Introduction to Solar

The solar energy flux represents the largest energy input into the terrestrial system. Despite its relatively low power density, this resource could potentially satisfy the global energy demand on its own. Increasing efforts are directed towards enhancing the performance of solar energy systems as well as towards reducing their fabrication and installation costs so that these systems can be deployed at a larger scale.

The overall energy conversion efficiency of photovoltaic devices increased steadily in the last decade through enhanced photon absorption and charge transport. Continuous development of novel device concepts, materials, and fabrication processes contributes to lowering the cost of solar power and hence to making it more competitive. Thin-film solar cells are regarded as a promising route for low-cost energy conversion. Inorganic thin films are relatively mature technologies with record efficiencies above 15%. Organic solar cells are at an earlier stage of development with efficiencies currently ranging from ~6% for polymeric heterojunctions to 10% for dye-sensitized cells. Further research in thin-film technologies is required to increase their efficiency up to the thermodynamic limits, to enhance their stability, and to further reduce their fabrication cost.

Solar thermal technologies are appropriate for large-scale energy production and can be combined with thermal energy storage systems, which addresses the issue of supply intermittency common to other renewable sources. The conversion of solar energy into chemical fuels, and particularly hydrogen, is another way of circumventing supply intermittency.

Recognizing the importance of solar energy for building a low GHG global energy portfolio, GCEP has been increasing its efforts in this area. To date GCEP has awarded five research projects in organic and inorganic thin films and one in bioelectricity.

Professor McGehee is developing ordered nanostructured photovoltaic devices that could be fabricated using reel-to-reel coating machines. This research may lead to devices that will a) efficiently split excitons and carry charge to electrodes, b) have improved packing of the molecules in the organic semiconductor to enhance its ability to carry charge, and c) have a modified organic-inorganic interface to prevent recombination of electrons and holes.

Professors Prinz and Grossman are exploring the possibility of capturing electricity directly from living biological cells by inserting nanoscale electrodes into the cells' chloroplasts. Generation of bioelectricity will occur by exploiting the electrical potential difference created by the photosynthetic process in the chloroplast. This will be achieved by placing the anodic electrode in the stroma of the chloroplast and the cathodic electrode in the lumen.

Professors Brongersma, Peumans and Fan are developing organic multijunction photovoltaic cells that use metal nanoscale features to enhance both photon absorption and charge transport. Transparent high-sheet-conductivity nanopatterned metal films are being used as conductors allowing parallel subcell connection, and metal nanostructures are being embedded in the active layers to enhance the photon absorption and charge separation efficiency.

Professors Bent, Harris and McGehee are applying atomic layer deposition (ALD) techniques to the fabrication of photovoltaics using nanostructured inorganic semiconductor composites. This approach is intended to increase the photon absorption of inorganic thin films by using the multiple junction concept and by increasing the optical path of light through the device by controlling the cell geometry at the nanoscale. As ALD deposition is applicable to high-throughput fabrication, this technology could potentially lead to low cost photovoltaics with good energy conversion efficiencies.

Professors Green and Conibeer of the University of New South Wales, Australia, are working on an innovative photovoltaic device based on integrating low-cost polycrystalline silicon thin films with higher bandgap semiconducting materials. These materials are synthesized using silicon quantum dots embedded in a matrix of silicon oxide, nitride, or carbide to produce two- or three-cell tandem stacks. By capturing different energies within the solar spectrum in each cell in the stack, a significant increase in the efficiency of silicon-based thin films is anticipated without adding appreciably to large-volume manufacturing costs per unit, thus decreasing installed system costs.

Professors Bao and McGehee are developing novel organic materials to be used in bulk heterojunction photovoltaics. The properties of these semiconducting polymers will be customized to increase the photon absorption efficiency in the IR spectrum (by reducing their optical bandgap), and to enhance the exciton transport (by generating, upon photoexcitation, triplet states that exhibit longer lifetimes than singlet states).