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Book of Abstracts

M.V. Lomonosov State University, Faculty of Physics

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DYNAMIC PROPERTIES OF SIFS JOSEPHSON JUNCTIONS

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Superconductor/insulator/ ferromagnet/ superconductor (SIFS) tunnel Josephson junctions exhibit interesting features like oscillatory behavior of the density of states (DOS) in the F-interlayer and 0-π transitions in the Josephson current [1]. Due to combination of tunneling type of conductivity and exchange field in a ferromagnet, these junctions are suitable for applications in quantum circuits. Here we present a quantitative study of the current-voltage characteristics (CVC) of SIFS junctions. In order to obtain the CVC we calculate the DOS in the F/S bilayer for arbitrary length of the ferromagnetic layer, using quasiclassical theory. For a ferromagnetic layer thickness larger than the characteristic penetration depth of the superconducting condensate into the F layer, we find an analytical expression which agrees with the DOS obtained from a self-consistent numerical method. We discuss general properties of the DOS and its dependence on the parameters of the ferromagnetic layer. In particular we focus our analysis on the DOS oscillations at the Fermi energy. Using the numerically obtained DOS we calculate the corresponding CVC and discuss their properties. Finally, we use CVC to calculate the macroscopic quantum tunneling (MQT) escape rate for the current biased SIFS junctions.

[1] A. S. Vasenko, A. A. Golubov, M. Yu. Kupriyanov, and M. Weides, Phys. Rev. B 77, 134507 (2008).

22TL-G-7

PROXIMITY-EFFECT SUPERCONDUCTING TRIPLET SPIN VALVE

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We study the critical temperature T_c of S/F1/N/F2 core structure, where the magnetization direction of the outer F2 is kept fixed by a source of the exchange bias or induced anisotropy, or by the shape anisotropy. The nonmagnetic metal layer N in between of the F1 and F2 layers provides exchange decoupling of them. This spin-valve structure is attached to the singlet superconductor layer S as an actuator to control the superconducting T_c of the latter. The basic idea goes up to the work by S. Oh *et al.* [1], however, we have taken into account the long-range triplet component of the superconducting pairing, which can be generated at noncollinear magnetizations of the F layers [2]. We demonstrate that T_c can be a nonmonotonic function of the angle α between magnetizations of the two F layers. The minimum is achieved at an intermediate α, lying between the parallel (P, $\alpha = 0$) and antiparallel (AP, $\alpha = \pi$) cases (see solution of the simplified problem for the S/F1/F2(∞) structure in Ref. [3]). This implies a possibility of the "triplet" spin-valve effect: at temperatures above the minimum T_c but below the both, T_c^P and T_c^{AP}, the system is superconducting in the domain of angles around the collinear magnetizations of the F layers, but non-superconducting in the middle. At the same time, considering only the P and AP orientations, we find that both, the "normal" $T_c^{AP} > T_c^P$, and the "inverse" $T_c^{AP} < T_c^P$ switching effects are possible depending on the choice of material properties and thickness of the layers [3-5]. With proper adjustment of the S-layer thickness the system can be driven into a regime of the re-entrant superconductivity as a function of the angle between magnetizations of the F1 and F2 layers [3,4]. It seems that observation of the unconventional "triplet" switching effect, or the re-entrant superconductivity in the S/F1/N/F2-type structures, could be an experimental indication of existence of the long-range odd triplet component of superconductivity in SF hybrids, predicted in Ref. [2].

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[1] S. Oh, D. Youm, and M.R. Beasley, *Appl. Phys. Lett.* **71** (1997) 2376.
[2] F.S. Bergeret, A.F. Volkov, and K.B. Efetov, *Rev. Mod. Phys.* **77** (2005) 1321.
[3] Ya.V. Fominov, A.A. Golubov, T.Yu. Karminskaya *et al.*, *JETP Lett.* **91** (2010) 308.
[4] R.G. Deminov, L.R. Tagirov, O.V. Nedopekin *et al.*, *Phys. Rev. B,* submitted.
[5] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin *et al.*, *Phys. Rev. Lett.* **106** (2011) 067005.

