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Designing electrically tougher materials

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ABSTRACT

Using an analogy between dielectric breakdown and fracture of solids, a phase field model is developed for the electric damage initiation and propagation in dielectric solids during breakdown. Instead of explicitly tracing the growth of a conductive channel, the model introduces a continuous phase field to characterize the degree of damage, and the conductive channel is represented by a localized region of fully damaged material. Similar as in the classic theory of fracture mechanics, an energetic criterion is taken: the conductive channel will grow only if the electrostatic energy released per unit length of the channel is greater than that dissipated through damage. Such an approach circumvents the detailed analysis on the complex microscopic processes near the tip of a conductive channel and provides a means of quantitatively predicting breakdown phenomena in materials, composites, and devices. This model is implemented into a finite-element code and several numerical examples are solved. With randomly distributed defects, the model recovers the inverse power relation between breakdown strength and sample thickness. Finally, the effect of microstructures in breakdown-resistant composites is demonstrated through numerical examples.