High Field Nonlinear Resistive SiC, ZnO-based Silicone Rubber Composites for Cable Field Grading:

MECHANISM(S), PROPERTIES AND FILLER TREATMENT

By

XIAOPING WANG

An Abstract of a Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the degree of
DOCTOR OF PHILOSOPHY
Major Subject: Materials Science and Engineering

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Prof. Linda S. Schadler, Thesis Adviser

Prof. Keith Nelson, Member

Prof. David J. Duquette, Member

Prof. Daniel Gall, Member

Rensselaer Polytechnic Institute
Troy, New York

July, 2009
(For Graduation December 2009)

ABSTRACT

In this research, the underlying high field nonlinear I-V physics for typical nonlinear resistive field grading composites, which have potential application as high voltage cable field grading materials were rigorously investigated for the first time. The targeted composites were *p*-SiC/silicone rubber (SIR) composites, with filler size ranging from nano to sub-micron and micron scale.

The results suggest that a thermally- or phonon-assisted high field nonlinear hole nearest-neighbor hopping transport across inter-particle SIR layer hypothesis is likely the governing and common nonlinear mechanism for all the studied *p*-SiC/SIR field grading composites. Charge carriers (holes) in nano and sub-micron SiC/SIR composites may transfer across hop sites within the inter-particle SIR layer, both having an average hopping activation energy in the order of ~0.4-0.5eV and average hopping distance of ~5-10nm, whereas holes in more packed micro-SiC/SIR may hop directly between neighboring SiC-SiC particles, with a shallow hopping barrier of ~0.1eV and potentially shorter hopping distance.

As is predicted by the hopping-based transport mechanism, results indicate that the composite low field resistivity, ρ_0, and nonlinearity exponent, α, both decrease as temperature increases. As filler loading increases, the composite resistivity as well as the onset nonlinearity field Ec also decrease, yet at certain intermediate filler loading the composite may show a subtle maximum nonlinearity exponent, α.

In an effort to explore appropriate pre-treatment process to develop alternative ZnO-based fillers for field grading application, pure ZnO was modified via a novel inorganic unsaturated aqueous SnF_2 treatment. The treated-ZnO/SIR composites possess nonlinear resistive properties comparable to nano Cu-doped ZnO/SIR and commercial micro-SiC/EPDM (ethylene propylene diene monomer) field grading composites.

Finally, in response to our ABB sponsor, fillers were screened for industrial high field grading applications. The 50nm & 150nm β-SiC, nano Cu-doped ZnO as well as ZnO treated after 0.23M SnF_2 27ºC/4min or 38ºC/1h were identified to be promising candidates.