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Correlation between the microstructure and the electrical properties of Si/Nb/Si trilayeres

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The reduction of the thickness of superconducting films, d, increases the disorder and leads eventually to the thickness-induced superconductor-insulator transition (d-SIT). Alternatively, the SIT may be induced in the film of fixed d by the application of the external magnetic field H (H-SIT). Both types of SIT are recently subjects of intensive studies which try to access the influence of disorder on the nucleation of superconductivity in the vicinity of SIT [1,2,3]. For this type of assessment it is very important to understand the precise nature of the disorder which exists in thin films. Recently, we have studied both types of SIT in the Si/Nb/Si trilayers with fixed thickness of Si (10 nm) and the nominal thickness of niobium layer, d, ranging from 20 nm down to about 0.3 nm. The samples are grown on glass substrates by sputtering in the high-vacuum chamber at room temperature, and the nominal d is determined based on the time of deposition. Preliminary measurements using low-resolution transmission electron microscopy (TEM) suggested that the actual d differs considerably from the nominal, and that diffusion of Si into Nb layer may take place [4], influencing the properties of the SIT.

In this study we present more detail evaluation of the trilayers microstructure, using the high-resolution TEM. From the data, we are able to determine actual d with good accuracy. The images show very sharp boundary between Nb and Si layers, what suggests that the diffusion of Si into Nb is not significant. Both the TEM, and the X-ray diffraction show that films with d above 4.4 nm have polycrystalline structure, which changes into amorphous for ultrathin films with $d < 3.3$ nm. The comparison between the microstructural and the electrical properties suggests that H-SIT is observed as soon as the samples become amorphous. On the other hand, the d-SIT is observed when d decreases below much smaller value of 1.2 nm.

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