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Hydrogen isotope exchange in tungsten irradiated sequentially to low-energy deuterium and protium ions

V.Kh. Alimov[1,2], B. Tyburska-Püschel[3], M.H.J. 't Hoen[4], J. Roth[3], Y. Hatano[1], K. Isobe[2], M. Matsuyama[1], T. Yamanishi[2]

[1]Hydrogen Isotope Research Centre, University of Toyama, Toyama 930-8555, Japan, Japan

[2]Tritium Technology Group, Japan Atomic Energy Agency, Tokai, Ibaraki, 319-1195

[3]Max-Planck-Institute for Plasma Physics, Boltzmannstraße 2, D-85748 Garching, Germany

[4]Institute for Plasma Physics Rijnhuizen, EURATOM-FOM, NL-3439 MN Nieuwegein, The Netherlands

Motivation

- Tungsten is foreseen as a plasma-facing material in fusion devices, such as ITER, DEMO.
- Tritium inventory in W materials exposed to thermonuclear D-T plasma would get close to the tritium safety limit in ITER and require removal of the retained tritium.
- One of possible ways to recover the retained tritium might be hydrogen isotope exchange.
- Hydrogen isotope exchange in W after sequential exposure to low-energy D and H plasmas and after sequential irradiation with low-energy D and H ions was studied in this work.

Summary

- It has been found that a major portion of deuterium initially accumulated in the D-implanted W is released under subsequent exposure to the H plasma or irradiated with the H ions.
- Depth profiling of D without and with subsequent H implantation shows strong replacement close to the surface near room temperatures, but extending to all analyzable depths at elevated temperatures.
- It may be suggested that the replacement processes occur both in vacancies and on the surface of pressurized cavities/cracks.
- A stress and high concentration of hydrogen atoms in the solute state maintained by the hydrogen ion irradiation are driving forces for the hydrogen replacement

Samples: polycrystalline ITER-grade W (A.L.M.T. Corp., Japan)

D(H) ion energy … 38 eV/D(H) D(H) ion fluence ……….. 10^{26} D(H)/m^2

D(H) ion flux …… 10^{22} D(H)/m^{2}s Exposure temperature ... 330-725 K

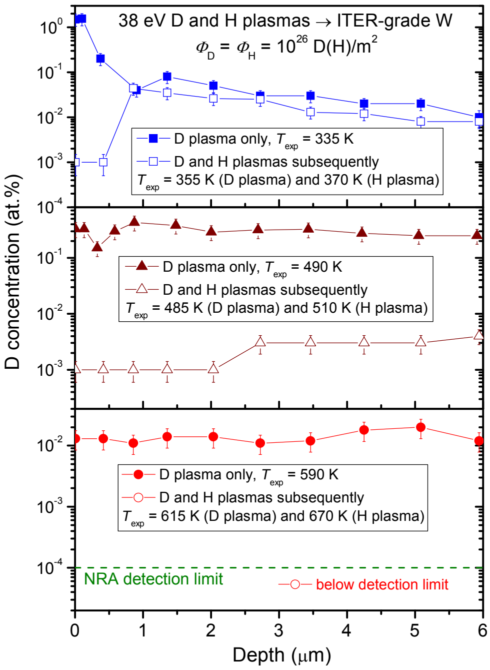
Samples: polycrystalline hot-rolled W (Plansee)

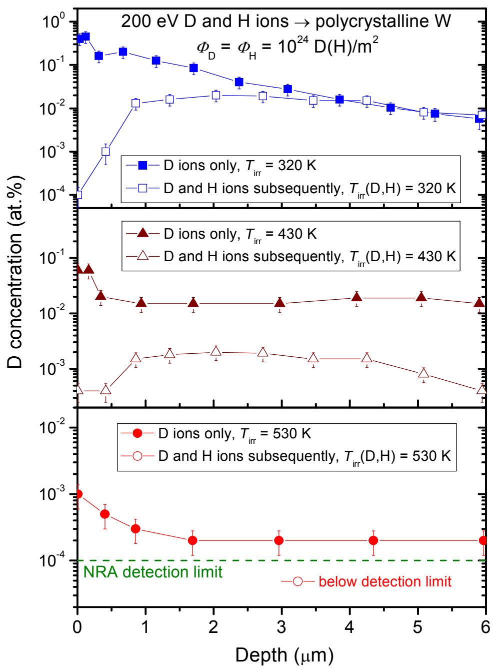
D(H) ion energy …. 200 eV/D(H) D(H) ion fluence ……….. 10^{24} D(H)/m^2

