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Heavy-ion irradiation effects in Ag–Cu alloy sheathed Bi-2223 tapes

Hiroshi Ikeda[a,*], Naoshi Kuroda[b], Tadashi Kambara[c], Kozo Yoshikawa[d], Ryozo Yoshizaki[a]

[a]*Institute of Materials Science and Cryogenics Center, University of Tsukuba, Ibaraki 305-8577, Japan*
[b]*Japan Atomic Energy Research Institute, Tokai-mura, Ibaraki 319-1195, Japan*
[c]*Institute of Physical and Chemical Research (RIKEN), Wako-shi, Saitama 351-0198, Japan*
[d]*Takasago Research Center, Mitsubishi Heavy Industries, Ltd., Takasago, Hyogo 676-0008, Japan*

Abstract

We have investigated the magnetic properties of Ag–Cu alloy sheathed Bi-2223 tapes with columnar defects parallel to the *c*-axis introduced by Xe-ion irradiation. We found that the irreversibility line in heavy-ion irradiated Bi-2223 tapes showed the shift toward higher fields. In addition, the irreversibility curve of the irradiated Ag–Cu alloy sample is located in the higher temperature side of the irradiated Ag sheathed tape even in the higher magnetic field than the matching field.

Keywords: Ag–Cu alloy; Irradiation; Irreversibility line; Bi-2223

1. Introduction

The heavy-ion irradiation has attracted much attention, since it produces columnar defects which yield a quite large pinning energy of high-temperature superconductors for vortices parallel to the defects [1]. Since the irradiation can introduce the defects in a controlled manner, it can be used as a useful tool to probe the response of flux line system to known defect structure. It is not trivial question, however, whether columnar defects act cooperatively with point defects to pin vortices or not. We have investigated the effect of columnar defects on the irreversibility line for the point pin enriched sample of Bi-2223 tapes.

2. Experimental

The Ag–Cu alloy sheathed tapes were prepared by the powder-in-tube method. Ag–Cu alloy sheaths in this study were filled with the Cu-poor Bi-2223 powder, since copper atoms were expected to diffuse into inner oxide core from the outer Ag–Cu alloy sheath. We have introduced Hf elements in the Ag–Cu alloy sheathed Bi-2223 tapes, which result in the improvement of the transport J_c. The details of the preparation method, and the fundamental properties of the samples were reported elsewhere [2]. Bi-2223 tapes with typically $3.0 \times 3.0 \times 0.1$ mm^3 were irradiated with 3.5 GeV $^{163}Xe^{31+}$ ion at the RIKEN ring cyclotron facility to introduce columnar defects along perpendicular to the tape surface direction. The total pin density was estimated to be 7.2×10^{10} cm^{-2}, which corresponded to a dose-equivalent matching field of $B_\phi = 1.4 \pm 0.2$ T. This type of irradiation has produced continuous amorphous tracks with the diameter of ≈ 6 nm throughout the thickness of the Bi-2223 sample. We estimated sample qualities using X-ray diffraction measurement and high-resolution transmission electron microscope. We confirmed that the Hf atoms were substituted for 0.5–1% of Sr by high-resolution analyzed electron microscopy (HRAEM) [3]. The magnetic properties were measured by using a superconducting quantum interference device (SQUID) magnetometer. The magnetic field was applied perpendicular to the wide surface of the tape.

* Corresponding author.
E-mail address: ikeda@bk.tsukuba.ac.jp (H. Ikeda)

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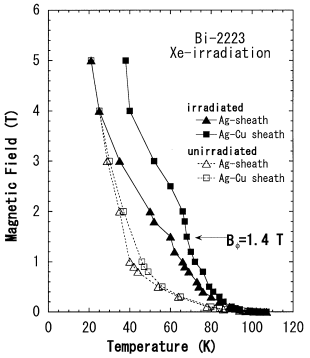

Fig. 1. The irreversibility temperature are plotted in H–T plane for the Ag and Ag–Cu alloy sheathed Bi-2223 tapes with columnar defects by solid symbols and for the unirradiated ones by open symbols, respectively.

3. Results and discussion

Fig. 1 shows magnetic field versus the irreversibility temperature (T_{irr}) for the Ag and Ag–Cu Cu alloy sheathed Bi-2223 tapes with columnar defects by solid symbols and for the unirradiated tapes by open symbols. We can see that the irreversibility line curve for the irradiated Ag sheathed tapes is located in the higher temperature side of the unirradiated ones below 4 T and merges to the one for the unirradiated samples at the field of about triplicate of B_ϕ. We found that the irreversibility line curve for the Ag–Cu alloy sheathed tapes was drastically shifted to the higher temperatures in the measured field up to 5 T by the Xe-ion irradiation. This behavior suggests that pinning force for the irradiated Ag–Cu alloy sheathed tapes is larger than that of the Ag sheathed ones. In fact, according to the results of the pinning force measurement, the field dependence of F_p of the Bi-2223 tape samples was improved by the Hf substitution for Sr due to the collective pinning [3]. Therefore, it is expected that the columnar defects will act as effective pinning centers in cooperation with the point defects induced by Hf doping.

4. Conclusion

We observed the effect of the columnar defects in the Bi-2223 tapes. We found the irreversibility curve of the irradiated Ag–Cu alloy sample is located in the higher temperature side of the irradiated Ag sheathed tape even in the higher magnetic field than the triplicate of the matching field B_ϕ.

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