A MICROSTRUCTURAL ANALYSIS OF HIGH VOLTAGE SURGE ARRESTER VARISTORS

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Varistor ceramics are the more common voltage transient suppressors and zinc oxide (ZnO)-based varistor ceramics have been the more used overvoltage protect device since that they were proposed by Matsuoka *et al.* [1] in 1969. In high voltage applications, the varistors are ceramic blocks used in surge arresters as shown in Figure 1a. The ZnO varistor exhibits highly non-linear current (I)-voltage (U) characteristics, owing to electrostatic barriers located at the ZnO grain boundaries. Electrical characteristics such as surge current and transient energy withstanding (energy absorption capability), leakage current, are correlated with distribution of these barriers in the volume of the ceramic and the homogeneity of grain size. The better the homogeneity of barrier distribution, the better the performances of the ZnO varistors [2].

Operationally, the aspects concerning the leakage current, energy absorption and heat dissipation capacities of a varistor ceramic, which emerge from its physico-chemical characteristics in microscale, are very important to the design, the performance and the degradation behaviour of these devices and surge arresters used in protection systems in a large variety of electric lines and power stations [3].

In this work is studied the electrothermal behaviour of varistor ceramic blocks used in high voltage surge arresters of transmission and distribution lines, relating this behavior to microstructural characteristics of the studied varistor ceramics. The varistor ceramic blocks used in high voltage surge arresters of transmission and distribution lines were microstructurally characterized and compared to the respective electrothermal behavior. Blocks of zinc oxide varistors with nominal voltage of 4.0 kV were studied (Figure 1b), by voltage-current and voltage-capacitance characterization curves, reference voltage test, impulse residual voltage, polarization tests and induced degradation tests (8/20 μs current impulses). The microstructural characterization was made by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). Figure 1c shows a block varistor destroyed after extreme degradation.

Figures 2a and 2b show a high densification of the ceramic bodies, although the heterogeneous character is pronounced, especially regarding the distribution of intergranular layers and spinel particles. Figure 2c shows the microstructure of a varistor block after catastrophic electrothermal runaway (extreme degradation condition); the area appears burned, as a result of a large increase in temperature, resulting in deterioration of intergranular layers, with the appearance of pseudo-porosity induced by electrothermal effect [4].

Figures 3a and 3b show ED spectra of the areas selected from Figure 2c, showing essentially the elements characteristics of a conventional varistor formulation. Already in Figure 3b the main elemental chemical components of the varistor are also present in the analysis, but have the presence of iron and cobalt. In the first case, probably derived from the diffusion of the metallization layer varistor or the physical-chemical degradation of the insulation layer of the device due to the high temperatures reached during the electrothermal runaway and in the second case, from the analysis in larger area because the cobalt has an amphoteric character on the doping of zinc oxide [5]. In comparison, Figures 3c and 3d show the average results of electrical and dielectric characterization of the varistor blocks studied. After non-destructive electrothermal degradation there was an increase in the resistive component of leakage electrical current, especially near the nominal switching voltage of the varistor blocks studied. From the results shown in Figure 3d it was verified that although the changes in capacitance are negligible, the changes in dielectric losses are very pronounced. Indeed, the discrepancy between these values before and after degradation are increasing throughout the range of polarization analyzed, up to 70% for voltages close to switching voltage. Corroborating previous results, Figure 3c, this behavior demonstrates the relevant role of the behavior of the resistive component of leakage electrical current on the capacitive component.

Thus, under the studied conditions, increases of the resistive component of the leakage electrical current and of the dielectric losses of respectively 60% and 70% were verified after the induced electrothermal degradation tests. Moreover, the region of the electrical behavior of the varistor more sensitive to degenerescence conditions was the linear (pre-breakdown) region.

References:
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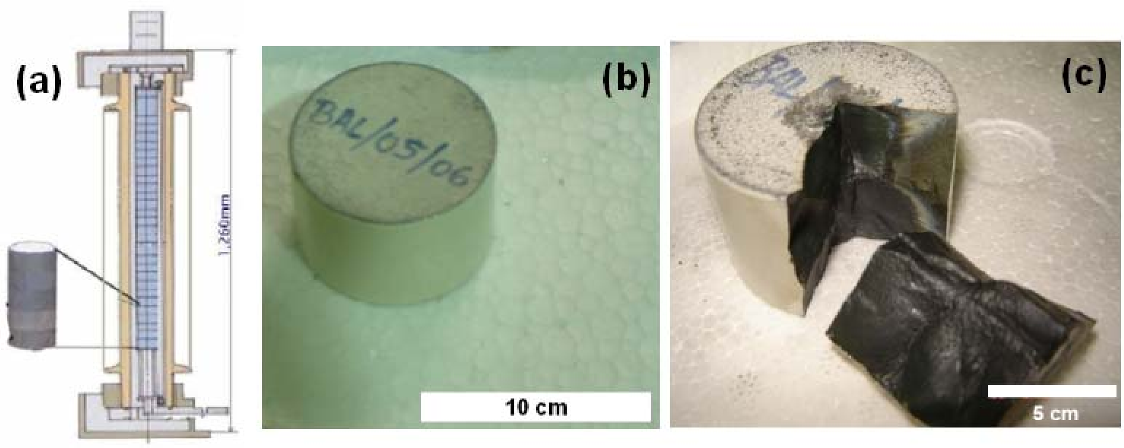

