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Effect of high Al_2O_3 content on the microstructure and electrical properties of Co- and Ta-doped SnO_2 varistors

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Abstract

Varistor behavior shows significant differences when the addition levels of different dopants like In_2O_3, Cr_2O_3, and Al_2O_3 are changed, thus stimulating current investigations on the SnO_2–Co_3O_4–Ta_2O_5 ceramic system. In this contribution, the influence of high additions of Al_2O_3 on the microstructure, structure and the electrical properties of SnO_2–Co_3O_4–Ta_2O_5 varistors ([98.95-X]%SnO_2–1% Co_3O_4–X% Al_2O_3–0.05% Ta_2O_5, where X = 0, 0.05, 0.1, 1 or 2 mol%) is investigated. Characterization techniques such as thermal analysis, scanning electron microscopy and X-ray diffraction with Rietveld refinement were used for specimen analysis. The endothermic peaks in the ceramic system containing Al_2O_3 additions between 0.05 and 1% are ascribed to the formation of the Co_2SnO_4 and $CoAl_2O_4$ spinel type phases. Doping the ceramic system with 1 and 2 mol% Al_2O_3 leads to the formation of 1.163 and 3.449%, respectively, of the spinel phase Al_2CoO_4, which acts as a grain growth inhibitor because grain size decreases in about 16% for both addition levels. The apparent grains homogeneity and narrowest monomodal grain size distribution for the specimens with 2 mol% Al_2O_3 confirm the inhibitory role. With the lowest level of Al_2O_3 (0.05 mol%) the nonlinearity coefficient reaches a maximum, after which it decreases and fades at the highest alumina level. A remarkable decrease of about 50% in the leakage current from the reference specimen´s value to that of the one with 0.05 mol% Al_2O_3 concurrently with an increase in about 40% in the nonlinearity coefficient favors the potential use of alumina in the SnO_2–Co_3O_4–Ta_2O_5 ceramic system.

1 Introduction

Since the introduction of zinc oxide (ZnO) as a large-nonlinearity material by Matsuoka about 50 years ago [1], varistors have been the subject of a plethora of investigations. Varistors are electrical resistors whose response depend on the applied voltage. And albeit ZnO paved the way in varistor research and set the standard as a successful, profitable material, nowadays, a large number of ceramics, including TiO_2 [2], $SrTiO_3$ [3], WO_3 [4], $CaCu_3Ti_4O_{12}$ [5], $BaTiO_3$ [6] and SnO_2 [7] are currently under intense investigation.

For more than two decades, investigations on the use of aluminum oxide (Al_2O_3) in ceramic varistors have been conducted [8–12], and its effects as a dopant of a variety of ceramics including ZnO, WO_3-based varistors, and ZPCCYA-based varistors have been related with the microstructure and electrical properties of the materials. However, most of the work done is reported on ZnO and using small amounts or low levels of Al_2O_3 additions. Accordingly, in ZnO varistors it was observed that depending on the system and Al_2O_3 additions, it may impact grain growth

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