§21. Flux Pinning Properties of Defects Nucleated by Neutron Irradiation in A15 Type Superconductor

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i) Introduction

We have investigated the flux pinning properties of defects nucleated by neutron irradiation in nuclear fusion reactor. It is empirically known that the improvement of the critical current density in the irradiated specimen is attributed either to increase in the flux pinning force by the nucleated defects, or to increase in the upper critical magnetic field. However, it has not yet been clarified which contributes mainly to the improvement. In this study, the effect of heavy ion irradiation larger than neutron irradiation was investigated for DyBCO coated conductor to study the flux pinning property.

ii) Experimental details

The specimen was an ISD (Inclined Substrate Deposition)-processed DyBCO coated conductor with DyBCO layer of 1.5 μm thick. The critical temperature was 89.7 K and the critical current in the self field at 77 K was 220 A before the ion irradiation.

The tape was cut for DC magnetization measurement by a SQUID magnetometer. Its size was 3.8 mm × 3.5 mm. The specimens were irradiated with gold ions with the energy of 320 and 200 MeV and Nickel ions of 200 MeV along the direction normal to the tape surface. The density of defects expressed in terms of the matching field, B_ϕ, was 1.0 and 2.0 T for gold ion irradiation and 5.0 T for Nickel ion irradiation, respectively. The radius of columnar defects[1)] and the critical temperature after the irradiation are listed in Table 1.

The DC magnetization was measured by a SQUID magnetometer in a magnetic field normal to the tape surface. The critical current density, J_c, was estimated using the Bean model.

iii) Discussion

The critical current density of DyBCO coated conductor before and after the irradiation at 70 and 77 K is shown in Fig.1. Firstly the effect of Au irradiation is argued. It is found that the critical current density at low magnetic fields is slightly degraded by the irradiation, and the degradation of the critical current density is more remarkable for the case of B_ϕ = 2.0 T. This is considered to be caused by degradation of the superconductivity around the defects.

On the other hand, the critical current density is enhanced at magnetic fields above 1 T for the case of B_ϕ = 1.0 T and at magnetic fields above 2 T for the case of B_ϕ = 2.0 T. Especially, the enhancement is significant for the case of B_ϕ = 2.0 T. The coherence length ξ is expected to be about 5 nm at 77 K. The elementary pinning force depends only on the coherence length ξ for r_0 larger than ξ. The enhancement of critical current density above 2 T is simply attributed to the higher probability for flux lines to encounter the larger defects.

For the case of the Ni ion irradiation, it is found that the critical current density is only slightly improved. This indicates that the flux pinning is not strengthened as expected by the nickel ion irradiation. This might be caused by small radius of columnar defects nucleated by nickel ion irradiation.

In addition, we investigated the flux pinning properties of specimens in more detail by analysis the observed results whit the flux creep-flow model[2)]. The theoretical result of critical current density is compared with experimental result in Fig. 1. It can be seen that the theoretical results explain the experimental results well.

iv) Summary

The effect of heavy ion irradiation on the critical current density was investigated for DyBCO coated conductor. The obtained critical current density is explained well by the theoretical model of flux creep and flow. However, the pinning properties of neutron irradiated Nb_3Sn is considered to be attributed either to an increase in the flux pinning force of defects nucleated by irradiation or to an increase in the upper critical magnetic field. Hence, detailed analysis of flux pinning with taking account of the upper critical magnetic field is necessary.

Table I: Specification of specimens

	energy(MeV)	r_0(nm)	B_ϕ(T)	T_c (K)
un-irradiated				89.7
Au	320	8	1.0	88.3
Au	200	5	1.0	88.9
Au	200	5	2.0	87.3
Ni	200	2	5.0	89.6

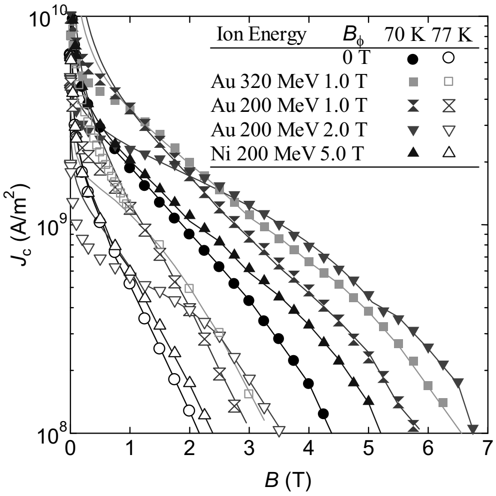

Fig. 1. Critical current density of DyBCO coated conductor before and after the irradiation at 70 K and 77 K. Symbols and solid lines represent the experiment and theoretical results, respectively.

1) Aasase, M. *et.al.*: Journal of Electron Microscopy, **51** (2002) s235
2) Kiuchi M. *et.al.*: Physica C **278** (1997)62