[5] A.I. Ekimov and V.I. Safarov, ibid. 13, 251 (1971) [13, 177 (1971)].
[6] M.I. D'yakonov and V.I. Perel', Zh. Eksp. Teor. Fiz. 60, No. 5 (1971) [Sov. Phys.-JETP 33, No. 5 (1971)].
[7] B.P. Zakharchenya, V.G. Fleisher, et al., ZhETF Pis. Red. 13, 195 (1971) [JETP Lett 13, 137 (1971)].
[8] Physics and Chemistry of II - VI Compounds (Translations), Mir, p. 261.
[9] G.E. Pikus, Phys. Rev. Lett. 6, 103 (1961).
[10] G.L. Bir and S.G.E. Pikus, Proc. VII-th Internat. Conf. on the Phys. of Semiconductors, Paris, p. 789, 1964.

# INFLUENCE OF MAGNETIC SCATTERING ON THE TUNNEL CURRENT OF SUPERCONDUCTORS

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We investigated the influence of magnetic scattering on the tunnel current of superconductors. The scattering magnetic impurities were deposited on the insulator layer of the tunnel junction on the side of the investigated superconducting metal. In preparing the junctions, we used dielectric masks ensuring constancy of the thickness of the investigated films. The insulation layer was produced by oxidizing an aluminum film, making it possible to monitor the

