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Deuterium Retention in Tungsten-rhenium Alloy

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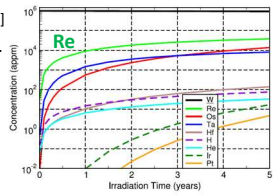
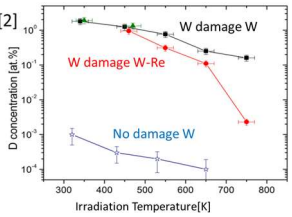
Background

- In fusion reactor, tungsten(W) transmutate into rhenium(Re) [1]
- Neutron irradiation causes displacement damage. Neutron damage is formed in the tungsten(W) and hydrogen isotope in W increase
- It is known that hydrogen isotope retention in damaged W sample increase two order of magnitude by without damaged W sample
- Hydrogen isotope retention in damaged W-Re is smaller than damaged pure W at higher temperature (T > 700 K)



[2]



The average of hydrogen isotope concentration up to 2 μm

Purpose

- Clarify the temperature dependence of hydrogen isotope retention in W-Re without displacement damage
- Clarify the Re concentration dependence of hydrogen isotope retention in W-Re with displacement damage

Summary

- Temperature dependence
  - T = 563 K
    Deuterium retention in W-3 wt.%Re and pure W were about the same
  - T = 663 K
    Deuterium retention in W-3 wt.%Re was about 6 times higher than pure W
- Re concentration dependence
  - Undamaged sample
    Inclusion of 0.1 – 5 % Re concentration resulted in 30 % reduction in deuterium retention
  - Fe^{3+} damaged sample
    Deuterium retention depended very weakly on Re concentration

Experimental

Pure W & W-Re alloy sample

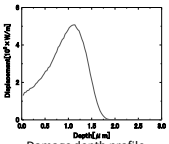
Without displacement damaged sample
- Hot-rolling (11 orientation), Re concentration: Re 3 wt.%
- Mechanically polished and annealed at 1173 K for 1 hour

With displacement damaged sample
- Re concentration : Re 0.1 wt.%, Re 1 wt.%, Re 5 wt.%
- Mechanically polished and annealed at 1173 K for 1 hour

Fe^{3+} irradiation damage in DuET at Kyoto Univ
- Incident energy : 6.4 MeV
- Irradiation Temperature : 573 K
- Damage : 0.5 dpa

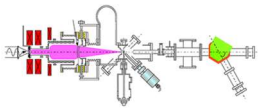
Neutron irradiation damage in CLLISTO at BR2
- Irradiation Temperature : 563 K
- Damage : 0.06 dpa
- Sample number : 13M-(31-32)BR

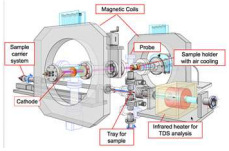
DuET facility



Damage depth profile

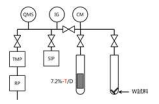
Deuterium Implantation
- D ion irradiation in HiFIT at Osaka Univ
- Ion Energy : 1 keV, Flux : ~10^{20} D m^{-2} s^{-1}
- Fluence : 1 x 10^{24} D m^{-2}, Temperature : 363 – 663 K
- D plasma exposure in CDPS at Tohoku Univ
- Bias : -110 V, Flux : ~3 x 10^{21} D m^{-2} s^{-1}
- Fluence : 1.2 x 10^{25} D m^{-2}, Temperature : 563 K





Deuterium retention measurement by Thermal desorption system(TDS)
- Temperature : RT ~ 1173 K, Heating speed : 0.1 K/s
- Temperature : RT ~ 1473 K, Heating speed : 0.5 K/s

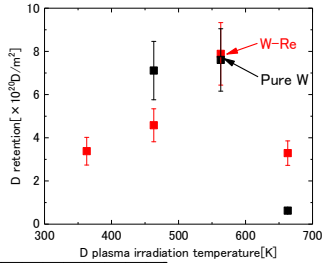
Tritium depth profile
- Tritium gas exposure temperature : 473 K, Etching : NaOH,
- Tritium intensity measurement : Imaging plate



