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

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Metal oxide varistors have been successfully used for many years for the protection of electrical systems against over-voltages, from electronic circuits to energy distribution networks. The key idea of the research project led within the Nexans Research Center 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.

A wet chemical technology, based on a sol-gel process, allows us to obtain ZnO powders with targeted characteristics: shape, grain size, doping…The present work is focused on the study of the fillers grain size influence on the electrical and mechanical properties of corresponding composites.

The study has been done on composite materials made from an insulating polymer matrix (silicone) in which ZnO fillers of different size are added. For all samples, the nature of the filler and the volume ratio were the same in order to allow comparisons. Four average grain sizes have been considered: 10, 25, 65 and 90 µm.

The composite samples are obtained mixing the matrix and the filler through an internal mixer.

1) Influence of the grain size on the electrical properties

The electrical properties measured were the current density, the permittivity and the electrical loss factor. The samples for electrical measurements were prepared through compression moulding into disc of 80 mm in diameter and 1 mm in thickness after mixing. All samples were cured at 120°C for 15 min and at 140°C for 6h.

The results of the electrical characterization clearly show the influence of the grain size on the electrical properties both in DC (Fig. 1) as well as in AC (Fig. 2). As reported in the literature for pure ceramic ZnO varistors, the smaller the grain size the higher the field threshold, as showed on the graphs below:

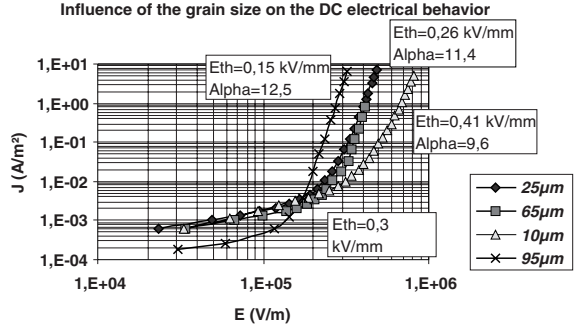

Fig. 1. Influence of the grain size on electrical behaviour under Direct Current

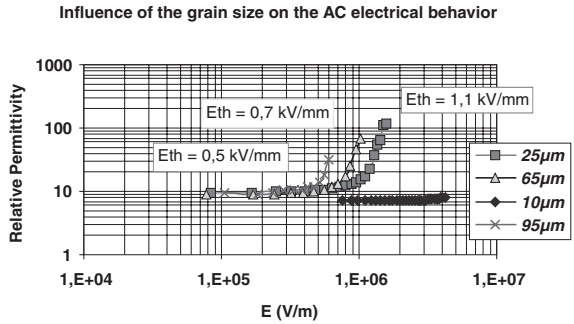

Fig. 2. Influence of the grain size on the electrical behaviour under Alternative Current

The same trend can be observed on AC characterization. Moreover, there is a shift in the field threshold between the resistive and the conductive zones. The field threshold at which the switch occurred is much more higher in AC as in DC. It seems that the higher the grain size the lower this shift is.

2) Influence of the grain size on the mechanical properties

The mechanical properties measured were the tear strength Fr (N/mm) on trouser tear specimen, the elongation at break εr (%) and the tensile stress at break εr (N/mm^2) on dumb-bell test specimen, the hardness (Shore A).

The results show that tear strength is low and increases when the grain size increases, the hardness of the composite follows the same trend. Tensile strength and elongation at break decrease with the increasing grain size.

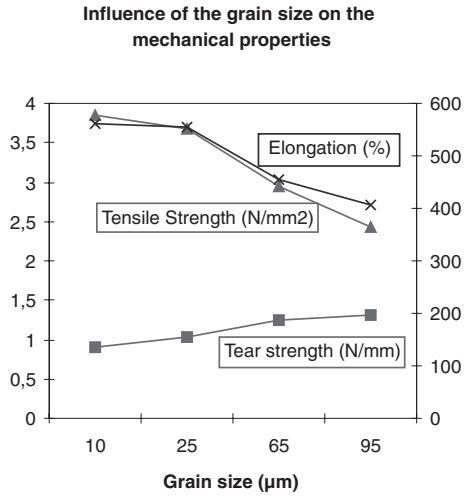

Fig. 3. Influence of the grain size on the mechanical properties

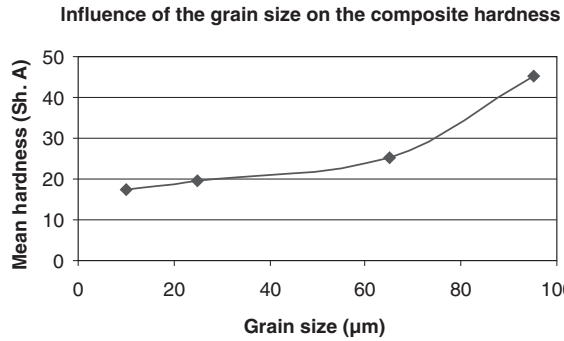

Fig. 4. Influence of the grain size on the composite hardness

The study give an overview of the effect of the grain size of an non-linear filler on the electrical and mechanical properties of the corresponding composite material. Depending on the application, medium or high voltage, it is possible to fit the electrical characteristics of the composite playing with the grain size of the filler and finding a compromise between electrical properties and mechanical resistance.