Frequency-dependent conductivity of granular metals

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We explore the frequency-dependent conductivity, σ, of granular metals (GMs). Granular metal comprise nanoscale metal islands embedded in a dielectric matrix. We target the metal volume fraction, φ, so that the few-nm diameter metal islands are separated by a ~1 nm dielectric barrier. These metal/insulator composites can be modelled as a complex resistor-capacitor network with complementary tunneling and capacitive conduction paths [1]. At low frequencies, ideal GMs are highly insulating with thermally-assisted tunneling between islands occurring at high E-fields. At high frequencies, capacitive transport dominates; conductivity increases orders of magnitude.

We compare M-SiN_x and M-YSZ (M = Mo or Co; YSZ = yttria-stabilized-zirconia) GM thin films grown via rf co-sputtering on sapphire. Frequency-dependent conductivity is evaluated using impedance spectroscopy at ambient and cryogenic temperatures. Temperature and field-dependent DC conductivity provide insight into tunneling mechanisms. Granular metal structure (Fig. 1a, b) and composition are determined by scanning transmission electron microscopy (STEM) and x-ray photoemission spectroscopy (XPS).

Through careful selection of the metal-insulator system and synthesis optimization, we prepared GM films having $\sigma_{MHz}/\sigma_{DC} > 10^5$ (Fig. 1c). This σ_{MHz}/σ_{DC} ratio was achieved for Mo-SiN_x using depositions conditions that significantly reduced the vacancies present in the sputtered insulator. Analysis of metal/insulator interfaces via XPS showed metal-oxide formation in M-YSZ and metal-silicide formation in M-SiN_x [2]. Control of deposition conditions can minimize these defects, allowing σ_{MHz}/σ_{DC} optimization for high-pass filters.

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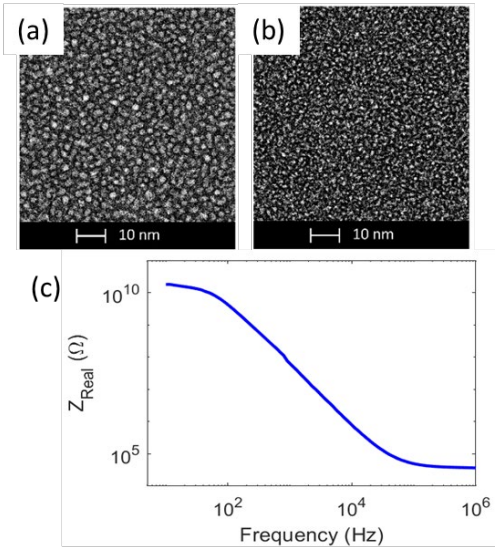

Figure 1: STEM of (a) Co-SiN_x and (b) Mo-SiN_x. In (c), complex impedance of Mo-SiN_x.

[1] H. Bakkali *et al.* Sci Rep **6**, 29676 (2016)
[2] S. Gilbert *et al.* J. Phys.: Condens. Matter **34** 204007 (2022)

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Date: September 23, 2022

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