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Nano-enhanced Metal Oxide Varistor Ceramics for High Voltage Surge Arresters

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Abstract – Zinc oxide (ZnO) nanostructured material has gained much interest owing to its wide applications for various devices such as solar cells, varistors, transducers, transparent conducting electrodes, sensors, and catalysts. On the other hand, there is an emerging demand for more efficient and reliability electrical protective devices especially for high voltage applications such as transmission and distribution grids and electric power substations. This work presents some results of microstructural and electrothermal characterization about the use of nano-enhanced metal oxides for the production of high performance rare-earth-doped ZnO varistor ceramics for applications in high voltage advanced surge arresters.

As the demand for electricity increases, also increases the need to use high and ultra-high voltage surge arresters in the protection of transmission and distribution power lines to prevent failures that can cause damages of the order of billions dollars. In this sense, the technology of surge arresters has sought to produce varistors showing high electrothermal performance and thus the way has been found in the search for nanostructured varistor ceramics to reduce the grain size (and thus make possible the increase of the switching voltage), increase the microstructural homogeneity and to maximize the non-ohmic electrical behavior [1]. In accord with these considerations, in the present work, nano-size ceramic powders were used in order to produce varistor ceramics with great electrical protective performance and better electrothermal stability than conventional varistors.

Appropriate weights of analytical reagent grade nanopowders were used to prepare the zinc oxide-based ceramics, whose chemical compositions (mol%) are given by ZB = $96.5{\cdot}ZnO\text{-}0.5{\cdot}Bi_2O_3\text{-}1.0{\cdot}Sb_2O_3\text{-}1.0{\cdot}CoO\text{-}0.5{\cdot}MnO\text{-}0.5{\cdot}Cr_2O_3$; ZP = $98.5{\cdot}ZnO\text{-}1.0{\cdot}CoO\text{-}0.5{\cdot}Pr_6O_{11}$; ZPC = $97.59{\cdot}ZnO\text{-}1.00{\cdot}Pr_6O_{11}\text{-}1.00{\cdot}Co_3O_4\text{-}0.20{\cdot}B_2O_3\text{-}0.20{\cdot}CaO\text{-}0.01{\cdot}Al_2O_3$; and ZPNC = $97.3{\cdot}ZnO\text{-}0.5{\cdot}Pr_6O_{11}\text{-}1.0{\cdot}Co_3O_4\text{-}1.0{\cdot}Nd_2O_3\text{-}0.2{\cdot}Cr_2O_3$. Nanosize material powders were processed by high-energy milling processing and sintering techniques [2]. The evolution of the resistive component of the leakage current (I_{LR}) with respect to time (t) was estimated from the equation $\Delta I_{LR} = I_{LR}(t) - I_{LR}(0) = K_R t^{(1/2)}$ from measurements to dielectric characterization of the varistor ceramic blocks.

Figure 1 shows SEM micrographs of ZPC and ZPNC sintered varistor ceramics, revealing fully-densified microstructures. Figure 2 shows the ΔI_{LR} time-dependent evolution curves and K_R (I_{LR} increment rate) obtained values, at 100^0C, for each system studied. This results indicates that the studied varistors are in the following descending order of stability: ZPNC, ZPC, ZP and ZB (in respect to leakage current increasing), which is the same descending order for the energy absorption capability [2], since the ZPNC system presented the slowest I_{LR} growth (smaller K_R values), since as much as bigger K_R value, then greater will be the trend to electrothermal degradation of the device, inasmuch as the ΔI_{LR} will grow more quickly. In fact, the K_R value to ZB is about 30% greater than the value to the ZPNC system. Among other conclusions, it was verified that the zinc oxide-based varistor ceramics doped with rare-earth oxides showed less tendency to increase of the leakage current than the conventional varistors, particularly in densification usual levels the ZPNC ceramics exhibited the best electrothermal behavior.

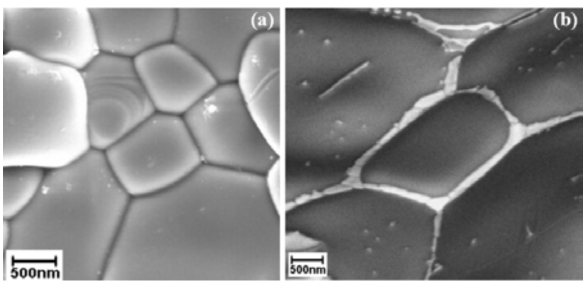

Figure 1: SEM micrographs of sintered varistor ceramic specimens: (a) ZPC; (b) ZPNC.

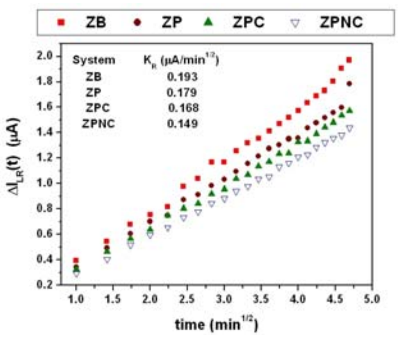

Figure 2: Electrothermal behavior according ΔI_{LR} curves (at constant temperature of 100^0C), for the varistor ceramic systems studied.

[1] G. R. S. Lira, D. Fernandes Jr, G. Costa, Proceedings of the International Conference on Power Systems Transients (2007) 120-125.
[2] J. G. M. Furtado, R. Dias, M. C. S. Nóbrega, E. T. Serra, Proceedings of the 63rd ABM Annual Congress (2008) 121-132.