Influence of Pore Size on Dielectric Breakdown in Plasma-Polymerized Films

Patrick D. Pedrow and Jen-ho (Ricky) Chang
Washington State University
Pullman, WA

For solid materials containing gas-filled pores, dielectric breakdown is usually preceded by gas-phase electron impact ionization and Fowler-Nordheim field emission at interfaces. These phenomena may be coupled. Gas-phase impact ionization by an electron can lead to an electron avalanche, which may be accompanied by light emission and photo ionization. As pore size shrinks, there is a limiting pore diameter (≈5 nm) where the number of gas molecules in the pore is nominally unity, and phenomena depending on multiple gas-phase events cease to exist. Pores are an integral part of most plasma-polymerized materials. In certain applications these materials must support large electric field intensities, and it is important not to stress a material beyond its dielectric strength. We are investigating dielectric breakdown in three organic films: plasma-polymerized aniline, acetylene, and tetrathiafulvalene (TTF). The motivation for selecting these precursor molecules include 1) pi bonds in a thoroughly studied material, 2) very small pore sizes, and 3) unique light emitting molecules, respectively. These films have been processed in our lab and dielectric breakdown measurements begun on plasma-polymerized aniline. Preliminary results show that dielectric breakdown voltage follows a Weibull distribution. Electrode material is selected from indium tin oxide, silver epoxy, stainless steel, gold, carbon, and aluminum. Film thickness is submicron with pores characterized by SEM and AFM. Electrical characterization of the films will include 1) low voltage (5-50 mV) ac impedance spectroscopy, 2) high voltage (1-1,000 V) variable frequency ac measurements of partial discharge and dielectric breakdown thresholds and 3) current-voltage characteristics for voltages below dielectric breakdown. Prospective applications include organic light emitting devices, organic insulators for electronic circuits, piezoelectric copolymer films, and polymer-based sensors.