Effect of Thermal Neutron Irradiation in Boron Doped Melt-Textured YBCO Superconductors

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Abstract

$Y_{1.6}Ba_{2.3}Cu_{3.3}O_x$ superconductors with different amounts of boron-doping have been synthesized using the MPMG technique. Undoped and boron doped samples were irradiated with thermal neutrons to study the effect of defects produced by the fission reaction, $B(n,\alpha)$ Li, on the pinning and the critical current. We observed that the pinning and the critical current density were improved as a result of thermal neutron irradiation. This improvement was slightly stronger for the boron-doped samples compared to the undoped ones.

Key words: ; Boron-doped ;Melt-textured ;Critical current;Thermal neutron irradiation;

1. Introduction

Different methods of introducing pinning centers for flux lines were tried to achieve higher critical current densities in YBCO materials. It was shown that thermal neutron irradiation has a important role in improving the pinning in lithium-doped Y-123 [1,2]. Since boron has a higher absorption cross section than lithium (absorption cross section is 945 Barns and 3837 Barns for ^6Li and ^{10}B for thermal neutron, respectively) , we expect that boron doping will be even more efficient in introducing defects as a result of thermal neutron irradiation. ^{10}B isotope (non-radioactive isotope which consitutes 19.9 percent in the natural boron) captures neutrons and local defects are created by the fission reaction $B(n,\alpha)Li$, where both alpha -particles and lithium have a high energy but a short travel range. In this work, we will investigate the effect of thermal neutron irradiation on pinning of boron-doped melt-textured YBCO samples.

2. Experimental

$Y_{1.6}Ba_{2.3}Cu_{3.3}O_y$ melt-textured superconductor was prepared using the MPMG technique [3]. Powders of Y_2O_3, $BaCO_3$ and CuO were mixed with a nominal composition of Y:Ba:Cu = 1.6:2.3:3.3. The mixture was calcined at 930 ^oC for 24 h. The calcination was repeated again to ensure the complete reaction. This composition was selected in order to introduce 211 particles into 123 crystals in the final structure. Then the calcined powders were heated to 1400^oC for 1-2 minutes in an yttria stabilized zirconia crucible and quenched to the room temperature using copper hammer plates. The quenched samples were ground and mixed well. At this stage, B_2O_3 powder was added to the Y-123 powder at 0.05, 0.1 and 0.5 wt% and mixed well. Then, boron-doped and un-doped powders were pressed into pellets at 2200 kg/cm^2 and placed in yttria-stabilized zirconia crucibles. After that, the samples were heated to 1100 ^oC, held for 24 min and cooled down to 1000 ^{o}C at the rate of 100 ^{o}C/h. This was followed by slow cooling at the rate of 3 ^{o}C/h down to 850 ^{o}C and more rapidly to the room temperature. Finally, the samples were annealed in the flowing of

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oxygen at 550 ^oC for 1 week. X-Ray diffraction patterns were indexed to Y-123 and Y-211 phases. Tc and magnetization loops were measured using a MPMS-5 SQUID magnetometer from Quantum Design, Inc. J_c values were calculated based on the extended Bean critical state model from the following equation (4). J_c= 20 Δ M/a(1-a/3b) where $\triangle$M is the width of magnetization loop in emu/cm^3, a and b ($a < b$) are dimensions of the rectangular cross section of the sample perpendicular to the applied field in cm and J_c is in A/cm^2. Thermal neutron irradiation of samples was performed in a TRIGA-MARK-II research reactor with the flux density $8.2x10^{12}cm^{-2}s^{-1}$. The corresponding thermal fluence was $1.476x10^{17}cm^{-2}$.

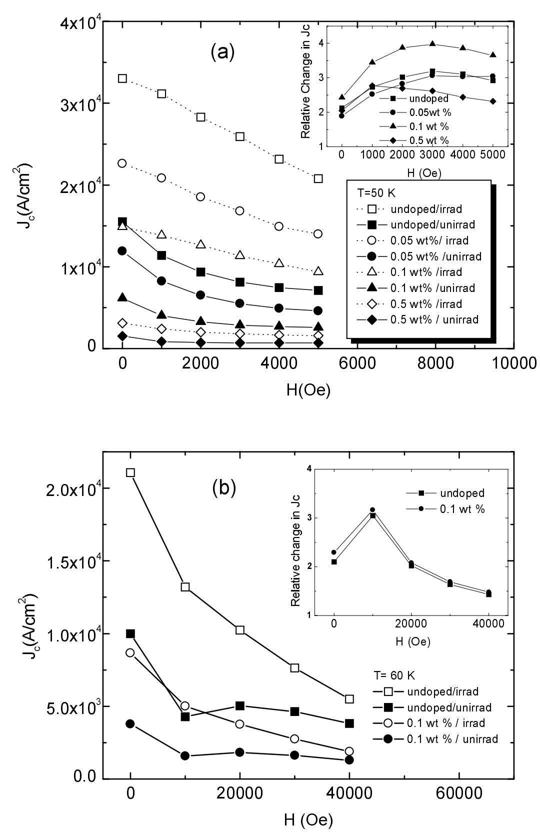

Fig. 1. Effect of thermal neutron irradiation on J_c of different levels of boron-doped samples at (a) T= 50 K (b) T= 60 K (Insets: Relative change in magnitude of J_c at different magnetic fields)

3. Results and Discussion

Critical temperature(T_c) was determined to be 87.3K, 86.9K, 86.4K and 81.7K for undoped, 0.05wt% B_2O_3 doped, 0.1wt% B_2O_3 doped and 0.5wt% B_2O_3 doped $Y_{1.6}Ba_{2.3}Cu_{3.3}O_x$ samples, respectively from field-cooled (fc) measurements in a magnetic field of 10 Oe. Figure 1(a) shows the effect of thermal neutron irradiation on J_c for different levels of boron-doping at T= 50 K. From the figure 1(a) , it is clear that irradiation is more effective for the 0.1 wt% boron-doped sample compared to the others. Relative change in J_c takes the maximum value at the magnetic field of 3000 Oe (see inset (a)). Figure 1(b) shows the effect of thermal neutron irradiation on J_c at T= 60 K and up to a maximum field of 5 Tesla for the undoped and 0.1 wt% B-doped samples . As seen, J_c slightly increases at higher fields (fishtail effect) for both the undoped and 0.1 wt% B-doped samples before irradiation. After irradiation, the critical current density is considerably enhanced . The fishtail behavior has disappeared , instead J_c decreases linearly with magnetic field. Inset (b) shows the relative change in J_c due to the irradiation. As seen, the J_c enhancement reaches a maximum at 1 Tesla and decreases at high fields for both samples. Irradiation is more effective for boron-doped sample compared to the undoped one. This means that there is a positive effect in improving the pinning due to fission reaction $^{10}B(n,\alpha)^7Li$. The reason why this effect is not strong may lie in the existence of large amount of Y-211 inclusions (30% 211 in 123) in the 123 matrix. The size of defects created by irradiation is smaller than the size of 211 particles. These smaller defects agglomerate at 211 particles. The accretion of defect clusters on 211 particles leads to a lack of defects in the 123 matrix and a lower contribution to J_c.

4. Conclusion

Thermal neutron irradiation of boron-doped Y-123 sample resulted in an improvement of flux pinning. The fact that this improvement is not very strong may be explained by agglomeration of a large fraction of the irradiation induced defects on 211 inclusions, so they don't contribute the pinning. We expect that pinning enhancement can be much stronger in 211-free samples. This will be checked in our future works.

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