Structure, residual stresses and properties of Al superconducting thin films fabricated by magnetron sputtering

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Superconductors attract a great potential for high-performance applications: electrical power transmission, eliminating the Joule effect; medical diagnostics; quantum interference devices and quantum computing, etc. Recent studies [1] have focused on finding new technological approaches allowing to sustain a stable superconductivity in thin films. Significant efforts were made in order to improve the scalability and robustness of thin (< 100 nm) film superconductors. However, the numerous fabrication issues still remain unsolved. In particular, the Al-based superconducting thin films, obtained via molecular-beam epitaxy [2], PVD [3] and magnetron deposition [4] exhibit different structural features and, as a consequence, various temperature ranges of a superconducting transition. The possible reasons, responsible for shifting of T_c, could be related with either grain structure or electron–phonon interaction. In order to reveal this issue, the series of Al magnetron-sputtered thin films were fabricated onto Si-substrate under different sputtering modes. The purpose of this work is to examine an effect of residual mechanical macro-stresses, distributed within Al thin films, on the critical superconducting temperature.

Thin (<100 nm thick) film deposition was carried out using a magnetron sputtering setup (developed by V. Stolyarov) onto [100]-Si substrate. Prior the deposition, the substrate was pre-cleaned by Ar^+ ions at low (<3 keV) energy. The parameters of the magnetron sputtering were as follows: the power of discharge was 50-200 W, the magnetron voltage was 173–571 V, the argon presser varied between $2 \cdot 10^{-2}$ Pa and $6 \cdot 10^{-3}$ Pa. Under these conditions, the estimated sputtering rate of 0.02–0.4 nm/s could be achieved. The XRD studies were performed by Panalytical Aeris X-ray diffractometer in the «Ω-2θ» mode in Cu-K_α radiation. TEM characterization was done by JEM 2100 at 200-kV accelerating voltage. The critical superconducting temperatures were measured by a four-probe method using the Coolab LD500 dilution refrigerator.

It has been found that the typical structure of the synthesized Al films is nanocrystalline (~63±20 nm) and possesses many inner defects (dislocation and twins). The comprehensive XRD examination has revealed a strong $<111>_{Al}$ texture and appearance of the residual compressive stresses (~ –150 MPa) oriented along the sample's surface. In turn, the critical T_c temperatures were measured to be around 1.2 K within a certain variation ±0.2–0.3 K depending on the structural phase-state of the Al films. The issues on the lattice distortion and superconducting performance were discussed.

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