Deuterium retention of carbon-tungsten mixed materials

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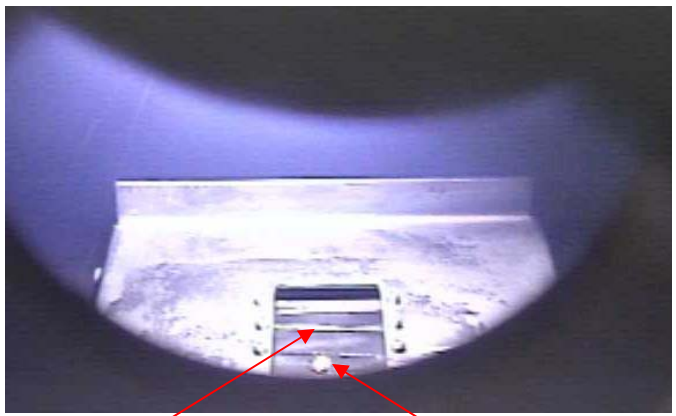
Workshop Agenda

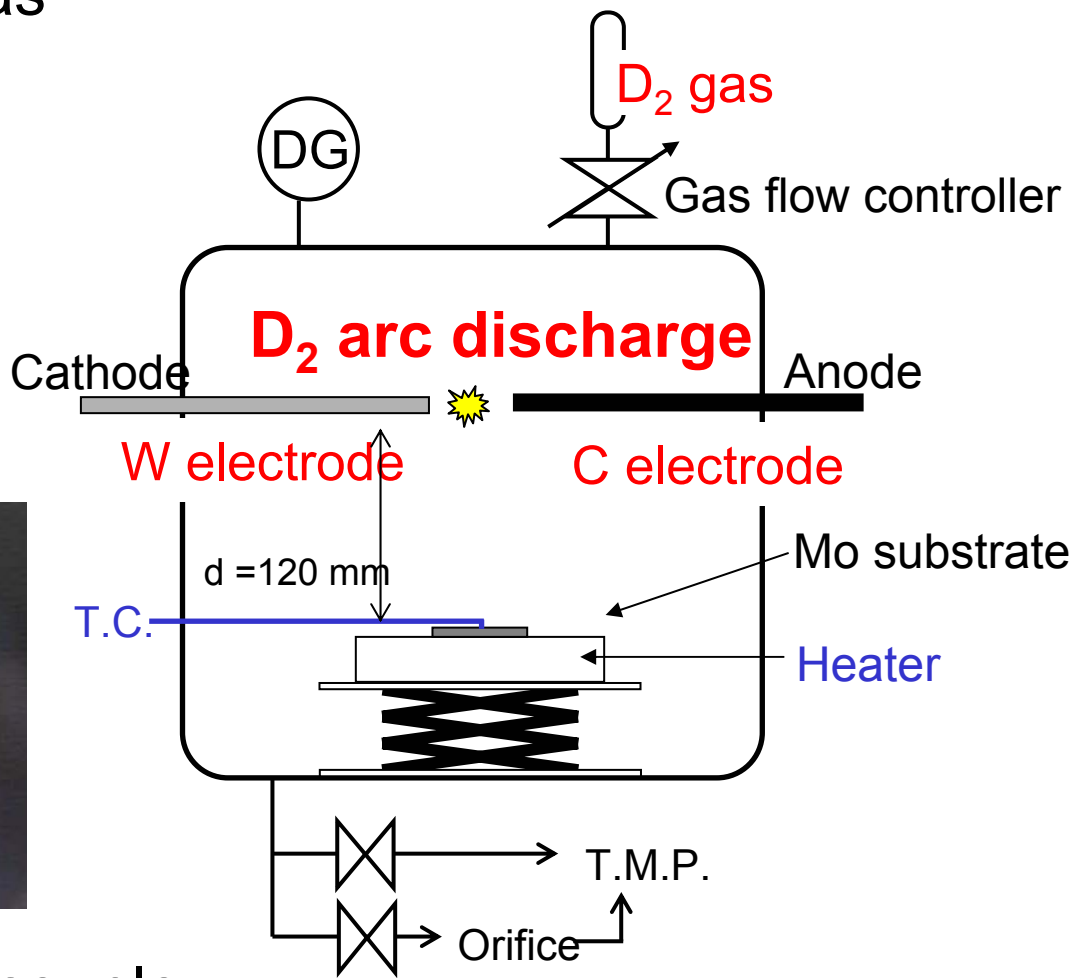
Objectives

- In the EDA of ITER, tritium retention of carbon materials has been investigated and evaluated.
- However, major tritium retention source of ITER is considered to be an in-vessel carbon dust, which is co-deposited with tungsten materials.
- The objective of this study is to characterize the tritium(deuterium) retention of the carbon-tungsten mixed material, which gives more realistic tritium retention of the in-vessel dust in ITER.

