Low-temperature transport in ultra-thin tungsten films
grown by focused-ion-beam deposition

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Motivation

• Amorphous tungsten alloys have higher superconducting critical temperatures than crystalline tungsten. [1]
• Tungsten composites deposited by focused-ion-beam (FIB) induced chemical vapour deposition (CVD) are amorphous and superconducting at low temperatures ($T_c \approx 5$ K). [2]
• FIB-CVD tungsten (FIB-W) thin films have been shown to be superconducting for thickness down to 25 nm. [3-4]
• Ultra-thin superconducting films undergo a superconductor-insulator transition depending on thickness. [5]
• FIB-W can be used to fabricate superconducting three-dimensional structures by direct-writing. [6]
• Potential applications of ultra-thin FIB-W films include single-photon detectors and qubits based on quantum-phase-slip centres.

Potential applications of ultra-thin FIB-W films

1. Take a silicon wafer with a layer of silicon oxide and gold pads deposited by optical lithography and physical vapour deposition.
2. Mill with the FIB through the oxide layer to a depth of about 300 nm, just below the Si/SiO$_2$ interface, leaving a substrate of amorphous Si.
3. Use FIB-CVD with tungsten hexacarbonyl (W(CO)$_6$) as a precursor gas to deposit the FIB-W ultra-thin film and electrical connections to the gold pads.

Geometry and topography

AFM images of sample A: height (left) and deflection (right).

• Scanning electron microscope (SEM) to determine the planar geometry and the quality of the film.
• Atomic force microscope (AFM) in contact mode to determine the thickness and the topography of the film.

AFM topography image (left) and extracted height profiles (right) for sample A.

References


Outlook

• Fabrication of ultra-thin films of varying thickness and width.
• Investigation of superconductor-insulator transition.

Previous work

• Superconductivity has been found in FIB-W films down to 25 nm thickness (from [4]):

Sample A

- Superconducting region

Sample B

- Non-superconducting region

SEM micrographs of two ultra-thin films deposited with the same conditions, but on slightly different substrates.

Fabrication details

• System: Carl Zeiss Crossbeam XB1540

Milling through silicon oxide:

- $P$ (Ga$^+): \approx 1$ nA at 30 kV
- Time: 100 sec
- Number of layers: 10

Deposition of ultra-thin film:

- $P$ (Ga$^+): \approx 5$ pA at 30 kV
- Area: 1 mbar x 10 nm
- Scan frequencies: 200 Hz x 20 kHz
- Time: 40 – 100 sec
- Precursor pressure: 2 – 3 $10^{-7}$ mbar

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