Characterizing the microstructure and electrical properties ZnO-based varistor ceramics doped with Al

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Abstract

ZnO-based varistors have become technologically important over the past thirty years because of their highly non-linear electrical characteristics and their large energy-absorption capacity. Dopants such as Bi2O3, Sb2O3, Mn3O4, Co3O4, Cr2O3 are typically added to the ZnO in amounts of a few tenths of a mol.%. The microstructure development is especially sensitive to the Sb2O3/Bi2O3 ratio. In very small amounts aluminum is a possible dopant, to increase the conductivity of the ZnO grains and enhance a varistors performance at high currents. Aluminum incorporates into the ZnO grains and influences the equilibrium of crystal lattice defects; depending on the site of its incorporation into the ZnO lattice it can act either as a donor or an acceptor, which defines its influence on the conductivity of the ZnO grains. The effect of Al is therefore very sensitive to the amount added to the varistor and also the sintering temperature and time. In this study, high-voltage ZnO-based varistor ceramics doped with Al were prepared. The influence of the Al doping in the range from a few ppm up to several thousand ppm on the microstructure development and grain growth, and current-voltage characteristics of the varistor ceramics, was analyzed. It showed that additions of Al in the range up to a few hundreds of ppm are optimal, and that they significantly and specifically influence the threshold voltage, nonlinear coefficient and leakage current of the varistor. The ZnO grain size decreases with increasing amounts of added Al, which contributes to the increase in the threshold voltage, except for the additions of about 50 ppm Al where some peculiarities in the ZnO grain growth were observed. The results raised a question about the possible mechanisms of the influence of such small amounts of Al on the grain growth in such a complex composition as found in a varistor.