22RP-G-8

PROXIMITY EFFECT IN SFF STRUCTURES

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Nowadays there is a considerable interest to the structures composed from superconducting (S) and ferromagnetic (F) layers. The possibility of π-states in SFS Josephson junctions due to oscillatory nature of superconducting order parameter induced into a ferromagnet was predicted theoretically and has been convincingly demonstrated by experiments [1]-[3]. It was also predicted that in Josephson junctions with several ferromagnetic layers it is possible to realize π-states even in the case when the F-layers are so thin that order parameter oscillations cannot develop there, but phase slips occur at the SF interfaces with finite transparency. This effect was predicted in [4] for

SFIFS junctions, where two SF-bilayers are decoupled by an insulating barrier 'I'. In this case phase shifts $\delta\varphi$ occur at each of the SF interfaces and saturate at $\delta\varphi = \pi/2$ with the increase of exchange field. As a result, total phase shift across the junction equals to π.

Recently, structures where two F-layers are coupled to a superconductor (FSF or SFF) attracted much attention since they may serve as superconducting spin valves, where transition temperature is controlled by angle α between magnetization directions of the F-layers [5]. The SFF structures with fully transparent interfaces were studied theoretically in [6], where it was shown that critical temperature in such trilayers can be a nonmonotonic function of the angle α.

In this paper we address important issue of the influence of interface transparency on singlet and triplet correlations in SFF structures and show that phase slips at both interfaces lead to a number of new peculiar phenomena. First, for parallel orientations of magnetizations in the F-layers, π-state in SFFIS Josephson junction can be realized as a result of two subsequent $\pi/2$ phase shifts at the interfaces. Second, the magnitude of long-range triplet component which is generated in SFF structures with varying angle α between the F-layer magnetizations, has anomalous dependence on α. Namely, contrary to the previous knowledge based on analysis of symmetric FSF or SFFS structures, the triplet component in SFF structures reaches maximum not in the vicinity of $\alpha=\pi/2$ and can be even zero for this configuration of magnetization vectors. We also show how these new effects manifest itself in the conductance of F layers and in the realization of 0-π transition in SFFIS tunnel junctions.

Support by BFBR grant Ф10Р-063 and RFBR grant 10-02-90014-Бел-а is acknowledged.

[1] A.A. Golubov, M. Yu. Kupriyanov, and E. Il'ichev, *Rev. Mod. Phys.*, **76** (2004) 411.
[2] A.I. Buzdin, *Rev. Mod. Phys.*, 77}, (2005) 935.
[3] F.S. Bergeret, A. F. Volkov, K. B. Efetov, *Rev. Mod. Phys.*, **77** (2005) 1321.
[4] A.A. Golubov, M.Yu.Kupriyanov and Ya.V. Fominov, *JETP Letters*, **75** (2002) 190.
[5] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin,, *et al. Phys. Rev. Lett.*, **106** (2011) 067005.
[6] Ya.V. Fominov, A.A. Golubov, T.Yu. Karminskaya, *et al.*, *Pis'ma v ZhETF* **91**, (2010) 329.

22OR-G-9

SIFS JOSEPHSON JUNCTION: FROM THE CLEAN TO THE DIRTY LIMIT

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The interplay between dirty and clean limits for Superconductor-Ferromagnet-Superconductor (SFS) Josephson junctions is a subject of intensive theoretical studies [1,2]. SIFS junctions, containing an additional insulator (I) barrier are interesting as potential logic elements in superconducting circuits, since their critical current I_c can be tuned over a wide range, still keeping a high I_cR_N product, where R_N is the normal resistance of the junction. They are also a convenient model system for a comparative study of the 0-π transitions for arbitrary relations between characteristic lengths of the F-layer: the layer thickness *d*, the mean free path *l*, the magnetic length $\xi_H=v_F/2H$, and the nonmagnetic coherence length $\xi_0=v_F/2\pi T_C$, where v_F is the Fermi velocity, *H* is the exchange magnetic energy, and T_C is the critical temperature of the superconducting electrodes. The spatial variations of the order parameter are described by the complex coherent length in the ferromagnet $\xi_F^{-1}= \xi_1^{-1}+ i\xi_2^{-1}$. It is well known, that in the dirty limit ($l<<\xi_{1,2}$) described by the Usadel equations both $\xi_1^2=\xi_2^2= v_F l/3H$ [3].

