§20. Study on Mechanisms of Superconductivity Change by Neutron Irradiation

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Purpose of this study is to investigate the influence of neutron irradiation on superconducting properties such as critical currents and flux pinning, and explore its fundamental mechanism. The influence of 14 MeV neutrons generated by the Deuterium-Tritium (D-T) reaction on superconducting material is one of the most important issues for the design of fusion devices using D-T burning plasma. Although there are some reports on the neutron irradiation effect on macroscopic superconducting property like a critical current density, the effects on the flux pinning in a mesoscopic scale has not been fully understood yet. In this study, we have carried out direct observation and analysis of trapped fluxoids by using scanning SQUID microscopy (SSM) to investigate the influence of neutron irradiation on flux pinning behavior.

We adopted a pure Nb thin plate as a sample in order to investigate in a simple system. By using Fusion Neutronics Source (FNS) at Japan Atomic Energy Agency (JAEA), we irradiated the samples with fast neutron of 14 MeV. The neutron fluence was about 10^{19} n/m^2. As shown in Fig.1, we have successfully observed the trapped fluxoids in the Nb thin plate, where white dots correspond to the trapped fluxoids. We can clearly see that the peak height of each fluxoids become more regular after the irradiation, whereas the number of anti-vortex and multi fluxoids structure can be seen in the initial sample. Variation of the statistical distribution of the peak heights of each fluxoiods can also be confirmed. This result strongly suggests that fluxoids are more stably pinned after neutron irradiation because of the introduction of nanoscale defects due to irradiation even though the fluence is relatively low, 10^{19} n/m^2. It is hardly possible to detect such variation with this level of fluence from standard measurements of critical current or magnetization in a macroscopic scale.

We also investigated magnetic field profiles of single fluxoid precisely. As show in Fig.2, we confirmed that the pinned flux profile has not changed after the irradiation. From this analysis, we can estimate magnetic penetration depth λ around the fluxoid, then can obtain superfluid density in the matrix. Present results show that the neutron irradiation with a flence of 10^{19} n/m^2 doesn't cause deterioration of superconductivity in the matrix. Furthermore, temperature dependence of the superfluid density can well be explained by the theory of *s*-wave gap symmetry with no degradation of T_c as shown in Fig. 3.

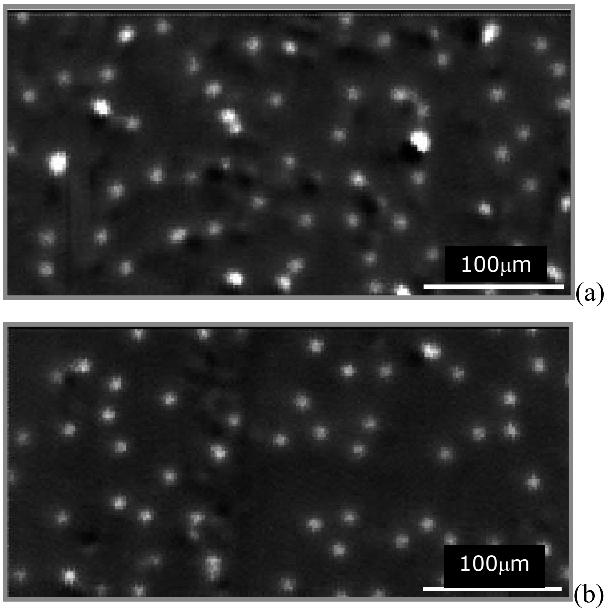

Fig. 1 Trapped fluxoids visualized by the scanning SQUID Micriscioy (a) before irradiation and (b) after irradiation.

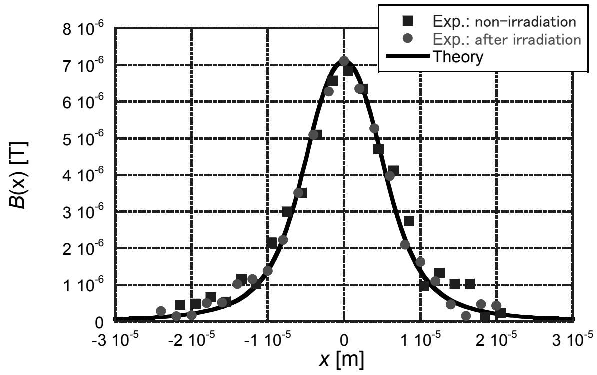

Fig. 2 Magnetic field profile of single fluxoid. Solid curve indicates theoretical calculation with the penetration depth λ of 140 nm.

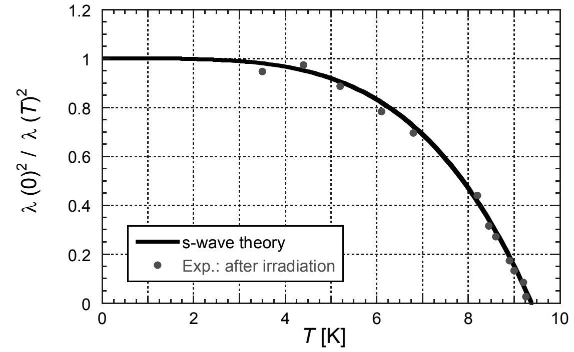

Fig. 3 Temperature dependence of superfluid density estimated from that of field profile of single fluxoid as shown in Fig. 2. Solid curve is the result from *s*-wave gap symmetry.