High re-deposition ratio of high-Z metals under plasma exposure in Magnum-PSI

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Excessive core plasma contamination in ITER or DEMO by erosion and inward transport of impurities from plasma facing components (PFCs) will lead to an undesirable reduction in fusion power. This therefore provides an upper limit on the gross impurity flux from the wall materials entering the core plasma. A high local re-deposition rate of eroded material can minimize core impurities and increase the lifetime of a PFC by reducing the net erosion rate. Until now there was rather limited experimental data on the localized re-deposition rate measured under ITER/DEMO divertor relevant plasma fluxes, where very high incoming particle fluxes and low ion and electron temperatures are anticipated. In this work dedicated studies to investigate the re-deposition ratio of several different metals (copper (Cu), molybdenum (Mo) and tin (Sn)) under a high flux plasma beam were carried out in Magnum-PSI [1]. Sn is considered as a prospective material for use in a liquid metal divertor in DEMO and previously indicated a high re-deposition rate [2,3]. Cu was chosen as a metal with a relatively high sputtering yield and which can visually indicate the presence of impurities on its surface, while Mo was used as a reference where sputtering should be negligible.
Samples were exposed to high particle fluxes of 0.3–8.5x10^{23} m^{-2}s^{-1} (B=0.2-1.0 T) in argon and helium plasmas with electron temperatures in the range 0.6–2.1 eV and with ion energies ranging from 38 to 59 eV. X-ray Photoelectron Spectroscopy identified that Mo from the clamping ring was the predominant impurity deposited, while Rutherford Backscattering Spectroscopy was used to determine the total mass gain from this deposition. Controlling for this impurity deposition, the re-deposition rate was determined via two methods: mass loss measured by micro-balance after exposures and mass gain on a quartz crystal microbalance measured during exposures. Both demonstrated a high level of consistency. For both Cu and Sn re-deposition rates greater than 99% were determined at high flux while Mo showed negligible erosion as expected. Considering the high plasma density and low electron temperatures plasma entrainment of neutral impurities is considered the most likely process which could cause such a high re-deposition rate, and mean free paths of a few mm are estimated. Such high rates imply that large gross erosion rates could be acceptable in DEMO. Particularly in the case where evaporation is the dominant erosion mechanism, which is the case for liquid metals such as lithium (Li) and tin (Sn), such a high re-deposition rate could also increase the temperature window for operation of such a PFC [4].

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