In this work the spatial distribution of the anomalous Green's functions and the Josephson current in the SIFS junction are calculated. The linearized Eilenberger equations are solved together with Zaitsev boundary conditions [5]. This allows comparing the dirty and the clean limits, investigating a moderate disorder, and establishing the applicability limits of the Usadel equations for such structures. We demonstrate that for an arbitrary relation between *l*, ξ_H, and *d* the spatial distribution of the anomalous Green's function can be approximated by a single exponent with reasonable accuracy, and we find its effective decay length and oscillation period for several values of ξ_H, *l* and *d*. The role of different types of the FS interface is analyzed. The applicability range of the Usadel equation is established.

The results of calculations have been applied to the interpretation of experimental data obtained on Nb|Al_2O_3|Cu|Ni|Nb Josephson junctions containing a Ni layer with moderate scattering [6].

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[1] F. S. Bergeret, A. F. Volkov, and K. B. Efetov, *Phys. Rev. B* **64** (2001) 134506.
[2] J. Linder, M. Zareyan, and A. Sudbo, *Phys. Rev. B* **79** (2009) 064514.
[3] A. I. Buzdin, Rev. Mod. Phys. **77** (2005) 935.
[4] A. A. Golubov, M. Yu. Kupriyanov, E. Il'ichev, *Rev. Mod. Phys.* **76** (2004) 411.
[5] A. V. Zaitsev, *Zh. Exp. Teor. Fiz.* **86** (1984) 1742 [*Sov. Phys. JETP* **59** (1984) 1015].
[6] A. A. Bannykh, J. Pfeiffer, V. S. Stolyarov, I. E. Batov, V. V. Ryazanov, M. Weides, *Phys. Rev. B* **79** (2009) 054501.

23OR-G-8

DENSITY OF STATES MINIGAP IN A SUPERCONDUCTOR – FERROMAGNET JUNCTION

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In last years there was an intense activity in studying the so called superconducting proximity effect in the superconductor (S) – normal metal (N) and superconductor – ferromagnet (F) hybrid structures [1]. It manifests itself in superconducting correlations penetration into non-superconducting material due to the mechanism of Andreev reflection, when electron is reflected as a hole at the interface of superconductor with other material, with corresponding formation of the Cooper pair inside the superconductor.

One way to probe the superconducting proximity effect is to study the density of states (DOS) in SN and SF hybrid structures. It is well known that the DOS on the free boundary of the normal metal layer of a SN bilayer exhibits the minigap, which is a manifestation of the superconducting proximity effect. The characteristic scale of the minigap is set by the Thouless energy ETh = D/d2 [2], where D is the diffusion coefficient in the normal metal and d is the thickness of the normal metal layer.

In this work we study the behaviour of the minigap in SF bilayers with respect to the parameters of the ferromagnetic metal. We can model the ferromagnet with just a single parameter – the exchange field h. It shifts the DOS for the two spin subbands in the ferromagnet in opposite directions, and therefore the critical value hc of the exchange field at which the minigap in the spectrum closes can be roughly estimated as hc ~ ETh [3].

We have checked this prediction by self-consistent numerical calculation of the DOS in a SF bilayer and found that it is in a good agreement with our data, hc ≈ 0.77 ETh [4]. However, this estimation will be different if we take into account other parameters of ferromagnetic metal. In this work we study the influence of the magnetic scattering parallel (perpendicular) to the quantization axis, and the spin-orbit scattering.