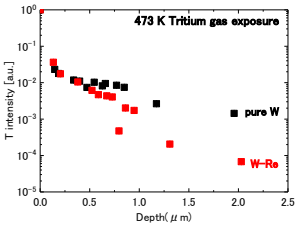
Results

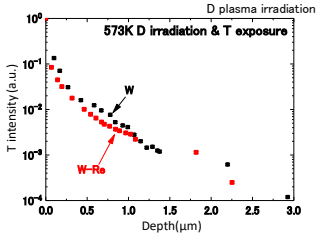
Without displacement damage

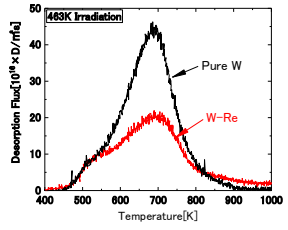
Temperature dependence
- At T = 463 K: D retention in W- 3 % Re is 50 % compared to pure W
- At T = 563 K: D retention in W- 3 % Re and pure W are about the same
- At T = 663 K: D retention in W- 3 % Re was about 6 times higher than pure W

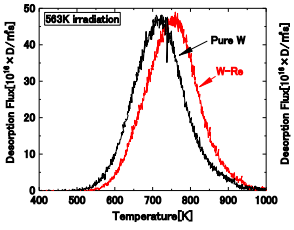


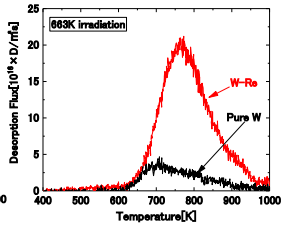
TDS spectrum & Tritium depth profile









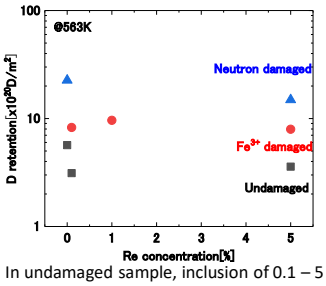


- At T = 463 K
  - ・At thermal desorption peak temperature, W-Re sample's desorption flux is 50 % compared to pure W
  - ・Decrease rate of the Tritium signal intensity is larger than W-Re as compared with W
- At T = 563 K
  - ・TDS spectrum of W-Re is shifted to the high temperature side as a whole compared to pure W.
- At T = 663K
  - ・At thermal desorption peak temperature, desorption flux of W-Re is 6 times higher than pure W

It is considered deuterium trapping energy of W-Re is higher than pure W

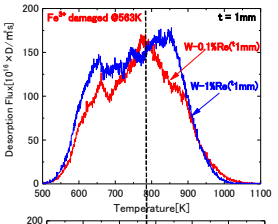
With displacement damage

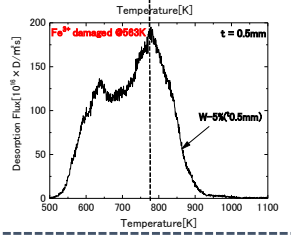
Re concentration dependence



- In undamaged sample, inclusion of 0.1 – 5 % Re concentration results in 30 % reduction in deuterium retention
- In the Fe^{3+} damaged Re-doped sample, deuterium retention depends very weakly on Re concentration

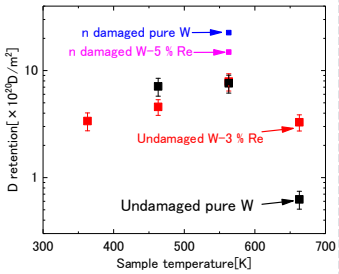
TDS spectrum





- Two temperature peaks can be seen regardless of the Re concentration.
- For samples with a thickness of 1 mm, the D release flux continues to the higher temperature side than the sample with a thickness of 0.5mm. This is thought to be due to the thickness of the sample.

Comparison between damaged and undamaged



- At T = 563 K
  - In undamaged sample, D retention in W- 3 %Re and pure W are about the same
  - In neutron damaged sample, D retention in neutron damaged W- 5 % Re is 60 % compared to pure W

Reference

[1] M.R. Gilbert and J.-Ch. Sublet, Nucl. Fusion **51** (2011) 043005 (13pp)
[2] Fei Ren, Journal of Nuclear Materials 491 (2017) 206-212

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