Mo-SiN$_x$ granular metal high-pass filters

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Granular metals (GMs) comprise a 3D network of metal nanoparticles embedded in a dielectric matrix. Over the past ~50 years, GM investigations have spanned fundamental physics to unique applications, including Au-SiO_2 GMs used as insulating contacts in vidicons, video cameras used in NASA's Apollo and Voyager missions [1]. As a controlled platform for electron transport studies, GMs exhibit tunneling transport (*e.g.* variable-range hopping, Poole-Frenkel conduction in Ni-SiO_2 GMs) and frequency-dependent conductivity $\sigma(\omega)$ in Pt-SiO_2 and Pd-ZrO_2 GMs [2-4]. These prior GM investigations focused almost exclusively on metal-oxide GMs. Our goal—to develop nanosecond-responsive high-pass filters for electrical grid applications—has advanced development of Mo-SiN$_x$ GMs that exploit these conductivity mechanisms.

High-dielectric strength SiN$_x$ is an attractive matrix for GMs, enabling Mo-SiN$_x$ and Co-SiN$_x$ GMs [5]. However, initial Mo-SiN$_x$ GMs showed weak $\sigma(\omega)$; thermally-excited resistive transport through defective SiN$_x$ overwhelmed the desired transport mechanisms. Fortunately, sputtering Mo-SiN$_x$ in a partial N_2 environment ameliorates these SiN$_x$ matrix defects. X-ray photoemission spectroscopy (XPS) analysis shows deleterious $MoSi_2$ is further reduced by annealing in H_2/N_2 forming gas (Fig. 1a). Improvements in SiN$_x$ insulator quality resulted in the desired many decades reduction in σ_{DC} (Fig. 1b). This evaluation of nanostructure and chemical structure has enabled optimization of high-frequency and high electric (E) field transport (Fig. 1c, d), key properties of high-pass filters for electric grid applications [6].

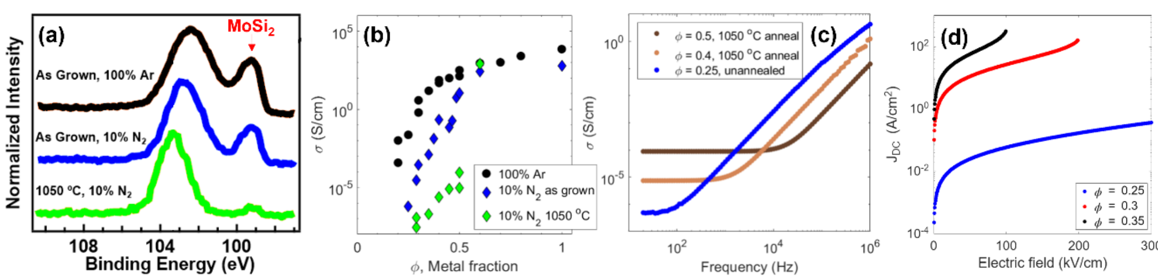

Figure 1: In (a), the Si 2p XPS spectra for Mo-SiN$_x$. In (b), σ_{DC} versus Mo fraction, φ. In (c), frequency response $\sigma(\omega)$. In (d), current density, J, increases with E-field and φ; Ohmic, Poole-Frenkel, and Fowler-Nordheim transport are observed.

This work was supported by the Laboratory Directed Research and Development program at Sandia National Laboratories (SNL). SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525. SAND2023-09502A.

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