[1] A. I. Buzdin, *Rev. Mod. Phys.*, 77 (2005) 935.
[2] A.A. Golubov and M.Yu Kupriyanov, *J. Low Temp. Phys.*, **70** (1988) 83; A.A. Golubov and M. Yu. Kupriyanov, *Sov. Phys. JETP*, **69** (1989) 805.
[3] R. Fazio and C. Lucheroni, *Europhys. Lett.*, **45**, (1999) 707.
[4] A.S. Vasenko, S. Kawabata, A.A. Golubov, M.Yu. Kupriyanov, C. Lacroix, F.S. Bergeret, and F.W.J. Hekking, unpublished (arXiv: 1101.0361).

23OR-G-9

CURRENT-PHASE RELATION IN JOSEPHSON JUNCTIONS WITH COMPLEX FERROMAGNETIC/NORMAL METAL INTERLAYER

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It is well known that critical current across a Josephson junction with ferromagnetic spacer may oscillate as a function of the ferromagnetic layer thickness, thus providing an existence of Josephson structures with negative critical current, so-called π-junctions [1-3]. In some classical and quantum Josephson circuits it is even more interesting to create φ-junctions, the structures having in the ground state phase difference φ, $(0<|\varphi|<\pi)$ between superconducting electrodes.

In order to have a φ-junction the current-phase relation (CPR) $I_S(\varphi) = A\,sin(\varphi) + B\,sin(2\varphi)$ should at least contain $sin(2\varphi)$ contribution. Moreover the amplitude of the second harmonic must obey the conditions $|B| > A/2$, $A > 0$, $B < 0$.

In this paper we have analysed several types of SFS and SIFIS sandwiches and have found that in practically interesting range of temperatures T□$0.1Tc$ the formulated above conditions cannot be realized.

However, we have demonstrated that for the recently proposed S-NF-S variable thickness bridges [4], it is possible to choose the junction geometry providing both 0-π transition and nonsinusoidal CPR. The areas of structure parameters which ensure the φ-junction existence in these structures are determined and classified.

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[1] A.A. Golubov, M. Yu. Kupriyanov, and E. Il'ichev, *Rev. Mod. Phys*., **76** (2004) 411.
[2] A.I. Buzdin, *Rev. Mod. Phys*., **77**, (2005) 935.
[3] F.S. Bergeret, A. F. Volkov, K. B. Efetov, *Rev. Mod. Phys*., **77** (2005) 1321.
[4] T.Yu.Karminskaya, A.A.Golubov, M.Yu.Kupriyanov, A.S.Sidorenko, *Phys. Rev. B* **79**, (2009) 214509.

23RP-G-10

SOLITARY REENTRANT SUPERCONDUCTIVITY IN ASYMMETRICAL FSF STRUCTURES

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Solving the boundary value problem for the Eilenberger function, the superconducting and magnetic states of asymmetric ferromagnet-superconductor-ferromagnet (F_1SF_2) nanostructures are

23PO-M-8

SUPERCONDUCTING TRIPLET SPIN VALVE F2F1S – GENERAL MODEL WITH ARBITRARY LAYER THICKNESSES AND BOUNDARY TRANSPARENCIES

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We study the critical temperature T_c of F2F1S trilayers (S is a singlet superconductor, Fi is a ferromagnetic metal), where the long-range triplet superconducting component is generated at noncollinear magnetizations of the F layers [1].

The F2NF1 heterostructure (N is a non-magnetic normal metal) with arbitrary thickness of the layers is a conventional spin-valve which plays a role of control element in the F2NF1S tetralayers. Earlier we demonstrated that T_c in such structures can be a non-monotonic function of the angle α between magnetizations of the two F layers [2,3]. The absolute minimum is achieved at an intermediate α, lying between the parallel (P, α = 0) and antiparallel (AP, α = π) configurations, we called this feature the "triplet" spin-valve effect. The role of the N layer in the F2NF1S structure reduces to separating magnetically the two ferromagnetic layers allowing them to rotate independently. If thinner than the coherence length, it has very small impact on superconductivity in the structure [3]. Therefore we can study the simplified F2F1S structure.

