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MAGNETO-OPTIC IMAGING OF PROTON-IRRADIATED HIGH T_c SUPERCONDUCTING THIN FILMS: A REVISIT OF $J_c(T)$ FUNCTIONAL AND FLUX PINNING ENHANCEMENT

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We have performed systematic quantitative measurements of the critical current density $J_c(B,T)$ for YBCO thin films proton-irradiated to various dosages using the MOI technique. Results for external magnetic fields up to 400Oe and temperature ranging from 5 to 80K are presented for a 600nm thick YBCO film irradiated by proton up to a dosage of $10^{16}cm^{-2}$ at 500 keV. While no significant differences were observed for T>50K, the J_c values consistently increased with the increasing external field for T<50K.

While magnetic susceptibility has been widely used for the determination of J_c, this quantity reflects the volume average without revealing the spatial variations of the physical properties of the material. In contrast, magneto-optical imaging (MOI) allows the direct observation of local magnetic properties of a superconductor. MOI is based on the large Faraday effect of Bi:YIG epitaxially grown on GGG substrates.[1] The ferrite garnet film (5 micron thick) is placed directly on top of the sample under study, and images are formed via a polarizing microscope with sample situated within the optical path of two crossed polarizers.[1] Perpendicular magnetic induction from the superconductor causes the polarization of incoming light to rotate and the rotated component can thus pass through the analyzer, carrying the signature of local magnetization. The circulating current density, which is J_c, can then be measured without similar errors from magnetization and transport measurement methods. This technique has been applied successfully to YBCO thin films, BiSCCO tapes, single crystals and melt-processed high-T_c materials.[2-5] Proton irradiation introduces flux pinning centers and enhances J_c in HTS films,[6] but the exact nature of temperature and dosage dependencies of J_c remains unclear. We hence hoped to gain some insight into these issues in the present work.

Fig. 1(a) shows the magnetic image of an HTS strip of width 2w, with the gray level indicting the perpendicular field intensity B_z. The profile $B_z(x)$ along the indicated line traversing the sample is as given in Fig. 1(b), where the strip width (2w) and interval of the zero-B_z region (2a) are clearly demonstrated. Based on a previous calculation,[7] the associated J_c is extracted from the equation: $a=w/\cosh(B_a/B_f)$, where B_a is the applied field and $B_f=\mu_0/\pi J_c d$ is a characteristic field for the given film geometry with d being the film thickness. The obtained $J_c(B,T)$ data are shown in the fig. 2, which indicate that J_c essentially has no field dependence for T>50K, but increases with field at lower temperature. At low field, the $J_c(T)$ fits well with Ginzburg-Landau theory, giving $J_c(T)=J_c(0)\times(1-(T/T_c)^2)\times(1-(T/T_c)^4)^{1/2}$, where T_c is the critical temperature, but deviations emerge at higher field. Shown in Fig.3 are the zero temperature critical current densities, $J_c(0)$, as derived from such fitting, which appear to increase linearly with B in the range of fields studied for the irradiated sample. In comparison, note from the figure that the field enhancement levels off beyond 200Oe for the non-irradiated sample. The origin of the field-enhancement in J_c is being investigated for various dosages of proton irradiation and will be reported elsewhere.

In summary, we have successfully used the MOI technique to determine the J_c of proton-irradiated HTS thin films. Magnetic field enhancement of J_c has been observed. This work was supported by the State of Texas through the Texas Center for Superconductivity at the University of Houston.

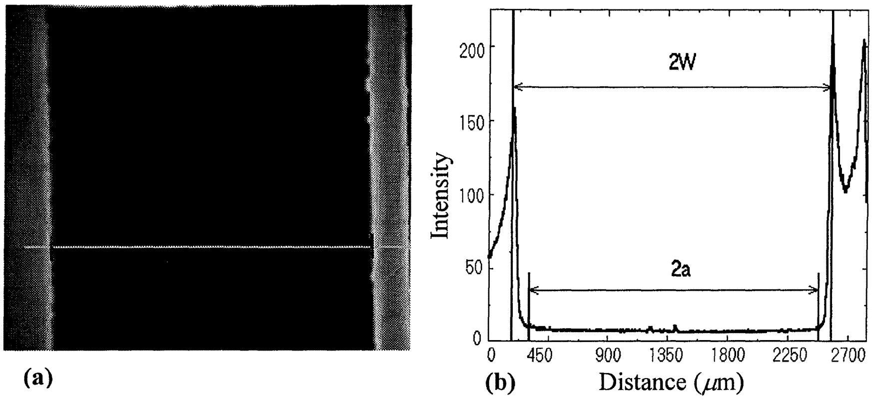

Figure 1. (a) MO Image of YBCO film (T=10K,B_a=143Oe). The traversing white line gives the cross-section profile of B_z shown in (b). (b) The peaks represent the boundary of YBCO strips.

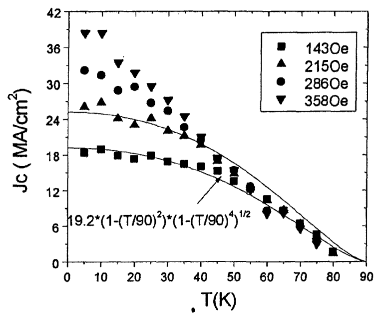

Figure 2. Jc(T) at different magnetic fields. Solid line is the fitting using G-L theory.

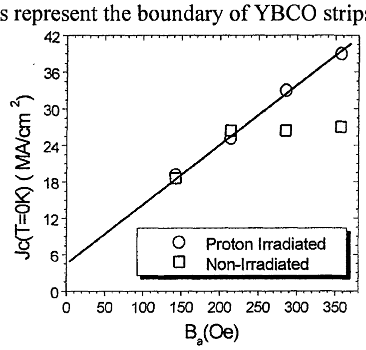

Figure 3. B-dependence of zero temperature Jc

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