Optimizing and Fine-Tuning Electrode Pore Sizes Utilizing Varying Ratios of the Immiscible Polymer Blend PAN-PS for High Energy Density and Wide Temperature Range Supercapacitors

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Supercapacitors (SC) are energy devices that have higher power densities and quicker charge times than lithium-ion batteries (LIB). The main issue with SC is their lower energy densities compared to LIB, and both LIB and SC lose efficiencies in extreme temperatures. Our work aimed to replace LIB and develop a high energy density SC by fine-tuning the pore sizes. We created a novel electrolyte. We fabricated four SC: Polyacrylonitrile(control) and three Polyacrylonitrile(PAN)-Polystyrene(PS) blends with PAN-PS ratios of 80:20, 90:10, and 95:5. We hypothesized that the PAN-PS ratio of 95:5 would have the highest energy density due to an optimal mesopore to micropore (Me: Mi) ratio. PAN and PS are immiscible polymers with different degradation temperatures; when carbonized, the PS degraded due to its lower degradation temperature, increasing porosity and surface area. All the PAN-PS blends exhibited higher energy densities than commercial SC due to the first ever formation of channels in the electrode. The PAN-PS 95:5 SC had the highest surface area of 3794 m2/g, leading to the highest energy density of 75.4 Wh/kg, which was 15 times greater than commercial SC. This was due to a Me: Mi ratio of 1.22, allowing for a balance between low resistance and high surface area. We proved that varying blend ratios controls the pore size distribution. Our PAN-PS 95:5 SC retained 97% of its capacitance over 4,000 cycles, maintained high energy densities throughout -50°C to 110°C, and had a tensile strength higher than that of Tin, indicating our SC’s high reliability in comparison to commercial SC. A vehicle simulation using our PAN-PS 95:5 SC demonstrated 40-49.5% higher fuel economies than vehicles with LIB. Our SC has applications in the automobile, medical, and defense industries.

Awards Won:

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