2-3. In-Vessel Materials and Components

In the Fusion Engineering Research Project, in-vessel materials and components are among the key research subjects. For the low activation structural materials study, efforts are focused on developing low activation vanadium alloys including enhancement of performance at high temperature and in irradiation and corrosive environments by changing basic composition, minor element, such as Y, addition, and thermo-mechanical treatments. Welding of the alloys is also a key issue and is being investigated. Characterization of radiation effects of the alloys and their joints is ongoing by neutron and ion irradiations. An effort is being made to fabricate Oxide Dispersion Strengthened (ODS) V-Cr-Ti alloys for advanced low thermal creep structural materials. Efforts are also being made for fabricating and characterizing ODS low activation ferritic steels including thermal aging effects. Also being carried out is precipitation of Reduced Activation Ferritic/Martensitic Steel (RAFM) and joining with ODS steels. These studies contribute to extending blanket design criteria.

Ceramic coatings for application to liquid blankets are being investigated in the Project. Major efforts are directed to development of Er_2O_3 coatings, which are promising candidates for MHD insulator coating for liquid lithium and Li-Pb blankets and tritium permeation barrier coating for Li-Pb and molten-salt blankets. Technologies of coating fabrication are being developed which are capable of covering complex surfaces including duct interiors. Currently MOD (Metal Organic Decomposition) and MOCVD (Metal Organic Chemical Vapor Deposition) are being investigated including potential use of double-coated layers. A new effort of measuring hydrogen leaking from a pipe with and without the coating was initiated. In addition, a new surface nitriding method of steel surfaces is explored for application to anti-corrosion and permeation barrier coating for liquid blankets. Efforts are being enhanced to characterize ceramic materials using photoluminescence, including characterization of the effects of radiation damage by in-situ measurements during ion irradiation. A study on hydrogen transport in Li-Pb was initiated as a basic study toward tritium control in liquid blanket systems.

Plasma-wall interaction studies are also being carried out. Fundamental studies on hydrogen transfer throughout the first wall and the structural components were carried out including plasma- and gas-driven permeation and counter flow from the breeding materials to the first wall. Also being carried out were plasma-surface interactions and hydrogen retention tests using steady-state H and He plasmas. In these studies, RAFM was used as the first wall material.

Atomic and Molecular Process studies are being carried out in NIFS extensively. In the framework of the Fusion Engineering Research Project, those studies which are relevant to plasma-wall interactions, impurity transfer from the first wall to edge plasma, performance of highly charged particles, power loss by impurity puffing, and atomic process in materials in irradiation environments, such as H and He transfer in defective materials, are being carried out. These include development of atomic and molecular numerical databases.

Design and trial fabrication of divertor elements for DEMO are being carried out using W, Cu and RAFM. Cu alloys have been revisited as divertor structural materials. Also carried out was a design of YAG laser dispersion interferometer for helical DEMO reactors.

The abovementioned researches are closely connected in the Fusion Engineering Research Project with Helical Reactor Design activity.

As research summaries in fiscal year of 2012, 19 reports by NIFS staffs and SOKENDAI students and 27 collaboration reports are presented in the field of in-vessel materials and component studies. The research was categorized into three fields, namely materials/blanket studies, PWI/PFC studies and atomic and molecular process studies as fundamentals for plasma-wall interactions. In the NIFS collaboration, researches with wider scopes are being carried out with more extensive options for materials, blankets and first wall/divertors and other systems.

Out of 27 collaboration reports, 17 collaboration research reports were presented for the materials and blanket studies. These include thermal aging effects of 9Cr-ODS steel, stress effects on radiation hardening of Fe-base alloys, development of SiC for flow channel insert of Li-Pb blankets, new steel-based composites enhancing thermal conductivity, and fatigue lifetime evaluation by small specimens as structural material studies, TEM analysis of ceramic coating, thermal property of shielding materials, dynamic property change of SiC under irradiation, investigation of hydrides for shielding, spectroscopy for characterizing functional materials, degradation of diagnostics mirrors, and optical absorption of CaF2 by radiation as functional materials studies, MHD pressure drop mitigation by insulator layers, corrosion in Li-Pb, irradiation effects on tritium retention, deuterium permeation tests, and neutron cross section benchmark study as blanket technology researches.

For PWI/PFC studies, 8 collaboration research reports were presented. These includes H and He behavior during mixed plasma exposure, hydrogen isotope behavior during ion irradiation, hydrogen isotope exchange in PFM, and dust imaging analyses as particle transport studies, surface property of SiC and surface modification of W as PFM studies, and transient critical heat flux as a divertor thermofluid study.

A report on A&M of H-C systems was presented as molecular process studies. A report was also presented on application of a CT injector for HHF tests.

(Muroga, T.)