Dielectric and Electrical Properties of Polymer Composites with High Aspect Ratio Fillers

by

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ABSTRACT

This thesis studies the effect of high aspect ratio fillers on the dielectric and electrical properties of polymer composites, such as dielectric spectroscopy, dielectric breakdown strength and electrical conductivity. Those properties are required for field grading applications in high voltage electrical apparatus and various energy storage applications. Fillers with both high aspect ratio and controlled properties are able to meet those requirements at a lower filler volume fraction than that of spherical particle filled composites.

In the thesis, the geometric factors of the composite microstructure, such as the filler shape and aspect ratio, were studied in combination with the filler property and composition. The effect of those geometric factors was examined by comparisons between the experimental data, analytical models and numerical simulation. $BaTiO_3$ fibers, graphene platelets and graphene oxide were studied as fillers and silicone rubber was used as the polymer matrix. Higher aspect ratio $BaTiO_3$ fibers were found to increase the composite dielectric constant compared to their low aspect ratio counterparts. Finite element analysis was performed to investigate how the composite dielectric constant was affected by the composite microstructure, such as filler shape, filler aspect ratio distribution, filler curvature, grain boundary and filler alignment. Studies on graphene platelets and graphene oxide showed the impact of filler property and composition on the dielectric properties of composites. The geometric parameters of composites, such as filler aspect ratio and loading were also found to have an influence on the dielectric breakdown strength of polymer composites. A model was proposed to correlate the electric field distribution in the polymer matrix and the dielectric breakdown strength of composites. In addition, by tailoring the oxidation state of graphene oxide filler, the composites were found to possess unique field dependent conductivity and excellent dielectric constant/loss for field grading applications. The mechanisms that lead to those interesting properties were analyzed and discussed.