Resonant tunneling in novel type Josephson heterostructures superconductor- doped semiconductor- superconductor

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MoRe-Si(doped by tungsten)-MoRe junctions have been fabricated by using thin films deposition techniques. Current-voltage characteristics (I-V curves) of the fabricated Josephson junctions have been measured at various temperature and magnetic field values. For the pure silicon barriers and silicon barriers doped by tungsten fabricated with small W concentration (~ 3-4at.%) we observed the existence of an over-barrier direct tunneling effect and a direct tunneling effect through an impurity level within the barrier. At relatively high concentrations (~ 6-9at. %) of tungsten in the silicon barriers an existence of a resonant tunneling effect is observed (if percolation limit is overcome) through localized levels of scattering centers (W atoms). Simultaneously, at some conditions in these junctions a superconducting Josephson current appears on the base of the resonant tunneling (see Fig. 1). Usually, the differential resistance values of the quasiparticle I-V curves of these junctions are high enough (10-100 times) in comparison to the differential resistance values of the quasiparticle I-V curves for the Josephson tunnel junctions with well-known direct tunneling and having the same values of their Josephson critical currents. So, it means the fabricated junctions have large enough values (up to 10-30) of the $I_C R_N$ product (Josephson critical current I_C multiplied by R_N – resistance of the junction in normal state). The reason of this phenomenon is unclear at the moment.

It is important and interesting that the high voltage asymptotes of the quasiparticle I-V curves of the fabricated junctions do not cross the origin of coordinates, it means they are not described by Ohm low in the high voltage region, and it means that the sufficient excess quasiparticle currents flow through these junctions (the asymptotes of the quasiparticle I-V are parallel to the Ohm low curves for the junctions in the normal state).

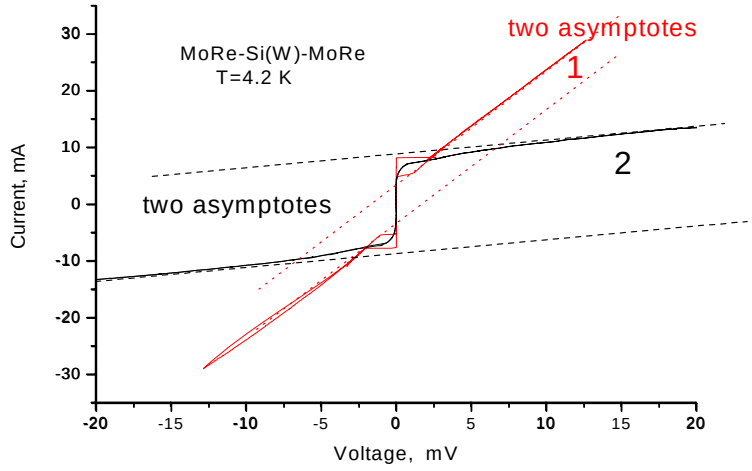

Fig.1. I-V characteristics of MoRe-Si(doped by W)-MoRe junctions with n_W ~ 6-9at.% : 1 – with hysteresis, 2 –without hysteresis and their asymptotes.

Basing on the predictions of the well-known Blonder-Tinkham-Klapwijk (BTK) theory model [1] from our point of view this is a real evidence of the existence of two S/N interfaces with very small barriers (Z ~ 1-1,5) on both sides of the fabricated junctions with resonant tunneling. The same interpretation of the excess quasiparticle currents appearance in our junctions can also be done on the base of multiple Andreev reflections in Josephson junctions. Let us take into account that the theory models should describe the current flow through a number of the scattering centers (i.e. through the tungsten atoms), every of these events could have small enough probabilities and these probability distributions depends on the kind of transparency distribution function in silicon doped by tungsten.

[1] G. Blonder, M. Tinkham. and T. Klapwijk, Phys. Rev. B, 25, 4515-4532 (1982).