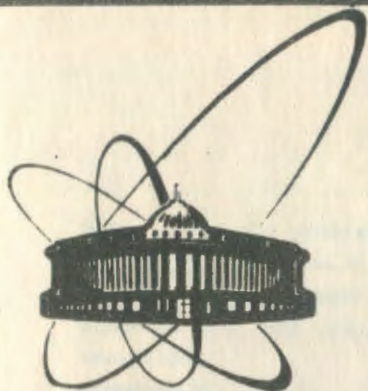


90-110



ОБЪЕДИНЕННЫЙ  
ИНСТИТУТ  
ЯДЕРНЫХ  
ИССЛЕДОВАНИЙ  
ДУБНА

S 49

E17-90-110

S. A. Sergeenkov

THERMOELECTRIC EFFECTS  
IN SUPERCONDUCTORS: THE ROLE  
OF FLUCTUATIONS AND WEAK LINKS

Submitted to "Journal of Superconductivity"

1990

There is an old problem of a thermal flux trapping inside a bimetallic loop (see, e.g., [1]). Namely, the measured flux [2] is considerably larger than that obtained by theory [3]. As Ginzburg [4] has recently noted: "The phenomenon remains unexplained." Detail information on thermoelectric effects in superconductors the Reader could find in the above-mentioned paper [4] and references therein.

One more question (we are dealing with here) is devoted to an excess thermal flux due to a weak-links behaviour of ceramic samples (within the effective Josephson medium approximation [5]).

Remember [4] that the total magnetic flux  $\Phi$  through a counter inside a bimetallic loop (where both conductors I and II are in the superconducting state) is:

$$\Phi = n \Phi_0 + \Phi_T, \quad \Phi_0 = hc/2e, \quad n = 0, 1, 2, \dots \quad (1)$$

The thermal flux contribution  $\Phi_T$  has a form [2,4]:

$$\Phi_T = \int_{T_2}^{T_1} dT (\Omega_{II}(T) - \Omega_I(T)), \quad (2)$$

where

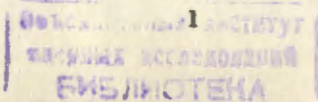
$$\Omega(T) = mcb/e^2 n_s, \quad b = \sigma s. \quad (3)$$

Here,  $\sigma$  is the conductivity,  $s$  is the Seebeck coefficient or thermoelectric power (TEP),  $n_s$  is the "concentration" of the superconductive electrons.

According to theory (see, e.g., [1,3]),  $b(T) \sim b(T_0)$  near  $T_0$ , while the measurements [2] lead to the following dependence:

$$b(T) \sim b(T_0) (1 - T/T_0)^{-1/2}. \quad (4)$$

Numerous explanations of such a divergence (see, e.g., [3] for discussions) have been suggested, but here we restrict ourselves to fluctuation-induced effects only. They are rather strong, in particular, for high- $T_0$  superconductors





(HTS) [6]. So, if this is the case, one needs to assume that the samples (Van Harlingen [2] dealt with) show a strong three-dimensional (3-D) fluctuation behaviour. In other words, it means that an excess conductivity  $\Delta\sigma = \sigma - \sigma_n$  behaves as :

$$\Delta\sigma_{3D} \sim \sigma_n c^{-1/2}, \quad (5)$$

where

$$c = |T - T_0| / T_0.$$

In view of Eq.(3), from Eq.(5) one obtains :

$$b_{3D}(T) = s(T)\sigma(T) \approx b(T_0) + b(T_0)c^{-1/2}, \quad (6)$$

in, at least, qualitative agreement with that measured (cf. Eq.(4)).

In HTS fluctuation effects have, mainly, a 2-D character [7]. In this case the following singularity should be observed :

$$b_{2D}(T) \sim b(T_0)c^{-1}. \quad (7)$$

It will be interesting to check this behaviour in thermal flux experiments with HTS.

Let us now turn to the second question announced above, and consider an excess thermal flux trapping via Josephson junction medium. It should be noted that thermoelectric effects in superconducting loops with a single junction have already been studied (see, e.g., [8] and references therein). The main point of the Josephson effective medium approximation (JEMA) [5] (not confuse with the ordinary effective medium approximation [9] which is used for the description of thermoelectric effects in granular superconductors) is the effective stiffness  $g$  of a superfluid condensate. Namely, for a uniform superconductor  $g = \hbar^2 n_s / 2m$ , while for the Josephson weak-link medium  $g = E_J d < \hbar^2 n_s / 2m$ , where  $E_J$  is the energy of weak links per unit area, and  $d$  is the size of a grain. Thus, in the frame of JEMA instead of Eq.(3) we have :

$$\Omega_J(T) = \hbar^2 c b_J / 2e^2 g, \quad (8)$$

where

$$g^{-1} = 2m / \hbar^2 n_s + 1 / E_J d.$$

Usually [5,7,9],  $b_J < b$  (where  $b(T)$  is defined by Eq.(3)). Let us calculate the enhancement of the thermal flux  $\Delta\Phi_T = \Phi_T^J - \Phi_T$  ( $\Phi_T$  is the thermal flux for a uniform superconductor, see Eqs.(2) and (3)) due to weak links. From Eqs.(2),(3) and (8) it follows that :

$$\Delta\Phi_T / \Phi_T \sim \Delta\Omega / \Omega = (b_J / b - 1) + (b_J / b) (\hbar^2 n_s / 2m E_J d). \quad (9)$$

Using typical values of HTS [5] :  $T_0 \sim 100$  K,  $d \sim 10^{-4}$  cm,  $E_J d \sim T_0 / d \sim 10^{-13}$  J/cm,  $\hbar^2 n_s / 2m \sim 10^{-9}$  J/cm, and  $b_J \approx 10^{-3} b$ , one gets  $\Delta\Phi_T / \Phi_T \sim 10^2$ . It seems to us, that such a prediction looks like a challenge to the experimenters (remind [1-3] that for uniform superconductor  $\Phi_T / AT \sim 10^{-4} \Phi_0$  per 1K). We do hope it will be accepted.

The author is indebted to Prof.V.L.Ginzburg, whose recently published paper [4] stimulated the present Communication, and to Profs.V.L.Aksenov and B.V.Vasiliev for their interest in the work and useful discussions.

#### REFERENCES

1. G.F.Zharkov, in *Superconductivity, Superdiamagnetism, Superfluidity*, V.L.Ginzburg, ed. (Mir Press, Moscow, 1987).
2. D.J. van Harlingen. *Physica* 109-110B, 1710 (1982).
3. V.L.Ginzburg and G.F.Zharkov. *Sov.Phys.Uspokhi* 21,381(1978).
4. V.L.Ginzburg. *J.Superconduct.* 2,323 (1989).
5. E.B.Sonin and A.K.Tagantsev. *Phys. Lett.* 140B,127(1989).
6. V.L.Ginzburg. *Physica* C153-155,1617(1988).
7. Ch.Laurent et al. *Solid State Commun.* 66,445(1988).
8. V.V.Ryazanov and V.V.Schmidt. *Solid State Commun.* 40,1055(1981).
9. M.Ausloos et al. *Solid State Commun.* 65,365(1988).

Received by Publishing Department  
on February 15, 1990.