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 structural materials study, efforts are focused on developing low activation materials, i.e. RAFM steels, ODS steels, vanadium alloys and SiC including basic characterization of advanced ODS steels with different Cr and impurity levels, thermal aging effects on microstructure and mechanical properties of RAFM steels, effects of Cr level or Ta addition on mechanical properties of vanadium alloys, thermal creep and ion irradiation–induced defect formation in V-4Cr-4Ti alloys, and joining of ODS steels with RAFM steels. The efforts also include test technologies such as nano-indentation of ion irradiated materials. These studies contribute to extending the 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. Technological improvement of coating fabrication and characterization are being made for Er_2O_3 including investigation of double layer coating and ion induced microstructure and luminescence for application to non-destructive inspection.

The liquid breeder blankets are the major target of blanket systems of the Project. For the liquid blanket development, control of mass transfer is essential. A construction of gas-pressure driven test loop for mass transfer analysis of liquid breeders was carried out. In addition, new idea of Ti powder dispersion in molten-salt for enhancing hydrogen solubility was investigated. Also carried out was improvement of hydride neutron shield, and neutronics investigation for blanket analysis.

Hydrogen retention and permeation in the first wall influences strongly the particle control and the fuel inventory. Experimental investigation of the hydrogen transport was carried out including the effects of surface treatment or ion/plasma irradiation in RAFM, and numerical analysis of hydrogen super-saturation layer.

Divertors are the key component for magnetic-confinement fusion reactors. In the Project, research on divertors are being carried out both for enhancing component technology and controlling plasma-wall interactions, the former including blazing of Cu and W, showing optimum fabrication conditions, surface modification of W, development of advanced Cu alloys, with potential of high strength and radiation resistance, and thermal and stress analysis of W and W coating.

Atomic and Molecular Process studies, including database development and management, is being carried out extensively but largely oriented to plasma-wall interaction issues in the Project, such as radiation power loss by impurity puffing, radiation intensity distribution measured by proton impact on W.

The abovementioned researches are motivated by and influencing strongly the ongoing Helical Reactor Design activity.

As research summaries in fiscal year of 2014 in the field of in-vessel materials and component studies, 15 reports by NIFS staffs and SOKENDAI students, and 26 collaboration reports were presented. 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, including underlying fundamental studies.

Out of 26 collaboration reports, 13 collaboration research reports were presented for the materials and blanket studies. The materials researches include comparison of 9Cr-ODS and 12Cr-ODS steels, nano-indentation of ion irradiated materials, defect production and fatigue of SiC, fracture toughness of V-4Cr-4Ti, He-bubble induced hardening, radiation effects on oxide coating, self-healing of the functional coating, thermal diffusivity/conductivity of shielding materials including fabrication of new hydrides. The blanket–oriented research includes three-surface insulted coating for MHD pressure drop suppression. In addition, radiation effects of hydrogen permeation barrier coating, defects formation in CVD processed SiC by ion irradiation and neutronics benchmark for blanket analysis were reported.

11 collaboration research reports were submitted for PWI/PFC studies, including plasma-induced permeation of RAFM, formation of fuzz structure in W, H retention in SiC/SiC, surface modification of W, impurity effects on retention, ion irradiation effects on retention in RAFM, permeation through W deposition layer, thermal trapping of T on W by gaseous exposure, H permeation measurements by electron stimulated desorption method, W coating on ceramics, thermal and stress analysis of W coating.

A report was presented concerning atomic and molecular database for light elements. Also submitted was a report on the impact of excited states of reflected H atoms on their recycling.

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