Removal of hydrogen isotopes from plasma-facing components in controlled fusion devices: an overview of methods for ITER

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Reduction of tritium inventory in plasma-facing components (PFC) is one of the most urgent and challenging tasks to be resolved to ensure the safe and efficient operation of a reactor-class fusion device, e.g. ITER. The most serious efforts are concentrated on fuel removal from carbon-based material. They have excellent power handling capabilities but chemical reactivity of H isotopes with carbon causes its erosion, migration in the form of hydrocarbons and, as consequence, fuel accumulation in C-D(T) layers co-deposited on PFC.

This contribution provides an overview of results obtained with several cleaning techniques tested over the years both on laboratory-prepared layers and on PFC from the TEXTOR tokamak : (a) chemical methods based on oxidative or nitrogen-assisted plasma; (b) photonic methods based on laser-induces fuel desorption or ablation of co-deposits; (c) thermal desorption (annealing) in vacuum or oxidative atmosphere at a broad range of temperatures. The emphasis was on three outstanding issues associated with every technique aiming at the reduction of fuel content: the efficiency of removal, the surface state of PFC following the treatment and dust generation. Major results are summarized as follows:

(i) Annealing in vacuum leads to effective fuel removal only at temperatures exceeding 1000 K; the process leads also to disintegration and flaking of the co-deposited layer.

(ii) During the oxygen glow in TEXTOR at wall temperature ~470 K, the laboratory-prepared carbonised layers are decomposed very efficiently: D and C contents are decreased by a factor of 50 and 20, respectively. However, the decomposition of co-deposits on PFC is much efficient as is strongly depends on the overall composition of mixed layer which, besides D and C, contain boron and metals originally eroded from the torus wall.

(iii) The H_2-N_2 glow assisted by ion cyclotron resonance pulses in TEXTOR at wall temperature ~470 K, does not reduce the fuel content.

(iv) Photonic cleaning effectively removes co-deposit and fuel but it also generates substantial amounts of dust.

The results show that to satisfy safety requirements fuel removal must be accompanied by dust removal. Implications of these results for in-vessel components (e.g.diagnostic first mirrors) in the next step machine will be discussed.