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INVESTIGATION OF THERMALLY ACTIVATED FLUX FLOW OF $YBa_2Cu_3O_7$/ $PrBa_2Cu_3O_7$ SUPERLATTICES IN MAGNETIC FIELDS PARALLEL TO THE a,b PLANE.

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$YBa_2Cu_3O_7$ is a strongly anisotropic 3D material. Our observations of thermally activated flux flow in magnetic fields perpendicular to the a,b plane show that the vortices are 3D-like in this material. Making multilayers of the type $YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ (YBCO/PrBCO) allows to increase the anisotropy and turn the material into a 2D system. We explore this 3D to 2D transition by investigating the thermally activated flux flow behavior in parallel applied fields. We find the parallel field dependence to be markedly different from the perpendicular dependence. At low fields and in multilayers with relatively thick individual layers we find that the activation is largely field independent. At higher fields we observe a crossover to a power law behaviour similar to what is observed in thick YBCO films. In multilayers with 24Å YBCO layers decoupled by thick PrBCO layers (>> 24Å) we find no broadening of the resistive transition up to 20 Tesla.

1. INTRODUCTION.

In the High Tc Superconductors (HTS) thermal fluctuations are important and single flux lines or flux bundles can be thermally activated. A manifestation of this unusual property is the observed broadening of the resistive transition in an applied magnetic field. It has been found that for the lower part of the transition ($\rho < 10^{-2}\rho_n$), the resistivity has a thermally activated flux flow behavior[1]: $\rho(T,H) = \rho_0 \exp(-U(T,H)/K_B T)$, where U is the activation energy.

The synthesis of $YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ (YBCO/PBCO) superlattices provides the opportunity to change the anisotropy of the material at will, and thereby to explore the role of the anisotropy on the flux line lattice and flux motion.

In this paper, we discuss our recent results on the behavior of the activation energies of a series of YBCO/PBCO multilayers for magnetic fields parallel to the a,b plane.

2. SAMPLE PREPARATION.

The samples were grown on polished (100) MgO substrates by single target dc magnetron sputtering. Two sputtering guns with stoichiometric YBCO and PBCO targets were placed 180° apart in our UHV system. The multilayers are obtained by the alternative deposition of YBCO and PBCO layers on heated substrates (650 to 700C). Preparation details can be found in ref.2.

3. RESULTS.

Figure 1 is a log log plot of the measured activation energies $\bar{U}$ for an YBCO thin film,and a 264Å/144Å, 192Å/144Å, 96Å/144Å and 24Å/96Å YBCO/PBCO superlattices in parallel (//a,b) magnetic field. These values have been extracted from the resistivity data by the standard Arrhenius technique; i.e. by plotting $\log(\rho(T))$ versus 1/T, and by defining $\bar{U}$ as the average slope in the interval $10^{-4}\rho_n < \rho < 10^{-2}\rho_n$.

For these measurements, a two axis rotating sample holder was used to align the film with respect to the magnetic field.

For the YBCO thin film, fig.1 shows that the activation energy decreases with the parallel applied magnetic field following a power law behavior. For the 264Å/144Å, 192Å/144Å and 96Å/144Å samples we observe similar overall behavior: At low field the activation energies are almost field independent, and at higher fields there is a crossover to a regime, where one recovers the behavior of the YBCO thin film. For an additionnal discussion of this point, see J.-M. Triscone et al., these proceedings.

A striking effect appears when the YBCO layers are very thin ($\leq$24Å) and the PBCO layers are large enough ($\geq$48Å) to avoid any Josephson coupling[3]. This is the case of the 24Å/96Å sample, where we observe that the activation energy remains nearly field independent up to 19.5T. This is well illustrated in fig.2 ,which displays resistive measurements of this multilayer from 0 to 19.5T and where no broadening of the transition in field can be observed.

A qualitative explanation for this behavior in parallel fields is the following: At low fields no vortices are present in the YBCO layers, and the crossover which is observed corresponds to the field at which the flux lines begin to penetrate the superconducting sheets, giving rise to a regime where dissipation due to thermally activated motion can occur, and to a field dependence.

Moreover, if we assume that H_{c1} can be estimated[4] as $H_{c1}=(2\lambda_{ab}\phi_0/\pi\lambda_c d^2)\ln(d/\xi_{eff})$, it results that H_{c1} will be of the order of 90T for a sample with d_{YBCO}=24Å, explaining the field "independence" of the 24Å/96Å sample up to 20T, and will decrease down to a few Teslas when the thickness of the superconducting layers increases up to 96Å or 264Å, involving that the crossover field could correspond to H_{c1} for these multilayers.

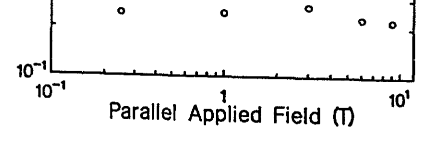

FIGURE 1
Double logarithmic plot of the measured activation energies $\bar{U}$(B) for different samples.

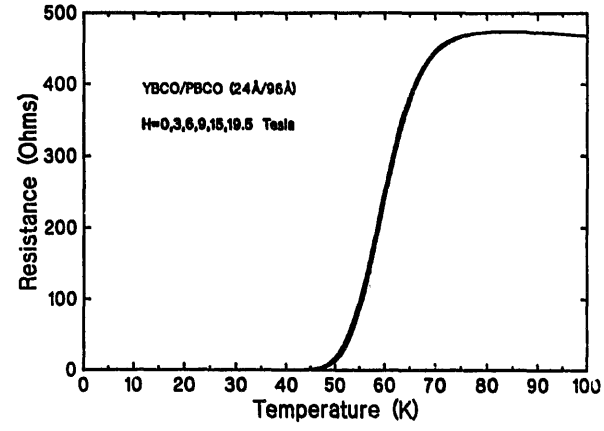

FIGURE 2
Temperature dependence of the electrical resistance of a 24Å/96Å multilayer in magnetic fields oriented parallel to the basal plane and ranging from 0 to 19.5T.

4. CONCLUSIONS.

We have determined the activation energies $\bar{U}$ for a series of YBCO/PrBCO multilayers for magnetic fields parallel to the a-b plane. For the multilayers with relatively thick YBCO layers, we observe a crossover from a "low field regime", where $\bar{U}$ is almost field independent, to a "higher field regime" where the observed behavior is similar to the YBCO thin film behavior. Finally, we find that R(T) of a 24Å/96Å multilayer does not show any broadening up to 20T.

REFERENCES.

1. T.T.M.Palstra, B.Baltlogg, L.F.Schneemeyer, and J.V.Waszczak. Phys Rev. Lett.,61,1662,(1988).

2. J.M.Triscone, Ø.Fischer, O.Brunner, L.Antognazza, A.D.Kent,and M.G.Karkut, Phys. Rev. Lett. 64, (1990).

3. O.Brunner et al. to be published.

4. See for instance, T.P. Orlando and K.A. Delin, Fundation of Applied Superconductivity, Adisen-Wesly, 1991, p388.