Threshold of critical current stimulated in thin-film bridges by UHF fields

S. A. Peskovatskiĭ and L. P. Strizhko
Khar'kov Institute of Radiophysics and Electronics, Ukrainian SSR Academy of Sciences

(Submitted 18 November 1978)

Pis'ma Zh. Eksp. Teor. Fiz. **29**, No. 1, 58–61 (5 January 1979)

Stimulation of the critical current in short bridges at low levels of UHF power was investigated experimentally. New qualitative properties were identified, including a threshold in the stimulating level of UHF power.

PACS numbers: 85.25. + k, 74.30.Gn

Investigations of the phenomenon of stimulated superconductivity in UHF fields in small-scale superconductors (SSS) are on the rise recently. However, the mechanism of this phenomenon remains an open question. Current results have enabled the study

 0021-3640/79/010053-04$00.60

of the maximum value of the increase of $I_c(T)$ and determination of frequency and temperature range of the effect. At the same time, the quantitative comparison of the results with theory failed to resolve the different points of view on the mechanism involved. Apparently, quantitative results of SSS concerning size, configuration, structure and physical uniformity have not been determined accurately and do not always provide useful criteria for elucidating the mechanism involved. In connection with this the present study of qualitative characteristics was made. Information on the mechanism of stimulation may derive from the functional dependence $I_c(P)$, specifically, study of the stimulated I_c at low-levels of UHF power P, because the behavior of $I_c(P)$ at low P differs significantly for the two proposed mechanisms.[1,2] For the stimulation mechanism proposed by Eliashberg,[1] $I_c(P)$ has a linear dependence whereas the mechanism proposed recently by Aslamazov and Larkin[2] is characterized by more complicated dependence of $I_c(P)$: it involves a linear increase of I_c which is preceded by an interval of suppressed I_c, i.e., there is a "threshold" level of the external signal, $I_c(P) > I_c(0)$ only for $P > P_0$. In known experimental studies, stimulated superconductivity at low UHF power levels (the initial range of function $I_c(P)$) was not specially studied; the available results as presented did not allow a definite statement to be made about the variation of $I_c(P)$ with low P. In connection with this, we report results of an investigation in the initial region of the function of $I_c(P)$, obtained with 3-cm and 6-mm UHF bands.

As samples we used bridges of constant thickness with the following dimensions $l = 0.6$–2 μm, $w = 0.6$–3 μm, $d = 40$–130 nm, which are prepared by scratching tin films on a mica substrate. UHF radiation was applied by coaxial cable and slotted line or by a narrow wave guide whose end was pressed to the substrate with the bridge. The volt-ampere characteristic (VAC) was recorded using the IZ7 and F116 amplifiers. The critical current was determined to be the current at which the voltage appearing on the bridge is equal to the path width, recorded automatically ($\approx$20–30 nV). Sample wires were used with radio-frequency filters, and the samples were placed in a superconducting screen. Stabilized temperature was obtained photoelectrically with respect to a slow drift ($\approx$2–3 sec) within 10^{-4} K.

Experimental results, some of which are shown in Fig. 1, exhibit the following features characteristic of most of the bridges investigated.

1. For low-power levels (0.01–0.015, corresponding to maximum increase of I_c) the value of I_c remained virtually unchanged. This threshold region of the function $I_c(P)$ is clearly shown by plotting $I_c(I_m) - I_c(0)$, where I_m is the amplitude of the current of the external signal. Careful plotting with the utmost accuracy possible of the results of other authors in the coordinates I_m, $I_c(I_m) - I_c(0)$ also indicates the existence of a threshold for stimulated superconductivity in UHF fields.[1)] We also obtained similar results in the 6-mm band, with the difference that because of the existence for this frequency of a temperature threshold[5]—also observed in our experiments—there occurred in the vicinity a threshold of the UHF power signal. For both bands there was no observation of a decrease in I_c preceding stimulation.

