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Dielectric breakdown of polymer composites: Experiments and phase-field simulations

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Polymer nanocomposites, which combines high dielectric permittivity (ε_r) of ceramics and high breakdown strength (E_b) of polymers, are promising dielectrics for high power electrostatic capacitors. Capable of delivering ultrahigh power, they are the major enabler for a number of modern electrical and electronic devices. Tremendous efforts have been made to break the adverse coupling between ε_r and E_b and raise their low energy density, make them viable for energy storage applications. Experimental results indicate that the interfaces between inorganic fillers and polymer matrix play critical roles in determining the E_b of the composites. Phase-field models are employed to simulate the complicated dielectric breakdown process in composites. It is revealed that aspect ratio and orientation of inorganic fillers are critical factors that could substantially change the distribution of local electric field and affect the propagation of breakdown path. Simulation results also show that breakdown paths are originated mostly at the interface between composite and electrodes as a result of charge injection from the electrodes under high electric field. Fillers of large energy band gap is capable of raising the energy barrier and suppressing the detrimental charge injection. In light of these findings, optimal structure designs of polymer composites with low loss are proposed and demonstrated.

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