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Monte Carlo simulations of charge transport and strain sensing properties of co-sputter deposited granular metal thin films

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Thin films made by sputter-depositing metal and ceramic materials have a large resistivity and high strain sensitivity with large transverse sensitivity. We develop a model based on sphere packings to investigate the influence of the disorder of diameters and distances on the piezoresistive properties.
Several ceramic-metal (cermet) films are fabricated, e.g. films of platinum and aluminum oxide or platinum and boron nitride. Their resistivities vary over many orders of magnitude. Strain sensitivity is in the range of 5 to 25. Their sensitivity to transverse strain is typically 70 % of the longitudinal sensitivity.
Using x-ray diffraction and transmission electron microscopy, it is found that the films consist of roughly spherical metal crystallites with a mean size of a few nanometers, separated by the amorphous ceramic.
A model for the composite materials is build based on morphology and analytical descriptions of charge transport. The latter is characterized by thermally activated electron tunneling and a Coulomb blockade due to the small crystallite size.
For a simulation of the system's global transport characteristics, a representation of the disordered array of nanocrystallites (NCs) with a certain size distribution is required. Sphere packing algorithms are utilized to create randomly arranged 3D structures with spherical NCs of a defined size distribution with a defined distribution of next-neighbor distances. Due to the random disorder, charge transport does not occur straight through the film, but along convoluted paths. Total conductivity if found by evaluating all next-neighbor conductivities; conductivity in unstrained and strained states leads to gauge factors.
Systems with various sizes, distributions and values of metal content are simulated and compared to the measurements. The elastic moduli of the components and the particle sizes have a large effect on the gauge factor. It is found that the achievable maximum of the gauge factor is reduced by disorder in the film.

Keywords
cermet
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