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ENHANCED FLUX CREEP AND NONEQUILIBRIUM OPTICAL RESPONSE IN YBaCuO EPITAXIAL FILMS.

E. Zeldov*, N. M. Amer, and G. Koren +

IBM T. J. Watson Research Center, Yorktown Heights, NY 10598-0218.

Two novel flux creep related phenomena in $YBa_2Cu_3O_{7-\delta}$ films are presented: a sharp onset of nonequilibrium optical response and a thermally activated electrical resistivity with logarithmic current dependence of the activation energy. This nonlinear current dependence is significantly different from the predictions of the standard flux creep model.

The dissipation mechanism in $YBa_2Cu_3O_{7-\delta}$ in presence of magnetic fields shows two distinctive regimes in the high and low resistivity ranges of the resistive transition. In former case, the V-I characteristics are linear and the photoresponse (PR) is purely bolometric. In the low resistivity range the resistivity is thermally activated, V-I characteristics are nonlinear and the PR is nonbolometric. We ascribe these two regimes to flux flow and flux creep, respectively[1,2]. In addition, we find that in the flux creep regime the activation energy at elevated currents drops logarithmically with current density. This result is significantly different from the predictions of the standard flux creep description and has important theoretical and experimental implications.

The study was carried out on microbridges of high quality $YBa_2Cu_3O_{7-\delta}$ films, as described elsewhere[1,3,4], with a HeNe laser beam serving as the excitation source in PR measurements. To determine the nonbolometric PR we normalize the measured PR by the temperature derivative of the resistivity, $d\rho/dT$, and the result is shown in Fig. 1. If the PR is purely bolometric this normalization procedure[3] results in a constant value which is the temperature increase of the sample due to optical illumination, while the presence of a nonbolometric signal will increase the result above this value. Fig. 1b shows that at various magnetic fields the PR is bolometric at resistivities above $\approx 15\%\rho_n$ and has a sharp onset of nonbolometric contribution at lower resistivities. In the low resistivity regime, the dissipation is dominated by flux creep and the absorbed light enhances the activation mechanism. In the flux flow regime the dissipation is not dominated by pinning and thus the PR is purely bolometric.

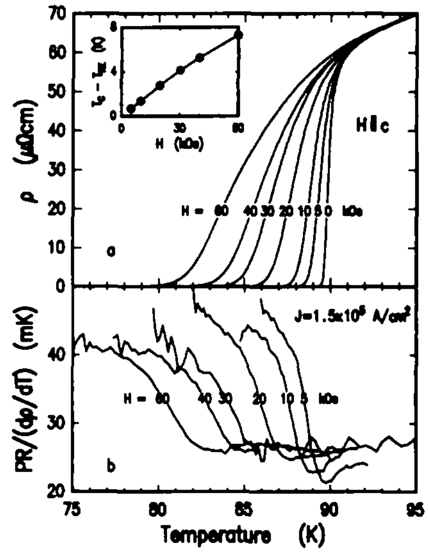

Fig. 1. The resistive transition (a) and the normalized photoresponse (b) of $YBa_2Cu_3O_{7-\delta}$ epitaxial film at various magnetic fields. Insert: the nonequilibrium PR onset temperature, T_{NE}, as a function of H.

*On leave from the Department of Electrical Engineering and Solid State Institute, Technion - Israel Institute of Technology, Haifa 32000, Israel.
+ Permanent address: Physics Department, Technion - Israel Institute of Technology, Haifa 32000, Israel.

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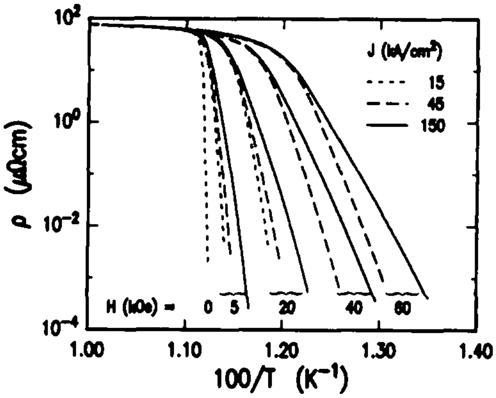

Fig. 2. Arrhenius plot of the resistivity at several representative values of magnetic field and current density.

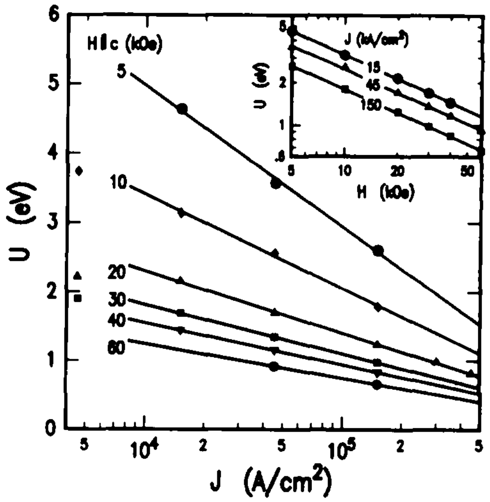

Fig. 3. The activation energy, U(0,H,J), as a function of current density and magnetic field as obtained from the fit of the experimental data to $U(t,H,J) = U(0,H,J)(1-t^2)(1-t^4)^{1/2}$. The lines emphasize the logarithmic dependence of U on J, and the power law dependence on H. The slopes of the lines in the insert are 0.88, 0.81, and 0.76 for current densities of 15, 45, and 150 kA/cm^2 respectively.

In the low resistivity region, as shown in Fig. 2, the resistivity is thermally activated with activation energy, U, depending on both the magnetic field and the current density. In addition, the slight bending of the curves can be fitted by a temperature dependent U of the $(1-t)^{3/2}$ type[5,6] ($t = T/T_C$). The magnetic field dependence of U is close to 1/H behavior as shown in the insert of Fig. 3, but is sensitive to the choice of the temperature function. However, the unique feature of Fig. 3 is the logarithmic current dependence of U at elevated currents and various magnetic fields. In this regime U has a form of $A_J(T,H)\log(J_0/J)$ with J_0 of the order of 3×10^6 A/cm^2. Such nonlinear current dependence is significantly different from the linear dependence predicted by standard flux creep description and has several important consequences. First, it may explain the usually observed power law V-I characteristics in high T_C materials. Using the obtained U, the voltage drop is given by

$$V = V_0\exp(-U/kT) = V_0\left(\frac{J}{J_0}\right)^{A_J(T,H)/kT}$$

which is a power law function of J rather than exponential. In addition, it may explain the low activation energy values obtained in magnetic relaxation experiments. The procedure for deriving U values from the relaxation data is based on the assumption of a linear current dependence, and will result in significantly underestimated values in this nonlinear case[1]. Finally, resistively measured critical currents in the flux creep regime have to be analyzed using the nonlinear activation energy result in order to yield a meaningful physical insight.

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