Mesoscopic Modelling of ZnO Varistors

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ABSTRACT

This newly developed modelling framework for the simulation of electric current flow in ZnO varistors is based on an equivalent circuit representation of the varistor microstructure where the grain boundaries are represented by nonlinear resistors in the circuit. The present approach extends to similar models introduced earlier by including the effect of mechanical stress on the grain boundary conductivity. This effect is based on the coupling between the semiconducting and the piezoelectric properties of ZnO. The stress-induced piezoelectric polarization modifies the interface charge at the grain boundaries. This changes the effective potential barrier and therefore leads to a stress induced modification of the current voltage characteristics of the grain boundary.

The model used for the calculation of single grain boundary conductivities is based on the theory of Blatter et al. and Verghese et al.. It includes a self-consistent solution for the interface charge and for the potential barrier of the boundary, taking into account the local stress in the grain. Using this model, the grain boundary potential barriers are parametrized with respect to voltage and piezoelectric charge density. Such tabulated data can be easily incorporated in the modeling of larger varistor structures.

2D and 3D varistor models are constructed using appropriate Voronoi tessellations. The stress distribution within the material is calculated by FEM. The electrical resistance of each grain boundary is then determined according to the local voltage and piezoelectric polarization charge. Finally, the electric current flow patterns within the microstructure and the corresponding current-voltage characteristic of the bulk material are obtained by solving the nonlinear circuit equations for each applied voltage and stress condition of the sample. The simulated characteristics reveal a significant sensitivity of the bulk electrical conductivity to stress. Furthermore, the simulations demonstrate the current concentration effect in the voltage breakdown region.

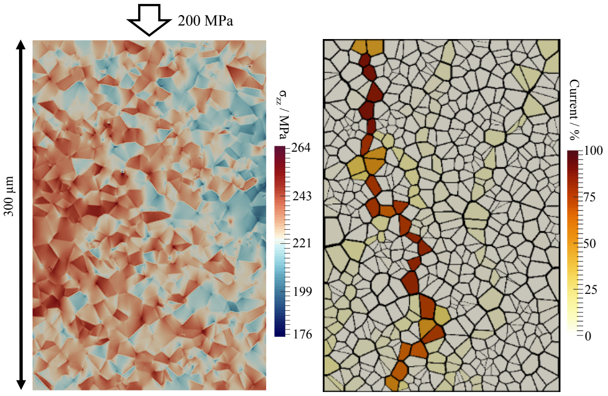

Figure 1: Stress distribution across a polycrystal with an average grain size of 10μm when subjected to a uniaxial compressive force of 200 MPa (left). Concentration of current flow through the same polycrystal in the voltage breakdown region (right).

REFERENCES

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