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 decouple vehicle energy use and emissions. 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.

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 to power 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 will design and synthesize a series of self-healing polymers with different mechanical properties and self-healing capabilities aimed at overcoming this problem. To date the team has improved on earlier work for Si electrodes containing self-healing polymer particles, where the electrodes delivered a high initial delithiation at 2620 mAh/g and the capacity was stable after 500 cycles.