DETERMINATION OF POTENTIAL BARRIER OF ZnO-DOPED VARISTORS

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The ZnO-based varistors is one of the MOV's and the non-linear properties of these materials are characterized by an electrical resistance that decreases as the applied voltage field increases. These characteristics are strongly dependent of chemical composition and processing variables, responsible for the formation of microstructure of varistors [1,2].

The difference between varistors and other ceramics is the formation of a polycrystalline material multiphase, for example, with semiconducting grains and an insulating layer at grains contours, which lead to formation of Schottky barriers, which are responsible for the non-linear behavior. The basic concept underlying varistor action is that the current/voltage characteristics are controlled by the existence of electrostatic barriers at the interfaces between grains. The origin of these barriers is interface charge stemming from lattice mismatch, defects and dopants at the grain boundary [2-4].

ZnO-doped was prepared as following: ZnO+0.5%-mol Bi_2O_3 (system I), ZnO+0.5%-mol Bi_2O_3+1.0%-mol Cr_2O_3 (system II), and investigated the dependence of such barriers on external voltage. These samples were sintered at 1200°C for 1 hour with heating and cooling rates of 5^oC/min. The electrical characterization was carried out on polished samples. The imagings of surface and Schottky barriers were analyzed using a Nanoscope IIIa atomic force microscope (AFM). The images are viewed side-by-side in real time with a scan speed of 0.8 Hz. The free sample surface was imaged using a NSC15 (MikroMasch) tip radius <10 nm, average force constant was 45 N/m. Imaging was carried out at room temperature.

The topographics images both System I and System II were presented in Figs. 1(a) and 2(a). The EFM images are showed from Fig. 1(b-e) to Fig. 2(b-e). The bright regions represent the accumulation of charges observed in certain regions of the grain boundary which indicates the presence of electrically active potential barriers. These results combine both the effect of grain size and number of electrically active interfaces, as reported previously [5]. The paths of electrical current in varistors are those with less resistance or routes with less contours, resistance, borders (or larger grains) and those with smaller grain boundary barrier [2-4]. If the grain size is uniform then, more electric current pass through of many parallel paths. Porosity and no grains uniform distribution effects need be avoided.

The surface potential clearly identifies a grain boundary (Fig. 3). Potential profiles were extracted from various positions along the grain boundaries in all the samples. Based on these profiles, the dimensions of the potential barriers at the grain boundaries were determined by EFM procedure at 432 nm both System I and System II (Fig. 3). These results indicate that the Cr_2O_3 do not responsible by change the width of the potential barrier. The width of the resistive layer, which is a function of the material's chemistry and processing, is not expected to be very sensitive to the applied voltage. No significant variation of high of the potential barrier was observed in Fig.3, possibly, due to poor contribution of the Cr to the material's conductivity.

Potential barrier height and width are both associated with an increase in the number of electrons and holes presented in the grain and grain boundary regions [5]. The amount of trapped electrons in the grain boundary regions, resulting from the segregation of dopants next to the grain boundaries, as well as the creation of positive defects in the depletion layer and negative defects at the interfaces (metallic vacancies), are also related to the potential barrier characteristics. Thus, potential barrier increases can be associated with increased effective grain boundary states. The basic concept underlying varistor action is that the current/voltage characteristics are controlled by the existence of electrostatic barriers at the interfaces between grains. The origin of these barriers is an interface charge stemming from lattice mismatch, defects and dopants at the grain boundary. The interface charge changes the Fermi level in the vicinity of the grain boundary, resulting in band bending.

