Development of High-Performance Polymer-Biomass Composites for Enhanced Energy Storage Capacities

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Dielectric capacitor is one of major categories for storing electric energy in our daily lives. The quest for high-performance dielectric capacitors is contingent upon the development of materials that exhibit both a high dielectric constant and high dielectric strength, thereby achieving superior energy storage density. Recent studies have suggested that fillers capable of forming hydrogen bonds with a polymer matrix can enhance the system's dielectric strength. Recently, a novel biomass known as Cellulose Nanocrystal (CNC) has emerged. CNC is noted for its hydroxyl-rich surface, which facilitates hydrogen bonding. Thus, formulating a composite that combines a polar polymer matrix—with inherently high dielectric constant—with CNC, known to bolster dielectric strength, presents a pathway toward innovating dielectric composites.

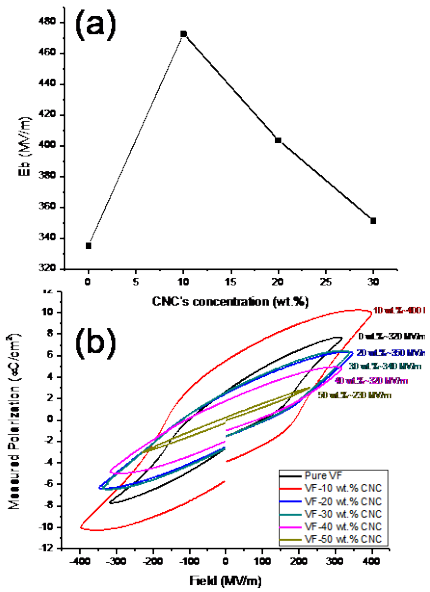

Fig 1. (a)The DC breakdown strength for P(VDF-HFP)-CNC composite with different CNC concentration; (b) The P-E loop at Maximum electric field for P(VDF-HFP)-CNC composite with different CNC concentration.

This study introduces a novel approach to developing high-performance and flexible dielectrics for energy storage: all-organic composites consisting of polymers with high dielectric constants [P(VDF-HFP)] blended with Biomass [CNC]. Figure 1 illustrates that incorporating CNC into the dielectric polymer increases the dielectric breakdown strength (E_b) by approximately 40%. Consequently, the charged energy storage density of the composite improves from 16.55 J/cm^3 to 28.40 J/cm^3. Furthermore, it is observed experimentally that these composites maintain high dielectric constants, flexibility, and transparency. These qualities position all-organic composites as promising candidates for the development of high-performance energy storage capacitors.

Keywords: polymer, cellulose nanocrystal, dielectric composite, energy storage, all-organic composites