Introduction to Advanced Materials and Catalysts

The development and advancement of materials is an overarching need in systems that extract, distribute, store or use energy. The performance of these systems depends on the properties of the materials: plastics, coatings, alloys and catalysts are some of the broad classes of materials used in current energy devices. Advancements in these materials optimize energy conversion processes, improve system efficiency, extend lifetime, and reduce CO_2 emissions. Although initially developed for a specific application, material properties may crosscut to other energy technologies or industries.

GCEP has several projects whose main focus is on materials development. Most of these are officially listed under their application area. Some projects have a materials component to their research. For example, research in the Hydrogen area includes studies of nanomaterials for hydrogen storage and NMR studies of fuel cell electrolytes. Studies in the CO_2 Separation and Capture area on advanced membrane reactors and development of innovative gas separation membranes involve development of materials with highly specific properties. The Solar area is replete with materials research for nanostructured photovoltaic cells. The studies listed above are all materials intensive investigations whose details can be found under their specific application areas in this report. The remainder of this section is dedicated to the four following investigation efforts:

Professors Christopher Chidsey, Daniel Stack, and Robert Waymouth are developing efficient catalysts for direct-hydrocarbon fuel cells. It is envisioned that these catalysts will be transition metal complexes immobilized on carbon electrodes. Specifically, various configurations of late-metal multi-metallic catalyst complexes are being investigated for their role as electrooxidation catalysts, and biologically inspired mono- and multi-metallic copper complexes are being examined as electroreduction catalysts.

Professor Paul McIntyre and Professor Shriram Ramanathan of Harvard University are exploring new approaches for low-to-intermediate temperature solid oxide fuel cells (SOFCs) using nanoscale-engineered metal-oxide electrolytes manufactured by atomic layer deposition. They are also exploiting photo-excitation effects to reduce the activation energy of the reactions occurring at the membrane surface.

Professors Dave Goodwin and Sosina Haile of the California Institute of Technology are combining advanced materials with advanced nano- and micro-scale fabrication methods to build high-performance, low operation-temperature SOFCs. Their approach consists in engineering the SOFC system as a whole: the physical structure of the anode, cathode and electrolyte along with the chemical structures of all three components. Contemplated materials are ceria for the electrolyte and the anode, and the advanced perovskite, BSCF for the cathode.

Professors Robert Waymouth, Christopher Chidsey, and Daniel Stack are extending their previous work on novel organometallic catalysts for the purpose of efficient hydrocarbon conversion. Here, they develop di-platinum based catalysts for both dehydrogenation of methane and activation of carbon-carbon bonds, and manganese-based catalysts for oxidation of water. Click chemistry is being used to covalently attach di-platinum based catalysts on graphite electrodes and manganese-based catalysts on conductive oxide electrodes.