MECHANISTIC ELECTRICAL BEHAVIOR OF CROSSLINKED POLYETHYLENE / SILICA NANOCOMPOSITES

By

Robert C. Smith

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Examining Committee:

J.K. Nelson, Thesis Adviser

L.S. Schadler, Member

S.J. Salon, Member

P.S. Dutta, Member

R.C. Degeneff, Member

Rensselaer Polytechnic Institute
Troy, New York

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ABSTRACT

In pursuit of better, engineered dielectric materials, nanocomposites consisting of a polymer/metal-oxide blend have been investigated. The current state of understanding about such two-phase systems is that the bulk properties depend upon the interfacial polymer that surrounds the included particles. As the size of those inclusions is reduced from the conventional (micron-sized) to the nanometric, the resulting *nanodielectrics* are increasingly products of the physics of interaction taking place in these polymer transition regions. Interest in nanodielectrics has grown within the last decade with the availability of ever-smaller nanofillers, and the appearance of several key research papers on the topic. An entirely new class of dielectric materials, whose electrical properties are unlike unfilled polymers and conventional composites, has been created.

This work combines the results of several tests to reveal the character of a crosslinked polyethylene (XLPE) matrix filled with a nanosilica particulate. Both bulk properties and the fundamental, mechanistic behavior of the interfacial region are reported. Results indicated that the introduction of silica nanoparticles into XLPE increased breakdown strength and voltage endurance, while at least partially mitigating the interfacial polarization that is typical of conventional composite dielectrics. Space charge accumulation was generally reduced, and bulk conductivity raised as the nanoparticle loading increased. Oxygen radical defects introduced by silica were shown to participate in the steady-state conduction. Further, a reduction in charge carrier trap depths was revealed for the nanofilled materials. High-frequency dielectric behavior was modeled by a simple geometric arrangement of spherical agglomerates surrounded by regions of relatively high conductivity but lowered permittivity. An interaction zone size of about 28 nm was determined, roughly equivalent to the 30 nm Debye shielding length of a Gouy-Chapman diffuse double layer put forth by Lewis in his nanodielectric model. It was concluded that the nanoparticles provide myriad shallow traps, aiding conduction as interaction zone percolation is approached, reducing accumulated space charge.