Aix Marseille université	**Ecole Doctorale** **Physique et Sciences de la Matière**

Post doc position

Physique des Interactions Ioniques et Moléculaires laboratory (PIIM)
Aix Marseille University

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Interaction of helium plasmas with tungsten surfaces in the context of controlled thermonuclear fusion

The subject of this research is within the framework of nuclear fusion development. ITER, currently under construction at Cadarache, will be the largest fusion reactor (tokamak). ITER's main objective is to demonstrate the efficiency of plasma combustion through the fusion reactions between two isotopes of hydrogen, deuterium and tritium, producing a helium and a neutron. In tokamaks, despite the confinement of the plasma by intense magnetic fields, some ions escape this confinement and interact with the materials in contact with the plasma. One of the most important challenges for the success of nuclear fusion is the development of materials that can tolerate the following extreme conditions: high thermal load (20 MW to 100 MW.m-2) and high particle flux of H and He isotopes (10^{24} m-2.s-1) with a range of impact energies from eV to keV.

Tungsten (W) is currently considered the most promising material, particularly for the divertor component, which plays a key role in extracting excess heat and particles. Its appeal is mainly due to its low sputtering efficiency, high melting point (3410°C), high thermal conductivity and good thermomechanical properties. However, despite these advantages, there are serious concerns about helium-tungsten interaction in a fusion plasma environment. It has been shown that interaction with He significantly affects the surface and subsurface, with the formation of dislocation loops, nanobubbles or W nanotendrils (known as fuzz). These structures, particularly nanobubbles, can modify the thermomechanical properties and increase the retention of tritium in the material, two major concerns for next-generation reactors. In addition, the accumulation of helium in the bubbles, the destructuring of the surface and a possible sudden release of helium and W atoms by the bursting of the bubbles, modifying the wall and the plasma, generate new, unexplored plasma-wall interactions whose consequences for the operation of ITER must be anticipated.

The aim of the proposed experimental work is to study the properties of tungsten under He irradiation and, more specifically, to quantify the Helium trapped in the bubbles formed, which are a few nanometres in diameter. The first stages in the formation of He bubbles in the W, their dynamics and evolution under the effect of thermal cycles will be analysed at micro- and nanometric scales. To this end, a study including preparation and pre-characterisation of the W sample, exposure to a He plasma and post-exposure characterisation of the distribution of bubbles and their He content will be carried out at the PIIM laboratory. Experimental techniques dedicated to the study of surfaces from the H2M team (C. Martin) such as electron microscopy, electron diffraction, atomic force microscopy, optical measurements as well as plasma implantation experiments with in-situ diagnostics from the PS team (G. Cartry) will be implemented by the candidate.

A large number of experimental parameters, from the characteristics of the sample (quality of the W, crystalline orientation, defects, etc.) to the He plasma exposure conditions (ionic energy, flux, fluence, surface temperature, etc.) are influencing He bubble formation and make the interpretation of the basic mechanisms of microstructure evolution complex. After exposure to He, the He bubbles formed are generally pressurised (several GPa) and, according to Laplace's law, the He content (atomic density) should decrease in inverse proportion to the radius of the bubble. To date, this has never been confirmed for the He-W system. To meet this challenge, the quantitative determination of the density of He atoms inside a bubble and its comparison with the shape (spherical or facetted), size and formation conditions will be carried out using the STEM-electron energy loss spectroscopy (-EELS) technique. Measurement of the 1s2 → 1s2p transition of the trapped Helium and of the plasmon of the W on the same spectrum will enable the He-W system to be analysed on an atomic scale and to develop our understanding of the trapping of He and the modification of W.

The candidate should have a taste for experiments and data processing (images, spectra). He/she should also have knowledge of nuclear fusion, and/or solid state physics, and/or plasma physics.