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Superconducting and normal properties of the set of Mo/Si superlattices with variable Si layer thickness

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We report the results of the superconducting and kinetic parameter measurements (transition temperature T_c, parallel and perpendicular critical fields H_{c2}, resistivity in the normal state) on a set of Mo/Si superconducting superlattices with a constant metal layer thickness $d_{Mo} = 22$ Å and variable semiconducting one d_{Si} (14–44 Å). Our data show a monotonic dependence of all measured parameters on d_{Si}. It is found that the Josephson interlayer coupling energy depends exponentially on the spacer thickness. The data obtained allowed us to determine the characteristic electron tunneling length for amorphous silicon with high precision. It is equal to 3.9 Å. Enhancement of interlayer coupling leads to the Mo/Si multilayer transition temperature increasing, in agreement with Horovitz theory and with the experimental data on high-T_c materials.

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Introduction

Artificial superconducting superlattices have been of enduring interest for a long time as a perfect model system for the study of layered superconductor physics. Their tunability, i.e., the possibility of changing independently and in an arbitrary way the thicknesses of the superconducting layers and non-superconducting interlayers (spacers) and of using a wide spectrum of constituting materials, makes artificial multilayers very attractive objects for the investigation of many fundamental properties. The dimensionality effects, the role of the intrinsic anisotropy and its influence on T_c, the thermal and quantum fluctuation effects, etc., belong to such properties. It is especially important that for these systems the fine control over the interlayer Josephson coupling strength, which has a most profound influence on the behavior of layered superconductors, may be achieved [1,2]. In spite of an obvious importance of direct investigations of Josephson coupling, such studies are very scarce because of the necessity of preparing a large set of the variable layer thickness superlattices with a big number of bilayers N, very high regularity of the layering and with extremely small «steps» in the spacer thickness between neighboring samples in the set. The latter circumstance is associated with the expected exponential dependence of the interlayer coupling parameter on the insulating or semiconducting spacer thickness [1]. Such a dependence, consistent with the picture of quantum-mechanical tunneling of the charge carriers through a barrier, follows from obvious physical considerations. In Ref. 1 the