Structure and superconducting properties of epitaxial niobium nitride films obtained by high temperature CVD

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Amphitheater Jean Besson

Jury:
Mme. Edwige BANO, Professeur Grenoble INP, Grenoble-IMEP-LAHC, (examinatrice)
M. Alexandre TALLAIRE, Chargé de recherche CNRS, Paris-IRCP, (rapporteur)
M. Georges CHOLLON, Chargé de recherche CNRS, Bordeaux-LCTS, (rapporteur)
M. Philippe THOMAS, Directeur de recherche CNRS, Limoges-IRCER, (examinateur)
Mme. Elisabeth BLANQUET, Directrice de recherche CNRS, Grenoble-SIMaP, (invitée)
M. François WEISS, Directeur de recherche CNRS, émérite-Grenoble-LMGP, (invité)

Abstract: The studies concern the development of superconducting devices for single photon detection. Niobium nitride (NbN) is a material suitable for the production of superconducting wires for the detector target. This work opens up perspectives on the development of epitaxial niobium nitride films on sapphire by the chemical vapour deposition (CVD) method. The production of thin films (5-100 nm) is carried out at high temperature (1000°C to 1300°C) from niobium chloride and ammonia diluted in hydrogen (H_2-NH_3-$NbCl_5$). The substrates are oriented single crystal sapphire (Al_2O_3) (0002), oriented aluminum nitride (AlN) (0002) and oriented magnesium oxide (MgO) (100). The study of epitaxial relations during the growth of niobium nitride on the sapphire substrate was first performed. Observation of the microstructures and crystalline orientations of the various films produced made it possible to highlight the relations between the surface state of the substrate and the mode of production of NbN growth. The prospects for the use of single crystal substrates such as MgO and AlN are presented in conclusion. The study of the growth process and the relations between the production conditions and the "quality" of thin films has made it possible to identify the experimental windows leading to epitaxial growth. The activation energy of the growth reactions and the oversaturation conditions conducive to epitaxial growth were calculated. The study of the relations between the structural properties and superconducting characteristics of films has made it possible to relate the superconducting transition temperature to the density of atomic defects, microstructural defects, the thickness of the films produced and their stress state. There is a linear relation between the interplanar space of planes parallel to the substrate and the superconducting transition temperature. Finally, the durability of ultra-thin films (5-8 nm) of niobium nitride was studied. In this study, the electrical and superconducting properties of films made at 1000°C and 1200°C on sapphire substrates and epitaxial layers of AlN were analyzed over a six-month period. The properties of the films change mainly during the first month. High temperature deposition limits the rapid degradation of the films and preserves their superconducting properties.