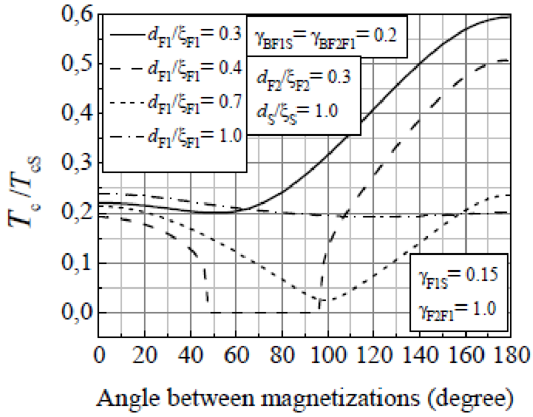

Figure shows dependence of the transition temperature T_c on the angle α between magnetizations, the outer ferromagnetic layer F2 having fixed thickness (see the legend). Here T_{cS} is the superconducting transition temperature for an isolated S layer. Tranparencies of the interfaces were taken typical for the SF-proximity systems (see the Figure legends). At small thicknesses d_{F1} of the middle ferromagnetic layer F1 (d_{F1}/ξ_{F1} = 0.3) the switching effect is standard, while at larger d_{F1} (d_{F1}/ξ_{F1} = 1.0) the effect is inverse. Curve for d_{F1}/ξ_{F1} = 0.7 demonstrates the triplet spin-valve effect. Moreover, the reentrant $T_c(\alpha)$ dependence (d_{F1}/ξ_{F1} = 0.4) is possible. In this situation the triplet spin-valve effect takes place even at $T = 0$. Figure shows a possibility of the spin-valve effect enhancement at approximately equal thicknesses of the F layers.

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[1] F.S. Bergeret, A.F. Volkov, and K.B. Efetov, *Rev. Mod. Phys.*, 77 (2005) 1321.
[2] Ya.V. Fominov, A.A. Golubov, T.Yu. Karminskaya *et al.*, *JETP Lett.*, **91** (2010) 308.
[3] R.G. Deminov, L.R. Tagirov, O.V. Nedopekin *et al.*, *Phys. Rev. B*, submitted.

23PO-M-15

SUPERCONDUCTING PHASE TRANSITION IN SUPERCONDUCTOR/FERROMAGNET MULTILAYERS

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The nucleation of superconductivity in finite multilayers consisting of alternate ferromagnet (F) and superconducting (S) layers has been investigated both experimentally and theoretically. We found that the transition width ΔT_c increases with increasing number N_{bl} of S/F bilayers in the multilayer in a well-defined manner, even though structural analysis indicates that interface roughness and thickness variations of the individual layers are small. Also, step-like features start to appear in the transition. The theoretical analysis made in terms of eigenvalues-eigenfunctions problem for the microscopic equations of the superconducting critical state derived in the diffusive limit (linearized Usadel equations).

For the preparation, we used weakly ferromagnetic $Pd_{81}Ni_{19}$ and superconducting Nb. The samples consist of Si/N_{bl}×($Pd_{81}Ni_{19}$/Nb)/$Pd_{81}Ni_{19}$ and were grown on Si(100) substrates by diode sputtering in an ultrahigh vacuum system as described in [1]. The structural properties were characterized by X-ray reflectometry (XRR) [2]. The series has formed by samples with N_{bl} running the values from 1 to 14 and the layer thicknesses d_S = 18.7 nm and d_F =2.2 nm.

