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 the compatibility of structural materials with molten-salt Flibe and liquid Li and development of ceramics coatings as basic studies for Flibe and liquid Li blankets.

Compatibility of Reduced Activation Ferritic/ Martensitic Steels (RAFM) with Flibe and Flinak was investigated by static immersion tests including collaborations with U. of Tokyo. Effects of purity and capsule materials were investigated. Selective dissolution of Cr to Flibe and Flinak was observed. HF concentration in Flibe and Flinak was measured by slurry pH measurement method. The analysis of corrosion products showed oxidation and fluoridation as basic processes of the corrosion.

Compatibility of RAFM with liquid Li was studied in static pots and thermal convection loops. The researches were focused on the effects of capsule materials and nitrogen levels. The transportation of carbon from JLF-1 to Li was highly enhanced when affinity of the capsule materials with carbon was high. Enhanced selective corrosion of JLF-1 with Li was shown in the case of high nitrogen impurity levels.

Coating of Er_2O_3 on low activation materials were investigated for application to MHD insulator coating of Li blankets and tritium barrier coating for Flibe blankets. Efforts were focused on fabrication with Metal Organic Chemical Vapor Deposition (MOCVD) coating and dip-coating methods, both of which have capability of coating on complex surfaces. High purity and crystallinity of the coatings were verified. Characterizations of electrical conductivity and hydrogen permeability are in progress. Radiation Induced Conductivity of SiC, which is a candidate of Flow Channel Inset of dual-cooled Li-Pb blankets, was evaluated and proved to be negligibly small.

Also carried out was the development of on-line hydrogen sensor for application to liquid blankets. An electrode was developed which has higher resistance to corrosion than the conventional ones. The annihilation process of the defects produced in Li_2TiO_3 was also investigated as a fundamental radiation effect study.

Based on the neutronics investigation and corrosion studies, liquid lithium blanket with RAFM structure was proposed as intermediate step to Li/V self-cooled blankets. As an advantage, the system may not require any ceramic coating.

The efforts in low activation structural materials are focused on enhancement of fabrication technology especially for W coating and joining with dissimilar materials for vanadium alloys and creep lifetime evaluation and improvement for vanadium alloys and RAFM. Plasma-sprayed W coatings were successfully fabricated on V-4Cr-4Ti and their physical properties were investigated. Based on the series of thermal creep experiments, creep fracture stress for the typical blanket conditions were predicted for RAFM. Also investigated was the potential thermal aging effect on the prediction. Improvement of creep deformation resistance was investigated by applying thermal and mechanical treatment to the standard V-4Cr-4Ti alloys.

In addition, neutron irradiation effects on weld joints of vanadium alloys were studied, including potential post-irradiation annealing effects.

In the superconducting magnet system field, there were several main important collaborations between Universities and National Institutions, i.e. the collaborative investigations with High Field Laboratory for Superconducting Materials (HFLSM) and International Research Center for Nuclear Materials Science (Oarai center) of Institute for Metals Research (IMR) in Tohoku University, Fusion Neutronics Source (FNS) in Japan Atomic Energy Agency (JAEA) and NIFS-JAEA collaboration program on mechanical property evaluation of radiation-proof insulation material for ITER TF coil, and NIFS collaboration research programs which covers some investigations related to the neutron irradiation. In addition, Atomic energy basic and fundamental initiative program adopted the proposal to install high magnetic field (15.5 T) superconducting magnet system at a radiation controlled area in Oarai center for effective utilization of hot laboratories.

The collaboration network to carry out the study on neutron irradiation effect on superconducting magnet materials has been established among NIFS, JAEA, NIMS, KEK, Universities and companies. The samples were provided by companies and institutions and the neutron irradiation was performed at FNS and JRR-3 (fission reactor) at JAEA. Post irradiated tests such as interlaminar shear strength (ILSS) tests at RT and 77 K, critical current tests at 77 K, critical temperature tests at FNS, and critical current and critical magnetic field tests in high magnetic field were carried out under the collaborative investigations mentioned above. Especially, the measurements of the superconducting properties at HFLSM using 28 hybrid magnet produced very interesting and valuable data on superconductivity research.

As for the insulation materials, GFRP fabrication procedure with vacuum impregnation was established and ILSS after irradiation to 10^{22} n/m^2 was obtained. Also, the changes in the critical current and the critical magnetic field of Nb_3Sn and Nb_3Al wires were clarified.

The data includes the Japan-first and the world-first results and is very helpful to a reactor design beyond ITER.

Radiation shielding performance for protection of a superconducting magnet system is one of important issues in fusion blanket designs. Investigations of the shielding performance of liquid Flibe cooled and Li cooled advanced blanket systems proposed in the FFHR2 helical reactor design have been conducted by neutron and gamma-ray transport calculations in the frame of collaborations on reactor design studies.

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