2014 2nd RUNNER-UP
CAMX POSTER SESSION COMPETITION – ENTRY # 58295

Improved Analysis of Nano-Composite Sensing Materials

ABSTRACT

Piezoresistive nano-composites show great promise as multifunctional materials and high elongation strain gauges. State-of-the-art models of the piezoresistive effect typically assume that the dominant contributor to overall resistance is a quantum tunneling effect across nano-gaps that exist between the conductive filler particles. The conductance across these gaps is given by an exponential decay function, with a rapid decrease in conductance as the gap distance increases. Hence a binary percolation model is currently applied to capture the aggregate behavior of the multitude of 'on/off' switches that activate as the sample is deformed and the gaps change. This research tests the validity of the assumption that the change in resistance of the gaps can be assumed to be binary, or if a more continuous approach provides increased accuracy. The binary assumption is tested by creating a square network in which each branch of the network represents a gap between conductive filler particles. To first validate the binary method, each branch of the network is assigned either a high (on) or a low (off) conductance. A binary percolation approach proved extremely accurate for this case. To then model the phenomena in a system where charge transport occurs primarily by tunneling, the distances of all gaps in the network were assigned to follow a normal distribution, and resistances of each branch were computed from this distance using the tunneling resistance equation. Using this method, the binary percolation model failed to capture performance of the test network. A novel multistate percolation model is then introduced and applied. This novel method is shown to provide more accurate modeling of the test network's performance. This model focuses on breaking the percolating region into several levels of conductance instead of just high and low conductance levels. It is shown that this method is substantially more accurate for predicting the macro resistivity of composites. The new model will allow improved analysis of conductive nano-composites for sensor and other applications.

PRIMARY AUTHOR

Nathan Scot Usevitch
Undergraduate
Brigham Young University
nusevitch@gmail.com

CO-AUTHORS

David Fullwood, Associate Professor, Brigham Young University
Anton Bowden, Associate Professor, Brigham Young University
John Yeager, Research Scientist, Los Alamos National Laboratory
Parker Rosquist, Undergraduate, Brigham Young University

ADDITIONAL INFORMATION

This new analysis approach allows for the design of more accurate and reliable high-elongation strain gauges made from piezoresistive nano-composites. This analysis technique shows that a common former assumption, that resistances between particles could be assumed to either high or low, can be dramatically improved by assuming several stages of resistance.

Focus Area(s)

Design and Engineering; Materials; Testing and Evaluation; Tooling; Instrumentation