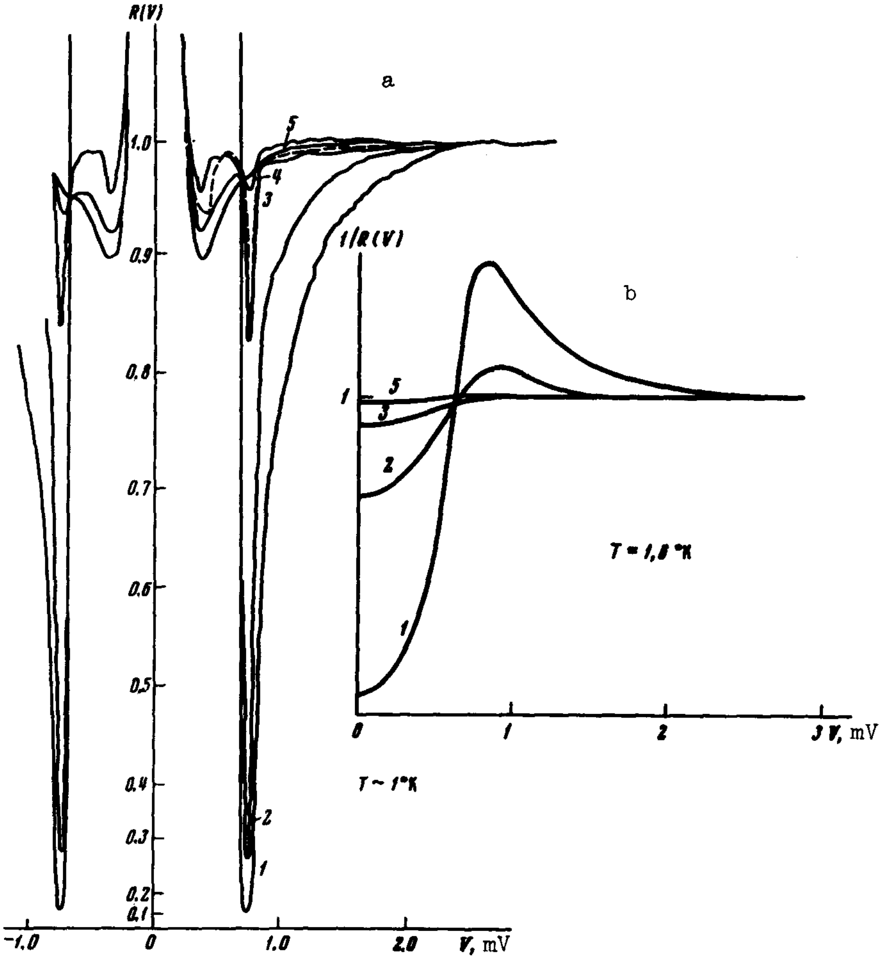

Fig. 1. R(V) and 1/R(V) characteristics of Al-I-Fe-Sn tunnel junction with different amounts of iron: 1 - 0.0 Å, 2 - 1.5 Å, 3 - 2.2 Å, 4 - 3 Å, 5 - 3.8 Å. The dashed curve is the calculated curve for $\sigma_n = 0.975$.

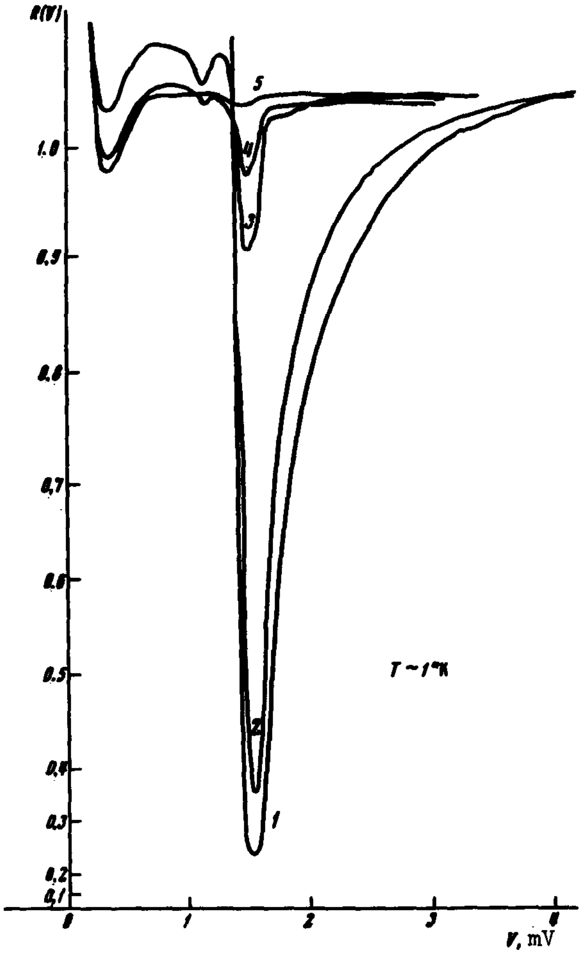

Fig. 2. R(V) characteristics of Al-I-Fe-Pb tunnel junctions with different amounts of iron: 1 - 0.0 Å, 2 - 0.15 Å, 3 - 0.35 Å, 4 - 0.55 Å, 5 - 0.75 Å.

quality of the junction against the characteristics of the aluminum, the measurements being carried out at temperatures ∿1°K. The scattering magnetic impurity was iron. In the experiment we prepared simultaneously a series of junctions with a magnetic-impurity content that differed by a factor 1.5 - 2. The investigated superconductors were tin and lead. The film thickness was calculated from the loss of weight of the evaporator and amounted to 500 Å for aluminum, 0.1 - 5 Å for iron, 3000 Å for tin, and 2000 Å for lead. During the course of the preparation of the samples, the vacuum of the system was not broken after the oxidation of the aluminum and the pressure was less than $10^{-6}$ Torr.

In the experiment, just as in [1], we recorded mainly the dV/dI ≡ R(V) characteristics of the samples.

Figure 1 shows results obtained for $Al-Al_2O_3-Fe-Sn$ samples with different amounts of impurity. As seen from this figure, the presence of the magnetic impurities leads only to a decrease of all the singularities of the R(V) characteristics of the tunnel junction. No noticeable displacement or smearing of the singularities was noted in the samples, and the singularity disappears completely at large amounts of impurity. This can be traced particularly clearly by the positions of the singularities connected with the energy gap. Similar results were obtained also for lead.

