Introduction to Completed Project Reports

In 2015, two programs within two areas came to completion: one in advanced materials and catalysts and one in grid storage.

Advanced Materials and Catalysts
Professors Robert Waymouth and Christopher Chidsey are working toward the reduction of carbon dioxide. Their approach is that of electrohydrogenation to produce a variety of renewable fuels. A series of molecular complexes have been prepared and shown to activate and/or reduce carbon dioxide, ketones, and protons. These advances illustrate the potential of highly reactive transfer hydrogenation catalysts to act as catalyst precursors for the reduction of CO_2 and other biomass-derived feedstocks to energy dense liquid fuels. These studies have helped illuminate the electronic and structural features of coordination complexes whose metal and coordinated ligands can function cooperatively to facilitate reactivity with protons, electrons, and carbonyl compounds such as ketones, and carbon dioxide. New classes of ketone reduction catalysts based on earth-abundant Mo and Co complexes have also been developed. In the fourth year of this project a new class of CO_2 reduction catalysts based on Re and Mn complexes ligated by redox-active azopyridine ligands were also developed. Overall this project has made important advances on two key fronts: (a) achieving a single step two-electron transfer in earth-abundant metal complexes, and (b) reducing CO_2 with a singly reduced metal complex. Both of these results help in achieving the desired chemistry with maximum energy efficiency. In addition, the research team has discovered a rapid Mn-based transfer hydrogenation catalyst.

Grid Storage
Professor Hongjie Dai and his team from Stanford researched large-scale batteries for grid storage, looking carefully at different chemistries and the electrocatalytic reactions at the electrodes. Their work is entitled "Photoelectrochemically Rechareable Zn-Air Batteries" and aimed to develop novel nanocarbon-inorganic hybrid materials for the hydrogen evolution, oxygen reduction and oxygen evolution reactions. Novel battery concepts were also developed such as an ultra-fast Zn-Ni battery and the aluminum ion battery. This work achieved a breakthrough by leading to the development of a high-performance rechargeable aluminum battery with high-rate capability using an aluminum (Al) metal anode and novel graphitic materials for the cathode and a safe, non-flammable ionic liquid electrolyte. The cell exhibited well-defined discharge voltage plateaus near ~2 V, and can afford short charging times (~1 minute) over > 7,500 cycles without capacity decay. This work was published in Nature and generated significant interest. Overall this project has resulted in ten publications including in several high impact journals such as *Science, Nature* and *Nature Communications*.