May 31, ...

EXTENDED ABSTRACTS

VOLUME 94-1

SPRING MEETING

SAN FRANCISCO, CALIFORNIA

MAY 22-27, 1994

Battery
Corrosion
Dielectric Science and Technology
Electrodeposition
Electronics
Energy Technology
Fullerenes
High Temperature Materials
Industrial Electrolysis and Electrochemical Engineering
Luminescence and Display Materials
Organic and Biological Electrochemistry
Physical Electrochemistry
Sensor

THE ELECTROCHEMICAL SOCIETY, INC.
10 South Main St., Pennington, NJ 08534-2896

"Long range proximity effect".
Possible explanation.

I.A. Devyatov, M.Yu. Kupriyanov.
Institute of Nuclear Physics,
Moscow State University
119899 GSP, Moscow, Russia.

The theoretical model for explanation of the so-called "long range proximity effect" temperature independent and extremely large supercurrent decay length ($\xi \approx 10-50$ nm) of the HTS Josephson junction [1,2] with semiconductor oxide interlayer is proposed.

It is suggested that the resonant tunneling via localized states (LS) in the interlayer is responsible for this effect.

In proving this assertion we assumed that LS are distributed uniformly in energy in the vicinity of the Fermy-energy) and over the interlayer and that their density is small enough so that the interaction of electrons occupied at different LS is negligible. The interaction of the electrons at one LS is also be not taken into account.

We also suggest that

i) the barrier height $(V-\mu)$ of the I - layer is well below the chemical potential μ

$$((V-\mu)/\mu)<<1;$$

ii) the decay length of the wave function in the barrier (the effective radius of LS) $\alpha^{-1} = (2m(V-\mu))^{-1/2}$ is satisfy the conditions

$$dT_c/(V-\mu) \le \alpha^{-1} \le d.$$

Here T_c is the critical temperature of the electrodes, 2d is the thickness of the barrier, m is the electron's effective mass. The last restriction practically means that the dominant channel for the current transport through the junction is the resonant tunneling via one LS on a trajectory so that the processes of the direct tunneling are unimportant.

Under this restrictions, starting from Gor'kov equations, using the expression for the critical current derived in [3,4] and the procedure of averaging over the positions and energies of the LS for the temperature dependence of the critical current one have:

$$J_c = \frac{8\alpha T\Delta^2}{eR_n} \sum_{\omega>0} \frac{1}{\omega^2 + \Delta^2} \int \frac{dz}{\omega C/2\pi T_c + B\mathrm{ch}(2\alpha z)}, \quad (1)$$

$$B = 1 + \frac{\omega}{(\omega^2 + \Delta^2)^{1/2}},$$

$$C = \frac{2\pi T_c}{V-\mu} \frac{\alpha d}{2} \left(\frac{\mu}{V-\mu}\right)^{1/2} \exp(2\alpha d).$$

Here T is the temperature, R_n is the resonant resistance of the junction at normal state, $\omega = (2n+1)\pi T$ are the Matsubara frequencies, Δ is the modulus of the order parameter.

From (1) it follows that $J_c(T)$ depends on parameter C which is proportional to ratio of the escape rates of the electron from LS due to thermal activation and due to resonant tunneling.

For $C \le 1$ the last process is dominated. In this limit the temperature dependence of J_cR_n product doesn't differ considerably from the predictions of Ambegaokar - Baratoff (AB) theory [5] (see Fig.1).

Increasing of the parameter C leads to suppression of the resonant tunneling processes due to thermal excitations and reduction J_c. It is interesting to point out that in this model it is possible to explain simultaneously the small values of J_cR_n product with its smooth temperature dependencies at $T \le 0.3 \div 0.4\ T_c$.

Figure 1 shows the numerically calculated $R_nJ_c(T)$ dependencies for various values of parameter C. Dashed line is the prediction of the AB theory, and circles, triangles and squares are experimental data [2] obtained for $YB_2C_3O_{7-\delta}/Y_{0.3}P_{0.7}B_2C_3O_{7-\delta}/YB_2C_3O_{7-\delta}$ step-edge junctions with different interlayer thicknesses (□ -75 nm, ▽ -50 nm, ○ - 25 nm). The theoretical curve for $C \approx 100$ fits well the data. It is important to note that the absolute values of the data are not differ greatly despite of the essential difference between the interlayer thicknesses. This fact can not be explain in the framework of existing SNS junction's models [6] as well as in the theory based on the tunneling via several LS on a trajectory [4]. All of them predict the exponential decay of J_c in the experimentally examined thickness interval.

So, we can conclude, that the proposed model based on resonant tunneling via one LS located in the barrier with the relatively small height is practically unique which provides to explain all scope of the data [2]. We believe that the model can be also applicable for interpretation of the properties of the HTS single grain boundary junctions and Low-T_c structures with the gapless semiconductor interlayer.

REFERENCES

1. M.Kasai, Y.Kanke, T.Ohno, Y.Kozono, J.Appl. Phys., 72, (1992), 5334.
2. C.Stolzel, M.Siegel, C.Adrian et.al., Ext.Abstr. of European Conference on Applied Superconductivity, (1993), 56.
3. L.C.Aslamasov, M.V.Fistul, Zh.Eksp.Teor.Fiz., 81, (1981), 382.
4. L.G.Aslamasov, M.V.Fistul, Sov.Phys.JETP, 56, (1982), 666.
5. V.Ambegaokar, A.Baratoff, Phys.Rev.Lett., 10, (1963), 486.
6. M.Yu.Kupriyanov, K.K.Likharev, Sov.Phys. Usp., 33, (1990), 340.