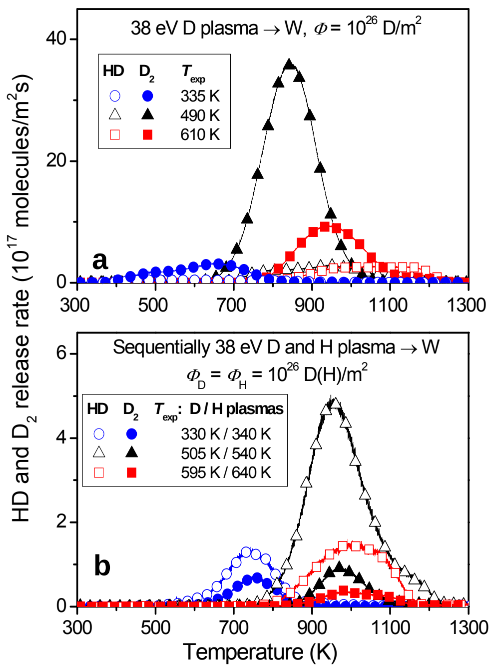
D(H) ion flux ……… 4×10^{19} D(H)/m^{2}s Exposure temperature ... 320-530 K

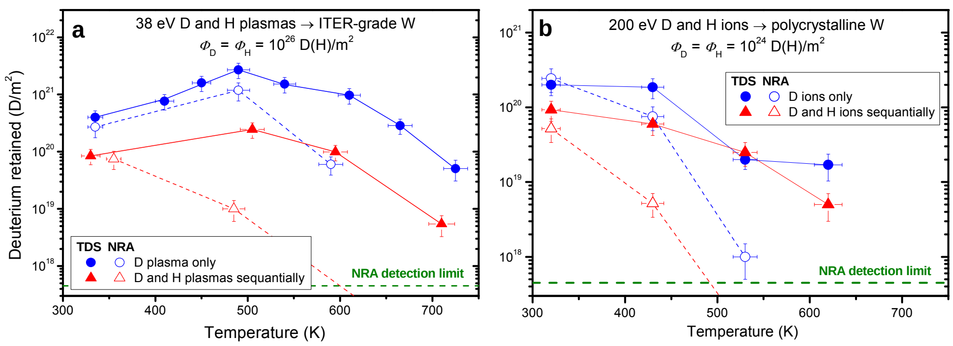
Investigation techniques

- D retention was determined by thermal desorption spectroscopy;
- D depth profiles were measured by the D(^{3}He,p)^{4}He nuclear reaction at a ^{3}He energy varied from 0.69 to 4.0 MeV allowing determination of the D concentration at depths up to 6 μm .
- Surface morphology was analyzed by scanning electron microscopy.









Results

- After D plasma exposure or D ion irradiation, deuterium is accumulated at depths of several micrometers, whereas the deuterium implantation range is several nanometers. The D concentration at depths of several micrometers reaches relatively high values of 0.01-1 at.%.
- The high D concentration and formation of blisters on the W surface suggest that a major part of deuterium is accumulated in the molecular form inside cavities
- A major fraction of deuterium initially accumulated in W is released under subsequent exposure to H plasma or irradiation with H ions.
- At near room temperature, the deuterium depletion is found at depths up to 1-2 μm.
- At exposure/irradiation temperatures above 430 K, the release of deuterium occurs from depths up to 6 μm and deeper layers.
- After exposure to D plasma, deuterium is thermally released in the form of D_2 molecules mainly.
- After sequential exposure to D and H plasmas, deuterium is release in the form of HD molecules.