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Ceramic and Nano-Polymer Capacitors for Energy Storage and Energy Transduction Applications

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This talk will consider new research that is targeting next generation capacitors for power inverter applications, and also energy storage. Starting first with the dielectric materials necessary for power invertors based on Silicon Carbide IBGTs and MOSFETS we need capacitor devices that perform with high volumetric efficiencies and have low high field losses under high drive conditions, the dielectric materials also need high reliability and high dielectric breakdown strengths over broad temperature ranges. In developing new inorganic dielectrics materials based upon nonlinear dielectrics we investigated new compositions with antiferroelectric based phase transitions, linear and weakly coupled relaxor ferroelectric phenomena, permitting high electrostatic energy storage with minimum dielectric loss at elevated temperatures. We will discuss the design strategies around these materials and demonstrate that such materials are made into prototyped Multilayer Ceramic Capacitors and maintain an electrostatic energy density above 10 J/cc up to temperatures of 240 ^{o}C. We will also report on an alternative technology considering nanocomposite designs with dielectric thermoplastic polymers we have also been designing high voltage polymer composites with exfoliated clay based nanofillers, where the inclusions are carefully dispersed and structured by a bi-axial stretching perpendicular to the electrodes that maximize dielectric breakdown and minimize space charge losses. Comparisons are made relative to zero filler content and random dispersions of the fillers. The textured nanocomposites show superior dielectric properties in terms of lower losses, high breakdown strengths, and better dielectric endurance. Finally, we will provide an update on our recent work on ultracapacitors are also being developed for very high energy densities and are showing extremely good leakage characteristics ideal for energy harvesting applications. We will demonstrate high power and high energy density performance in prototyped capacitors with a single walled carbon nanotubes assembled into high density binderless electrodes, PVA based electrolyte with phosphoric acid, and nanofillers. We will also show a Li-ion asymmetric capacitor with an expanded voltage window, that has very low leakage characteristics (less than 10% over two months) and shows very high Columbic efficiency and demonstrated charge-discharge for over 10000 cycles and high energy densities highly suited to energy harvesting applications.

Keywords: energy storage, breakdown strength, nanocomposites, high temperature, ultracapacitors