SYNTHESIS AND CHARACTERIZATION OF Mo-Nb FILMS SUPERCONDUCTING AT 100-200 mK

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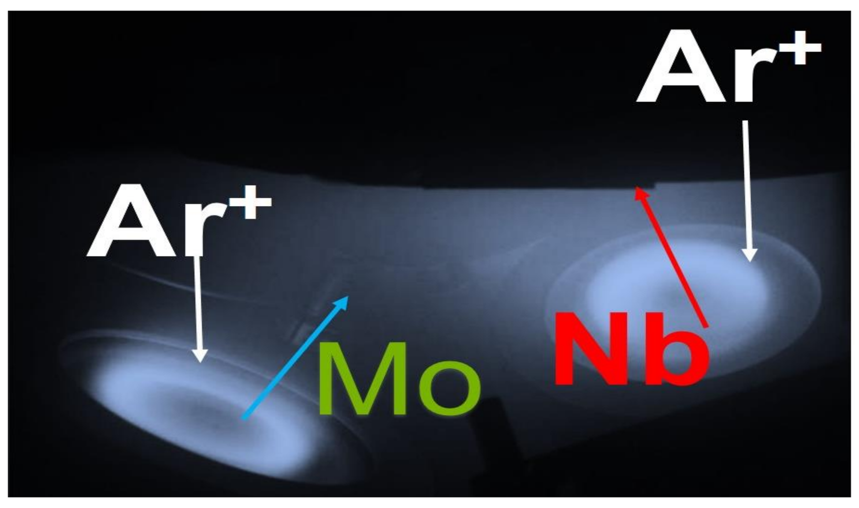
ABSTRACT

We have developed a new transition edge sensor material with critical temperature in the range 100-200mK. The new material is a solid solution of two superconducting components, Mo_xNb_{1-x}, co-sputtered from two high-purity single-component targets. The critical temperature, Tc, has a minimum (dTc/dx=0) at intermediate concentration of the components. We have optimized deposition parameters and composition to provide films with a sharp superconducting transition at ~150mK. We investigated structural features of the films and surface morphology using XRD and SEM. The XRD measurements indicate that grown films are polycrystalline, with a preferred orientation along the (110) crystal direction, and a clear correlation between superconducting properties and film microstructure.

