11. Fusion Engineering Research Center

The researches in Fusion Engineering Research Center are categorized into (1) basic research for liquid blankets, (2) R&D for low activation materials and (3) fusion-relevant research for superconducting magnet with emphasis on radiation effects.

Major efforts of the liquid blanket research are on development of coating for corrosion resistance, electrical insulation and hydrogen permeation suppression, and on compatibility of structural materials with liquid breeders.

Coating of W and Cr on low activation structural materials was investigated with the vacuum plasma spraying and the chemical vapor deposition, respectively, for suppression of the corrosion in molten-salt. The coated specimens showed enhanced corrosion resistance in oxidizing and fluoridizing environments.

Coating of Er_2O_3 on low activation materials were investigated for MHD insulator of Li blankets and tritium barrier for Flibe and Li-Pb blankets. Er_2O_3 coating on Reduced Activation Ferritic/Martensitic (RAFM) steels with Metal Organic Decomposition (MOD) were studied. The hydrogen permeation reduction factor was estimated to be only 1/15 to 1/35 at 400 to 700°C, probably due to pores formed by immersion in liquid Li. Oxide layers on the substrate may be responsible for the limited performance.

Efforts were also made on fabrication of the coating with Metal Organic Chemical Vapor Deposition (MOCVD) to apply on complex surfaces. The coating rate was increased by switching Er complex from DPM to IBPM.

Compatibility of RAFM with Li, Pb-Li and Flinak was investigated in flowing conditions. Depletion of Cr was commonly observed. A compatibility model was developed which can evaluate the mass loss of the steel by the mass transfer: Δm_d, erosion-corrosion: Δm_e, and electrochemical corrosion: Δm_v. Also carried out was corrosion tests of SUS410-SUS410, SUS316-SUS316 and SUS410-SUS316 TIG welded joints in Li.

Corrosion characteristics of AlN, Y_2O_3, Er_2O_3 and Al_2O_3 in Flinak were studied for molten salt blanket system by static immersion tests. AlN indicated superior compatibility in molten Flinak. Also carried out was the development of on-line hydrogen sensor for application to liquid blankets. On-line monitoring with improved electrodes was demonstrated in molten Flinak.

Studies for the development of low activation vanadium alloys focused on characterization of radiation response and exploration of advanced alloys for enhanced operation temperature. The effects of heat treatment on radiation induced microstructure and mechanical properties were investigated for V-4Cr-4Ti. Neutron irradiation can induce re-distribution of solutes and precipitates, which can change the optimum heat treatment temperature previously determined by examinations without irradiation.

As a mean to increase the thermal creep resistance of V-4Cr-4Ti, strengthening by cold working and aging was examined. The proper treatment enhanced the creep lifetime at relatively high stress level. However, the improvement at low stress level was limited.

As for RAFM steels, influence of stress during thermal ageing on mechanical properties was investigated. The stress enhanced softening and reduced the creep lifetime.

In the superconducting magnet field, the collaboration network concerning irradiation effect on superconducting magnet materials has been developed and produced very important results described below. Participants are NIMS, Tohoku Univ., Osaka Univ., Kyushu Univ., JAEA and so on. Osaka Prefecture Univ. (Frontier Science Innovation Center) jointed in 2009 and performed gamma ray irradiation up to 10 MGy with ^{60}Co facility. At Oarai center in Tohoku Univ., 15.5 T superconducting magnet was installed in the radiation control area and the full system operation with a variable temperature insert will be done by the end of 2010 fiscal year using 500 A power supply.

Superconducting properties of Nb_3Sn, NbTi and Nb_3Al wires irradiated up to 3.1 x 10^{21} n/m^2 with 14 MeV neutron were measured in this year again. The critical current (Ic) of Nb_3Sn wire in the lower field increased remarkably as an increment of the neutron fluence. The border magnetic field where Ic starts to get away from the non-irradiated Ic curve shifts to the higher magnetic field when the neutron fluence increases. The magnetic flux pinning force would be strengthened and Ic would increase in the higher field when the irradiation damage increases. At the same time, the A15 crystal structure would be disordered resulting in the decrease of the critical temperature. However, change in the critical field was not observed clearly. Preparation to carry out the flux pinning observation on Nb foil with a SQUID microscope has started in Kyushu Univ. and the irradiated samples will be transferred from FNS in JAEA to Kyushu Univ. in the near future. The magnetization of the heavily irradiated Nb_3Sn wire was measured with SQUID and it was noticed that the sample irradiated to 4 x 10^{24} n/m^2 showed non-superconducting at 4.5 K.

The blended insulation materials with cyanate ester and epoxy resins were trial-fabricated with 10 polyimide films and 11 glass cloth sheets. The weight fraction was changed 100% cyanate ester to 80/20 of epoxy/ cyanate ester. The samples were sent to JRR-3 and the fission neutron irradiation up to 1 x 10^{22} n/m^2 (>0.1 MeV) will be carried out in 2010. The gamma ray irradiations to 1 MGy and 10 MGy were performed. The blended resin GFRP did not show the degradation of interlaminar shear strength (ILSS) after 10 MGy irradiation, though the normal epoxy resin GFRP presented big drop of ILSS by 10 MGy irradiation.

To improve Jc of V_3Ga superconducting wire, the fine particle of the high Ga content Cu-Ga was investigated. The average particle size was decreased by the jet-milling. The thicker V_3Ga layer was formed around interface between V matrix and fine particle powder filament.

Radiation shielding performance of liquid Flibe cooled and Li cooled blanket systems proposed in the FFHR2 helical reactor design have been investigated for protection of a superconducting magnet system by neutron and gamma-ray transport calculations in the frame of collaborations on reactor design studies.

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