Introduction to Exploratory Projects – Ongoing and Completed

In addition to deep research into high-risk, high-impact fundamental science and technology, GCEP also funds smaller exploratory efforts. These exploratory projects can be funded for up to one year, and have budget limits of up to $100,000 each. The goal of these projects is to quickly evaluate the feasibility of a novel concept. If such an investigation proves successful, the investigators may apply for regular GCEP funding.

Two exploratory projects have been completed this year, while five additional exploratory efforts are ongoing through 2012.

Professor Fan is investigating the possibility of a novel means of transferring power to moving vehicles via magnetically coupled resonating coils located in the roadbed and in the vehicles. An exciting aspect of such wireless transfer techniques is that they provide great flexibility for power distribution in the transportation environment. One could also envision a wireless focusing scheme, which allows concentration of energy to a selected point in space, and hence further reducing the stray field. The overall aim of our project is to explore many of these flexibilities in the context of transportation applications. The success of this program may prove to be a very significant step forward towards the possibility of unlimited range electric mobility.

The project by Professor Solgaard aims to develop passive solar concentrators that do not require complex control mechanisms for continuous pointing at the sun. Traditional problems with concentrating systems hope to be overcome by creation of an Axially Graded Index Lens (AGILE) that takes advantage of the fact that sunlight enters the system through an aperture of unity index; and is absorbed in a semiconductor with $RI{\sim}3.5$. This enables a concentration factor of $3.5^2 = 12.25$, in addition to the factor of ~ 5 that is available with traditional optics. The maximum concentration factor is therefore ~ 60. Focusing the light to an area of just a few percent of the input aperture makes the large scale deployment of highly efficient, but expensive, photovoltaics a realistic and practical possibility.

The project by Professor Swartz on efficient cell-free hydrogen production from glucose reached the one year completion date. The goal of the project was to develop scaleable technology that will efficiently convert glucose and xylose, the primary products of cellulosic biomass digestion, into hydrogen using a cell-free system. This project has led to the successful engineering of a production organism to achieve increased hydrogenase production at least 10-fold higher than ever before reported. As a consequence of this and further manipulations of the system Professor Swartz and his group have demonstrated hydrogen production rates that suggest commercial hydrogen productivities approximately 10-fold greater than current ethanol productivities on the basis of MJ of fuel value per liter of capacity per unit time.

Professors Cui and Fan are teaming up to investigate novel nanocone and nanodome-like structures for efficient inorganic thin-film solar cells. The proposed concept consists of a light trapping sub-wavelength inorganic nanostructured substrate, on which solar cell layers can be deposited, potentially resulting in efficient light absorption and charge collection, and hence enhanced conversion efficiency, even at reduced absorber layer thickness. Initial proof of concept studies on amorphous-Si systems will be extended to CdTe and CIGS. Low-cost and high-throughput manufacturing methods to mass-produce such nanostructured substrates will also be developed. If successful, this work could lead to low processing-cost PV technologies using a fraction of the active material currently needed. This could have a significant impact on the PV market and foster the widespread deployment of photovoltaic systems.

Professors Haile and Giapis and Dr. Ciucci are researching means to combine advanced materials with scalable nano- and microscale fabrication methods to build solid oxide fuel cell structures with unparalleled performance (power output of 10 W/cm^2 at 600 °C) at reasonable cost. They propose to construct cells supported on ceria-coated porous metals, where the support component serves as *both* the redox stable, coking-resistant anode and the mechanically robust, interconnect/current collector.

In the area of Advanced Combustion, Professor Capelli of Stanford University carried out Fundamental Studies of Plasma Air Separation. This exploratory work investigated the physics necessary to advance the development of a low power, small scale, air separation unit (ASU) based on non-equilibrium plasma discharges (PD-ASU). The preliminarily design and selection of the test geometry of the air passage, plasma electrodes and discharge type; constructing a prototype of the PD-ASU unit; and simulating the unit using commercial software (COMSOL) to improve the separation performance were the main focus of this study.

Professors Clemens and Salleo have been investigating ion-beam assisted deposition (IBAD) of textured templates that can be used to make efficient crystalline-Si thin-film solar cells. The idea behind this approach is that ion beams can be used to selectively determine the crystal orientation of the deposited crystalline films. By means of this technique, one can grow a polycrystalline film with well-aligned grains and therefore "smoother" grain-to-grain interfaces. As a result, the charges generated within the light-absorbing thin-film would undergo much fewer recombination processes at the grain boundaries and the overall conversion efficiency of the photovoltaic cell would be substantially improved.