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Neutron Irradiation Effect on Superconductivity of ReBCO Tapes

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Deuterium and tritium reaction generates 14 MeV neutrons and most of the generated neutrons are captured by blankets and plasma vacuum vessel (VV) and the energy of these neutrons will be exchanged to electricity. The rest can penetrate the components and reach superconducting (SC) magnets outside of the VV. A recent study on neutron mapping in fusion reactors has expanded to include thermal neutrons, and one research shows the huge number of thermal neutrons would exist in the SC magnets. At the same time, ReBCO tapes have been developed. Therefore, GdBCO, EuBCO and YBCO tapes were taken as test materials for the research on neutron irradiation effect on the superconductivity. The neutron irradiation was carried out at Japan Research Reactor #3 (JRR-3) located at Tokai in Japan. The maximum fast and thermal neutron fluence were 1.46 x 1021 n/m2 and 8.29 x 1022 n/m2, respectively. Several noble researches have been already conducted at Vienna using TRIGA MARK II. Since JRR-3 has perfectly different neutron flux envelope from TRIGA, the effect of the thermal neutron was focused on in this study. In addition, the ReBCO layer was pealed and scratched out after the irradiation and the analysis with a Ge detector was carried out to check the isotopes in ReBCO layer.
153Gd was detected by the Ge detector after the irradiation and this is good evidence that Gd transmutation occurred during the irradiation. The GdBCO irradiated with no Cd shielding showed no superconductivity even at 5 K. The shielding with 75 μm and 125 μm thick Cd foil has significant effect in preventing degradation of the critical temperature (TC) and this is also clear evidence that the thermal neutron degrades the superconductivity of GdBCO.
Gd has five stable isotopes and 155Gd and 157Gd have huge cross sections for thermal neutron on the order of 106 barns. This {n,γ} reaction will be the reason for the degradation. There are three considerations on the mechanism for the degradation.
(1) The Gd atoms will be released by the recoil from the {n,γ} reaction.
(2) Oxygen atoms will be removed from the perovskite crystal, creating lack of oxygen.
(3) Exchange of electron during Gd transmutation will disturb the electric potential on the CuO2 planes.
It is expected that the further study will make the mechanism clear.
On the other hand, EuBCO without Cd shielding showed some degradation but the Cd shielded samples presented the same properties as the non-irradiated sample. YBCO does not show the degradation at all by the irradiation, and TC was improved a little by the fast neutron. This improvement would be caused by the relaxation of internal strain in the YBCO layer.
The information on IC and BC2 after the irradiation will be presented at the workshop.

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