References:

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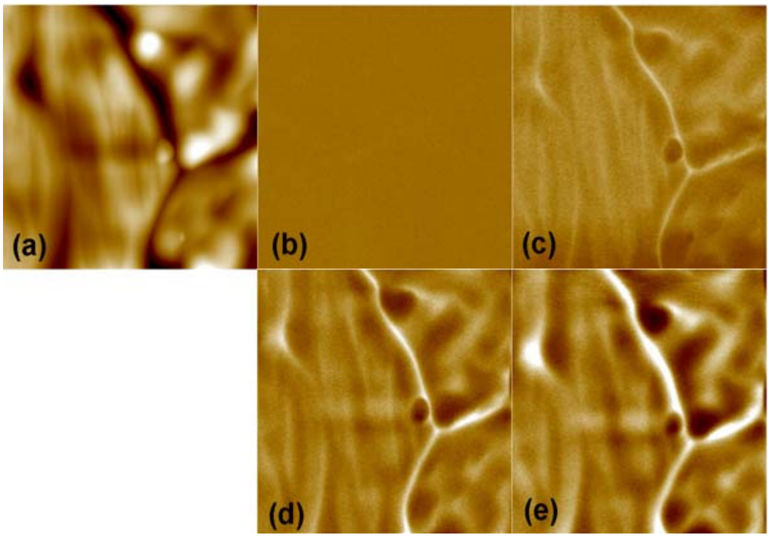

Figure 1 – Analysis of system I (10×m ×10μm): topography (a); profiles EFM with application of external voltage: 0 V (b), 4 V (c), 8 V (d), and 12 V (e).

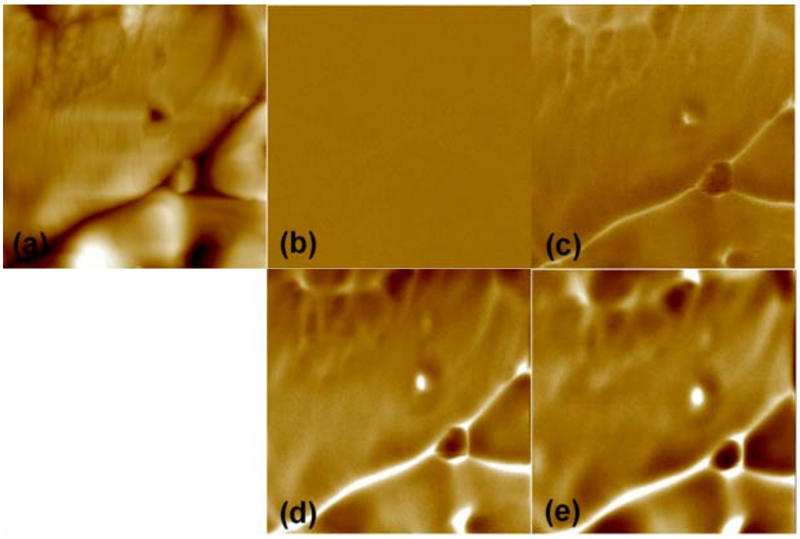

Figure 2 – Analysis of system I (10×m ×10μm): topography (a); profiles EFM with application of external voltage: 0 V (b), 4 V (c), 8 V (d), and 12 V (e).

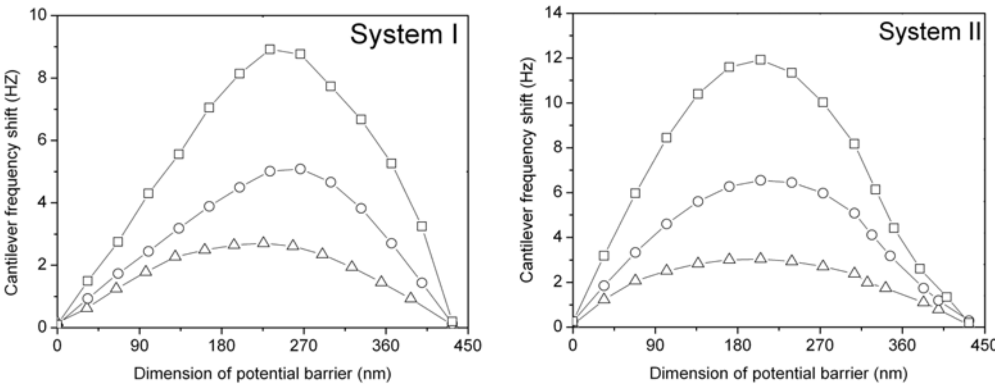

Figure 3 – Schottky barrier behavior obtained by EFM both System I and System II: 4 volts (Δ), 8 volts (O), and 12 volts (□);