For the theoretical investigation of the critical states of prepared structures, the boundary problem for the set of Usadel equations is solved by the matrix method [3]. As a result, for each structure of the series, the set of N_{bl} critical eigenstates with eigen critical temperaures $T^{(k)}$ ($k = 0,1,\ldots, N_{bl}$-1), which enumerated in accordance with numbers of the eigenfunctions nodes, is derived. The parameters of the model are estimated by the simultaneous fitting of the experimental dependence of the critical temperature T_c of $Pd_{81}Ni_{19}$/Nb bilayers (which belongs to the considered layered system) versus thickness of Nb layer [4], and the asymptotic of experimental $T_c(N_{bl})$ dependence.

The result of the comparison of the experimental and theoretical data is the following. The set of eigenvalues $T^{(k)}$ covers, and, for large N_{bl}, almost precisely matchs to the transition width ΔT_c. We elaborated a model of a multistep phase transition by passing of the eigenstates with different $T^{(k)}$. This model includes the mechanisms of interaction of the bias transport current with induced spontaneous vortex current [3,5].

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[1] C. Cirillo et al., *Phys. Rev B*, **75** (2007) 104510.
[2] A. Vecchione et al., *Surface Science*, submitted.
[3] V.N. Kushnir, M.Yu. Kupriyanov, *Pis`ma v ZhETP*, submitted.
[4] C. Cirillo et al., *Phys. Rev B*, **80** (2009) 094510.
[5] S.L. Prischepa et al., *Pis`ma v ZhETP*, **88** (2008) 431 [JETP Lett. 88 (2008) 375].

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[1] V.I. Zdravkov, J. Kehrle, G. Obermeier, et al. Phys. Rev. B **82**, 054517 (2010).

24OR-G-4

SUPERCONDUCTING CRITICAL TEMPERATURE AND MAGNETIC INHOMOGENEITIES IN SUPERCONDUCTOR/FERROMAGNET/SUPERCONDUCTOR TRILAYERS

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The effect of the exchange energy variations in weakly ferromagnetic alloys on the superconductive resistive transition of Superconductor/Ferromagnet/Superconductor (S/F/S) trilayers is studied. Critical temperature, T_c, and resistive transitions versus the F-layer thickness, d_F, have been analyzed in Nb/$Cu_{0.41}Ni_{0.59}$/Nb and Nb/$Pd_{0.81}Ni_{0.19}$/Nb trilayers. We show that the $T_c(d_F)$ dependence and the width of the resistive transition curves $R(T)$ are sensitive to magnetic inhomogeneities in the F-layer for values of d_F^* corresponding to thickness where the π-superconducting state is established.

In particular we observe that, for the Nb/$Cu_{0.41}Ni_{0.59}$/Nb trilayers, a broadening of the $R(T)$ transitions is observed in the π-phase thickness region, for d_F □ d_F^*, where the width $\Delta T_c = 0.6$ K, while for thickness $d_F << d_F^*$ and $d_F >> d_F^*$ the resistive transitions are sharp and $\Delta T_c \approx 0.1$ K. It was proposed that such broadening at d_F □ d_F^* can be due to in-plane inhomogeneity of both S and F materials which generates a network of Josephson 0- and π- contacts with a subsequent spontaneous nucleation of vortices [1]. On the other hand for the Nb/$Pd_{0.81}Ni_{0.19}$/Nb trilayers the $R(T)$ transitions are sharp and ΔT_c do not exceed 0.1 K for all the values of d_F.

Since the specular X-ray reflectivity measurements performed on these samples revealed similar values of the interfacial roughness for both the studied systems [2,3], we exclude the possible geometrical inhomogeneity of the samples as a reason for $R(T)$ broadening. At the same time the Ni clustering is much more pronounced in $Cu_{0.41}Ni_{0.59}$ films with respect to $Pd_{0.81}Ni_{0.19}$ one.

