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 composition and impurity levels, effects of thermal history during the fabrication on microstructure and mechanical properties of ODS steels, dissimilar joining of ODS and RAFM steels, thermal creep tests and irradiation effects including helium effects and ion-neutron irradiation correlation for RAFM and V-4Cr-4Ti alloys. The efforts also include advancing test technologies such as fatigue test with small specimens and micro-indentation. These studies contribute to understanding the materials' performance in fusion conditions and extending the blanket design criteria.

Ceramic coatings for application to liquid blankets are being investigated in the Project. Efforts are directed to development of ceramic coatings such as Er_2O_3, which are promising candidates for MHD insulator coating and tritium permeation barrier coating. Technological improvement of coating fabrication and characterization are being made for ceramic coatings including MOCVD coating of Er_2O_3, hot pressed multilayer V/Ti/AlN coating, adhesion strength evaluation, hydrogen permeation, irradiation-induced microstructural change and luminescence.

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. Hydrogen solubility of Ti powder dispersed molten-salt for enhancing hydrogen solubility was investigated. Also carried out was improvement of hydride and carbide neutron shields.

Hydrogen retention and permeation in the first wall influences strongly the particle control and the fuel inventory. Experimental investigation of the hydrogen transport by exposure to plasma was carried out including the effects of surface impurities and He pre-irradiation for RAFM.

W is the most promising plasma facing material and thus various fabrication and characterization efforts were made for W including fabrication of grain boundary strengthened W alloy, W/Cu joints, W coating on CFC and hydrogen behavior in W. Also carried out were atomic and molecular (A&M) process studies including ion-induced radiation, charge exchange process and radiation power loss by impurity gas puffing, in addition to A&M database for W.

As for the charge exchange processes, a study on forbidden X-ray transitions following charge exchange in collisions of O^{7+} with He was carried out.

Cu alloys are being revisited for application to divertor heat sink materials, and efforts are being made to enhance the properties by nano particle dispersion.

Also being investigated with increasing interest are liquid metal divertors, such as tests for the vertical jet concept and interaction of liquid metals with plasma. Vacuum pumping in divertor area is also a critical issue because of neutron and tritium environments. A new vacuum pumping system of Cryopump without regeneration process was designed and is being manufactured,

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

As research summaries in fiscal year of 2015 in the field of in-vessel materials and component studies, 21 reports by NIFS staffs, guest scientists, SOKENDAI and Internship students, and 27 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 27 collaboration reports, 8 collaboration research reports were presented for the materials and blanket studies. The materials researches include effects of oxygen impurity on properties of 9Cr-ODS, He effects on irradiation hardening of steels, irradiation effects, hydrogen permeation and luminescence of ceramic coatings for blankets, and fabrication and characterization of shielding materials. The blanket–oriented research also includes three-surface insulated coating for MHD pressure drop suppression.

15 collaboration research reports were submitted for PWI/PFC studies, including plasma-induced hydrogen retention and permeation of RAFM steels and W, fabrication and characterization of W and Cu alloys, impurity transport and heat transfer analysis, and diagnostics technology.

3 reports were presented concerning atomic and molecular processes and database, all of which treat W related processes.

A report was presented for a new neutron detector for liquid blanket benchmark tests.

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