2. Exceeding the threshold level lead to a near-linear increase in I_c with respect to UHF current over a sufficiently wide range of external signal values. Linearity of the portion of the curve of increasing I_c with respect to the external signal current was

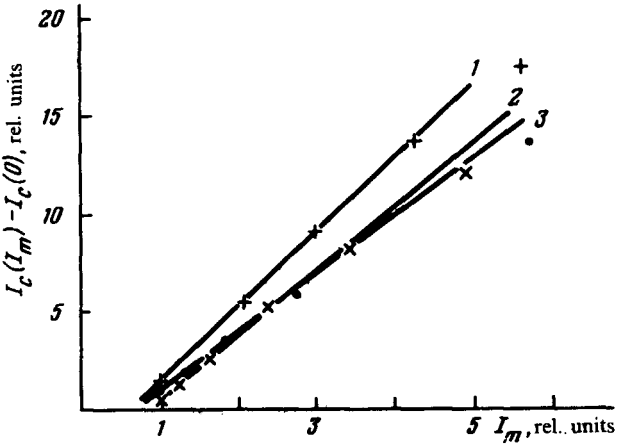

FIG. 1. Stimulated I_c in 3-cm band of UHF field. Size of bridge in μm: 1—$k = 0.8$, $w = 1.2$, $d = 0.08$. 2—$l = 0.8$, $w = 1.4$, $d = 0.07$. 3—$l = 0.5$, $w = 3.3$, $d = 0.07$. I_c and the relative units of the difference $I_c(I_m) - I_c(0)$—μA, corresponding to: *1*—101.7 and 10.4; *2*—49 and 1.9; *3*—55 and 5.1.

observed for most bridges, and only in individual cases nearly-linear dependence in power could be indicated. Processing of reported results[4] also points to existence of a linear increase in UHF current.

3. A near-linear section in subsequent increase in the level of UHF results in a smooth maximum and a region of rapid decrease of I_c (step-like, with hysteresis in VAC). Previously, rapid decline in I_c was observed in many works and its occurrence, including its appearance in VAC hysteresis, was commonly associated with network overheating of the bridge to a temperature $T > T_c$.[3] In our case when the UHF signal was switched on, we also observed both a shift in the onset of the resistive region of hysteresis in VAC toward the direction of larger currents (i.e., it might have indicated stimulated superconductivity also in this case) with concurrent appearance of the usual steps, and simultaneous steps in VAC at the level of UHF greater than that causing discrete fluctuations in I_c. It is necessary, obviously, to assume the existence of additional causes of the rapid decrease in I_c.

Thus, in the 3-cm and 6-mm UHF bands, there appears a threshold in the stimulated critical current of short bridges which, although absent in the mechanism of Ref. 1, may be linked with the stimulation mechanism discussed in Ref. 2 and found functioning in short SSS. This cannot be contradicted by the existence of a threshold in stimulated I_c in long geometrically-uniform films.[5] The scatter of T_c usually present in long films (0.02–0.03 K)[6] produces physical non-uniformities in geometrically uniform films over the investigated range of temperatures. Equally, observations of the region of the stimulated curves linear in current for $I_m > I_{m_0}/P > P_0$ may not be associated with the mechanism of Ref. 2 where for $P > P_0$ the increase in current should probably be linear with power, and requires further investigation.

[1]During preparation of this paper for publication, Ref. 5 was published, which also mentioned a case of existence of a threshold in UHF power.

[1]G.M. Eliashberg, Pis'ma Zh. Eksp. Teor. Fiz. **11**, 186 (1970) [JETP Lett. **11**, 114 (1970)] Zh. Eksp. Teor. Fiz. **61**, 1254 (1971) [Sov. Phys. JETP **34**, 668 (1972)].
[2]L.G. Aslamazov and A.I. Larkin, Zh. Eksp. Teor Fiz. **74**, 2184 (1978) [Sov. Phys. JETP, **47**, 1136 (1978)].
[3]Yu. I. Latyshev and F. Ya. Nad', Zh. Eksp. Teor. Fiz. **71**, 2158 (1976) [Sov. Phys. JETP **44**, 1136 (1976)].
[4]J.A. Pals, Phys. Lett. **61A**, 275 (1977).
[5]V.M. Dmitriev and E.V. Khristenko, Fiz. Nizk. Temp. **4**, 821 (1978) [Sov. J. Low Temp. Phys. **4**, 387 (1978)].
[6]W.J. Skocpol, M.R. Beasley, and M. Tinkham, J. Low Temp. Phys. **16**, 145 (1974).