For this reason the experimental data have been analyzed applying the approach developed by Tagirov to describe superconducting/strong ferromagnetic systems [4,5]. In the present case the aim was to take into account the possible presence of Ni segregation in the alloys. The model successfully reproduces with reasonable values of parameters the data for the Nb/$Cu_{0.41}Ni_{0.59}$/Nb system, as well as for the Nb/$Pd_{0.81}Ni_{0.19}$/Nb one. The results of the fitting procedure confirm the absence of strong Ni clustering in $Pd_{0.81}Ni_{0.19}$ films, while the quantitative estimate of the exchange energy in the Ni clusters present in $Cu_{0.41}Ni_{0.59}$ films is in good agreement with the literature.

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[1] S.L. Prischepa et al., *Pis`ma v ZhETP*, **88** (2008) 431 [JETP Lett. 88 (2008) 375].
[2] S.L. Prischepa et al., *Solid State Phenomena*, **152-153** (2009) 478.
[3] A. Vecchione et al., *Surface Science*, submitted.
[4] L.R. Tagirov, *Physica C*, **307** (1998) 145.
[5] B.P. Vodopyanov, L.R. Tagirov, H.Z. Durusoy, A.V. Berezhnov, *Physica C*, **366** (2001) 31.

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SUPERCONDUCTING THERMO-ELECTRIC BOLOMETER WITH HIGH IMBALANCE OF TUNNELING THROUGH THE SIN TUNNEL JUNCTION

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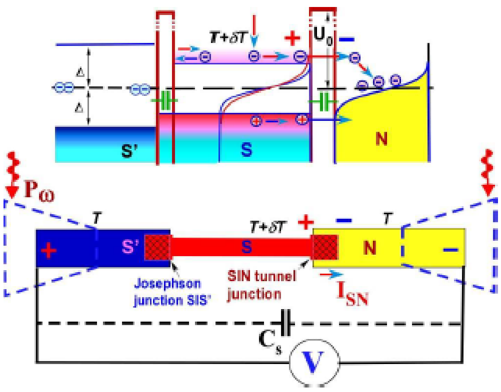
The novel concept of the Zero-Biased Thermo-Electric Bolometer (TEB) has been recently proposed [1]. The bolometer is based on a charge-to-voltage conversion in a Superconductor-Insulator-Normal (SIN) Tunnel Junction. The absorption of photons in the superconducting absorber leads to excitation of quasiparticles, tunneling through the SIN junction in zero-biased mode with some imbalance of quasielectrons and quasiholes and generation of voltage. The thermoelectric voltage is determined by accumulation of tunneling charge in an external capacitance. Conversion efficiency is very high and voltage response comparable with a superconducting gap is easily achieved. All properties of the TEB are determined by charge imbalance in absorption and tunneling. The imbalance was quite low for previously realized systems with SIN tunnel junction (0.01 for Smith-Tinkham realization [2]).

Fig 1. Sketch of the proposed Thermo-Electric Bolometer (TEB) based on a Charge-to-Voltage Convertion of quasiparticles excited in superconducting nanoabsorber by an RF signal. The convertor is working in a novel mode as an integrator of charge that has tunneled through the SIN junction. The self-biased SIN tunnel junction is used for the generation of a voltage which appears due to the different probability of tunneling for quasielectrons and quasiholes to the normal metal.



We propose a radically new method of advanced TEB with high imbalance of quasielectrons and quasiholes tunneling through the SIN junction. The concept is fully based on large difference in tunneling probability of quasielectrons and quasiholes through the low potential barrier SIN junctions. For that goal, the TEB with AlOx barrier of height U_0=1.7 meV should be replaced Cr-based or Ti-based systems with a low potential barrier. Estimation of tunneling probability and imbalance for Pb/Cr_2O_3/Pb junction with U_0=20 meV, superconducting gap 2Δ=2.7 meV, thickness of the barrier d=5 nm [3] using quantum-mechanical transparency gives Imbalance = 0.7 (!) that is very high figure for TEB [1].

Having a bias-free thermo-electric bolometer working at low temperatures is very attractive for applications. However, the thermo-electric Seebeck coefficient is dramatically decreased at low temperatures for ordinary metals and semiconductors. In contrast, the proposed TEB with