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Effect of columnar defects on the vortex dynamics in BSCCO 2212 single crystals

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The form of the dynamic relaxation of high quality BSCCO 2212 single crystals irradiated with 2.25 GeV Au ions to produce columnar defects along the crystallographic c-axis, is reported. It is found that below 10K, the columns do not significantly inhibit flux motion once the vortex density exceeds the column density. Above 10K, and at low vortex densities, the columns depress the dynamic behaviour in a systematic way as a function of temperature. At high vortex densities, the columns are decreasingly effective as the temperature is raised and in a manner which is a non linear function of irradiation dose.

1. INTRODUCTION

Detailed theoretical prediction of an elastic vortex medium in the presence of correlated disorder exists in the form of the Bose glass theory [1]. Confirmation of this theory from relaxation measurements has been made at high temperatures only [2]. At low temperatures the situation is complicated because of the interplay between point disorder and columnar defects. Consequently, the study of the influence of columns on the dynamic behaviour of flux lines at lower temperatures is much less studied.

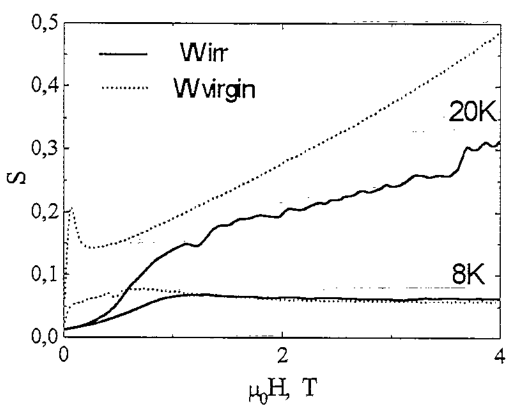

Figure 1. S vs $\mu_0 H$ for unirradiated and irradiated crystals W with a matching field of 0.5T.

2. RESULTS AND DISCUSSION

Data are presented from two BSCCO 2212 single crystals KV (T_c = 90K) and WV (T_c = 89K) and their irradiated counter parts KI (T_c = 84K, B_φ= 2T) and WI (Tc = 87K, B_φ= 0.5T), where B_φ is the matching field associated with the 2.23 GeV Au ion dose. Magnetisation measurements were made with an Oxford Instruments VSM. From the form of the M-H loop at different sweep rates the dynamic creep rate $S = d\ln\Delta M/d\ln H'$ was extracted, where $H' = dH/dt$ is the field sweep rate [3].

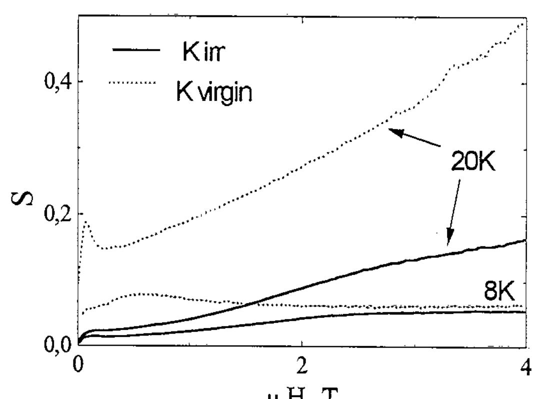

Fig 2. S vs $\mu_0 H$ for unirradiated and irradiated crystals K with a matching field of 2T.

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Fig. 1 and fig. 2 show the dynamic creep rate S versus field for the unirradiated and irradiated crystals at 8K and 20K. The creep rates in both the unirradiated crystals WV and KV are identical at 8K and 20K indicating similar densities of underlying point disorder. At 8K, both irradiated crystals show depressed creep rates at low fields, but for $B \geq 2B_\varphi$ S approaches the unirradiated crystal value. At 20K, significant depression of dynamic behaviour occurs in the irradiated crystals for $B \gg B_\varphi$ The depression depends on the irradiation dose.

