4th International Symposium on
Energy Challenges & Mechanics
- working on small scales

11-13 August 2015
Aberdeen, Scotland, UK

Surface modified ceramic-polymer nanocomposites for energy storage

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Accepted for publication on 6th March 2015

The increase in demand of electrical energy for military, personal power, and grid-scale stabilization applications necessitates high-energy density, high-power density storage methods. Although dielectric capacitors have long life, excellent fatigue characteristics, and the highest power densities, their low energy densities, and high cost/kWhr, prevents them from being used for next generation energy storage. The energy density of a capacitor is determined by two material properties: the dielectric constant and the breakdown strength. Most work in the field of dielectric energy storage has focused on maximizing one while sacrificing the other. However, for fundamental understanding and commercial progress to be made, both properties must concurrently be improved. Ceramic-polymer nanocomposites have the potential to accomplish this by combining high dielectric ceramics with high dielectric strength polymers. Reported energy densities, however, are far below theoretical values due to extrinsic defects that are present at the interface between the high-k ceramic nanoparticle and the polymer during the mixing process. Through polymer grafting and surface functionalization of the nanoparticles, these flaws can be eliminated, improving the overall quality of the breakdown strength and the energy storage potential (>32 J/cm^3). As mentioned earlier, although energy density is an important metric, the best long-term metric for practical applications is the cost/kWhr. Towards this end, all large-scale production techniques must utilize high throughput processing, such as inkjet printing, doctor blading, and photonic curing, in order to develop materials with a disruptive impact. Through functionalizing bottom-up grown nanoparticles with polymers which not only improve the energy density, but also increase dispersion within ink systems, thick film capacitors can be printed and cured, enabling rapid production of inexpensive, high-energy density materials.

Keywords: nanocomposite; surface functionalization; capacitors; inkjet; photonic curing

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