Effect of the presence of He in Fe-based materials on the D retention at low and high flux/fluences

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In a thermonuclear reactor, materials will be irradiated with hydrogen isotopes and helium (He), neutrons, and heat fluxes. The possibility of using reduced-activated ferrite-martensitic, RAFM, steels not only as structural materials, but also as the plasma-facing material in some places of the thermonuclear reactor is considered. Also, these steels, together with a new generation oxide dispersion strengthening (ODS) steels by the addition of Y2O3 particles are considered as promising materials for fast neutron fuel cladding. In this regard, the study of the accumulation of He and deuterium (D) in RAFM steels and surface modification under the plasma irradiation is critical for the design of materials in fusion reactors. In this work, we investigate the influence of initial structure and chemical composition of RAFM steels on the accumulation of He and its effect on the D retention under various experimental conditions (ion energy from 20 eV to 3 keV, temperature of 300-700 K and flux/fluence of 10^{17}-10^{21} at/m2s/10^{19}-10^{25} at/m2). It was shown that the accumulation of deuterium in ODS steels is higher compared to Eurofer because of the high density of nanoparticles and smaller grain size. It is shown that the retention and migration of D in steels is determined by the conditions on the surface of steels. At energies higher than the sputtering threshold (>50 eV) and fluence above 10^{23} D/m^2, nano-structured near-surface layers are formed, enriched with tungsten due to the preferential sputtering of light elements with low atomic number and radiation-induced segregation. Such nano-structured near-surface layers enriched with tungsten are formed on all types of investigated steels, regardless of the Cr concentration or the presence of yttrium oxide nanoparticles. However, no formation of such structure at low flux/fluences is observed. The sputtering coefficient was found as a function of temperature and ion flux and fluence. The co-implantation of D and He ions increases the surface modifications. Both the sputtering and the presence of He in steels modify the surface layer of steels and lead to a decrease in D accumulation at high flux/fluences. However, the presence of He increases the D retention at low D fluences. It was found that the retention of D was the higher for steels irradiated with a plasma gun after 10 pulses (mimicking the ELM's-like events) compared to the D retention after stationary low-energy plasma exposure, which indicates the dominant effect of ELM-like events on the retention of D compared to normal operation regime. The effect of He on the D retention at various experimental conditions is discussed.