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GROWTH OF NIOBIUM FILM ON SAPPHIRE(001)

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A structure of deposited film is determined by an interaction of arriving atoms with these of substrate and with those already stacked on. In case of ions having the kinetic energy in the range of tens electronvolts and falling into hot target, the interaction is dominated by an inelastic scattering with the stacked atoms, which happen during the subplantation few tens of angstroems inwards the film. Continuous ions influx to the near-surface part of the film accompanied by an enhanced vibration and mobility of constituent atoms and followed by a gradual cooling and crystallisation occurring when the new material accumulates above, facilitates the growth of compact and dense material composed of large crystallites.

Ultra High Vacuum Cathodic Arc (UHVCA) deposition method utilises the ions produced in explosive spots on the cathode, gaining there an energy about 100 eV and subsequently transported in the discharge channel towards the substrate to form pure films of regular and dense morphology. One of the most demanding application of such deposited films is particle accelerator technology where the Nb films have been proposed to coat inner walls of copper RF cavities. Such obtained superconducting cavities may, in some applications, replace the bulk niobium ones.

The aim of these studies is to describe the growth of the Nb film on the single crystal sapphire. It was accomplished by complementary measurements of X-ray Diffraction patterns (XRD) and Extended X-ray Absorption Fine Structure (EXAFS) performed for a series of Nb/sapphire(001) samples having various thicknesses ranging from about 3 nm up to more than 500 nm. These two methods, enabled the structural analysis of samples showing long or short range of crystalline order, respectively.

Diffraction patterns measured in $\omega/2\theta$ coupling for the films thinner than 15 nm, showed only single, broad maximum corresponding to Nb(110) planes (Fig. 1), which is the strongest among all of that crystal. It indicated small out-of-plane extent of diffracting crystallites.

For the films thicker than 15 nm a narrow component was observed on the background of broaden maximum. The pattern did not show peaks form any other planes. That indicated the presence of large crystallites of the same orientation such that Nb(110) planes were parallel to sapphire(001) face layers.

The films thicker than 400 nm showed diffraction patterns containing further reflections characteristic for the Nb crystal, which is typical for polycrystalline metallic film.

The shorter range of crystalline order in the early grown part of film as compared to the part stacked on it during the further deposition, was verified with the Nb K-edge EXAFS measurements performed in fluorescence yield mode. Absorption fine structures for films having the thickness less than or and equal to 5 nm differ from that obtained for thicker films by a specific spectral feature observed at k = 4 Å^{-1} (Fig. 1). Model multiple scattering calculations performed for Nb bcc crystal showed that the distinctive feature originates from the scattering paths involving fifth and sixth coordination shells. The lack of that feature for thin films was interpreted as a result of crystalline order range shorter than five coordination shells.

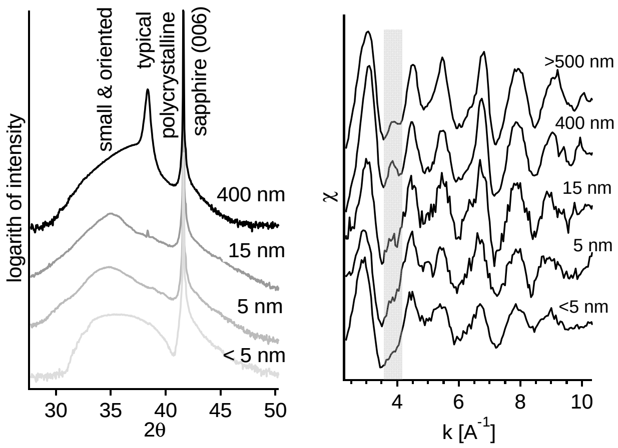

Figure 1. XRD $\omega/2\theta$ patterns and EXAFS measured Nb/sapphire(001) films of various thicknesses

The obtained results show that polycrystalline niobium does not grow directly on the sapphire substrate. Its growth follows the formation of the layer containing extremely small crystallites and subsequently the layer of larger and oriented crystallites. As a result, the film of the thickness larger than 400 nm contains three pronouncedly different phases of niobium.

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