No such results were observed earlier in any of the known numerous investigations of the influence of magnetic impurities on the tunnel current of superconductors [2]. This is connected with the fact that the magnetic impurities usually penetrated into the interior of the metal and changed primarily the state of the entire superconducting system.

As is well known, interaction with the magnetic moment causes destruction of the superconducting pair. We shall examine the experimental results under the simplest assumption that the presence of magnetic impurities causes the superconducting characteristics to appear only on part of the contact area $\sigma_S$, whereas the remaining part of the contact $\sigma_n = 1 - \sigma_S$ operates like a normal metal.

Then

$$\frac{1}{\rho(V)} = \frac{1 - \sigma_n}{\rho_S(V)} + \frac{\sigma_n}{\rho_n(V)}, \qquad (1)$$

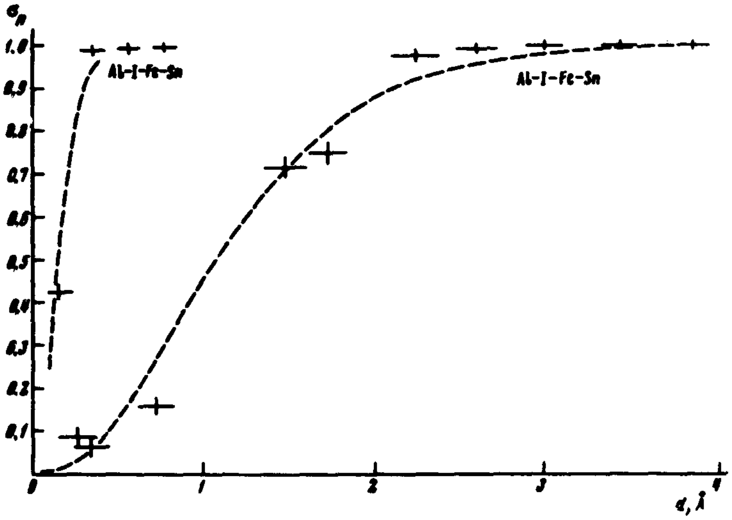

Fig. 3. Dependence of $\sigma_n$ on the amount of iron.

where $\rho_S(V)$ is the resistivity of a junction of the type Al-I-S, where S is a superconductor (Sn or Pb), and $\rho_n(V)$ is the resistivity of a junction of the type Al-I-M, where M is the normal metal,

$$\rho_S(V) = \frac{R_{SS}(V)}{R_{NN}}, \quad \rho_n(V) = \frac{R_{SN}(V)}{R_{NN}}.$$

It turned out that it is possible to choose values of $\sigma_n$ such that the calculated R(V) curve coincides satisfactorily with the experimental one under the assumption that $\rho_S(\infty) = \rho_n(\infty)$ (see Fig. 1).

Figure 3 shows a plot of $\sigma_n$ against the calculated thickness d of the iron film. For thicknesses d less than 1 Å, where the possible error in absolute value could reach 30%, the data presented are averaged over all samples of one series. The obtained data make it possible to determine the radius $r_S$ of the scattering of the electrons by the magnetic impurities. For the FeSn system, $r_S = 3 \pm 1$ Å, and for the FePb system $r_S = 8 \pm 2$ Å.

Such a strong change of the characteristics of the tunnel junction, as shown in Figs. 1 and 2, can be observed only in the scattering of electrons by magnetic impurities. In the case when a nonmagnetic metal is used in place of iron, no sharp change of the characteristics is observed up to thicknesses ∿100 Å. The changes observed in this case are well described from the point of view of the "proximity" effect [3, 4]. By the same token, the employed method makes it possible to reveal, by measurement of the superconducting characteristics, the presence of a small amount of magnetic metallic impurities in the junction. As follows from the curves of Fig. 3, a magnetic moment was observed for iron layers less than 0.5 Å thick, in contact with the tin or the lead.

