Effect of organo-clay on dielectric properties of silicone rubber

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Abstract. Dielectric elastomers are highly deformable smart materials capable of actuation under electric fields [1,2]. To study the effect of organically modified Montmorillonite (OMMT) on dielectric properties of silicone rubber as a commercially available dielectric elastomer, OMMT was added to this rubber at two levels of 2% and 5% using high shear mixing. Composites were characterized by X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Atomic Force Microscopy (AFM). The XRD patterns showed that ordered crystallite structure of clay loses its ordered structure leading to disappearance of diffraction peaks. SEM and AFM micrographs depicted good dispersion and uniform distribution of the organo-clay. Tensile properties and dielectric properties of the composites were measured under AC electric fields, and results were compared with the reference silicone rubbers with no OMMT. It was shown that storage and loss dielectric constants of base silicone rubber increase when it is compounded with OMMT.

Experimental

Silicone rubbers used in this study were High Temperature Vulcanized (HTV) silicone rubber from Shenzhen APR (APH-20) in high consistency rubber form. The organo-clay Montmorillonite (Cloisite 15A) was obtained from Southern Clay Inc. High-shear mixing of HTV with 2% and 5% by weight OMMT was performed in a Brabender internal mixer. Then, the cross-link agent, Dicumyl Peroxide, was added to the compound on a two-roll mill in 50 °C for 20 minutes. Finally, the compound was hot pressed to complete the vulcanization process.

X-Ray diffractometer of type X’pert by Philips was employed to study changes in crystalline structure of the organo-clay as a result of dispersion in the rubber matrix. Scanning Electron Microscopy (SEM) micrographs were obtained using XL30 apparatus from Philips with excitation voltage of 20 KV. Atomic Force Microscopy (AFM) on the surface of samples was performed using DME SPM-Prober Station 150. Mechanical properties were measured using an Instron 5565 according to standard ASTM D412. Finally, Frequency dependent dielectric properties were measured by LCR-meter apparatus produced by INSTEK.

Result and Discussion

According to Figure 1, the larger main peak related to Bragg diffraction from 001 planes in the silicate crystal of pure OMMT has been disappeared in composites which means either represent high level of silicate dispersion/exfoliation, or the existence of a disordered/intercalated structure of clay platelets.

Micrographs of Figures 2, taken at different magnifications for both clay contents in HTV composites, show a well distribution of small rod-shape cross-section of clay bundles, especially for 2% clay content.

Atomic Force Microscopy (AFM) was employed to confirm the degree of dispersion of OMMT in the composites. Figure 3 complements the XRD graphs in confirming that extent high-shear mixing disperse the organo-clay in the rubber matrix.

Mechanical properties, tensile strength and elongation at break, of Composites of HTV silicone rubber mixed with OMMT enhanced. These results prove fine dispersion of OMMT in HTV silicone under high-shear mixing which leads to disordered clay layers and improved mechanical properties.

The frequency dependent storage ($\varepsilon''$) and loss ($\varepsilon''''$) dielectric constants for HTV silicone rubber and their composites are presented in figures 4. These figures illustrate enhancement in both $\varepsilon''$ and $\varepsilon''''$ as a result of OMMT addition which led to additional polarization mechanisms. This includes interfacial polarization or accumulation of space-charges at the interface between rubber and heterogeneous inclusions with higher permittivity than rubber as well as distortion and amplification of electric fields around filler particles, especially flat platelets [3, 4].
Conclusion

Ionic nature and platelet shape of silicate layers in OMMT as well as large initial basal spacing and modifier concentration of Cloisite 15A used in these study, allowed for both dielectric permittivity and loss in these composites under AC electric fields. Interlayer spacing and dispersion of clay bundles, were detected by XRD, SEM, and AFM. The results of tensile properties in uniaxial tension also proved effective dispersion of organo-clay under extensive melt mixing.

Figure 1. XRD diffractograms

Figure 2. SEM micrographs of silicone and nanocomposites

Figure 3. AFM micrographs from the surface of HTV + 5% OMMT composite at two scales: (a) 5 µm and (b) 750 nm.

Figure 4. Effect of OMMT on dielectric permittivity and dielectric loss of HTV silicone

References