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INTERPLAY OF SUPERCONDUCTING AND INSULATING PHASES IN THE METASTABLE HIGH-RESISTANCE STATES OF THE $Ga_{50}Sb_{50}$ ALLOY

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INTERPLAY OF SUPERCONDUCTING AND INSULATING PHASES IN THE METASTABLE HIGH-RESISTANCE STATES OF THE $Ga_{50}Sb_{50}$ ALLOY

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Temperature dependences of the resistance R(T) of the alloy GaSb at different stages of its transformation from the high-pressure metastable metallic (M-) phase into the an insulating (I-) phase are measured. Absolute values of R at these stages span more than eight orders of magnitude. The superconducting (S-) transition takes place in the low-resistance states at $T \simeq 4.6$K. It gives way to a steep increase of the resistance, i.e. to an insulating transition *at the same temperature* in the high-resistance states.

In three dimensions (3D), the quasireentrant superconducting(qrS-) transition usually takes place near the localization threshold [1]. Recently, some experimental indications appeared that qrS-transition can be realized not only in granular material but in the homogeneously disordered material as well [2] or, at least, in materials which cannot be treated as random mixture of conductors and insulators. In this connection, we compared in this paper the R(T) dependence above the onset of the qrS-transition with that at low temperatures where R increases with reducing T.

Our material, the alloy $Ga_{50}Sb_{50}$, is one of those alloys which under the high pressure can be obtained in a metastable M-phase and then transformed into I-phase by heating [3]. Dosing the heating, one can get a row of intermediate states and measure the dependence R(T) in them at low temperatures. The alloy Ga-Sb apparently transforms in accordance with the fractal scheme: the I-phase appears as a fractal structure thinning and entangling the current paths [4]. Indeed, even after the initial resistance of the sample has been increased by 8 (!) orders of magnitude (estimated starting value of resistivity being 100 .cm) we did not reach the state which could be regarded as an I-state judging from formal extrapolation to T=0 of the conductance (T).

The first four orders of magnitude in changing R are not accompanied by any changes of the S-transition. This confirms that only a part of the sample is yet involved into the transformation. The physical properties of those domains where the S-transition preserved remain unchanged but their volume reduces rapidly and their topology becomes more complicate. Further increase of R leads to appearance of tails in the transition curves first and then to the qrS-transition [1,2]: the resistance fails to become zero and starts to increase with lowering the temperature.

Fig.1 exposes the experimental data. The states are labelled by number q

$$q = \log (R/R_{in})_{T=6K} ,$$

where R_{in} is the resistance of the sample in the initial state. It can

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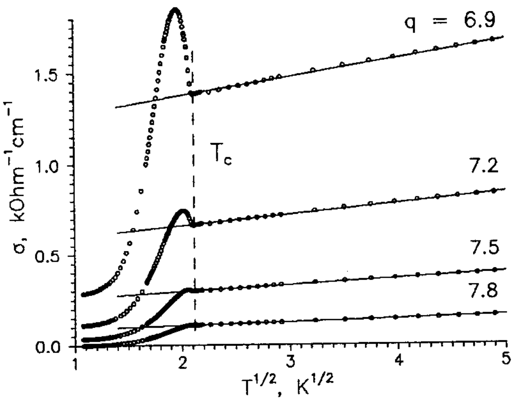

Fig.1

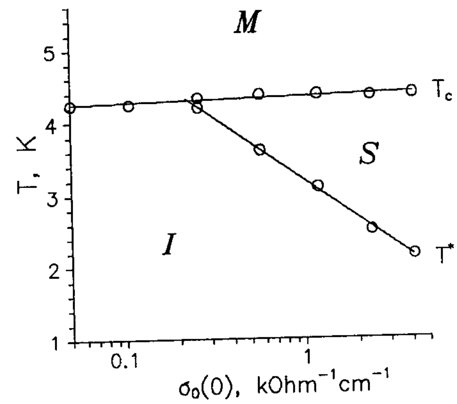

Fig.2

be seen from the curve q=7.8 that in the high-resistance states there is no natural S-response at all: a transition does exist at the temperature T_c but the resistance at $T < T_c$ increases instead of decreasing.

It follows from Fig.1 that at $T > T_c$ and with q large enough the changes in the conductance are proportional to $T^{1/2}$. The straight line

$$\sigma_0(T) = \sigma_0(0) + aT^{1/2}$$

describes the data above T_c. Below T_c the difference $\sigma(T)-\sigma_0(T)$ may change the sign at some temperature T^*. Let us take $\sigma_0(0)$ as a parameter of the state and plot T_c and T^* vs $\sigma_0(0)$. Than we get three domains in the (σ_0,T) plane which can be named M-, S- and I-domains - see Fig.2.

The most natural explanation of the observed phenomenon would suppose that current paths cross a kind of a S-I-S-...-structure with non-Josephson but quasiparticle tunneling currents through I-domains. It is not clear yet whether such approach is valid. Maybe we need quantum approach instead, treating the system as a whole and involving such ideas as spin density waves, paired electron crystals [5], or supposing finite magnitude of the order parameter and existence of the Cooper pairs at the I-side of the S-I transition [6].

A similar phenomenon - a crossover between S- and I-transitions depending on the conditions of the experiment has been seen in quasi-1D conductor $TaSe_3$ [7]. The similarity is emphasized by the fact that the dimensions of the conducting domains on a fractal structure may turn to be rather low.

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