C.10.2.4.

Influence of the grain size on electrical and mechanical properties of non-linear materials

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Abstract: Metal oxide varistors have been successfully used for many years for the protection of electrical systems against over-voltages. The key idea of the research project described herein is to combine the electrical properties of ZnO powders typically used for varistors with the advantageous processing properties of polymers; creating a family of innovative dielectric materials. The role of the grain size of ZnO fillers on mechanical and electrical properties of composites made from a silicone matrix has been studied.

Keywords: non-linear, composite, grain size, mechanical and electrical properties, power accessories

Résumé: Les varistances à base d'oxydes métalliques sont utilisées avec succès depuis plusieurs années pour la protection des systèmes électriques contre les surtensions. L'idée du projet décrit ici est de combiner les propriétés électriques de poudres de ZnO utilisées pour les varistances avec les avantageuses propriétés de processabilité des polymères en créant une famille innovante de matériaux diélectriques. L'étude porte sur l'influence de la taille des charges de ZnO sur les propriétés électriques et mécaniques de composites élaborés à partir d'une matrice (silicone).

Mots clés: non-linéarité, composite, granulométrie, propriétés mécaniques et électriques, accessoires d'énergie

1. Introduction

The ability of polymers to act as electrical insulators is the basis for their widespread use in the electrical and electronic field. But interest in multifunctional materials has grown during the last years. The key idea of the project described herein is to combine the electrical properties of ZnO powders typically used for varistors with the advantageous processing properties of polymers; creating a family of innovative dielectric materials. As such materials present a non-linear electrical behavior, they could be used for field grading to protect electrical systems, among others power accessories, against over-voltage damages [1,2,3]. The objective of this study is to examine the influence of the grain size of ZnO fillers on the electrical and mechanical properties of composites made from a silicone matrix.

2. Experimental procedure

2.1 Materials

The polymer matrix used in this study was Liquid Silicone Rubber (LSR), Silopren 2540 available from GE Bayer Silicones.
Zinc oxide powder was grinded and sifted to obtain four lots of the same nature but having the following mean grain sizes: 10, 25; 65 and 95 µm. The particle size distributions are identical for each lot.

2.2 Preparation of samples

The polymer matrix and the filler were mixed in an internal mixer at room temperature. Degassing of the blend was done during 5 min. The filler ratio for all composites was 25 vol.-%. This ratio previously determined ensures percolation.
The specimens for the electrical measurements were compression moulded into discs which were 80 mm in diameter and 1 mm in thickness. The specimens for mechanical tests were compression moulded into plates that were 2 mm in thickness. All samples were cured at 120°C for 15 min and at 140°C for 6h.

2.3 Characterization of electrical properties

The electrical properties measured were the current density (under DC), the permittivity (ε_r) and the electrical loss factor (tan δ), both under 50 Hz AC.
Specimens were put on a sample holder consisting of a disc-shaped HV electrode made from Aluminium with a diameter of 70 mm to be fixed using a screw on an insulating rod and a LV electrode consisting of a central electrode (diameter 50 mm) and an outer guard ring (diameter 70 mm), also made from Aluminium. The conducting lead to the HV electrode was shaped in a way allowing to minimize corona discharges in air.