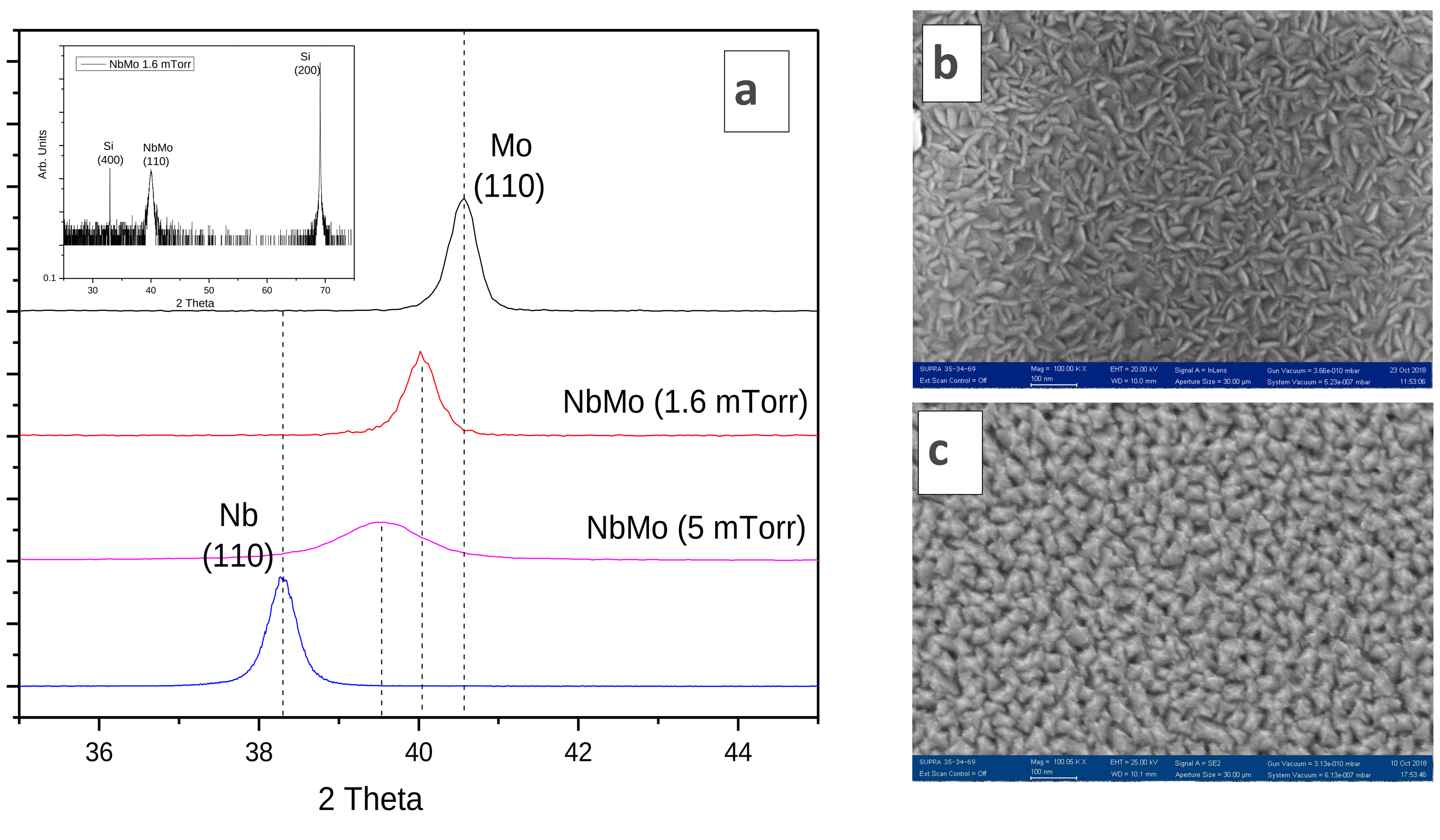
FILM PREPARATION

- The deposition was carried out by co-sputtering in a DC confocal magnetron system.
- High purity Mo (99.997%) and Nb (99.999%) targets were used for preparing Mo-Nb films.



- In order to control composition, the films were deposited with different deposition rates, r_{Mo} (fixed) and r_{Nb} (varied), for the Mo and Nb targets.
- Small difference between Mo and Nb atomic radii and similar outer shell electron structures allow the formation of substitutional solid solution films where Nb atoms can be incorporated into the Mo bcc crystal lattice.

