A new composition of ceramic varistor: SnO_2 doped with (Co, Nb, Al)

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Abstract. A new ceramic voltage sensor based on SnO_2 doped with Co, Nb and Al has been successfully synthesized by ceramic route. The ceramic compact exhibited excellent non-linear current–voltage (I – V) characteristics with $\alpha \approx 24$ and $E_{1\text{mA}} \approx 700$ V/mm.

Keywords. Varistors; non-linear coefficient; breakdown field.

1. Introduction

Zinc oxide based non-linear ceramic voltage sensors have proved to be very important components of many electric/electronic circuits as a surge suppressor (Gupta 1990). The non-linear properties derived from the systematic studies on the current–voltage (I – V) characteristics have been well understood on the basis of grain–grain boundary phenomenon (Levinson and Philipp 1986). These high field varistors with large non-linear coefficient (α) are microstructurally engineered to suit the requirements for diverse technological applications (Gupta 1992). In addition, there is a need for a low field varistor with high α values for VLSI circuits. In the search for the newer materials, titania (TiO_2), strontium titanate (SrTiO_3) and composites are being developed (Modine and Hgatt 1988; Zhou and Yu 1994; Yang and Wu 1995). In continuation of our earlier work on varistors, we recently examined a new composition based on SnO_2 doped with cobalt, niobium and aluminium for a possible non-linear behaviour in I – V characteristics (Kharat *et al* 1992; Santhosh *et al* 1996). In this communication, we report for the first time the observation of excellent non-linear behaviour for the novel composition of SnO_2 : Co, Nb, Al compacts.

2. Experimental

Appropriate molar quantities of AR grade SnO_2 , CoO , Nb_2O_5 , Al_2O_3 in the required proportions (98.9:1:0.05:0.05) were thoroughly mixed in a ball mill. The resulting mixture was cold pressed into green compacts and subsequently sintered at various temperatures of 1200–1350°C for 2 h in air. For the high quality electrical measurements the pellets were lapped to 0.8 mm thickness. Uniform coating of silver paint was applied on both sides of the pellet as electrodes and was cured at 600°C in air.

These ceramic compacts were characterized for (i) I – V measurements [Keithley 610C electrometer, Aplab 7161 and 7323 power supply], (ii) powder/phase analysis [Philips PW1730 X-ray diffractometer] and (iii) microstructural analysis [Leica Cambridge 430 scanning electron microscope].

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Figure 1. Current-voltage characteristics of the new composition of SnO_2 varistor.

Figure 2. X-ray diffraction pattern of the SnO_2 sample sintered at 1250°C .

3. Results

Figure 1 shows the log-log plot of I - V characteristics of SnO_2 pellet sintered at the optimum temperature of 1250°C . It shows excellent non-linear behaviour with $\alpha \approx 24$ and a high breakdown field of $\approx 700 \text{ V/mm}$. Since the non-linear behaviour of these

Figure 3. Scanning electron micrograph of the SnO₂ pellet.

materials are generally related to an effective grain boundary formation, we checked the microstructural characteristics by taking X-ray diffraction pattern and the SEM fractograph. The X-ray powder diffraction pattern of this material is shown in figure 2. No phases other than the rutile SnO₂ is seen in XRD pattern. The SEM fractograph of this sample is shown in figure 3. The grain size is distributed in the range 3–5 μm . The different parameters of this SnO₂ varistor material derived from the above measurements seem to point out that this material has properties similar to ZnO varistors. Attempts are being made to obtain a uniform distribution of well defined grains with homogeneously distributed dopants which will in turn improve the non-linear behaviour of this material.

In conclusion, a new composition of SnO₂ doped with Co, Nb and Al exhibited excellent non-linear I - V behaviour.

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