Effects of 2.6-GeV uranium irradiation on $(Ba,K)Fe_2As_2$ single crystals

T. Tamegai,*[1] T. Taen,*[1] F. Ohtake,*[1] S. Pyon,*[1] T. Kambara,*[2] Y. Kanai,*[3] and A. Yoshida*[2]

Through extensive studies on the recently discovered iron-based superconductors (IBSs), the transition temperature T_c in rare-earth-based iron-oxyarsenides has been increased up to ~55 K within a short period of time. However, the critical current density, J_c, at low temperatures is not large enough. Despite the lower T_c in IBSs compared with that in cuprate superconductors, IBSs have smaller electromagnetic anisotropies and are considered to be attractive for practical applications. J_c can be enhanced by introducing artificial pinning centers. It is well known that the most efficient way to improve the J_c characteristics is to pin vortices with columnar defects (CDs) created by swift particle irradiations. In high-temperature superconductors, the existence of CDs enhances J_c dramatically.[1)]

One of the most extensively studied IBSs, $Ba(Fe_{1-x}Co_x)_2As_2$, with the highest T_c (~24 K) is readily available in a large single crystal. Its J_c reaches 1×10^6 A/cm^2 at T = 2 K, which is potentially attractive for technological applications. We expect that J_c in $Ba(Fe_{1-x}Co_x)_xAs_2$ can be enhanced by introducing CDs that can pin vortices. However, it is well known that morphologies of irradiation-induced defects strongly depend on various parameters such as ion energy, stopping power of incident ions, thermal conductivity, and perfection of the target crystal. Hence, it is still an open question as to what kind of defects can be created in IBSs under a specific condition. Our preliminary study using 200 MeV Au ions has successfully demonstrated that CDs can be introduced and J_c is enhanced by a factor of 5 at low temperatures.[2)] In our previous irradiation in IBS performed at RIKEN, we have used heavier and more energetic 2.6 GeV Uranium (U) ions and found that U also enhances J_c in $Ba(Fe_{1-x}Co_x)_2As_2$[3)]. In this case, however, magnetic hysteresis loop shows an interesting dip structure at low magnetic fields; such a dip has not been observed in the case of Au irradiation. One of the possible origins for this dip is that pinning by CDs is not effective in the remanent state of a thin-plate superconductor, where flux lines have a strong curvature due to the strong demagnetization effect.[4)]

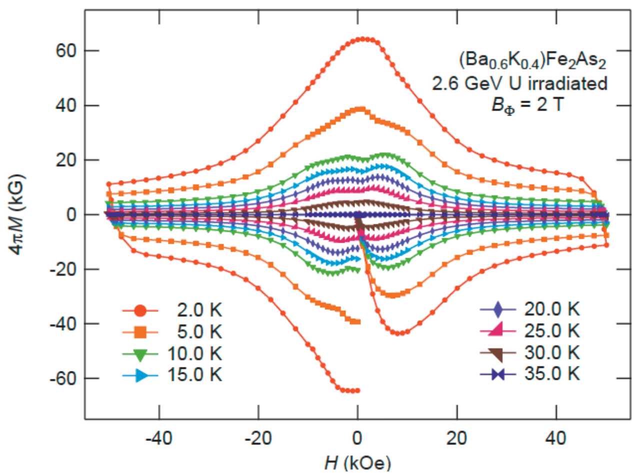

Fig. 1. Magnetic hysteresis loops of 2.6-GeV U-irradiated $(Ba_{0.6}K_{0.4})Fe_2As_2$ (B_Φ = 2 T) at several fixed temperatures.

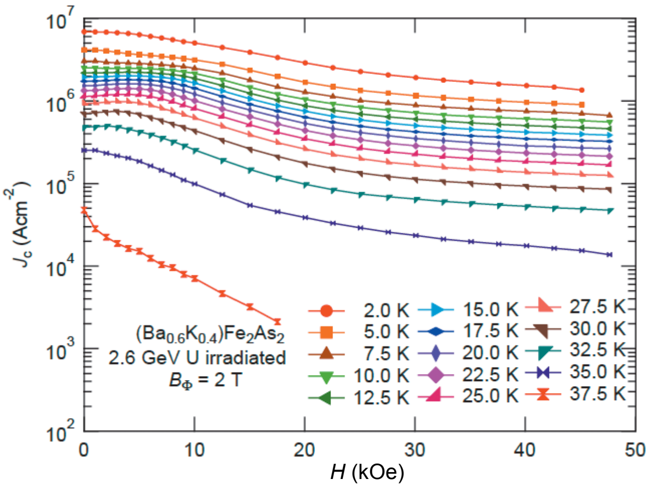

Fig. 2. Magnetic field dependence of J_c in 2.6-GeV U-irradiated $(Ba_{0.6}K_{0.4})Fe_2As_2$ (B_Φ = 2 T).

This year, we have explored similar irradiation effects on another promising IBS, $(Ba_{1-x}K_x)Fe_2As_2$. Figure 1 shows the magnetic hysteresis loops of the 2.6-GeV U-irradiated $(Ba_{0.6}K_{0.4})Fe_2As_2$ at B_Φ = 2 T and at low temperatures. Except for temperatures close to T_c and 2 K, the width of the hysteresis loop is diminished at lower fields, which is similar to the dip structure observed in the case of the U-irradiated $Ba(Fe_{1-x}Co_x)_2As_2$[3)]. In Fig. 2, we convert the width of the hysteresis loop into J_c using the Bean model. After the irradiation, J_c at T = 2 K under a self-field reaches 7×10^6 A/cm^2, which is larger than that in the case of $Ba(Fe_{1-x}Co_x)_2As_2$. It should be noted that J_c at T = 25 K and H = 45 kOe is ~2×10^5 A/cm^2, which is larger than the technologically required value for superconducting wires.

*[1] Department of Physics, The University of Tokyo
*[2] RIKEN Nishina Center
*[3] Atomic Physics Laboratory, RIKEN

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