Growth mode and strain effects in the superconducting properties of Nb thin films on sapphire

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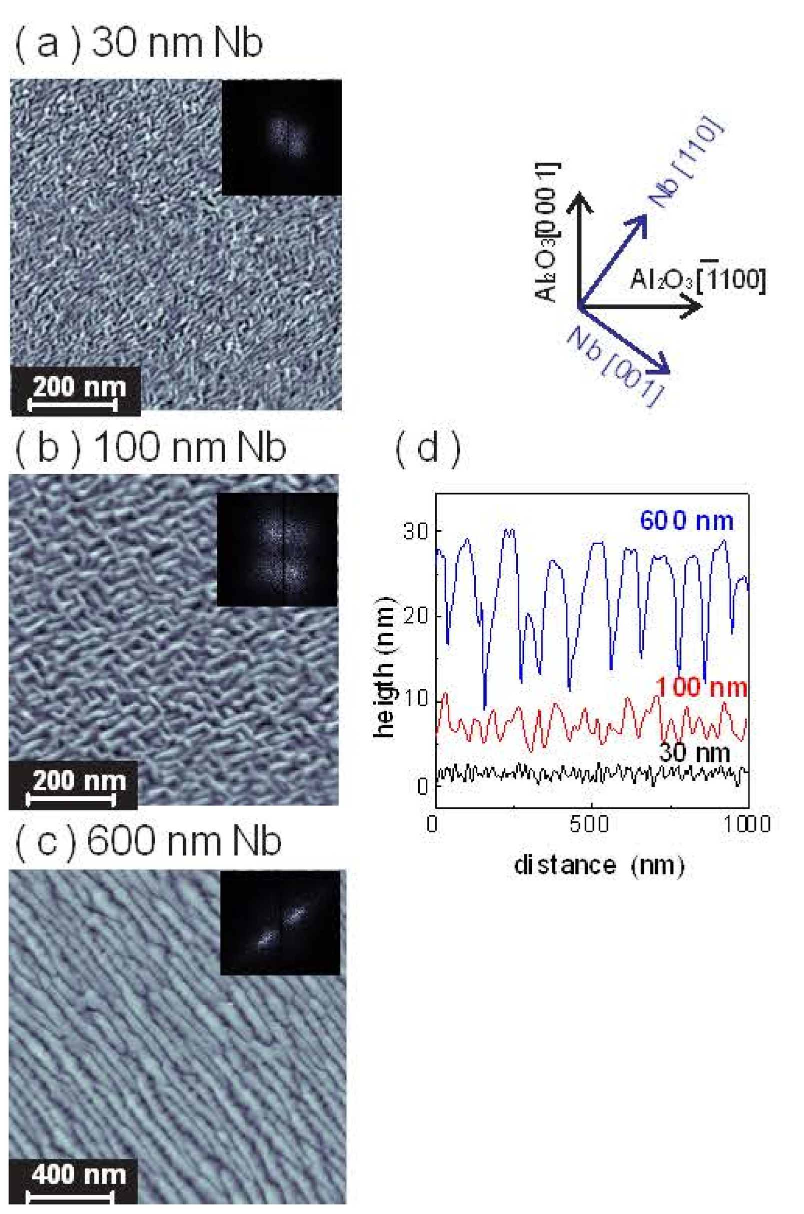
Introduction

Superconducting thin films and multilayers have attracted the attention of the scientific community due to the promise of overcoming the maximum field gradients that SRF cavities can withstand, pushing them above 100 MeV/m [1]. Nevertheless, in order to achieve the desired properties, special attention needs to be devoted to the epitaxy and growth mode of such thin films, taking into account multiple aspects such as crystalline quality, lattice strain, grain size, etc. We present a complete correlation between morphology, structure and superconducting properties such as critical field, critical temperature and complex susceptibility for single crystal Nb(110) thin films sputter deposited on a-plane sapphire substrates. **We have observed that in general, single crystal films exhibit better superconducting performance when compared with polycrystalline ones. The results reported here indicate that interfacial strain effects must also be considered when evaluating the feasibility of such films for SRF cavity applications**

