Effect of Thermal Neutron Irradiation on the Pinning Properties of TSMG Sm-123 Superconductor

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Abstract

Changes in the magnetic behavior of melt-textured $Sm_{1.6}Ba_{2.3}Cu_{3.3}O_x$ superconductor due to thermal neutron irradiation were investigated at 50 K and 77 K. It was observed that J_c was enhanced up to 5 times in magnitude after a irradiation fluency of $1.476x10^{17}cm^{-2}$. We discuss which types of pinning centers can be responsible for the observed behavior.

Key words: ; Sm-123 ;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 density in $high-T_c$ superconductors. Melt-texturing is an efficient method to improve the critical current density. It has been also shown by many groups that thermal neutron irradiation is a highly effective method to introduce pinning centers. Despite the fact that melt-textured Sm-123 superconductor has a high T_c and J_c value, a little work has been done on this system. Also, according to our knowledge , effect of thermal neutron irradiation in this compound was not studied before. In the present work, we present the effect of thermal neutron irradiation on pinning properties of melt-textured Sm-123 superconductor.

2. Experimental

$Sm_{1.6}Ba_{2.3}Cu_{3.3}O_{7-x}$ samples were prepared by the Top-Seeded-Melt-Growth technique. The powders of Sm_2O_3, $BaCO_3$ and CuO were mixed in appropriate concentrations to yield a net composition of $SmBa_2Cu_3O_y + 0.3Sm_2BaCuO_5$. Mixed oxide powder was calcined at 1000^oC for 40 h and ground in an agate mortar. Then the powder was pelletized and a MgO single crystal with a suitable thickness ,which was used as a seed material, was placed on the top of the pellet before furnacing. Then, it was melted at 1115^oC for 1 h in the flowing nitrogen with 1 vol% O2. Then, first the temperature was lowered rapidly to 1045^oC, and slowly at a rate of 0.2^oCh^{-1} to 1030^oC and finally more rapidly to room temperature. Observations by polarized microscope show that sample has large single crystalline grains with dimensions 1-2 mm. X-Ray diffraction patterns were indexed to Sm-123 and Sm-211 phases. Finally, the samples were annealed in the flowing of oxygen at 550 ^{o}C for 1 week. T_c 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 (1). 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

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is in A/cm^2. Thermal neutron irradiation of samples was performed in a TRIGA-MARK-II research reactor with the flux density $8.2x10^{12}cm^{-2}s^{-1}$.

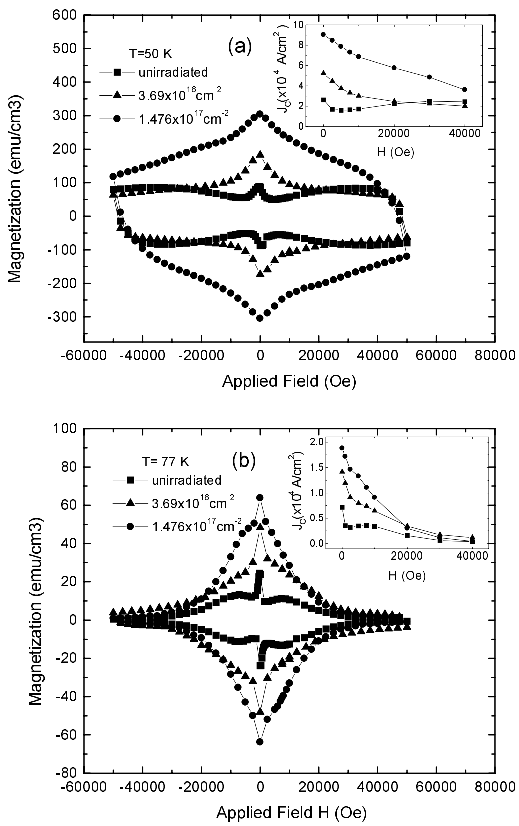

Fig. 1. Changes in magnetization loop of the samples with thermal neutron irradiation (a) at T= 50 K (b) T= 77 K. Insets: J_c versus magnetic field graphs at different irradiation fluencies.

3. Results and Discussion

Critical temperature (T_c) was determined to be 92.5 K from both field-cooled (fc) and zero-field-cooled (zfc) measurements in a magnetic field of 10 Oe and it is observed that there is no change after irradiation. Figure 1(a) and 1(b) shows the magnetization loop of the sample measured at T= 50 K and 77 K, respectively before and after thermal neutron irradiation. It is observed that there is a secondary peak in M-H loop at 50 K. This is most probably due to the field- induced pinning which is the characteristic properties of Sm, Nd and Eu based superconductors(2). This field- induced pinning occurs due to the oxygen deficient clusters in 123-matrix. The secondary peak effect has disappeared with thermal neutron irradiation. This can be connected to the fact that defects created by irradiation may change the pre-irradiation defect structure either through direct replacement of small point defects by a larger irradiation defects or by statistical rearrangement of certain atoms (most probably oxygen atoms in our sample). As seen from figure (a) and (b), irradiation is more effective at 50 K and low magnetic fields. At 50 K , the increase in J_c is 5 times at low fields and decreases down to 3.5 times as the field approaches 1 Tesla. The increase in J_c at 77 K is 4.8 and 2.5 in low and high fields (1 Tesla) , respectively (see inset (a) and (b)). This difference between the enhancement factors of J_c at 50 K and 77 K can be attributed to the presence of both point like defects and larger defects. It can be discussed in more details as follows. Small defects existing in the sample before irradiation can grow by agglomeration of newly created defects on them during neutron irradiation(3). The larger defects are more effective at higher temperatures and lower fields. Sharp decrease of J_c at 77 K and low magnetic fields also proves the presence of larger defects. Considering the fact that defect size must be around coherence length for an efficient pinning and coherence length of the flux lines increases with temperature, point like defects may not contribute to the pinning at high temperatures. Therefore, higher enhancement at 50 K comes from the contribution of point like defects on pinning in addition to the contribution of larger defects. But, at 77 K, small defects becomes inefficient.

4. Conclusion

Thermal neutron irradiation resulted in a strong increase of critical current in the hall temperature and field range studied. However, this increase was found to be stronger at lower fields and temperatures. This can be explained by the presence of small defects which become inefficient as temperature or fields increases.

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