IAEA FEC 201

Contribution ID: **270** Type: **Poster**

Retention and Release of Hydrogen Isotopes in Tungsten Plasma Facing Components: Understanding and Controlling with an Integrated Approach

Thursday, 20 October 2016 14:00 (4h 45m)

Fusion fuel trapping (retention) and release from plasma facing components (PFC) is one of the critical issues for ITER and for any future industrial demonstration reactor such as DEMO. Therefore, understanding fundamental mechanisms behind hydrogen isotopes retention in first wall materials is necessary. We developed an approach that couples dedicated experimental studies with modelling at all relevant scales, from microscopic elementary steps to macroscopic observables, in order: 1. to gain insight in the fundamental interactions between fusion fuel and wall materials; 2. to build a reliable and predictive fusion reactor walls model. This integrated approach is applied to tungsten first wall materials with an additional goal in mind: addressing the efficiency of a laser-based method to release in a controlled manner the retained fuel from PFC. Indeed, it remains to assess if thermal gradients involved in Laser Induced Desorption (LID) techniques could be beneficial or detrimental to the bulk distribution of trapped fuel.
In this contribution, a large set of complementary techniques (PAS, SEM, AES, NRA, TDS…) is used to shed light on the origin of fuel trapping. The experimental dataset is exploited to initialize parameters of a fusion reactor walls model under development. This model based on Macroscopic Rate Equations (MRE) includes all elementary steps: implantation of fusion fuel, defects creation, fuel diffusion in the bulk or towards the surface, fuel trapping on defects, release of trapped fuel during a thermal excursion of PFC. This MRE model is supported by a multi-scale description thanks to Density Functional Theory (DFT) and Object Kinetic Monte Carlo (OKMC) calculations.
Advances in the development of the MRE wall model are presented. In particular, we were able to unambiguously justify the use of a multi-trapping site model for tungsten by showing that a single trap type –single trapping energy model was not able to reproduce an extended parameter space study of a well characterized samples exhibiting a single desorption peak. Microscopic identification of the trap type responsible for fuel retention in tungsten is thus on the right track. This new macroscopic model is used for developing a new LID method aiming at depositing locally a controlled amount of laser radiation in order to induce the release of trapped fuel without damaging PFC.

Paper Number

TH/P6-26

Country or International Organization

France

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Session Classification: Poster 6

Track Classification: THD - Magnetic Confinement Theory and Modelling: Plasma–material interactions; divertors, limiters, SOL