STRUCTURAL FEATURES OF THE FILMS



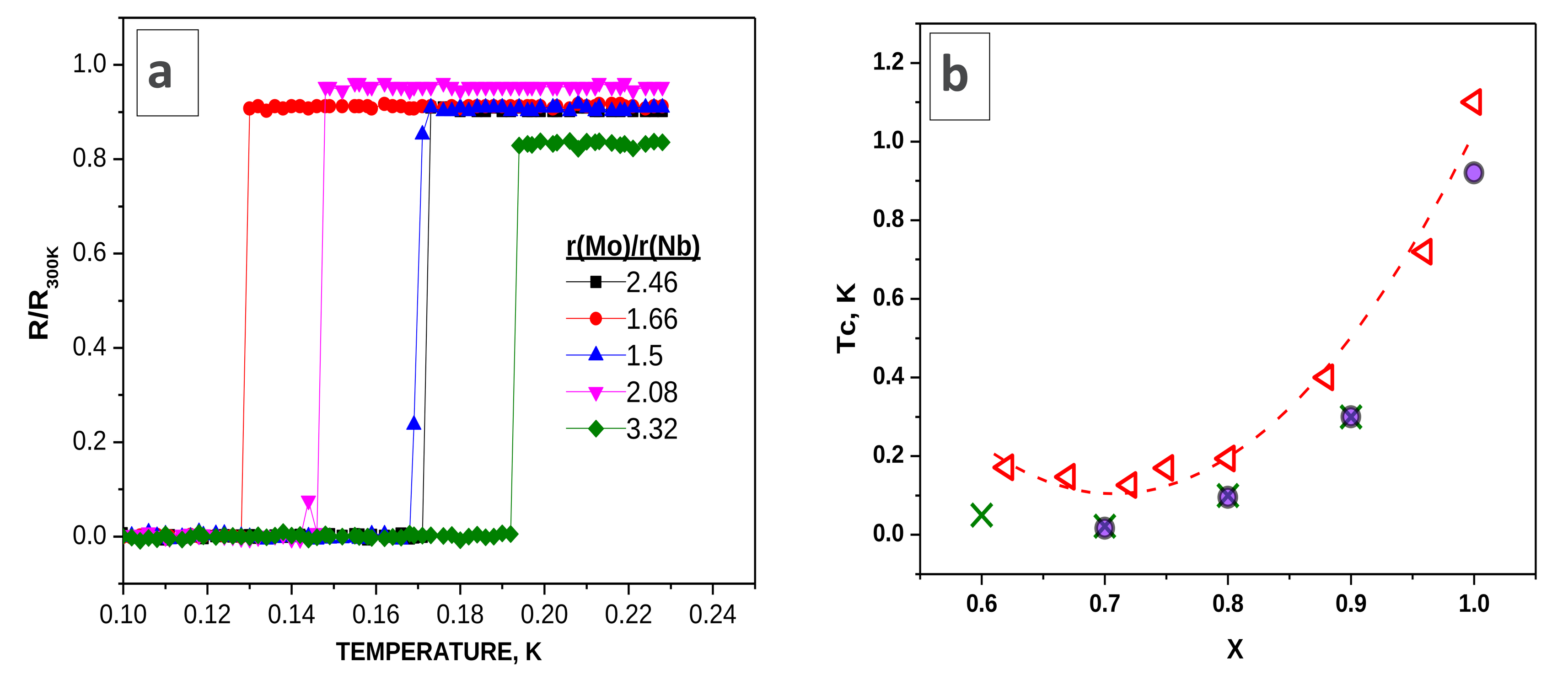
a -XRD diffraction pattern of 200nm Mo, Nb and Mo-Nb films co-sputtered at deposition rate ratio r_{Mo}/r_{Nb} ~1.7. The inset shows a full scan of Mo-Nb sample; b,c–SEM images of Mo-Nb films deposited at 1.6mTorr (b) and 5 mTorr (c).

- The difference in atomic size of the constituents induces lattice strain.
- The film obtained at 1.6mTorr demonstrates good crystallinity , density, and has sharp superconducting transition at 128mK.
- High pressure (5mTorr) gives more amorphous microstructure, with intergranular voids. This film does not exhibit superconducting transition above 10mK.

