Deuterium retention in various pre-damaged tungsten materials as a function of the exposure temperature

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Motivation

- During Iter operation, 14 MeV fusion neutrons will not only introduce new traps for tritium in tungsten but also will transmute W into a compound containing about 3% Re after one year.
- To account for these effects, deuterium retention in different batches of damaged tungsten materials exposed to D plasma has been investigated as a function of the exposure temperature.
- Based on these results, the dependence of the D concentration in the radiation-induced defects on the exposure temperature was obtained for W materials and 97W-3Re compound.

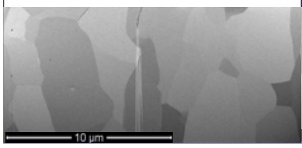
Experiment

- All samples were self-irradiated above the saturation dpa (displacements per atom) level for D retention, i.e. 0.25 dpa (for E_{th} = 90 eV), using 20 MeV W ions
- The pre-damaged samples were exposed to high-flux, low-energy D plasma at various temperatures ranging from 350 to 750 K.
- The deuterium depth profiles were measured by means of NRA using the D(^{3}He,α)p reaction. The trap density was determined in the damaged zone.
- The total D retention was measured by TDS.

Materials

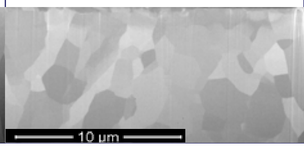
Plansee Iter-grade → **P-IG**

- grains perpendicular to the surface
- grain size 1-10 μm
- mechanically polished and outgassed at 1200 K for 2 h



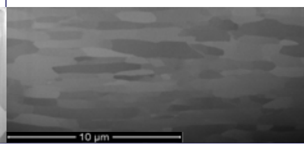
Japanese Iter-grade W → **J-IG**

- grains quasi-perpendicular to the surface
- grain size 1-5 μm
- mechanically polished and outgassed at 1470 K for 30 min



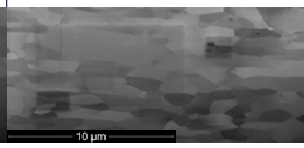
MF-Standard → **MF-W**

- grains parallel to the surface
- grains size 1×(2-5) μm
- mechanically polished and outgassed at 1200 K for 2 h



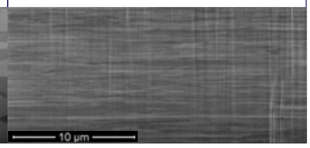
Goodfellow → **GW**

- grains parallel to the surface
- structure and grain size similar to MF-W
- mechanically polished and outgassed at 1200 K for 2 h



Goodfellow 3% Re → **GW-Re**

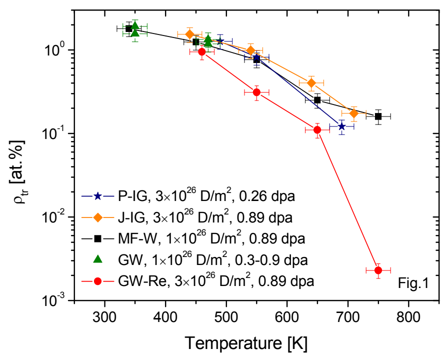
- grains parallel to the surface
- grains are much thinner than in MF-W and GW
- foils 50 μm → no polishing, no thermal treatment



Results

Assumptions : all traps are populated, one trap corresponds to one D atom.

Trap density, ρ_{tr}, dependence on the exposure temperature



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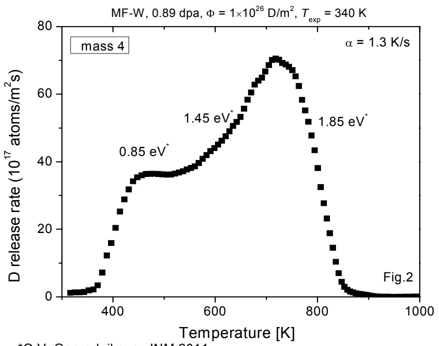
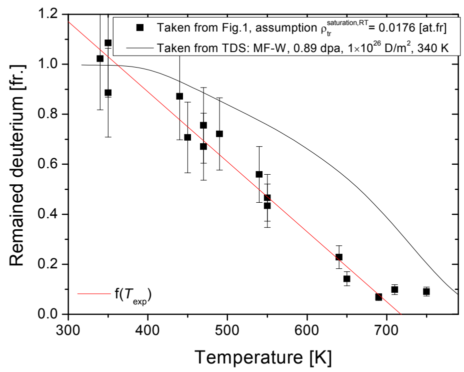


*O.V. Ogorodnikova, JNM 2011

⇒



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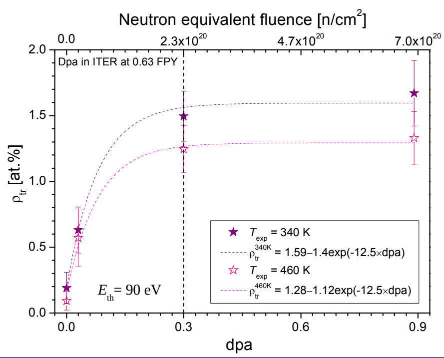
ρ_{tr} dependence on the exposure time (dpa)



⇒

$$\rho_{tr}(t, T_{exp}) = \rho_{tr}^{saturation,RT} \cdot f(T_{exp}) - 1.4 \cdot f(T_{exp}) \cdot exp\left[-12.5 \times \frac{N_d \Phi_n^{flux} t}{\underbrace{N_W}_{\text{dpa}}}\right]$$

$\rho_{tr}^{saturation,RT}$ – ρ_{tr} measured at saturation dpa at RT

$N_d \left[\frac{10^7 \text{displ}}{\text{ion}\cdot\text{m}}\right]$ – no. of displacements

Φ_n^{flux} – neutron flux

N_W – tungsten density

$$f(T_{exp}) = 2.01 - 0.0028 \times T_{exp}$$

[1] J.C. He et al., JNM 377 (2008) 348–351
[2] B. Tyburska et al., JNM 395 (2009) 150–155
[3] A.V. Golubeva et al. JNM 363–365 (2007) 893–897

Summary

- The results indicate that in all materials investigated , D concentration in the radiation-induced defects decreases with increasing exposure temperature.
- In all samples but these with Re, the D concentration is comparable, but for 97W-3Re targets it drops somewhat faster with temperature, a behavior which was not observed in undamaged W containing Re [3].
- The reason for that can be found in TEM observations of neutron-irradiated pure and Re-containing tungsten [1]. These studies show that in the presence of even small amounts of rhenium, the number of defects created during damaging is lower in comparison with pure tungsten.
- Based on these and our previous studies [2], we derived a function for the trap density dependence on the plasma exposure time and wall temperature which can be used for a tritium inventory prediction for Iter.

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