Introduction to Completed Project Reports

Nine GCEP research programs have reached completion during the past year in four portfolio areas of Hydrogen, Solar, Biomass, Carbon Capture and Separation, and Advanced Combustion. In some cases, GCEP receives portions of a final report because of the differences in the start times of the various sub-contracts that have multi-institutional collaboration.

Hydrogen

In the hydrogen portfolio area, a research program addressed hydrogen storage as C-H bonds on carbon nanotubes was completed by a multidisciplinary team with Dr. Anders Nilsson from the Stanford Linear Accelerator, Bruce Clemens from Materials Science and Hongjie Dai from Chemistry. This team has worked together since the inception of GCEP on hydrogen storage programs and continued to receive funding on programs that took on new concepts from the existing work. This work brings to a close the last of three sequential programs that began in 2003.

Solar

In the area of solar energy, four programs were completed this year. Professor Zhenan Bao in Chemical Engineering completed a project to develop a carbon nanotube (CNT)-based transparent electrode technology for photovoltaic applications. Her research developed an experimental method to selectively separate metallic from semiconducting nanotubes and to control the morphology of the metallic nanotube network to optimize both the film transparency and the sheet conductivity. They have selected aprotic amidines, a new class of SWNT solvent, and demonstrated these are effective to disperse single-walled nanotubes into solutions.

Professors Gavin Conibeer and Martin Green of the University of New South Wales completed a long-standing program to develop a proof-of-concept device of a hot carrier solar cell using abundant and non-toxic nanostructured materials. Last year, there was a final report submitted on the theoretical studies of the fundamental energy transfer mechanisms between hot electrons and phonons and on the experimental setup requirements for the physical characterization and performance measurements. This final report concludes the work from the remaining institutions in the collaboration including the University of New South Wales, Insitut de Recherche et Developement sur l'Energie Photovoltaique (IDERP), Paris and the University of Sydney.

Professor Harry Atwater of the California Institute of Technology, Professor Mark Brongersma of Stanford University, and Professor Alfred Polman of the Foundation for Fundamental Research on Matter (FOM), The Netherlands, applied plasmonic technologies to enhance the performance of nanocrystalline semiconductor-based thin film photovoltaics. The project has been very successful in leading the field and catching the attention of the community with 13 publications, including a 2010 review article in Nature Materials that has been cited over 500 times and a subsequent 2012 Perspective Article in Nature Materials

Professors Nicholas Melosh and Zhi-Xun Shen investigated a novel photon-enhanced thermionic concept that combines photon- and thermal-excitation in a semiconductor material to increase the efficiency of thermionic electron emission compared to current systems. The experimental results validated the concept and predicted physics for the PETE process and exhibited the need to improve carrier recombination and high temperature material stability.

Biomass

In the area of biolignin, two of four programs were completed. Professors Clint Chapple and Alan Friedman at the Purdue University focused on establishing an enzymatic toolbox for the production of lignin modification molecules (LMMs). They took three parallel approaches to the identification and characterization of LMM-synthesizing enzymes and focused on three classes of catalysts. This work has identified specific genes and enzymes that could be used to modify lignin biosynthesis. They have also found that other opportunities for lignin modification may lie within a plant's own biochemical diversity.

Professor Wout Boerjan at the University of Gent worked towards new types of degradable lignin. The long-term vision for the project is to identify natural products or target molecules that can be biosynthesized in energy crops, translocate through the plasma membrane and cross-coupled with lignin units such that the final lignin polymer is more susceptible to chemical cleavage, or is more hydrophilic, or is less cross-linked with hemicelluloses. The group metabolically profiled 250 natural Arabidopsis accessions and identified several of the target molecules in this model system. Ideally, the structures of the target molecules would be very similar to traditional monolignols so that they can be exported to the wall using the same transport system.

Carbon Capture and Separation

Shingo Kazama is the new group leader, heading a team of scientists at The Research Institute of Innovative Technologies for the Earth (RITE) in developing CO_2-selective membranes. By engineering the chemistry and morphology of such membranes at the nanoscale, the group has made significant improvements to membrane performance. The technology described in the report uses a novel and effective supercritical CO_2 directing method. This team has been funded by GCEP on various membrane separation technologies since 2006.

Advanced Combustion

Professor Chris Edwards' program pursued engines that reduce exergy loss by conducting combustion at states of extreme energy density. The team successfully constructed a free-piston device that can achieve compression ratios in excess of 100:1 and exhibited high efficiency. Most of the research results were reported in the 2011 Technical Report. The success of this work led to follow-on funded work in sootless diesel, and a progress report for that project can be found in Section 2.6.2.