speakers at symposium

circuit current densities resulting from efficient carrier collection in radial or coaxial p-i-n structures and robust photovoltaic elements even under highly concentrated solar illumination.

Professor Shriram Ramanathan (Harvard) introduced the science of ultra-thin oxides, particularly tuning microstructure-electrochemical property relationships in fluorite-structured systems. By utilizing oxide superlattices and by controlling the oxygen partial pressure, novel energy materials can be synthesized. The fabrication of on-chip solid oxide fuel cells utilizing ultra-thin oxide films for high performance portable energy was subsequently explained in detail.

Dr. Gilles Dennler (Konarka Technologies Inc., Lowell, MA) reported encouraging progress on conjugated polymer-fullerene bulk-heterojunction solar cells performed in collaboration with Professor Alan J. Heeger (UC Santa Barbara). The new Konarka's organic photovoltaic cells are expected to soon be into commercial production.

Professor Robert Blankenship (Washington University in St. Louis) demonstrated how the photosynthetic membranes can be considered as natural bio-energy conversion devices. He listed several molecular complexes that serve as antennas by absorbing photons and delivering the energy to the reaction centers.

Photosynthesis is a collection of the most advanced and efficient systems Nature has crafted to convert solar energy into an electrical potential and again into chemical compounds for energy storage. Thus, Bio-solar cell and bio-fuel cell represent the emerging frontier in green energy sources. Professor Eric Diau and co-workers (National Chiao Tung University, Taiwan) have reported a detailed study on excited state dynamics of porphyrins sensitized solar cells with various linker lengths.

Professor Venkatesan Renugopalakrishnan (National University of Singapore, Harvard, and Northeastern University) reported advances in the feasibility of bacteriorhodopsin as bio-photosensitizer in excitonic solar cell. His Lab has engineered mutants of bacteriorhodopsin to enhance thermo-stability and to favor the charge separation when the photons are absorbed. Professor Gerald Audette (York University Toronto) discussed bio-fuel cells based on Glucose Oxidase (GOx). These devices are assembled with anodes from cross-linked GOx clusters localized on multiwalled carbon nanotubes.

In an inclusive approach to the state of nano and interfacial science in regards to environmentally responsible energy recovery, Professor Somasundaran (Columbia) delivered a comprehensive overview on green nanostructures for enhanced energy recovery. A consequential outcome of correlation between structure and performance makes the importance of naturo-structures in terms of both orientation and conformation at the nanolevel that will prove powerful in enhancing the efficiency of energy extraction, whether from coal or oil or nuclear or solar sources.

It is clear that as natural models are environmentally benign, it is incumbent on us to explore development of such structures for designing biosolar cells. Evidently, accurate probing of all the above phenomena requires us to have new and improved equipment to explore phenomena in the super thin fast world. As an example, application of scanning electrochemical microscope in the discovery of photo catalysis for was illustrated by Professor Allen J. Bard (University of Texas at Austin).

The best processes will result from a confluence of ultra small science with ultrafast engineering. It was clear during the meeting that the future is indeed promising but challenges are enormous, warranting the attention of the best minds in the world and collaboration amongst them.

For further reading

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