Experimental advances to unveil the fundamental mechanisms of the interaction between charged particles and nuclear fusion relevant materials

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In future nuclear fusion reactors (e.g., ITER), the tungsten divertor will withstand expected hydrogen isotopes (HI) and helium (He) ion fluxes of 10^{24} m^{-2} s^{-1}. The interaction of the HI and He plasmas with tungsten can induce material modifications, from microscopic lattice defects to mesoscopic damages such as near-surface bubbles and surface blisters [1-3]. Such (near-)surface modifications can be responsible, for example, of an increased fuel inventory in the reactor walls [4] and affect the optical properties of tungsten due to both an increasing surface roughness and a change of electronic properties of implanted materials. A cursory knowledge of the evolution of the divertor's optical properties during plasma interaction represents a risk as it may lead to inaccurate thermography measurements of plasma-facing components during reactor operation [5,6]. The proper functioning of fusion reactor therefore seems to be linked to a better understanding of the fundamental mechanisms controlling the interaction of charged particles (HI and He ions) with tungsten.

In this contribution we discuss different experimental studies performed to understand the fundamental mechanisms of interaction between charged particles and nuclear fusion relevant materials. In particular, we focus on three aspects:

1) The study of the deuterium retention in pristine tungsten assessing the importance of tungsten natural defects, i.e. defects that are present in tungsten after manufacturing (grain boundaries, dislocations, vacancies, native oxide…) and before fusion plasma induced-damage. Here, we compare the retention behavior of deuterium in single-crystal tungsten and on recrystallized polycrystalline W samples [7-9]

2) The role of the He^+ flux in He retention on W(110) single crystal. The experimental results are benchmarked against modeling works [10, 11] and the different mechanisms behind He retention, i.e. He trapping around vacancies and He self-trapping, are discussed.

3) The study of negative ion surface production in hydrogen plasma in interaction with a low work function electride material focusing on the in-situ measurement of the material work function during plasma irradiation [12]. We discuss the potential interest of these experimental findings for fusion applications, e.g. Neutral Beam Injectors in tokamak.

The experimental results are obtained at the PIIM laboratory (Aix-Marseille University, CNRS, France) using an arsenal of plasma and surface science technics: ion mass and energy spectrometry analysis, temperature programmed desorption, Low Energy Electron Diffraction, Auger spectroscopy, X-ray and UV Photoelectron Spectroscopy.

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