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The sintering time influence on the electrical and microstructural characteristics of SnO_2 varistor

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Abstract

The variation of the electrical properties of a well-known tin oxide varistor composition in relation to the sintering time for temperatures of 1300 and 1350 °C was studied in this work. It was verified that the barrier voltage value, v_b, varies according to the varistor sintering time. Stable electrical barriers between 2.0 and 2.4 V/barrier produce varistors with non-linear coefficients higher than 35, independently of the sintering temperature. The variation of the grain size in relation to the sintering time was 45.1% for sintering at 1300 °C and 33.6% for sintering at 1350 °C, considering the minimum time of 1 h and the maximum of 12 h, with considerable variations in the respective electrical breakdown fields. Therefore, the sintering time is a very important variable which should not be despised in the project of tin oxide varistor production.

Keywords: SnO_2; Varistors; Microstructure; Electrical properties

1. Introduction

The varistor is a device which provides protection against tension peaks in industries and residential electrical and electronic systems. It can also be used as a surge arrester in substations and electrical power transmissions and distribution lines [1]. This protection function is possible due to the varistor non-linear electrical property that is given by the relation $I=C\cdot V^{\alpha}$, being α the non-linearity coefficient, V, the applied voltage, I the current and C a constant. Nowadays, the constant use of electrical and electronic devices in all areas of life has generated research and development of protection devices which are more and more efficient in order to ensure this equipment will work adequately. The first varistors were developed from silicon carbide (SiC) and germanium (Ge) semiconductors [1]. In 1970 the zinc oxide (ZnO) varistors, which revealed superior properties, were developed by Matsuoka [2]. An alternative to the ZnO varistors appeared in 1993, with the patent of invention "SnO_2 based varistor compositions and processing" [3]. A lot of research on the dopants effect, electrical properties and SnO_2 varistors conducting mechanisms, has been reported in the literature [4–9]. However, there has been little concern over the time processing variables and sintering temperature. In this sense, this work aims at verifying the influence of sintering

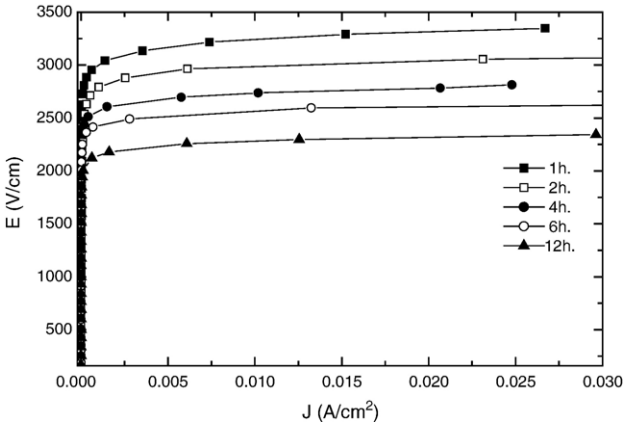

Fig. 1. $J\times E$ curves of varistors sintered at 1300 °C at different times.

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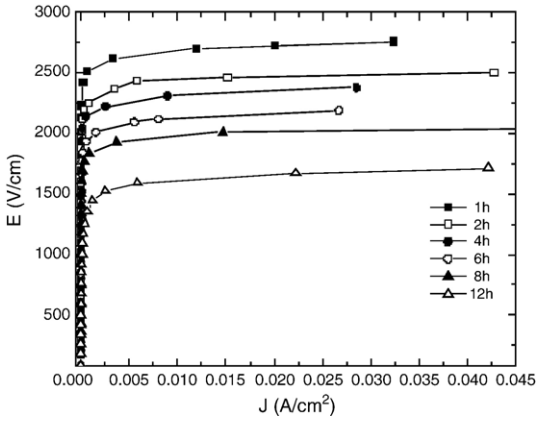

Fig. 2. $J \times E$ curves of varistors sintered at 1350 °C at different times.

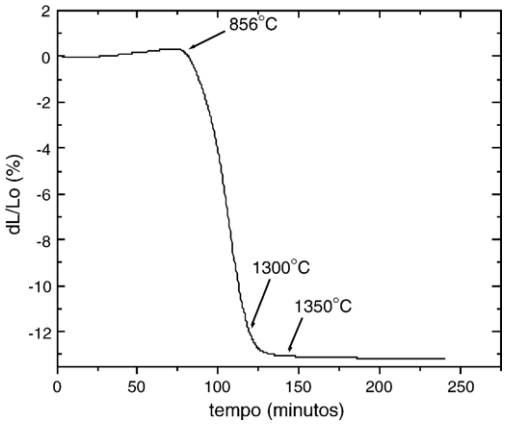

Fig. 3. Linear shrinkage evolution during sintering of the porous compact varistor heating at 10 °C/min rate and sintering time of 2 h at 1350 °C.

time variation upon electrical and microstructural characteristics of ceramic sintered at 1300 and 1350 °C.

