DIELECTRIC PROPERTIES ANALYSIS OF HDPE/SIO$_2$ NANODIELECTRIC MATERIALS FOR FUTURE CABLE INSULATION

Jérôme CASTELLON, Laurent BANET, Ioana PREDA, Serge AGNEL, Alain TOUREILLE, Institut d'Electronique du Sud – Université Montpellier 2, Montpellier (France), jerome.castellon@ies.univ-montp2.fr,laurent.banet@ies.univ-montp2.fr, ioana.preda@ies.univ-montp2.fr,serge.agnel@ies.univ-montp2.fr,alain.toureille@ies.univ-montp2.fr

Eric DAVID, Abdelkhaled SAMI,Ecole de Technologie Supérieure, Université du Québec, Montréal(Canada), eric.david@etsmtl.ca, abdelkhaled.sami@polymtl.ca

Michel FRECHETTE, Institut de Recherche d'Hydro-Québec, Québec, Montréal(Canada), frechette.michel@ireq.ca

ABSTRACT

The nanotechnologies are emerging in the field of future insulations for HVDC links. Innovative materials, usually called "nanodielectrics", are associated with the incorporation of nanoparticles in a polymer matrix in order to improve their performances. In this work, after analyzing the dispersion of nanoparticles in the matrix with the SEM analysis, the HDPE based samples filled with nanosilica particles were electrically characterized by broadband dielectric spectroscopy, conduction current and space charge measurements. The weight %-content of the silica filler was varied as a parameter. Neat HDPE and nanofilled HDPE samples up to 4 %weight have been studied and a classification of these materials vs. their space charge build-up was done.

KEYWORDS

Nanodielectrics, HVDC, Power Cables, Space Charge, Electric Field, HDPE insulation

INTRODUCTION

The presence of nanoparticles in a polymer matrix affects the electrical properties of final materials [1]. The resulting materials are usually called polymer nanocomposites (PNC) [2]. The incorporation of nanoparticles in a polymer matrix usually has a beneficial impact on the electrical properties of PNC This work concerns PNC with different silica nanoparticle contents in a matrix of high density polyethylene (HDPE). The following sections are giving a description of the sample preparation and their analysis. At first, the structure analysis of the nanostructured polymer was performed using scanning electron microscopy (SEM). Then, the broadband dielectric spectroscopy was used to assess the quality of the particle distribution. In parallel, an evaluation of the ability of these different materials to accumulate space charges was performed considering the applied electrical constraints.

Space charge measurements were performed on four samples of HDPE nanocomposites (0, 1, 2 and 4 wt% nano-SiO$_2$ content) versus applied electric fields up to 30 kV/mm for fixed periods of 40 hours at 70 °C. In ord er to complete the electrical analysis, conduction current measurements were made at various applied fields up to 30 kV/mm at 70°C.

SAMPLE PREPARATION

Polyethylene based nano-composites were prepared using extrusion melt compounding as a dispersive method. Nanoparticules of silicon dioxide (silica) with a nominal size of 15 nm were supplied by Nissan Chemical Industry in the form of a colloidal solution of isopropanol. They have not been organically modified. Polyethylene without any additive was provided by DOW Chemical in the form of a thin powder. The melting temperature, as measured by differential scanning calorimetry (DSC), was 130∘C, the density was 0.95 g cm^{-3} and the melt-flow index was 35 g (10 min)$^{-1}$. The polyethylene powder and nanoparticles were mechanically premixed for 15 min before their introduction into the extruder. The mixture was fed into the extruder and the compounding was conducted using twin screws rotating speed of 100 rpm and a temperature profile of 200℃, 220℃, 250℃, 2 50℃, 250℃, 220℃, and 200℃ in the sequential heating z ones from the hopper to the die. The melt temperature and pressure were continuously recorded during compounding. After compounding, the material was extruded from a die that had three cylindrical nozzles of 4 mm in diameter in order to produce cylindrical extrudates. These were cooled at room temperature and pelletized with an adjustable rotating knife located after the water bath into 5 mm long cylinders. Infrared measurements were conducted on the various samples obtained by this procedure and no noticeable oxidation occurring during processing was observed. Pellets obtained after extrusion were then hot pressed at 160℃ for 5min under 5 MPa into plates of various thickness between 500 µm and 1 mm.

Samples with a nominal concentration of 2% and 4% wt of nanosilica were prepared using the procedure previously described. Thermogravimetry analysis were conducted on both samples and the filler content after the complete pyrolysis of the polymeric matrix was 1.71 and 3.87%, which was in good agreement with the nominal concentration.

SCANNING ELECTRON MICROSCOPY

SEM was used to observe the particle dispersion in the polymer matrix. 4% by weight nanoSiO$_2$ particles of 15 nm was dispersed in HDPE matrix. But the manufacturing process does not properly disperse the silica in HDPE.The nanometric additives possibly lead to additional reactions, and a different intimacy with the matrix.