Structure and Transport Characteristics of Tunnel Junctions with Hybrid Semiconductor Barriers with Quantum Dots

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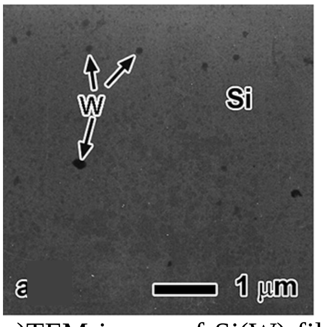
Now the activity aimed at fabrication and investigation of semiconductor heterostructures (tunnel junctions) with quantum dots and quantum wells in the barriers is well known, and a large number of devices based on them have been designed.The use of self-organization effects is one of the most effective technological techniques for the creation of quantum dots (metal clusters) in the semiconductor barriers. At ultra-low temperatures, the semiconducting heterostructures demonstrate current-voltage characteristics with an unusual characteristic shape. A single or several current peaks caused by electron tunneling through the allowed states in the barrier were observed in such CVCs.A distinct first peak in related current-voltage curves has got a special name, Fermi-edge singularity since this feature appears when both the Fermi energy level of one electrode and that of the levels in the quantum dot are matched.

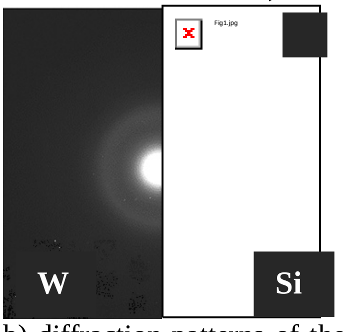
We have studied thin-film superconductor - semiconductor (with quantum dots) - superconductor MoRe–Si(W)–MoRe junctions where electrons are tunnelling through a single or several quantum dots within the Si(W) barrier.We have revealed the presence and characteristics of the tungsten clusters in silicon-based Si(W) films with a transmission electron microscope (TEM) JEM-2000FX. For the comparison, thefabricated modelSi(W) layers of a thickness about 200 nm were studied with a TEM at an accelerating voltage of 200 kV.

The results of this study are shown in Fig.1. It was found that tungsten clusters formed inside the silicon layer with a diameter of 30 -100 nm. Based on the Si(W) film diffraction patterns, see Fig.1 b), it can be concluded that both silicon and tungsten layers were amorphous – indeed, only characteristic halos are seen in the diffraction patterns in Fig. 1 b) which indicates on an amorphous state of the material. The broadening of the pattern can be understood if we consider the possibility of combining two patterns from Si and SiO phases.The TEM data indicate that, under our experimental conditions, nano-scaled 10-50 nm-thick tungsten clusters with a distance from 100 up to 1000 nm between them are formed within the amorphous silicon matrix.

Current-voltage characteristics of the MoRe–Si(W)–MoResamples were measured in a wide voltage range from -900 to 900 mV at temperatures from 4,2 K to 8 K and we have observed resonant current peaks in the CVCs at bias voltages from 40 to 300 mV that were symmetrical for positive and negative voltages. In the studied heterostructures, metal clusters inside the barrier behave as quasi-one-dimensional quantum dots, hence, the charge transport can be adequately described by scattering matrices within the quantum model of one-dimensional charge transport.



a)TEM image of Si(W) film with 200 nm thickness;



b) diffraction patterns of the Si film and W cluster in it;

Fig. 1.