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In Situ TEM Characterization of Nanostructured Dielectrics

Ming-Siao Hsiao[1,4], Yifei Yuan[2,3], Christopher Grabowski[1,4], Anmin Nie[2,3], Reza Shabazian-Yassar[2,3], Lawrence F. Drummy[1]

[1] Materials and Manufacturing Directorate, Air Force Research Laboratories, WPAFB, OH 45433
[2] Department of Mechanical Engineering, Michigan Technological University, Houghton, MI 49931
[3] Physics Department, University of Illinois at Chicago, Chicago, IL 60607
[4] UES, Inc., Dayton, OH 45432

Polymer nanocomposites are being considered as potential materials for high energy capacitor due to the possibility of obtaining high dielectric breakdown strength characteristic of the organic matrix and large dielectric permittivity from inorganic filler [1,2]. However in most case the increase in the content of inorganic ceramic filler in polymer nanocomposite inevitably causes a decrease in the dielectric breakdown strength due to the agglomeration of fillers, the existence of defects, and inorganic-organic interfacial effects. Many studies have attempted to improve the compatibility of organic and inorganic, however in the large majority the dielectric breakdown strength is poor and the dielectric loss is high. Additionally, as nanostructured dielectrics are a relatively new class of materials for this application, reports of investigating fundamental mechanisms of dielectric breakdown for the dielectric nanocomposite on the nanoscale have been limited.

Recently the dielectric performance of novel hairy polymer grafted nanoparticle assemblies has been compared to that of blended polymer nanocomposites; these two particular materials systems possessed well-dispersed morphology on the naonscale and had low dielectric contrast. It was shown that “hairy” polymer grafted nanoparticle assemblies showed substantial improvement in reducing dielectric loss and maintaining charge/discharge efficiency [3].

Here we presented *in situ* TEM observation of these hairy polystyrene grafted SiO_2 nanoparticle assemblies (PS @ SiO_2 NPs, aHNP-PS-1) during pre-breakdown/breakdown process using a TEM MEMS device and STM-TEM holders [4]. Fig. 1 shows the deposition of thin PS @ SiO_2 NPs film, prepared by cryo-microtoming, across two electrodes on rectangular Si_3N_4 window in TEM MEMS device for in situ TEM experiment. HAADF-STEM images show the PS @ SiO2 nanoparticles are well dispersed. Fig. 2 shows in situ TEM of a PS @ SiO_2 NPs film during a continuous voltage ramp within a STM-TEM holder, and significant microstructural morphology changes of the film at different electric fields were evident. Fig. 3 shows both morphology and electrical properties of PS @ SiO_2 NPs assemblies before and after breakdown, and it was found that a highly conductive, tree-like structure formed after breakdown. Several additional phenomena including nanoparticle motion and electrostriction were observed. Surprisingly, the measured breakdown strength of PS @ SiO_2 NPs film from in situ characterization can reach more than 900 V/μm when the assemblies on the nanoscale approach defect-free state [5].

References:

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[5] The authors acknowledge support from the Air Force Research Laboratory

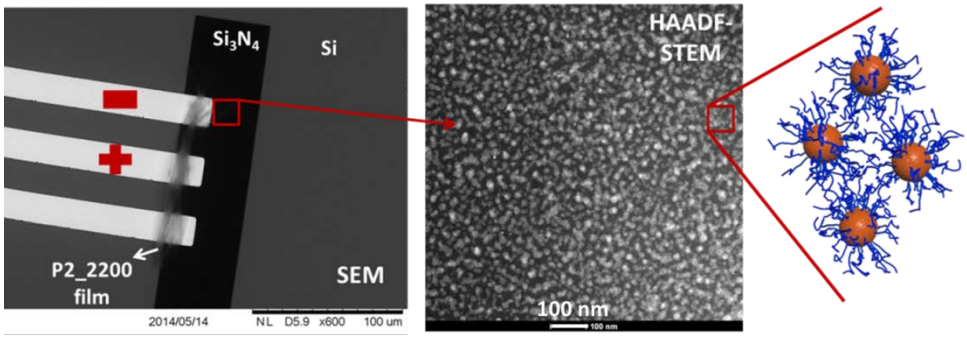

Fig. 1 SEM image of a cryo-microtoming PS @ SiO_2 NPs film depositing across two platinum electrodes on rectangular silicon nitrile window in the TEM MEMS holder. HAADF-STEM image shows silica nanoparticles disperse well in the polystyrene.

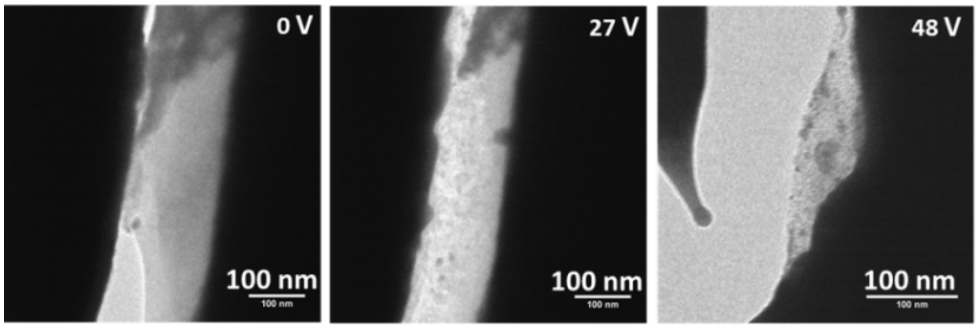

Fig. 2 *In situ* TEM observation of a PS @ SiO_2 NPs film at different electric field.

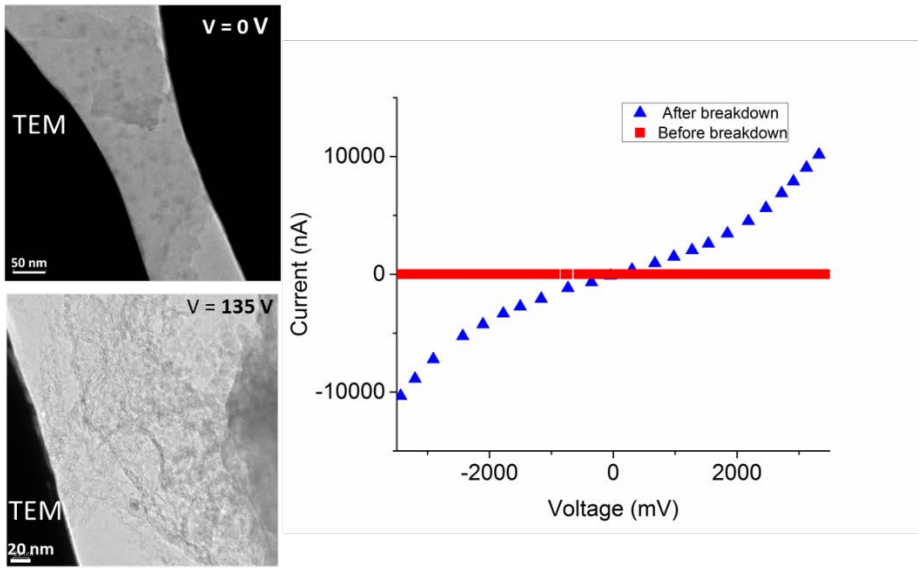

Fig. 3 Morphology and conducting behavior of a PS @ SiO_2 NPs film before and after breakdown, respectively.