NANODIELECTRIC MATERIALS FOR HIGH VOLTAGE DEVICES

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Introduction

Adding nanoparticles to the matrix of polymeric materials produces nanodielectrics that can greatly improve the thermal, mechanical and electrical properties of the polymeric composites. Nanodielectrics are a class of materials containing at least one phase at the nanometer scale and their benefits come in the form of increased endurance and enhanced breakdown strength of the materials [1]. It is only in the past few years that attention has been given to the application of nanodielectrics in the field of electrical insulating materials [2, 3]. Nanodielectrics can last longer than conventional composites and thus reduce the need for maintenance and extend the life of high voltage equipment. Due to their superior breakdown strength nanodielectrics can be used more efficiently at higher electric fields and this greatly decreases cost and saves energy.

The electrical properties of nanodielectrics can be improved if the nanoparticles are well dispersed [4]. One of the problems is that the nanoparticles agglomerate easily because of the high surface energy and conventional mixing techniques cannot usually break up these agglomerates. Another problem is the incompatibility of hydrophilic nanoparticles with a hydrophobic polymer, which results in poor interfacial interactions.

Polypropylene (PP) is extensively used as a dielectric in power capacitors and cable wraps as well as in layer and phase separators for rotating electrical equipment and transformers. It has excellent mechanical, thermal, and electrical properties and provides outstanding resistance to moisture, grease, and oils. A thermoplastic such as polypropylene can be reinforced with small quantities (up to 4% by weight) of nanoparticles to not only achieve better chemical and thermal properties but also improved dielectric properties, such as electrical breakdown strength, surface and volume conductivity and resistance to partial discharges. Nanoparticles, such as natural clay, have many impurities which cannot be easily removed. Hence, in this paper nanoparticles of synthetic clay are embedded in PP. Electroluminescence emission and Pulsed Electro-acoustic techniques are employed to compare the properties of PP with and without the nanoparticles.

Experimental

Sample Preparation

The nanocomposites were prepared in four steps: compounding, diluting, film blowing and film rolling, which have been described earlier [5]. Thin films, 130 µm thick and 30 mm in diameter, of three materials, isotactic PP with 0, 2, and 4-wt% of organosilicate referred to in this text as PP-0%, PP-2%, and PP-4%, respectively were used.

Measurements

Each side of the film was sputtered with gold electrodes having a diameter and thickness of 25 mm and 30 nm, respectively. Space charge distribution and electroluminescence emission were measured when each sample was individually subjected to an ac electric field. The experimental techniques for electroluminescence (EL) detection and space charge resolution with the Pulsed Electro-Acoustic (PEA) method have been described earlier [5].

Results & Discussion

The total number of EL pulsed emitted from the three materials subjected to ac electric field up to 24 kV/mm is shown in Fig. 1. Both nanomaterials, PP-2% and PP-4%, emitted less light than PP-0%. This suggests that less charge is injected into the nanodielectrics than the conventional material.

To verify this, the PEA technique was employed to measure the space charge distribution in the three materials. The space charge distribution in unaged and aged samples is shown in Fig. 2. The charge distribution was initially obtained by applying a low negative dc field (10 kV/mm) to the unaged samples. This field is below the charge injection level and the

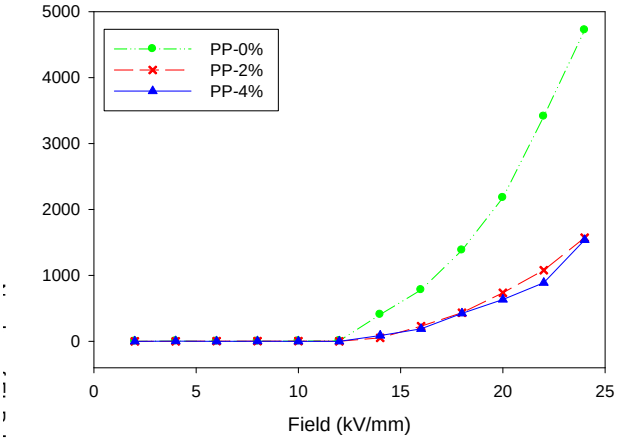

Fig. 1 EL emission in the three materials as a function of the of the ac electric field

curves show that there is no charge in the unaged samples. The three materials were then aged with a negative dc field (40 kV/mm) and the space charge distribution was monitored after 24 and 120 h. The amount of charge in the three materials increased with the time of aging. All three materials developed a homocharge peak ~15 µm from the positive electrode and a hetrocharge peak ~18 µm from the negative electrode. The polarity and amount of charge that develops during aging depends on the type of interface produced between the electrodes and the dielectric material.

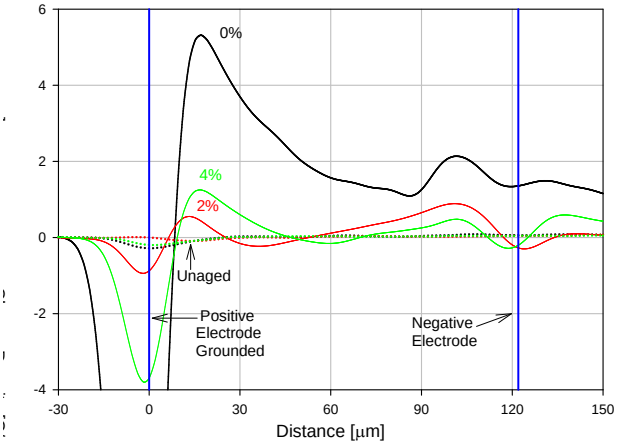

Fig. 2. Space charge distribution in the three materials: unaged (dotted curves) and aged for 120 h (solid curves).

However, during aging there was less charge accumulation in the nanodielectric materials as compared to PP-0%. This can explain why smaller number of EL pulses is emitted from the nanodielectrics as compared to PP-0%. At any value of the applied field, nanodielectrics decrease the amount of electrical charge that can be injected into the material as compared to the conventional dielectrics. This suggests that nanodielectrics can be used at much higher fields in power devices.

Conclusions

The addition of small quantities of nanoparticles into polypropylene decreases the amount of light emitted due to electroluminescence under ac electric field. This is because, as verified by the PEA technique, less charge is injected into the nanodielectric as compared to the conventional material. Thus adding small quantities (up to 4% by weight) of organosilicates to polypropylene can produce nanodielectrics for power devices, such as in high voltage capacitors and transformers, which operate at very high electric fields.

References

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