1. Morphology

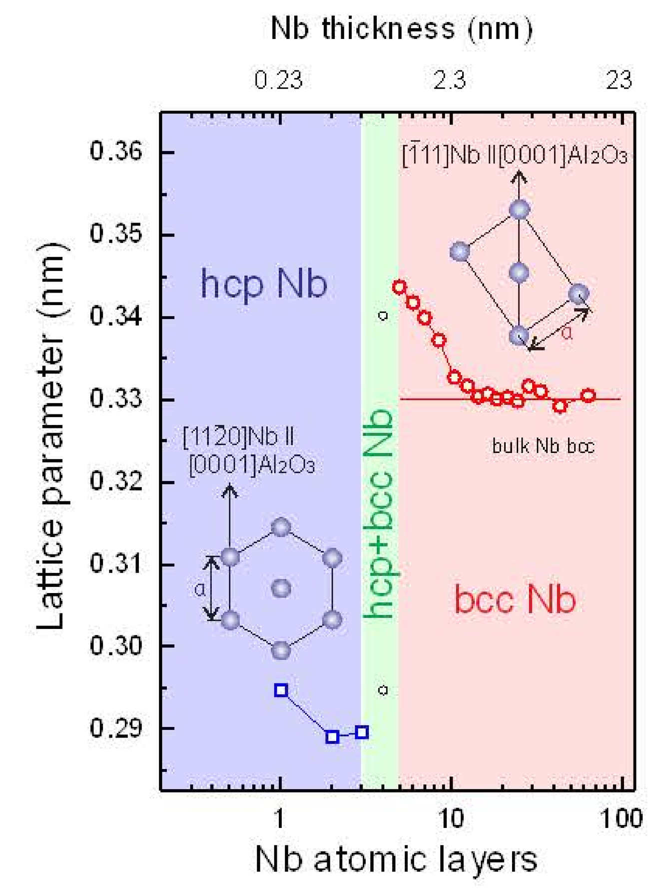
Nb thin films were sputter deposited on a-plane sapphire with thicknesses ranging from 1 atomic layer to 600 nm.

Atomic Force Microscopy (AFM) topography images clearly show the evolution of the morphology. An initial **biaxial anisotropy** is observed for thicknesses up to 100 nm. For higher thicknesses an **uniaxial anisotropy** is observed.

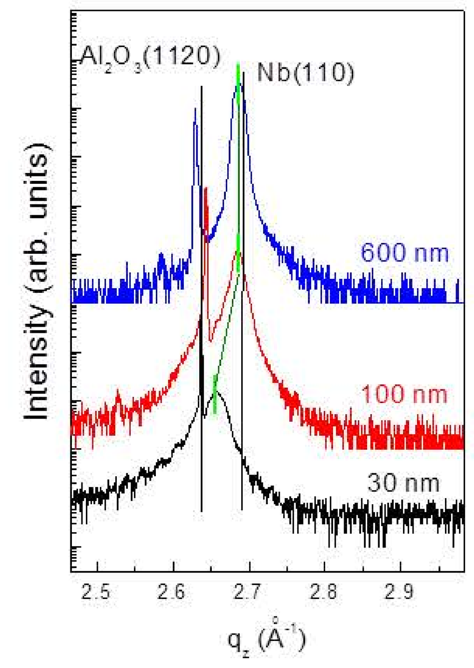


2. Structure

Using Reflection high energy electron diffraction (RHEED), we observe hexagonal Nb surface structure for the first 3 atomic layers followed by a strained *bcc* Nb(110) structure and the lattice parameter relaxes after 3 nm.



X ray diffraction scans show clear Nb(110) structure where strain is relaxed as the films get thicker.

