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ASYMMETRIC DOUBLE-BARRIER TUNNEL JUNCTIONS IN NIOBIUM NITRIDE

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It is shown that the tunnel junctions created from NbN–I–Pb are essentially asymmetric double-barrier junctions. Formation of persistent Andreyev's state in such junctions is analyzed.

It is generally agreed that the major parameter of a contemporary computer is the amount of energy consumed during fulfillment of an elementary operation, or the number of elementary operations (n) referred to one Joule. At the present time, there is no consensus on which physical principles will be embedded in transistors of the future. Because of this, research and development of devices with nanometer dimensions is still in progress, for example, the single-electron transistors suggested by K. K. Likharev, the Josephson superconducting junctions, neural networks, molecular devices, etc.

A concept proposed in [1] states that double-barrier junctions of SINIS type (superconductor — insulator — normal metal — insulator — superconductor) are in the present time most promising from the viewpoint of using them as elementary building-blocks of the nanometer size for new computers.

Today the overwhelming majority of tunnel and Josephson's devices are fabricated in niobium thin films. It is known, however, that niobium itself is a strong getter, which imposes a number of limitations on the technology of fabrication of devices in niobium. Most difficult is application of niobium at development of technologies intended for manufacture of miniature devices. The gettering properties of niobium become an obstacle in application of modern advanced methods of lithography (electron-beam, X-ray, etc.) for fabrication of miniature junctions.

Because of this, the present work is devoted to investigation of possibilities and prospects of application of niobium nitride (NbN) as a material for fabrication of tunnel and Josephson's junctions. It has been stated that the tunnel junctions in niobium nitride are most promising among the tunnel and Josephson structures already known — from the viewpoint of their application in creation of classical cryogenic computers and devices, and quantum computers.

The tunnel junctions of NbN–I–Pb type were produced in niobium nitride films with the critical temperature of the superconducting junction T_c from 15.7 K to 17.1 K. The dielectric tunnel barrier was grown by thermal oxidation of the film surface directly after the spraying process [2]. The diagrammatic sketch of the "niobium nitride — insulator — lead" tunnel junctions is given in Fig. 1. Figure 2 shows the current-voltage characteristic of one of the tested NbN–I–Pb junctions. The prospects of practical application of the asymmetric double-barrier tunnel junctions of superconductors are disclosed in [3].

Since the niobium nitride surface is treated by ions to clear it from reagents, some part of the niobium nitride surface layer becomes a superconductor with a lowered T_c, so that it may become an interlayer of the normal metal. Then a "film — surface layer" interface is formed making possible the Andreyev scattering of quasi-particles during the current flow through the junction. Actually, the junction turns into an asymmetric double-barrier tunnel junction with its barriers substantially different in terms of transparency.

Consider the model of the superconductor — interlayer — superconductor structure in the ballistic marginal conditions for the case when the interlayer thickness d is less than both elastic and uncorrelated lengths of scattering. We

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