Figure 1 – (a) Cross-section of a 72 kV Toshiba gapless surge arrester showing the stacked varistor ceramic blocks; (b) example of a varistor ceramic block for high voltage applications; (c) the block shown in (b) after catastrophic electrothermal runaway (extreme degradation).

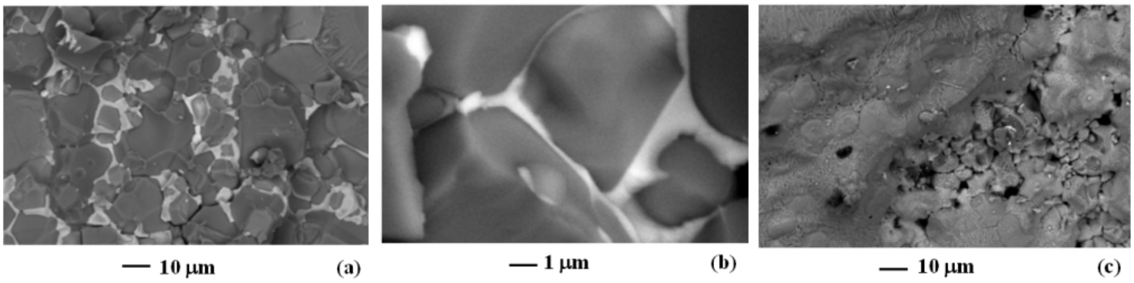

Figure 2 – (a) Electron image (SE) of the fractured surface of a varistor block studied; (b) detail showing the heterogeneity of the intergranular layers; (c) a region of a varistor block after catastrophic electrothermal runaway.

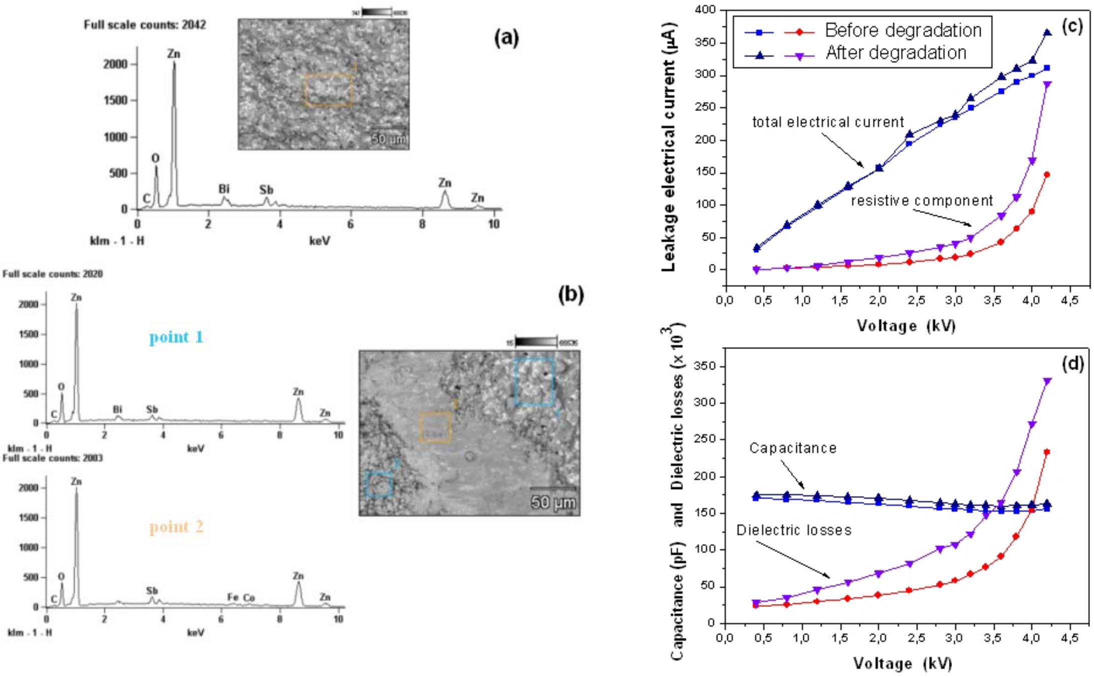

Figure 3 – ED spectra of regions of a varistor block studied: (a) non-degraded; (b) after degradation. Before and after degradation: (c) leakage electrical current and resistive component behaviors; (d) dielectric characteristics (capacitance and dielectric losses).