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High-Frequency Shunt Behavior in Granular Metals

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Granular metals (GMs) are a class of disordered materials comprising metal nanoparticles (NPs) dispersed within an insulating matrix. As a result of their nanostructure, GMs exhibit complementary resistive tunneling and capacitive charge transport properties. These parallel processes give GM's a high-pass filter like behavior [1], such that the conductivity displays a power-law behavior as a function of the drive frequency. Due to their high breakdown electric-field strength and high-pass nature, GMs make for attractive shunt devices for high-power, high-frequency applications

In this work, GMs are grown via radiofrequency co-sputtering using molybdenum (Mo) and silicon nitride (Si_3N_4) targets[2]. We show that the Mo NP size, density, and spacing is controllable via the growth conditions and post-growth annealing recipes (Fig. 1A). Manipulating the intercalation of the Mo NPs enables great control of the GM electrical properties. The effect of Mo metal fraction and annealing temperature on GM conduction is investigated via temperature-controlled impedance spectroscopy (Fig. 1B, C).

Here, a universal power-law distribution in the conductivity is observed, characteristic of many disordered material systems [3,4]. These GMs exhibit conductivity swings on the order of σ_{MHz}/σ_{DC} of 10^6. Vertical shunt devices with 0.5 cm^2 GM active area are fabricated on antimony-doped conductive silicon (N-type). These films shunt 25 Amps at 2.25 MV/cm (Fig. 1D).

This systematic investigation and fabrication of functional GM films serves to bridge the gap between the processing, structure, and electrical properties of GMs and more generalized disordered systems.

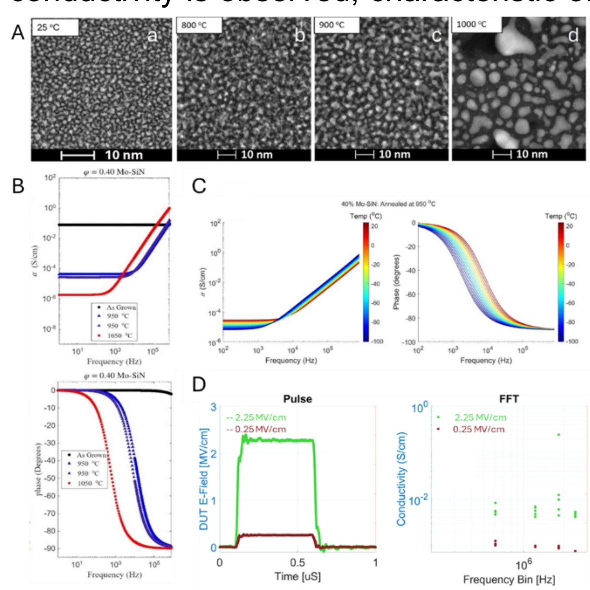

Figure 1: (A) TEM micrographs of GM (Mo-SiN$_x$) nanostructure, following progressive annealing steps (B) Resistive-Capacitive conduction shift with excitation frequency (C) Universal power law response with temperature dependent turn on (D) High-field shunt capability and E-field enhanced conduction

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