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CROSS-LIKE FILM STRUCTURES, MICROWAVE IRRADIATION STIMULATED SUPERCONDUCTIVITY AND JOSEPHSON EFFECT

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Abstract.- Cross-like tin film structures are studied. Superconductivity stimulated by microwave irradiation was observed on homogeneous films in a wide range of mean free paths $\lambda$ and agrees quantitatively with Eliashberg's theory. In a weak portion created by passing transverse current $i$ through it, the relative effect increases. At high $i$ near $T_C$ irradiation-induced Josephson steps appear in $V$-$I$ curves.

Fig. 1 a):

Cross-like thin film structures were studied experimentally (figure 1a, insert) on tin films 800-1000 Å thick with mean free path $\lambda = 350-2000$ Å. The preset sample geometry was obtained photolithographically. Small $\lambda$ was provided using Ar ion irradiation. Studies were made on both homogeneous and locally weakened films, the latter being obtained by passing the transverse control current $i$.

In both cases the critical current $I_c$ increases due to microwave irradiation ($\gamma = 9-23$ GHz). The film homogeneity was examined by several methods in addition to the visual one. To provide a higher probability of homogeneity over the film length, a separate examination of 30 μm arms of the cross was made. Quantitative agreement between experimental and Galenko's theory $I_1$ served as a criterion. For most samples the second critical current, step widths corresponding to the appearance of phase slip centre (PSC) and the voltage intervals between the steps were consistent with the theory to within 5-10%. The agreement between experimental and theoretical currents corresponding to the appearance of separate PSC was somewhat worse ($\sim 20\%$).

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Fig. 1 b):

Another evidence for homogeneity was a quantitative agreement of $I$-$V$ curves for two 30 μm films of a single sample at different $T$ with and without irradiation. Experimental $I$-$V$ curves agree qualitatively and quantitatively (to within less than 10%). The $T_C$ rise under irradiation was observed for no tin samples. Qualitatively, the stimulation
effect to a high extent was determined by the mean free path. With $\xi = 2000\AA$ an $I_c$ increase under irradiation was revealed starting with $T_1$. With $\xi = 350\AA$ this increase is observed at $T = 3.74\, K$ ($T_c = 3.804\, K$).

We solved numerically Eliashberg's equation for tin samples. The calculated $T$-dependence of $\Delta^2$ at different $\frac{\xi}{\lambda}$ is shown in figure 2. The notation is similar to that in /2/. The maximum experimental $\alpha \approx 0.001$ ($\xi = 2000\AA, A_0 = 500\, m, \lambda_N = 1\, ohm, L = 10^{-10}\, henry$). The calculation shows the absence of $T_c$ rise and proves that with increasing $\xi$ the stimulation effect grows too. The experimental maximum $T_c$ increase was achieved at certain $\lambda$, then as $\lambda$ grows, $I_c$ falls, very sharply at the end (almost a jump). In the region of $\lambda_c$, hysteresis starts to appear even near $T_c$, i.e. much earlier than the heat hysteresis occurs in the $I$-$V$ curves without irradiation. A sharp drop in $I_c(\lambda)$ occurs as the reverse critical current reaches zero. The temperature of the stimulation effect onset $T_1$ and $I_c(\lambda)$ maximum may be accounted for assuming that the experimentally observed critical current making allowance for stimulation $I_{ce} = I_c - I_0$, where $I_0$ is the microwave current amplitude, $I_c$ is found on the bases of Eliashberg's equation solution. We assume that $\Delta^2$ is linearly dependent on $\Delta T$ and $\alpha$. As seen in figure 2, it is quite a good approximation. With $\frac{d\Delta^2}{dT} = 0$ $I_0$ magnitude is found, which corresponds to the effect maximum. $T_1$ at which the $I_c(\lambda)$ maximum first appears, is found from the condition $I_0 > 0$ with $I_0$ substituted. The agreement of calculated and experimental $T_1$ for a sample with $\xi = 350\AA$ is surprisingly good (to within 0.001 K). For a pure sample ($\xi = 2000\AA$) the calculation gives $T_c - T = 0.001K$ (experimentally the effect onset is difficult to find because of fluctuations). The calculated behaviour of the $T_c(\lambda)$ dependence agree qualitatively with experiment (the match with the microwave track is unknown).

If $i \neq 0$, the relative stimulation effect increases /4/. It is likely that in addition to the Eliashberg mechanism, some mechanism of "smearing" the order parameter minimum of type /3/ must be involved. Weak link in our samples was produced at the expense of additional break of pairs in the region of crossing /4,5/ (as the transverse film transforms into a resistive state). In figure 1a) the sample $I$-$V$ curves are shown for different control currents $i$, i.e. the dynamics of a transition from a homo-

![Fig. 2](image_url)

References

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