Microscale investigations on double Schottky barriers - the key elements of varistors

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Abstract
Modern varistor components used as overvoltage protection devices are based on n-doped zinc oxide ceramics. The macroscopically observed highly non-linear current-voltage characteristics, showing a high resistance at low voltages and high conductivities above a certain switching voltage, is the averaged result of a complex network of current path through the grains and grain boundaries of the ZnO ceramics. Actually the current-limiting effect is caused by grain boundaries between ZnO-grains which act as so-called double Schottky barriers due to some space charges forming electrical barriers. These "micro-varistors" are the elementary resistor elements in the electrical materials network and therefore its functional properties have to be understood and designed.
In this work, a number of delicate, complementary experimental methods are used in order to investigate the varistor behavior of single grain boundaries with respect to the microstructure: micro lock-in infrared thermography (MLIT) (Fig. 1) to detect current paths, a micro 4-point method (M4PM) system (Fig. 2) to measure the current-voltage characteristics between single ZnO grains, electron back scattering diffraction (EBSD) to determine grain orientations and different variants of scanning probe microscopy (Fig. 3) to get informations about topography, potential distributions, and orientations of polar crystal axes.

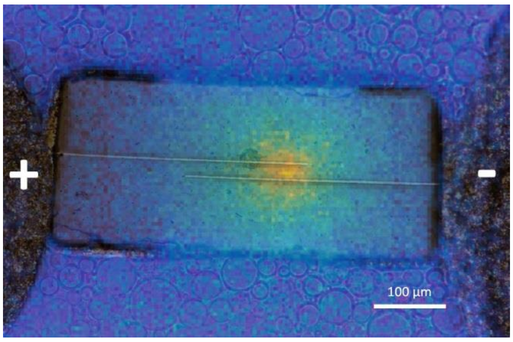

Fig. 1: MLIT image of a varistor; warm colors indicate a dominant current path.

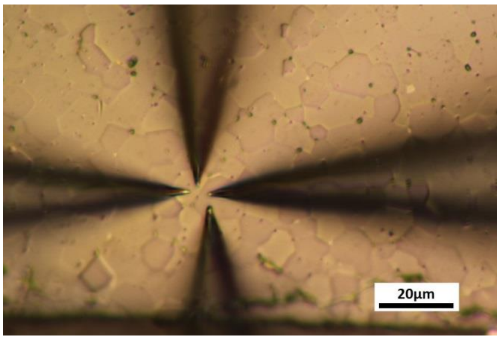

Fig. 2: Micro 4-point measurement bet-ween two individual ZnO grains.

A pronounced asymmetry of the current voltage characteristics with respect to current direction has been observed, which is influenced strongly on the crystal orientations of the neighboring grains and the mechanical stress state.
The obtained results were used to setup a physical model of the single micro-varistor and finally of large networks representing the macroscopic material.

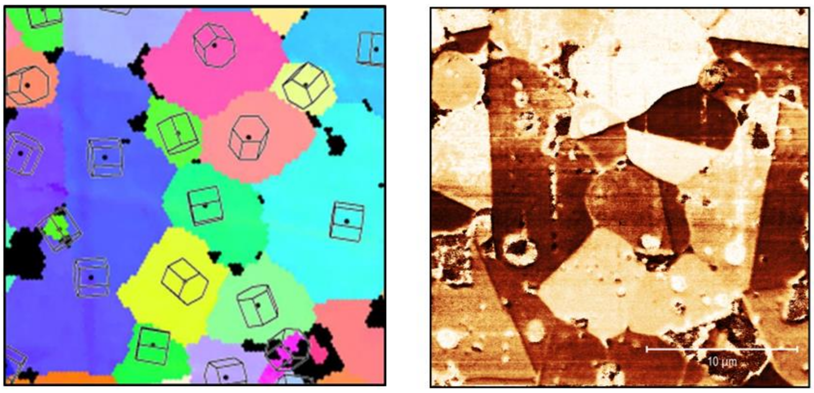

Fig. 3: EBSD- and PFM-image (Piezo Force Microscopy) showing twin boundaries within single grains.

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