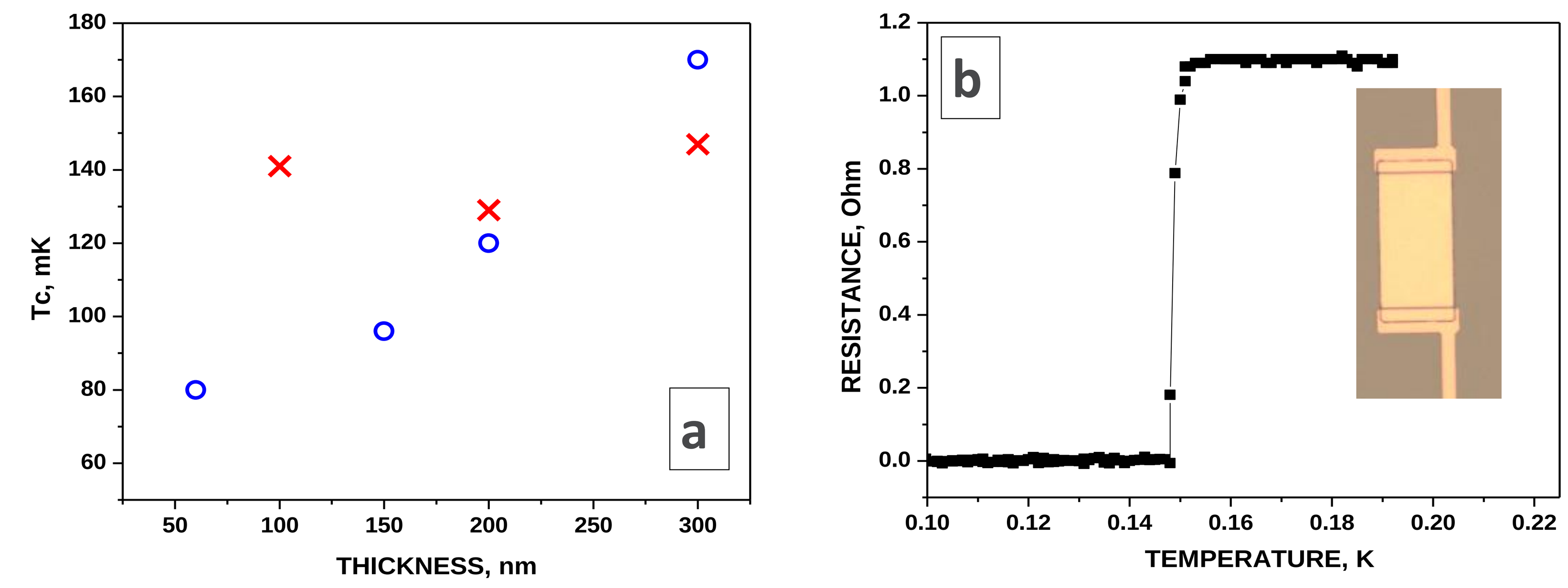
MOTIVATION

- There are limited options for superconducting materials with critical temperature within the range 100-200mK, which is important for far-infrared and millimeter-wavelength detectors. Only combination of different materials enables to achieve of Tc in this range.
- Mo and Nb have identical body centered cubic (bcc) crystal structure, close atomic size, and minimal difference in electronegativity. These features allow the formation of a continuous series of Mo_xNb_{1-x} complete solid solutions.
- Early experimental study of Mo-Nb solid solutions prepared from high purity components individually melted and then mixed and annealed at 2100-2500C showed decreasing of the critical temperature of the samples over the entire concentration interval with the minimum about 16mK [1].

SUPERCONDUCTING TRANSITION CHARACTERIZATION



a- superconducting transitions of 200nm Mo-Nb films prepared at different deposition rate ratio r_{Mo}/r_{Nb}; b-superconducting transition temperature of the Mo_xNb_{1-x} films (red triangles) as a function of composition; green crosses - theoretically computed [2]; purple circles - experimentally obtained for bulk samples [1].



a - blue circles -critical temperature vs Mo-Nb films thickness (r_{Mo}/r_{Nb} = 1.66), red crosses- prepared with RF substrate bias. b- Superconducting transition of ($Mo_{0.7}Nb_{0.3}$) transition-edge sensor with thickness -315nm, length-60um, width 30um.

SUMMARY

- Developed a new transition-edge sensor material (Mo_xNb_{1-x} solid solution) with controllable critical temperature in the range 100-200mK.
- Optimized the deposition parameters and composition to provide films with a sharp superconducting transition at ~150mK.
- Weak dependence of Tc on composition at intermediate concentration of the components and high corrosion resistance are attractive features of the new material.

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1. R.A.Hein et al., Rev. Mod. Phys., 149-153, (1964); 2.A.M.Vora, Physica C, 470, 475-481, (2010);

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