§30. 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 from the direct observation of fluxoids.

We selected pure Nb thin plate as a sample in order to investigate in a simple system. After rolling, we annealed the sample at 800 degrees of Celsius for 10 hours, and polished Nb surface for finishing. This process results in the thickness of the Nb plate about 300 μm. By using Fusion Neutronics Source (FNS) at Japan Atomic Energy Agency, we irradiated the samples with fast neutron with 14 MeV and 10^{19} n/m^2. After irradiation, the sample was transferred to radiation controlled area at Kyushu University (KU) for detailed measurements under the authorization between FNS and KU. To transfer the sample to KU, we registered nuclide Nb_m^{92} to KU last year.

Trapped fluxoids in the Nb thin plate was measured by scanning SQUID microscope in which a Nb based SQUID sensor is coupled with a 10 μm in diameter pickup coil. By scanning the sensor on the sample surface with a step distance of 2 μm, we obtained high resolution image of perpendicular (z) component of the magnetic field on the sample surface.

In Fig. 1, we showed the image of trapped fluxoids at 4.2 K in the irradiated sample. Each fluxoid shows quite similar field distribution. The z-component of the magnetic field, B_z, is calculated by analytical expression[1] of single flux quantum. Averaging B_z over the pickup coil area, we obtained theoretical curve shown by the solid curve in Fig. 1. From fitting between measurements and theoretical calculation, we estimated the distance z from the sample surface and magnetic penetration depth λ to be 3.2 μm and 100 nm, respectively.

In Fig. 2, we also showed obtained images in the initial un-irradiated sample in the similar measurement condition of Fig. 1. Field profile of each fluxoid, however, shows large scattering. If we assume that the variation comes from the change of λ, it spreads between 500 nm to 1 μm. Since the sample is un-irradiated pure Nb, it is difficult to assume such large difference of λ. As a possible another explanation, we assumed thermal fluctuation superposed on the fluxoid profile. Namely, due to weak pinning in the annealed sample, fluxoid position possibly be fluctuated during the measurements. We calculated field profile assuming Gaussian type noise with the parameter of thermal displacement, u_{th}, of the central position of the fluxoids. Theoretical calculation can fit experimental results with reasonable agreement as shown in Fig. 2.

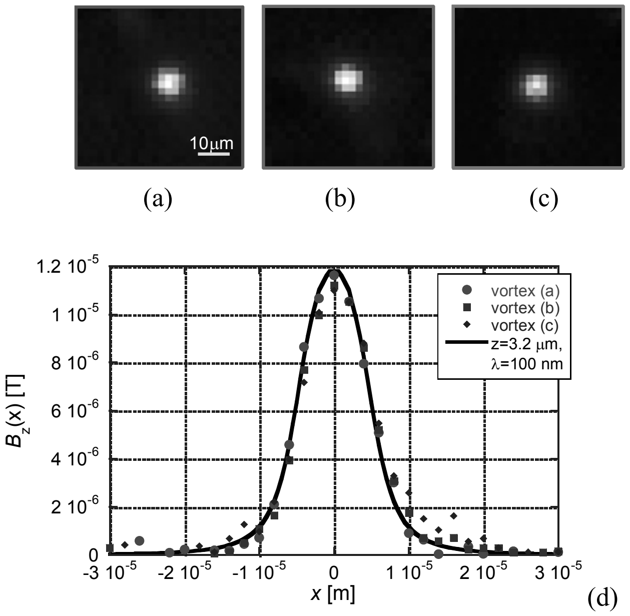

Fig. 1 Trapped fluxoids in neutron irradiated Nb thin plate: (a), (b), (c) 2-dimensional image observed by scanning SQUID microscope and (d) cross-sectional field profile. Solid curve is theoretical calculation.

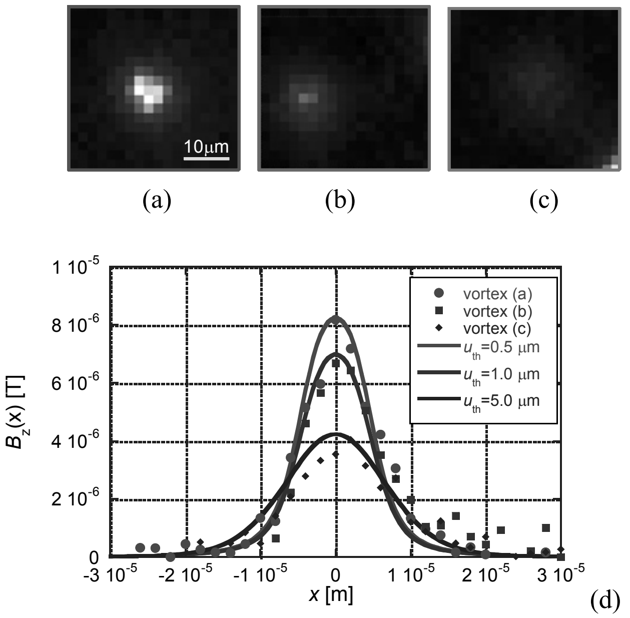

Fig. 2 Trapped fluxoids in initial un-irradiated Nb thin plate: (a), (b), (c) 2-dimensional image observed by scanning SQUID microscope, and (d) analysis assuming thermal displacement u_{th}.

These results suggest that local defects induced by the neutron irradiation pin the fluxoids, and then suppress the influence of thermal fluctuation.

1) R.B. Dinner et al., *Rev. of Scientific Instruments*, **76** (2005) 103702.