LARGE AREA NB NANOLAYERS WITH ADVANCED SUPERCONDUCTING PROPERTIES AS A BASE FOR SUPERCONDUCTING SPINTRONICS

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Abstract. High quality Nb nanoscale films of large area (7 × 80 mm^2) and constant thickness were deposited by DC-magnetron sputtering in commercial "Leybold Z400" vacuum system. Homogeneity and proper thickness of the Nb layer provided by the target-holder movement during the DC sputtering using specially constructed arrangement based on controllable DC motor with a gear. Rutherford backscattering spectrometry was used for precise thickness measurements. The increase of superconducting critical temperature (>1.5 K for films with comparable thickness) and of superconducting coherent length (up to 30–35%) in comparison with films prepared by common technique is reported.

Keywords: Superconductivity, spintronics, thin films, magnetron sputtering, nano-size Nb layers.

1. Introduction

Niobium superconducting thin films (d_{Nb} = 5 ÷ 15 nm) and multilayers are the base of various superconducting electronic devices. For example, single Nb films are used for different applications such as mixers[1] and detectors[2] of electromagnetic radiation. Nb film with a large value of the electron mean-free path is necessary to reach the intermediate frequency bandwidth larger than 10 GHz for the diffusion-cooled hot-electron bolometer mixer.[3]

The design of spintronic superconducting devices based on the hybrids is the object of intense investigations for last decades.[4] The investigation of proximity

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effect in Superconductor/Normal metal (S/N) and Superconductor/Ferromagnet (S/F) nano-size layered structures require technological approach yields high quality superconducting films with constant thicknesses and advanced superconducting properties. The common material for superconducting electronics, Nb, has as an advantage relatively high temperature of superconducting transition, T_c 9.2 K. Unfortunately, Nb has enhanced getter capability whereas adsorbed gases intensively affect the superconducting properties especially for nanoscale films. On the other hand, S/F superconducting structures with Nb nano-layers demonstrate main interesting physical phenomena based on space oscillation of the order parameter due to proximity effect.[5–7] Reliable producing of the most applicable range of superconducting Nb layer thicknesses, 5–15 nm (keeping $d_{Nb} \approx \xi_{Sc}$ – superconducting coherence length) with reproducible high quality and T_c close to the bulk value is a challenge for constructing superconducting devices based on proximity effect.[4,5] The efficient technological approach for fabrication of the set of the samples with equal superconducting layers was demonstrated in.[8] The disadvantage of this approach is relatively low T_c of Nb layer (6.4 K for single Nb layer with $d_{Nb} = 31$ nm).[8]

The increase of T_c for deposited Nb films is possible under deeper vacuum conditions inside the system, by optimizing the substrate temperature or deposition rate.[9,10] The protection cup and buffer layers from neutral material (Al_2O_3 or Si for example) could be used to avoid impurity penetration in Nb layer. From the other hand, the experimental setup of vacuum system and the necessity to avoid the interdiffusion with other hybrid components often restrict Nb layer's quality improvement.

2. Methodology

The samples were prepared by magnetron sputtering on a flame-polished glass substrates or on commercial (111) silicon substrates kept at room temperature. The base pressure in the "Leybold Z400" vacuum system was about 2×10^{-6} mbar; pure argon (99.999%, "Messer Griesheim") at pressures of 8×10^{-3} mbar was used as a sputter gas. The targets, 75 mm in diameter, from Nb, Si were pre-sputtered a few times for 3–5 min to remove contaminations from the targets surface as well as to reduce the residual gas pressure in the chamber during the pre-sputtering of Nb. As the next step we deposited silicon buffer layer with RF magnetron to obtain clean interface for the subsequent niobium layer. To provide homogeneity and proper thickness of the Nb layer the target-holder was moved during the DC sputtering using specially constructed arrangement based on controllable DC motor with a gear. With this setup we were able to achieve the average growth rate of the Nb layer 1.3 nm/s (the steady-state deposition rate would be about 4 nm/s) which is close to the optimal value for magnetron