STRUCTURAL COMPOSITE CAPACITORS, SUPERCAPACITORS, AND BATTERIES

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Many U.S. Army applications require storage and release of electrical energy, necessitating the use of energy storage devices such as batteries and capacitors. Due to weight and volume concerns, there exists a need to reduce the mass and volume burdens created by these devices. One approach to utilizing these systems more efficiently is to engineer multifunctional devices that, in addition to storing and releasing energy, can also be used to carry structural loads. This presentation will review ARL's work on engineering structural batteries, supercapacitors, and capacitors. All of these devices leverage materials and fabrication techniques used in conventional fiber-reinforced polymer matrix composite materials.

Structural capacitors are fabricated by interleaving thin metallized papers and polymer films between structural dielectrics composed of continuous glass fiber-reinforced epoxy. High dielectric energy density is achieved by minimizing voids and inclusions in the dielectric, ensuring complete cure, and maintaining consistent electrode spacing. These structural capacitors are able to achieve energy densities above 0.1 J/g while maintaining mechanical properties comparable to structural composites.

Structural supercapacitors are fabricated using a salt-loaded polymer electrolyte with continuous carbon fiber electrodes. Homopolymer, copolymer, nanocomposite, and gel electrolytes have been studied to achieve an appropriate balance of mechanical and electrolytic properties.

Techniques to increase the capacitive surface area of the carbon fiber electrodes, while maintaining good mechanical properties, are under evaluation. Separators are placed between electrode layers to prevent electrical shorting while permitting ion transport. Selecting efficient separator materials that provide robust electrical isolation while permitting mechanical bonding and load transfer is a critical challenge.

Structural batteries utilize structural electrolytes and separators similar to the structural supercapacitors. In contrast to the supercapacitors, the anodes of the structural batteries can effectively utilize unmodified carbon fiber fabrics. Structural cathode materials under development include thin-film coated metal meshes, screens, and foils. Engineering the morphological details at the interfaces of the current collector, active cathode material, and electrolyte remains a topic of continued study.

The talk will also include a general discussion on multifunctional design, and performance metrics that can be used to engineer mass-saving and volume-saving multifunctional materials.