2. Experimental procedure

Raw materials of analytical grade in form of oxides were employed in the ceramic processing, with the following origin: SnO_2 (CESBRA), Co_3O_4 (RIEDEL), Nb_2O_5 (CBMM) and Cr_2O_3 (VETEC). The composition 98.90% SnO_2 + 1.00% CoO + 0.05% Nb_2O_5 + 0.05% Cr_2O_3 (mole percent) was kept fixed throughout this study. The composition was ball milled in a high-density polyethylene jar (NALGENE), using high purity zirconia cylinders (ZrO_2) as grinding media. High purity ethyl-alcohol (SYNTH) was added in the jar at 1:1 mass/alcohol proportion. After grinding time, the resulting suspension was dried at 100 °C/12 h. The powder resulting was sieved in a 100 mesh sieve. The samples in the cylindrical shape (13 mm diameter and 1 mm thickness) were compacted at 75 MPa using a uniaxial press. The samples sintering was carried out in a silicon carbide tubular furnace at 1300 and 1350 °C temperatures, within variable times of 1, 2, 4, 6, 8 and 12 h. The samples were then slowly cooled to room temperature at 180 °C/h rate. After sintering, the samples surfaces were superficially rectified and silver electrodes (DEGUSSA) were deposited on their surfaces. In order to eliminate the excess of solvent and fix the electrodes, the samples were thermally treated at 700 °C for 30 min. The electrical measurements $I \times V$ were carried out using a stabilized electrical source (TECTROL TCH 3000-2) and two digital multimeters (FLUKE 8050 A). The values of V and I were normalized for electrical field E (V/cm) and current density J (A/cm^2). The non-linear coefficient (α) was obtained by linear regression of the experimental points using a logarithmic scale around 1 mA/cm^2 and the breakdown electrical voltage (E_b) was obtained at this current density. For

Table 1
Effect of the time and temperature sintering on the electrical properties and average grain size

Time (h)	E_r (V/cm)	d (μm)	α	v_b (V/barrier)
T = 1300 °C				
1	2989	5.6	31	1.7
2	2870	7.0	41	2.0
4	2565	8.3	41	2.1
6	2449	9.9	42	2.4
12	2134	10.2	42	2.2
T = 1350 °C				
1	2515	8.1	43	2.0
2	2273	10.1	45	2.3
4	2166	10.6	39	2.3
6	1964	10.8	36	2.1
8	1841	11.0	43	2.0
12	1403	12.2	25	1.7

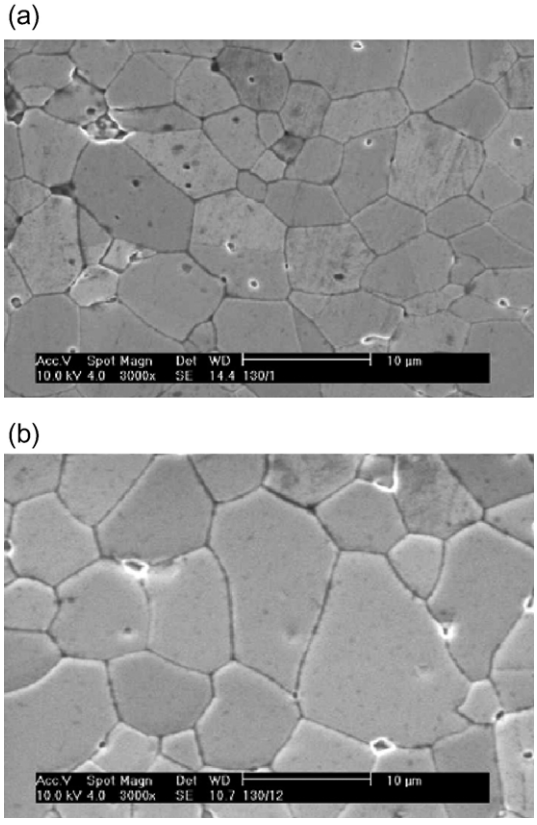

Fig. 4. Microstructures of the samples sintered at 1300 °C for different times: (a) 1 h and (b) 12 h.