Efficacy of porous tungsten/liquid lithium as a Plasma Facing Component for fusion devices

A. Kapat, D. Curreli, F. Bedoya\textsuperscript{d}, K.B. Woller\textsuperscript{a}, J.P. Allain\textsuperscript{b}

\textit{University of Illinois at Urbana-Champaign, Champaign, IL 61820, USA}
\textsuperscript{a}Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
\textsuperscript{b}Pennsylvania State University, University Park, PA 16802, USA

Kapat2@illinois.edu

The high heat (10-15 MW/m\textsuperscript{2}) and particle fluxes (~10\textsuperscript{24} ions/m\textsuperscript{2}s) in future fusion devices [1] may restrict the lifetime and applicability of solid tungsten (W) due to recrystallization, changes in surface morphology, and erosion, which must stay below ~20ppm to prevent radiative cooling of the core. Material systems are under development that have the favorable bulk properties of W while reducing and recovering from the impact of Plasma-Material Interactions (PMI) on W by introducing an interfacial material that is compatible with both the impinging plasma as well as the structural W below the interface. One such system is a porous tungsten-liquid metal hybrid system, having the bulk, thermomechanical properties of a high defect sink (increased morphology threshold [2]) W foam [3], that has demonstrated such in an inertial fusion environment [4] while being a scaffold for a liquid metal (Li in the case of this study) with favorable PMI properties.

In this study, the feasibility of a hybrid material system composed of porous W, made via spark plasma sintering, and liquid lithium (Li) as plasma interface is examined. Liquid Li compatibility is tested two different ways. Surface stability is determined by static wetting angle measurements at surface temperatures from 200°C to 400°C in vacuum in the Materials Characterization Test Stand (MCATS) at the University of Illinois. Li deposition, percolation, and replenishment tests are done with \textit{in-operando} surface monitoring by ion scattering spectroscopy (ISS) and x-ray photoelectron spectroscopy (XPS) in the Ion Gas-Neutral Interactions with Surfaces (IGNIS) \textit{in-situ} Surface Science facility. Deuterium (D) inventory and depth profile in porous W that has been coated with a 1μm Li layer that is then melted is quantified with \textit{in-operando} nuclear reaction analysis (NRA) after 60 eV D\textsuperscript{+} plasma exposure to a fluence of 2E24 m\textsuperscript{-2}. The retention behaviour relative to Li percolation is quantified with \textit{in-operando} elastic recoil detection (ERD) as well as \textit{post-mortem} secondary ion mass spectrometry (SIMS). A 1-D model is used to study and quantify the extent of surface protection due to heat flux dissipation via a radiative vapor shield [5, 6].