Study the erosion of RAFM steels with the linear plasma device GyM

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The use of bare reduced activation ferritic martensitic (RAFM) steels, like Eurofer-97, has recently been envisaged as a possible option for the recessed elements of the first-wall of DEMO. The erosion by hydrogenic charge-exchange neutrals (CXNs) can significantly affect the lifetime of these components and needs to be assessed properly \cite{1}. RAFM steels are iron-based alloys containing small amounts of high-Z elements like tungsten, W (\approx 0.4 \text{ at.\%} for Eurofer-97). The erosion behavior of RAFM steels, being multi-component alloys, is non-trivial. First, the different alloy components are eroded differently by hydrogenic particles. Second, depending upon temperature, the onset of thermal diffusion and segregation of the different elements can occur. The interplay of selective erosion and thermal effects may significantly change the composition and morphology of the RAFM steels surface, resulting in a sputtering yield, Y, far from that of the pristine samples.

Present work reports on the investigation of the RAFM steels erosion behavior when exposed to the deuterium plasma in the GyM linear device. Ion flux in GyM of $10^{20}$-$10^{21}$ ions m$^{-2}$s$^{-1}$ is suitable to simulate the CXNs flux impinging on the recessed components of the DEMO first-wall. In particular, the erosion dependence of RAFM steels on the deuterium ions fluence, $\Phi$ ($\leq 10^{25}$ ions m$^{-2}$), energy (100-300 eV/ion), and temperature of the samples, $T$ ($\leq 1000$ K), was addressed. Iron-tungsten coatings, model system of RAFM steels, were considered first \cite{2}. The attention was then shifted to the more complex and most prominent Eurofer-97. As a comparison, the erosion of the ferritic Hiperfer (and Crofer) steel, also interesting for nuclear fusion applications, has been also recently investigated. The (flat/polished) specimens were deeply characterized both before and after the exposure. The sputtering yield was evaluated by profilometry and mass loss. SEM and AFM were used to study the evolution of morphology and roughness of the specimens. Compositional changes were investigated by means of a wide range of surface analysis techniques featuring different depth and lateral resolutions: ToF-SIMS, XPS, EDXS, RBS and LEIS. Considering Eurofer-97, we found that the sputtering yield significantly changes with the plasma fluence and sample temperature, as expected. However, the peculiar behavior of Y with $\Phi$ and $T$ is subtly related to the morphological evolution of the samples. SEM-EDXS showed the development of a “corral-like” morphology with W-enriched dendrites whose size clearly increases with the temperature of the sample, at the expance of a lower coverage, reaching a height of $\sim 1$ µm at the maximum $T$ and $\Phi$. A compositional change of the surface layers of the exposed Eurofer-97 specimens, with a strong W-enrichment, was concurrently detected using different surface techniques. An attempt to compare the results of the different methods was carried out and here presented.


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