Energy Materials: Meeting the Challenge

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Increasing awareness of environmental factors and limited energy resources have led to a profound evolution in the way we view the generation and supply of energy. Although fossil and nuclear sources will remain the most important energy provider for many more years, flexible technological solutions that involve alternative means of energy supply and storage need to be developed urgently. The search for cleaner, cheaper, smaller and more efficient energy technologies has been driven by recent developments where materials technology will play a particularly important role in meeting the needs of the future.

The most pronounced breakthroughs are currently taking place for technologies using renewable energy sources. At the same time, the use of these technologies requires reliable and effective ways of storing energy, and exciting developments are occurring in the fields of hydrogen storage, rechargeable batteries, capacitors and high-temperature superconductivity.

Among various energy conversion systems, fuel cells are an important enabling technology for the Hydrogen Future and offer cleaner, more-efficient alternatives to the combustion of gasoline and other fossil fuels. Although the potential benefits of hydrogen and fuel cells are significant, many challenges, technical and otherwise, must be overcome before hydrogen and fuel cells will offer a competitive alternative for consumers. These challenges include hydrogen production and delivery, hydrogen storage, fuel cell cost and durability, safety and public acceptance.

With regard to energy storage, future electrical and power distribution systems will critically depend on advances in dielectric materials with high energy and power densities. Advanced electric guns and high-power microwave systems will require pulsed power units that store 10-500 MJ and utilize large-volume capacitors. Since capacitors occupy >70% of the overall volume in conventional power converters, capacitor performance, size, cost, and reliability must be dramatically improved to meet the requirements of current and future energy storage systems.

Dielectric permittivity and applied electric field magnitude are key parameters governing capacitor energy density. The applied electric field in a capacitor is significantly lower than the intrinsic dielectric breakdown field, and capacitor energy densities for pulsed power and power electronic capacitors are typically 10 J/cm3 in a fully packaged capacitor, new approaches must be developed to substantially increase intrinsic dielectric energy densities while achieving reliable operation near the dielectric breakdown limit. The presentation will address the recent research activities on the development of solid oxide fuel cell and high energy density capacitor materials at Missouri S&T.

On the education site, a course on “Energy Materials” is one of the educational programs offered on the Missouri S&T campus. The objective of this multidisciplinary course is to focus on what materials-based solutions provide and to understand how the rational design and improvement of chemical and physical properties of these materials can lead to energy alternatives that can compete with existing technologies.