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 and thermomechanical treatments. 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 characterizing microstructures and mechanical properties of ODS low activation ferritic steels including thermal aging effects. 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. In addition, a new surface nitriding method of steel surfaces is explored for application to anti-corrosion coating for liquid blankets. Efforts are being enhanced to characterize ceramic materials using photoluminescence, including characterization of the effects of radiation damage. Also being carried out is the compatibility studies for liquid breeder blankets such as vanadium alloys with liquid breeders. In addition to materials degradation, mass and heat transfer in the blanket flowing system is under investigation including that of hydrogen.

Plasma-wall interaction (PWI) and plasma facing component (PFC) studies are also being carried out, some of which are performed mainly in the LHD Projects. In the Fusion Engineering Research Project, fundamental studies on hydrogen transfer throughout the first wall and the structural components including plasma-driven permeation and counter flow from the breeding materials to the first wall, and plasma-surface interactions using steady-state H and He plasmas are studied using RAFM 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, and atomic process in materials in irradiation environments are mainly being carried out. These include database development for improved spectrometry of the first wall impurities such as W, Ne, Fe, and Li in highly charged states.

These researches are closely connected in the Fusion Engineering Research Project with Helical Reactor Design activity. In the NIFS collaboration, in addition to the above researches, those with wider scopes are being carried out with more extensive options for materials, blankets and first wall/divertors and other systems.

As research summaries in fiscal year of 2011, 18 reports by NIFS staffs and SOKENDAI students and 22 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.

For the materials and blanket studies, 22 reports were presented in total. These include efforts to improve high temperature mechanical properties and radiation resistance of low activation vanadium alloys by compositional and microstructural control such as optimization of thermomechanical control, addition of Y, and nano-particle dispersion and reduction of grain sizes by mechanical alloying. Also carried out is characterization of radiation effects of weld joints. Characterization of ODS Ferritic Steels including thermal aging effects, and of ceramic materials including SiC/SiC composites by luminescence, electrical property measurements and thermal desorption spectrometry, small specimen test technology research including fatigue tests, and coating fabrication and characterization for use as the first wall were carried out. Blanket researches include design, development and characterization of coating and functionary gradient layers for MHD pressure drop mitigation, tritium permeation reduction and corrosion protection for liquid breeder blankets including ceramic layer coating and surface nitriding, and compatibility of liquid breeders with structural materials. Thermofluid and heat transfer tests were also carried out for blanket application.

For the PWI/PFC studies, 7 reports were presented including plasma and gas-driven permeation of hydrogen, plasma interactions with RAFMs, retention of H and He, erosion and mass transfer of Plasma-Facing Materials including thermal loading effects, and development and characterization of W and W alloys for PFM. Hydrogen retention in dust particles and electrical conductivity of warm dense W were also investigated.

For the atomic and molecular process studies, 10 reports in total were presented including radiation charge exchange and power loss by impurity puffing, fundamental data for spectrometry of W and other elements, atomic collision and plasma process of highly charged W, atomic and molecular database such as charge transfer cross sections including the measurement and calculation efforts, and model and simulation of H retentiom in BeTi and Hydrocarbons.

In addition, a Helical DEMO-oriented electron density measurement system was investigated.

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