It is of interest to note that in normal state of the metal (in a field $H > H_c$ or at $T > T_c$), we observed no symptoms of any giant anomalies at V = 0. These have recently been ascribed in a number of theoretical and experimental papers to the scattering of electrons by magnetic impurities [5 - 7].

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[1] N.V. Zavaritskii, Zh. Eksp. Teor. Fiz. 43, 1123 (1962) [Sov. Phys.-JETP 16, 793 (1963)].
[2] F. Reif and M.A. Woolf, Phys. Rev. Lett. 9, 315, 1962; M.A. Woolf and F. Reif, Phys. Rev. 137, A557 (1965).
[3] S.M. Freake and C.J. Adkins, Phys. Lett. 29A, 382 (1969).
[4] C.J. Adkins and B.W. Kington, Phys. Rev. 177, 777 (1969).
[5] J.E. Christopher, R.V. Coleman, Acav Isin, and R.C. Morris, Phys. Rev. 172, 485 (1968).
[6] J. Solyon and A. Zavadowski, J. Appl. Phys. 39, 705 (1968).
[7] Appelbaum et al., Phys. Rev. 160, 554 (1967).

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# POSSIBILITY OF PRODUCING AN INVERTED MEDIUM FOR LASERS BY MEANS OF AN EXPLOSION

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In gasdynamic lasers (GDL) and amplifiers, inversion of the population of the vibrational states of certain molecules results from rapid expansion of a previously heated mixture of molecular gases [1 - 8]. The composition of the gas mixture is chosen such that when it expands the collision-relaxation times $\tau_1$ and $\tau_2$ of the final (1) and initial (2) laser levels satisfy the condition $\tau_1 << \tau_2$ [9]. In addition, the rate of the expansion should be sufficiently high so that the depletion of level 2 as a result of relaxation be slower than as a result of adiabatic cooling of the gas mixture.

In the present paper, to obtain inverted population of the vibrational levels of the molecules, it is proposed to use a new class of strongly-exothermal chemical reactions accompanied by explosion. It has been shown that in free expansion of the explosion products (EP) of certain explosive substances (ES) the aforementioned conditions can be realized without using gasdynamic devices such as nozzles or slits.

The problem consists of choosing ES whose EP have a gas composition which makes it possible to realize the required relaxation scheme, analogous, for example, to that used in known GDL [2, 10, 11]. This requirement can be satisfied by a number of gaseous and condensed ES [12, 13]. The rate of expansion of the EP, heated in accordance with the type of the ES to $(2 - 5) \times 10^3$ °K, reaches $10^5 - 10^6$ cm/sec, i.e., it is comparable with and even higher than the gas-stream velocity in GDL. The explosive reaction of an acetylene-air mixture of stoichiometric composition [14]:

$$\begin{aligned}0.081 C_2H_2 + 0.202 (O_2 + 3.76 N_2) &= 0.162 CO_2 + 0.081 H_2O \\ &+ 0.757 N_2 + 26 \text{ kcal/mole EP},\end{aligned} \tag{1}$$

can serve as an illustration.

Let us examine in greater detail the physico-chemical processes occurring during the explosion [12 - 15], confining ourselves to the case of cylindrical symmetry. Assume that a detonation wave is excited in a tube of diameter d, filled with a mixture of $C_2H_2$ and air. It is known [14] that at a pressure above 0.5 atm combustion goes over into detonation in an initial mixture with volume concentration 8 - 14% $C_2H_2$ if spark ignition is used and the tube has $d \geq 18$ mm. The velocity of the detonation wave depends little on the pressure and equals $1.8 \times 10^5$ cm/sec. An exothermal chemical reaction takes place on the front of the detonation wave and supports the existence of the wave. The reaction gives rise to EP that are thoroughly mixed into presumably a mixture of ideal gases with composition corresponding to the equation of the reaction (1). The temperature of the flame of a stoichiometric acetylene-air mixture is