



Thickness dependence of the superconducting properties of γ -Mo₂N thin films on Si (001) grown by DC sputtering at room temperature

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ABSTRACT

We study the crystalline structure and superconducting properties of γ -Mo₂N thin films grown by reactive DC sputtering on AlN buffered Si (001) substrates. The films were grown at room temperature. The microstructure of the films, which was studied by X-ray diffraction and transmission electron microscopy, shows a single-phase with nanometric grains textured along the (200) direction. The films exhibit highly uniform thickness in areas larger than $20 \times 20 \mu\text{m}^2$. The superconducting critical temperature T_c is suppressed from 6.6 K to ≈ 3.0 K when the thickness decreases from 40 nm to 5 nm. The residual-resistivity ratio is slightly smaller than 1 for all the films, which indicates very short electronic mean free path. The films are in the superconducting dirty limit with upper critical field $H_{c2}(0) \approx 12$ T for films with thickness of 40 nm, and 9 T for films with thickness of 10 nm. In addition, from the critical current densities J_c in the vortex-free state, we estimate a penetration depth $\lambda(0) \approx (800 \pm 50)$ nm and a thermodynamic critical field $H_c(0) = (500 \pm 80)$ Oe.

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1. Introduction

Transition–metal nitrides (TMN) display a wide range of electronic and mechanical properties which are promising for technological applications. Devices based in superconducting thin films include tunnel junctions [1], hot electron bolometers [2], single photon detectors [3], etc. The molybdenum nitrides possess several crystalline phases: γ -Mo₂N (cubic) with superconducting transition temperature $T_c \sim 5$ K [4], β -Mo₂N (tetragonal) with $T_c \sim 5$ K [5] and δ -MoN (hexagonal) with $T_c \sim 12$ K [6,7]. The synthesis of bulk γ -Mo₂N and δ -MoN usually requires high-pressure and high-temperature [7–9]. The extreme conditions usually applied for the synthesis of bulk specimens can be avoided by growing thin films. Molybdenum nitride thin films have been grown by several techniques such as reactive sputtering [10], pulsed laser deposition (PLD) [11], thermal

nitration [12] and chemical methods [13]. The properties of the MoN_x films strongly depend on the actual growth conditions, and consequently on the processing parameters [10,14]. The microstructure of the films is directly related to the resulting superconducting properties. A superconductor with very few structural (crystalline and impurities) defects and electronic mean free path (l) much larger than the intrinsic coherence length ξ_0 is in the “clean limit”. If disorder increases then l decreases, and the superconductor reaches the “dirty limit when $l/\xi_0 < 1$ ”. Increasing disorder reduces the effective ξ and enlarges the penetration depth λ , thus increasing $\kappa = \lambda/\xi$, while maintaining the product $\xi\lambda$ constant to first approximation [15].

Most of the technological applications based in superconducting TMN thin films require uniform electronic properties on large areas [16–18]. In addition, some devices such as single photon detectors require uniform superconducting properties in paths printed in very thin films [19]. Recently, the synthesis of superconducting γ -Mo₂N thin films in the dirty limit has been reported [20]. The particularity is that the films were grown on oxidized silicon wafers as substrates at room temperature. The simplicity in the growth

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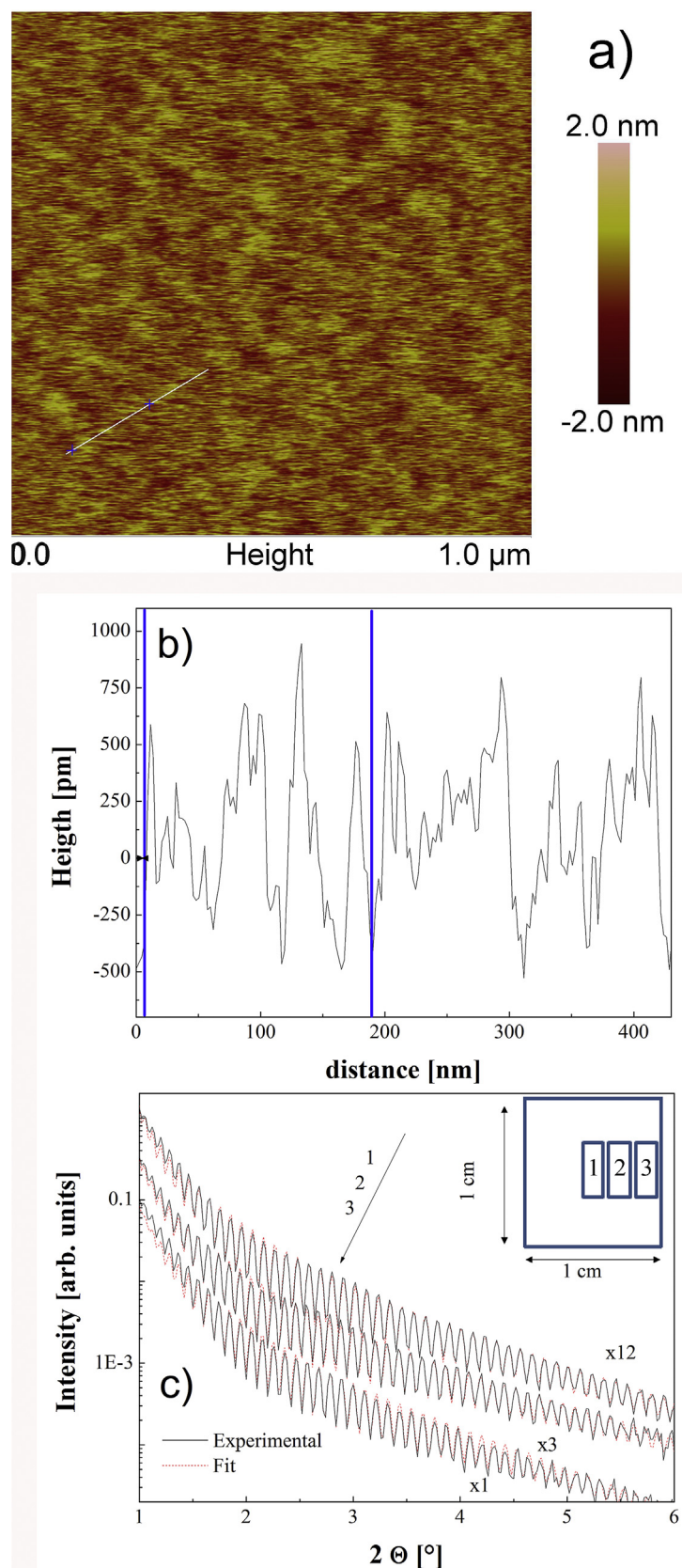


Fig. 1. a) AFM image of a 5 nm thick γ -Mo₂N grown at room temperature on 8 nm AlN/Si (001). b) AFM profile of the region indicated in a). c) Low angle reflectivity for a 80 nm thick γ -Mo₂N film.

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