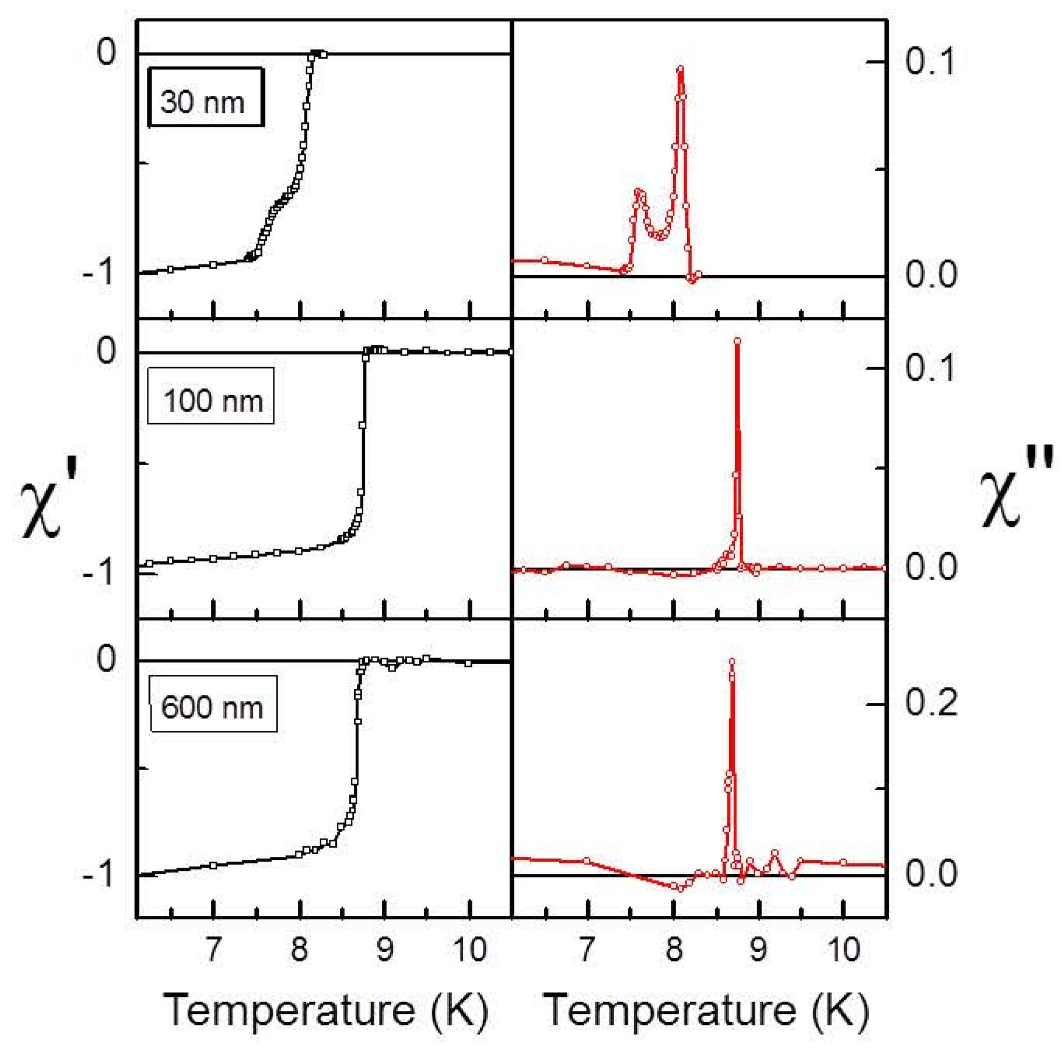


3. Superconducting properties

Susceptibility AC measurements were performed using SQUID magnetometry.

$$\chi(\omega) = \chi'(\omega) + i\,\chi''(\omega)$$

$\chi'(\omega)$ describes the behavior of the system in phase with the incoming AC field and the imaginary part $\chi''(\omega)$ accounts for the energy losses in the system.



The thinner 30 nm thick Nb film exhibits a χ' susceptibility transition with two steps accompanied by two peaks in the χ'' susceptibility due to the contribution of strained Nb at the interface.

Conclusions

- An initial **biaxial anisotropy** is observed for thicknesses up to 100 nm while for higher thicknesses an **uniaxial anisotropy** is observed.
- A hexagonal Nb surface structure is observed for the first 3 atomic layers followed by a strained *bcc* Nb(110) structure where the lattice parameter relaxes after 3 nm.
- AC Susceptibility measurements clearly show effects arising from the first strained atomic layers.

References

[1] A. Gurevich, Applied Physics Letters **88** (1), 012511 (2006).

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