Abstract of Presentation

Impact of high-energy particle irradiations into iron-pnictide superconductors

Abstract :

Just after the discovery of superconductivity at T_c~26 K in iron-pnictide superconductor [1], extensive research on the mechanism of superconductivity and possible applications of this new class of superconductors have been initiated. Successful growth of high-quality single crystals of Ba-122 (K, Co, P substituted) and Fe(Te,Se) with reasonable sizes have made it possible to perform several vital measurements. It is well known that the low-energy excitation gives a clue to the gap structure in superconductors. Measurements of specific heat, thermal conductivity [2], nuclear magnetic resonance [3], etc., can offer important clues for the behavior of quasi-particles that governs the low temperature properties of superconductors.

On the other hand, technological advances of novel superconductors depend heavily on how much current can be carried without dissipation, namely, the value of critical current density, J_c. Iron-based superconductors also face the same problem. While the transition temperature T_c is increased up to 55 K in rare-earth-based iron-oxyarsenides within a short period of time [4], J_c at low temperatures is still not high enough [5–7]. Although the transition temperature of iron-pnictide superconductors is still lower than cuprate superconductors, introduction of pinning centers can enhance the critical current density and make this system more attractive for practical applications. It is well known that the most efficient way to improve the critical current density is to pin vortices with columnar defects created by swift particle irradiation. In high temperature superconductors, columnar defects enhance J_c dramatically [8]. Intermetallic iron-arsenides $Ba(Fe_{1-x}Co_x)_2As_2$ with T_c 24 K is readily available in large single crystalline form [7] and its J_c reaches 10^6 A/cm^2 at T = 2 K, which is potentially attractive for technological applications [5–7]. We expect that J_c in $Ba(Fe_{1-x}Co_x)_2As_2$ could be enhanced by introducing columnar defects that can pin vortices. However, it is well known that 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, etc. We have successfully demonstrated that columnar defects can be introduced by 200 MeV Au irradiation and J_c is enhanced by a factor of six at low temperatures [9]. However, there are several differences compared with cuprates. One example is the continuity of columnar defects. Columnar defects in $Ba(Fe_{1-x}Co_x)_2As_2$ is

Abstract of Presentation

not continuous, probably due to the lower energy deposition rate in the case of 200 MeV Au. Critical current density as a function of magnetic field and its relaxation are explored and compared with those in unirradiated crystal. We find that the relaxation rate is strongly suppressed by irradiation. In addition, low-field anomaly in the relaxation rate in unirradiated crystal is wiped away by modest irradiation with matching field of 20 kG. In order to understand and optimize the effect of heavy-ion irradiation, we need to compare the effect of different ions with lower and higher energy deposition rate. We have already tried 200 MeV Ni, 800 MeV Xe, and 2,6 GeV U irradiations. In all cases except for 200MeV Ni, we observe clear enhancements of J_c. However, details seem to depend on the ion species and/or their energies.

We have also studied the effect of proton irradiation up to 1×10^{16} cm^{-2} into $Ba(Fe_{1-x}Co_x)_2As_2$ with different doping levels with an aim to systematically explore the effect of disorder on T_c, resistivity, and J_c. We find that the effect is largest in overdoped crystal, which may indicate that different superconducting states are realized in spite of similar value of T_c in these two samples. Quantitative analysis of the disorder on T_c may help to clarify the pairing symmetry in Fe-pnictides. Proton irradiation also enhances J_c by a factor of 3 at low temperatures. The effect is comparable to 200 MeV Au irradiation at 20 kG matching field. However, the behavior of the field dependence of the normalized relaxation rate is different, which may give a clue for the origin of the anomaly in the relaxation rate.

[1] Y. Kamihara *et al*., J. Am. Chem. Soc. **130**, 3296 (2008).
[2] M. Yamashita *et al*., Phys. Rev. B **80**, 220509 (2009).
[3] Y. Nakai *et al*., J. Phys. Soc. Jpn. **77**, 073701 (2008).
[4] Z. A. Ren *et al*.,, Chin. Phys. Lett. **25**, 2215 (2008).
[5] R. Prozorov *et al*., Phys. Rev. B **78**, 224506 (2008).
[6] A. Yamamoto *et al*., Appl. Phys. Lett. **94**, 062511 (2009).
[7] Y. Nakajima, T. Taen, and T. Tamegai, J. Phys. Soc. Jpn. 78, 023702 (2009).
[8] L. Civale *et al*., Phys. Rev. Lett. **67**, 648 (1991).
[9] Y. Nakajima, Y. Tsuchiya, T. Taen, T. Tamegai, S. Okayasu, and M. Sasase, Phys. Rev. B **80**, 012510 (2009)