Introduction to Advanced Transportation

Fundamental research can play a role in reducing greenhouse gas emissions associated with growing global transportation energy use by enabling technologies that either significantly reduce the energy requirement of transportation or reduce greenhouse gas emissions associated with the fuel chain. Reducing the energy requirement for transportation may be accomplished by reducing vehicle mass, smoothing the operational speed profile, and reducing viscous and contact friction. Specific technical challenges in these areas include the low-cost production of high-strength, low-weight materials and the technical foundation to enable automated vehicles.

A project that began in 2015 is led by Professor Dauskart examining vehicle light-weighting with polymeric glazing and moldings. There is a strong desire in the transportation community for a molding process, which would allow a wider range of shapes and aerodynamic designs in addition to providing weight reduction. The team is working on improving the durability, performance and lifetime of the material and its processes. The team uses an experimental approach towards a manufacturing method based on atmospheric plasma deposition and performs detailed surface analytical measurements and targeted physical testing. To date, they have demonstrated a deposition method that fabricates coatings in a one-step process, significantly overcoming challenges in what is typically a three-step process. Future plans involve incorporating UV protection and other functional coatings. The lab also plans on bringing online a new mass spectrometer detection tool to improve process diagnostics.

Fuel chains with low net greenhouse gas emissions include portable storage of low-carbon electricity and carbon-based fuels synthesized from low-carbon energy. Significant technical challenges in this area include developing batteries with high energy density and stability, and developing classes of low-cost catalysts capable of efficiently converting low-carbon energy into and out of forms amenable for portable storage. There is currently one active program in this area that addresses the problem of electrical storage in light-duty electric vehicles.

Professors Bao and Cui are doing research towards developing a high energy density lithium ion battery using self-healing polymers. The lithium-ion battery (LIB) is a very promising energy storage candidate for powering electrical vehicles. Although current lithium ion batteries have been very successful for portable electronic devices, they have not yet met the requirements of a mass market for electrical vehicles. Much higher specific energy/energy density (3-5x) is needed. Improving the energy density of LIBs requires exploiting new materials for battery anodes and cathodes, such as silicon and sulfur. Specifically, if silicon is used to replace graphite anodes, the theoretical specific charge capacity is ten times higher. These materials experience extreme, unavoidable expansion and contraction during the lithiation and delithiation processes which lead to rapid morphology deterioration of the electrode materials (cracks, electrical isolation or particles, pulverization, etc), which dramatically reduces the battery lifetime to a few charge-discharge cycles. These researchers are designing and synthesizing a series of self-healing polymers with different mechanical properties and self-healing capabilities aimed at overcoming this problem. To date they have obtained a much clearer mechanistic picture for longer cycle life with the biggest practical limitation of their current self-healing polymer being its low rate capability. Next year, they plan to address this issue through new elastomeric materials, electrochemical characterization, and exploration of a slurry manufacturing method. Their aim is to enable the next generation of Li-ion batteries for transportation with 30% higher energy density than currently available.