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# Neutron Irradiation Effect on Superconducting Magnet Materials
# 超伝導マグネット材料の中性子照射効果

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A fusion reactor will generate 14 MeV neutrons after Deuterium-Tritium fusion reaction. The neutron will reach superconducting magnet and activate superconducting strand and insulation materials. The change in superconducting properties was studied and the radiation effect on interlaminar shear strength of insulation composite was investigated. Also, an effort to install 15.5 T superconducting magnet and a variable temperature insert was succeeded at Oarai center in Tohoku University and the commissioning is undergoing. This paper reports some topical results on the neutron irradiation effect on the superconducting strand and the composite with cyanate ester – epoxy bended resin and the status of the new systems.

## 1. Introduction

To study the mechanism of neutron irradiation effect on superconductivity of $Nb_3Sn$ strand and to construct a database for a design and a construction of fusion magnets, irradiation tests were carried out using a fission reactor and 14 MeV neutron facility. In parallel with irradiation on the $Nb_3Sn$ strand, a study on interlaminar shear strength (ILSS) of a composite with polyimide films, glass clothes and cyanate ester – epoxy blended resin was performed. Since the samples were activated by the irradiation, all tests after irradiation were carried out in a radiation control area in Tohoku University and Japan Atomic Energy Agency (JAEA). To carry out the superconducting tests with activated ones in high magnetic field, a new test facility consists of 15.5 T superconducting magnet and a variable temperature insert was installed at a radiation control area in Oarai center, Tohoku University.

This paper will present some topical results and introduce the new facility.

## 2. Neutron Irradiation Effect on Nb3Sn Strand

The $Nb_3Sn$ strand with 0.7 mm diameter was irradiated at 14 MeV neutron source at Fusion Neutronics Source in JAEA. Then the sample was sent to Tohoku University and the superconducting properties were measured with 28 T hybrid magnet. The results of critical current are shown in Fig. 1 as a function of magnetic field. After the irradiation, the critical current increased especially in the lower magnetic field. As far as the results obtained, the increase of the critical current in the higher magnetic field started after a certain amount of the neutron fluence. It suggests that the flux pinning force was strengthened by the irradiation and the strengthening was improved with an increase of the neutron fluence.

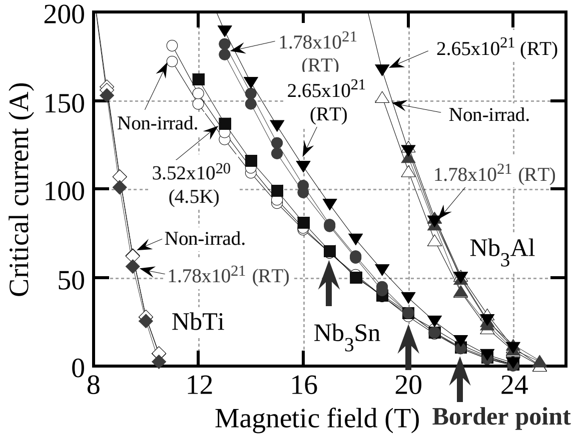


Fig. 1 Change in critical current against magnetic field after 14 MeV neutron irradiation

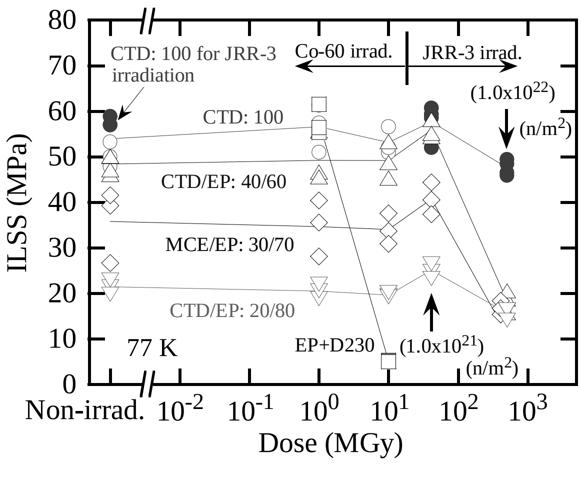


Fig. 2 ILSS at 77 K of composites with polyimide film, glass cloth and blended resin against dose.

## 3. Irradiation Effect on Composite Material

The blended resin with cyanate ester and epoxy was used for fabrication of the composite with polyimide film and glass cloth. The blended ratio was changed and the samples were irradiated at JRR-3 (fission reactor). After the irradiation, the ILSS was measured at 77 K in the radiation control area at Oarai center. The results are shown in Fig. 2. Since the gamma ray irradiation is very hard in JRR-3 (2.5 MGy/hr), the data were plotted against gamma ray dose. In Fig. 2, CTD and MCE mean a cyanate ester resin and EP presents epoxy resin. EP+D230 means a 100% epoxy resin with hardener of D230 and it is a reference data. The initial ILSS is affected by the ratio and the composite with lower ratio showed lower ILSS. The reason is clear, because of luck of the hardener for epoxy resin. The samples with 100% cyanate ester resin endured about 500 MGy although all other samples dropped.

## 4. A New Superconducting Facility

15.5T superconducting magnet with a RT bore of 52 mm diameter was installed together with a shielding structure. It is a conduction cooling type magnet with GM refrigeration and no use of liquid helium or liquid nitrogen. The insert was designed for the magnet and has a capacity of sample current of 500A and sample temperature of 4.2 K to over 20 K. The magnet can be cooled down in four days and the sample in the insert can be cooled down in about four hours. The dependence of the critical magnetic field on the sample temperature with the sample irradiated to 1.0 x $10^{22}$ n/$m^2$ was evaluated.


Fig. 3 15.5T superconducting magnet (lower) and variable temperature insert (upper) at Oarai center.