Nanostructured materials under irradiation: their capabilities as plasma facing materials in fusion reactors

R. Gonzalez-Arrabal [1,2], A. Lopez-Cazalilla[3], C. Cupak[4], M. Fellinger[4], H. Biber[4], A. Redl[4], J. Garcia-Navas[1,2], F. Aumayr[4] and J. M. Perlado[1,2]

[1]Instituto de Fusión Nuclear y [2] Departamento de Ingeniería Energética, Universidad Politécnica de Madrid, 28006 Madrid, Spain
[3]Institute of Applied Physics, TU Wien, Fusion@ÖAW, 1040 Vienna, Austria
[4]Department of Physics, University of Helsinki, 00014 Helsinki, Finland
raquel.gonzalez.arrabal@upm.es

Nuclear fusion is a promising option for providing clean energy with high-power density and reliable power supply. There are two main approaches to fusion energy: magnetic confinement fusion (MCF) and inertial confinement fusion (ICF). Both of them have recently achieved important milestones, showing that we are on the right path to make fusion energy a reality. However, there are still some challenges which need to be addressed before going to commercial power plants. One of them is the development of plasma facing materials being able to withstand the harsh conditions taking place in these reactors (large thermal loads and radiation fluxes) [1].

So far, coarse-grained tungsten (CGW) is considered one of the most promising candidates as PFM in future fusion reactors since it fulfills most of the highly demanding requirements. However, it has important drawbacks, such as its ability to retain and to interact with light atomic species easily, mainly hydrogen and helium, which leads, among other fatal effects, to: fuzz formation [2], sputtering of the PFM surface, as well as surface blistering, cracking, and exfoliation [3]. Moreover, in the case of MCF, sputtering will additionally affect the energy confinement efficiency by introducing radiative losses which can result in interruption of the reactor operation. Therefore, there is a need to identify alternative materials with better radiation resistance than CGW.

Nanostructurization of W by introducing a large density of grain boundaries (GBs) and/or by producing engineered surfaces with a large surface area, such as needles and foams, have been shown to improve radiation resistance [4–9].

In this talk, based on experimental and multiscale computer simulation data, we will discuss the effectiveness of grain boundaries and free surfaces to release H and He atoms. We will also show the influence of surface finishing on the sputtering yield for W nanoneedles irradiated with low energy ions.

References

[1] R. Gonzalez-Arrabal *et al.* Matter and Radiation at Extremes. 5 (2020) 055201. https://doi.org/10.1063/5.0010954.
[2] G. Valles *et al.*, Journal of Nuclear Materials. 490 (2017) 108–114. https://doi.org/10.1016/j.jnucmat.2017.04.021.
[3] N.J. Dutta, *et al.* Journal of Nuclear Materials. 452 (2014) 51–56. https://doi.org/10.1016/j.jnucmat.2014.04.032.
[4] G. Valles *et al.* IActa Materialia. 122 (2017) 277–286. https://doi.org/10.1016/j.actamat.2016.10.007.
[5] M. Panizo Laiz *et al.* Nucl. Fusion. (2019). https://doi.org/10.1088/1741-4326/ab26e9.
[6] P. Díaz-Rodríguez *et al.* Emergent Mater. (2022). https://doi.org/10.1007/s42247-021-00344-w.
[7] D. Fernández-Pello *et al.* Journal of Nuclear Materials. 560 (2022) 153481. https://doi.org/10.1016/j.jnucmat.2021.153481.
[8] A. Rivera *et al.* Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms. 303 (2013) 81–83. https://doi.org/10.1016/j.nimb.2012.10.038.
[9] P. Díaz-Rodríguez *et al.* Nucl. Fusion. 60 (2020) 096017. https://doi.org/10.1088/1741-4326/aba092.