Fig. 3 shows $S(B)$ between 12 and 28K for crystal KI. There is a change in slope at B_φ= 2T. Fig 4 shows S normalised by temperature for the data shown in fig. 3. A dramatic scaling below B_φ is observed across the entire temperature range. In this regime S can be simply written as $S(B) = T / U(B)$ where $U(B)$ is a temperature independent pinning energy. The field dependence of U implies that it is not simply related to single particle-single vortex pinning. A fit to $U(B)$ gives approximately $U \propto B^{-2}$.

Above B_φ significant numbers of vortices start to occupy interstitial sites between columns because it is energetically unfavourable for two vortices to be pinned on the same column [4] and the scaling breaks down. In this case it is expected that the dynamics are strongly influenced by vortex-vortex interactions and point defect pinning. The creep mechanism in unirradiated BSCCO is thought to be plastic [5] at temperatures of the order of 20K. Unless the vortex-vortex interactions are considerably stronger than the columns, then elastic models are still unlikely to be applicable in the irradiated crystals. The scaling of S/T breaks down below 10K at all fields as a result of the domination of point defects over the columns.

4. CONCLUSION

The columns improve pinning most dramatically at T > 30K up to fields of the order of $2B_\varphi$ [6]. At T<10K the columns suppress creep rates signifantly at fields less than $2B_\varphi$. However at intermediate temperatures, the interplay between point defects, columns and vortex-vortex interactions inhibits vortex motion up to fields much greater than $2B_\varphi$

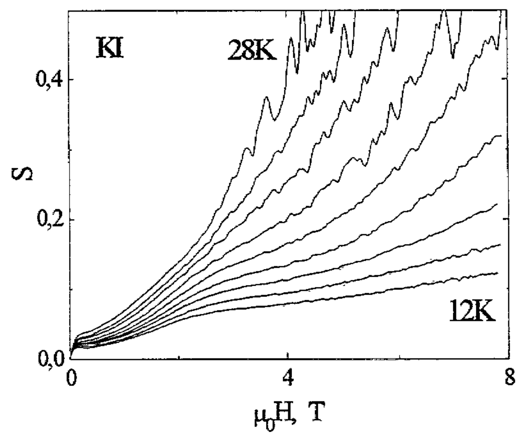

Figure 3. S vs $\mu_0 H$ for irradiated crystal KI with 2T matching field every 2K between 12K and 28K.

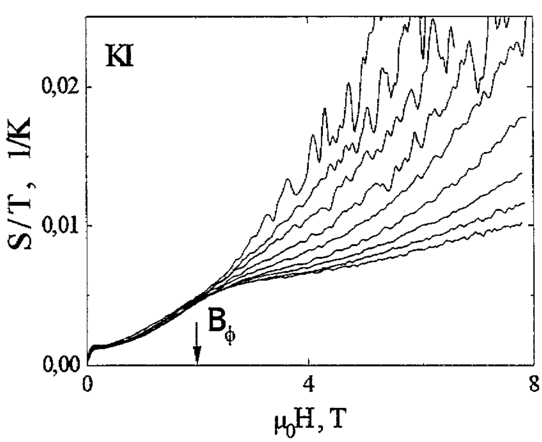

Figure 4. S/T vs $\mu_0 H$ for irradiated crystal KI with 2T matching field every 2K between 12K and 28K.

REFERENCES

1. D. Nelson and V. N. Vinokur, Phys. Rev. B.**48** (1994) 13060.
2. M. Konczykowski, N. Chikumoto,V.M. Vinokur and M. V. Feigelman, Phys. Rev. B **51** (1995) 3957.
3. L Pust, J Kadlecova, M Jirsa and S Durock, J. Low. Temp. Phys., **78** (1990) 179.
4. G. S. Mkrtchyan and V. V. Shmidt, Sov. Phys. JETP **34** (1972) 195.
5. C. J. van der Beek, PhD University of Leiden 1992.
6. J. Totty et al, Proc. 8th IWSS, World Scientific Press, p389.