

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 CO₂ 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 CO₂ 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 three following investigation efforts:

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 are developing new classes of molecular electrocatalysts for the efficient oxidation of chemical fuels. A novel click chemistry method is investigated to covalently attach the catalysts on a variety of functionalized carbonaceous and metal oxide electrodes.

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 Sossina 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 of 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.