INTERPLAY OF SUPERCONDUCTING AND INSULATING PHASES IN THE METASTABLE HIGH-RESISTANCE STATES OF THE Ga<sub>50</sub>Sb<sub>50</sub> 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 $T \approx 4.6$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 $q$

$$q = \log \left( \frac{R}{R_{\text{in}}} \right)_{T=6K},$$

where $R_{\text{in}}$ is the resistance of the sample in the initial state. It can
Fig. 1

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 $\sigma_0(0)$. Then we get three domains in the $(\sigma_0, T)$ 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.

REFERENCES

2. V. Gantmakher, V. Teplinskii et al., JETP Letters 56, 309 (1992)