Study of the retention mechanisms for Hydrogen isotopes in Be containing mixed materials relevant for ITER. Clarifications of redeposited layers influence on Hydrogen isotopes retention and desorption

Composite and multilayered thin films with beryllium, tungsten and carbon content are of interest for the components exposed to fusion plasma from their use within ITER (International Thermonuclear Experimental Reactor) point of view. During ITER operation, due to erosion processes, material transport and redeposition phenomena together with introduction of plasma energy, mixed materials will be formed seeded with gaseous inclusions from the fuel used, from residual atmosphere or from injection process of certain noble gases to obtain a higher stability of the fusion plasma.

The knowledge of the complex atomic intermixing process and related structural and thermal properties of thin films and multilayers involving typical elements used in plasma facing components is still limited and requires a further special attention. Laboratory experiments on tungsten, carbon and/or beryllium containing thin film structures (either homogeneous or heterogeneous) are necessary for a better prediction of the unavoidable redeposition processes taking place in ITER. The impact of hydrogen absorption and of the oxygen/nitrogen presence on both the surface and on the structure and properties of the films will be mainly addressed.

These data are crucial for the assessment of potential thermo-mechanical degradation and dust formation, which are of great significance not only for the operation but also for machine safety and licensing. Reactive seeding impurity elements (e.g. nitrogen) may also form stable mixed material layers influencing both recycling and erosion properties of plasma facing materials. There are still large uncertainties in the prediction of in-vessel tritium inventories, particularly because of the still largely unknown influence of mixed-material layers on tritium retention and removal. This holds not only for corresponding data on the mixed layers themselves but also for their influence on these processes in the bulk material underneath. Additional experiments are required to fill the gaps in the respective data sets.

Project objectives

Formation and characterization of mixed material layers including chemical compounds and alloys that appear either by using different materials facing the plasma in the device either by using gaseous elements as impurities.

Complex characterization in order to identify the interfacial atomic diffusion, material mixtures and chemical phases in Be/W, and C/W bilayers. The research will be focused on the role of the thickness and growing order of the film components in the multilayer structure as well as on the thermal treatments and high pressure Ar, N_2, He gases on the above mentioned characteristics.

Investigation of phase formation, phase stability and structure of chemical phases in W-based compounds formed during reaction of tungsten and beryllium with other species from the plasma (e.g. H and its isotopes D, O, C and noble gases). Study concerning the retention mechanisms for H and its isotopes, He, Ne and surface composition, structure and temperature influence.

Also a great accent will be on aluminum use as beryllium substituent in fundamental studies regarding plasma-wall interaction.

Collection of data on fuel retention, fuel release and permeation from mixed surface layers with and without gas inclusions. Analysis of these layers by IBA (Ion Beam Analysis) is very important to determine film depth profile, gaseous inclusions like He, N, Ne and H isotopes. These data together with other structure and morphological analysis will give a complete image of the obtained thin films characteristics.

Detailed working schedule

- **Preparation of** ITER mixed materials seeded with specific gases as H isotopes, He, Ne, O by plasma co-deposition using the **Thermionic Vacuum Arc (TVA) method**. The substrates have different thicknesses and elemental relative concentrations of the type: **Be-C, Be-W, C-W, Al-W, Al-C seeded with the gaseous inclusions mentioned before.**
- Characterization of the prepared samples using Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), X-ray Photoelectron Spectroscopy (XPS), X-ray Diffraction (XRD)
- **Ion Beam Analysis (IBA)** to determine the elemental concentration of Be, C, W, Al as well as the gaseous inclusions. Also, **depth profile determination** is very important for these substrates to verify their homogeneity. It is important that the films have the same elemental relative concentrations on **their entire depth.**
- Studies on H isotopes trapping by nuclear reaction analysis (NRA) at IFIN-HH and release mechanisms by thermal desorption spectroscopy (TDS) within Low Temperature Plasma laboratory, NIPLRP.

Relevance to ITER

It is more or less clear that ITER walls will be all-metal, consist of separated area of Be and W. Tungsten/beryllium films will be formed due to W/Be erosion and followed deposition on any of both materials. For such new films hydrogen retention and diffusion parameters are unknown. This project will provide new basic data for more accurate modelling.

Also, the obtained results will be compared with the analysis performed on the witness samples from the anterior campaigns obtained during JET reactor (Joint European Torus) operation from Culham, UK. In the future, thin layers will be obtained using TVA method to give as accurate as possible the redeposited layers on witness samples from JET to analyze more detailed their behavior from ITER optimal operation point of view.

To accomplish the project goals, the following measurements will be carried out on 30 samples taken from JET fusion reactor and on 30 samples prepared at NIPLRP.

1. RBS, ERDA measurements: 10 days/ beam
2. NRA measurements: 15 days/ beam
3. PIXE measurements: 10 days/ beam

Data analysis and interpretation: 30 days.

Involved teams: NIPLRP, Low Temperature Plasma laboratory: 3 persons

IFIN-HH, laboratory…………….