Experimental apparatus

- C-W mixed material was produced by D_2 arc discharge.
  - Arc current : 70 A
  - Arc voltage : 16-17 V





Test procedure

1. Surface polish of Mo substrate
2. Degassing of Mo substrate at 900^{o}C for 10 min
3. Arc discharge(Two Mo substrates at a time)
4. Weight measurement of both substrate(→ deposition amount)

5. Deuterium retention estimation by TDS
5. Characterization
   - 5-1 C-W atomic ratio by AES
   - 5-2 Surface morphology by SEM
   - 5-3 Crystal structure of carbon by Raman spectroscopy

Test sample

- C/W atomic ratio → 78/22 ~ 37/63
- Substrate temperature → RT ~ 873 K
- Deuterium gas pressure → 1 ~ 21 Pa

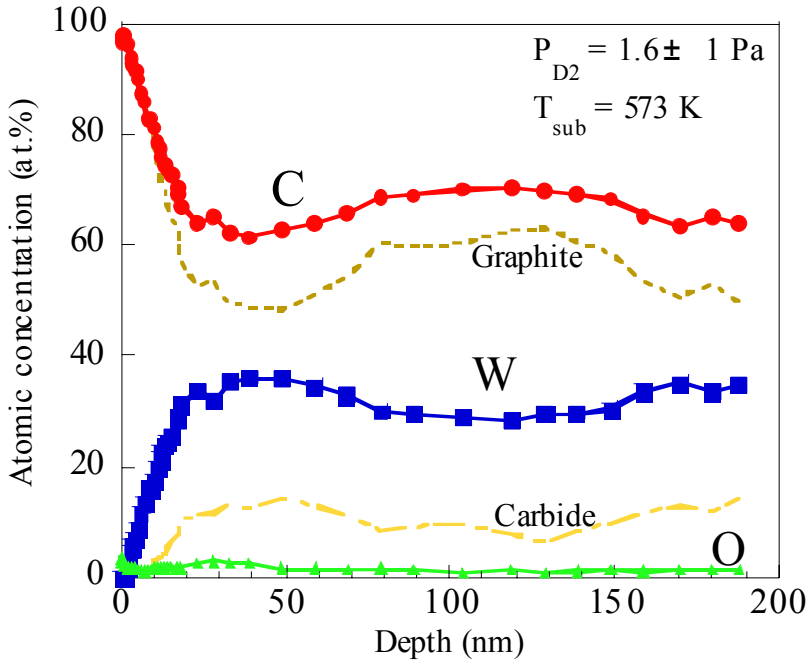
Carbon dust (C/W=100/0) was also prepared as a reference.

Particle flux → C-W mixed material : ~10^{19}(atoms/m^2/s)
Carbon dust : ~10^{20} (atoms/m^2/s)
at a deuterium flux of 10^{21} ~ 10^{22} (atoms/m^2/s)

Energy → Arc discharge voltage : 16 ~ 17 V
Carbon and tungsten : several eV
(mainly sublimation)

- Atomic ratio and surface morphology -

C/W atomic ratio by AES

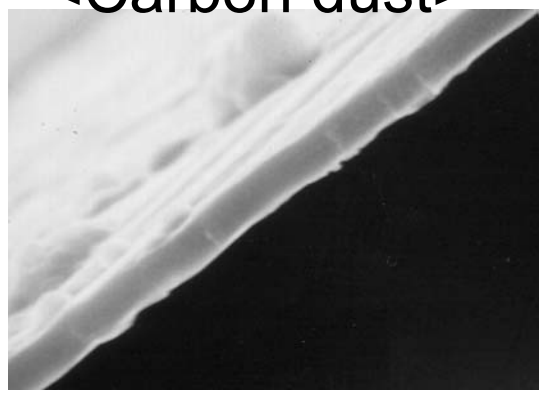


The C-W mixed material was successfully produced by the D_2 arc discharge method.

Surface morphology by SEM

<C-W mixed material>

<Carbon dust>

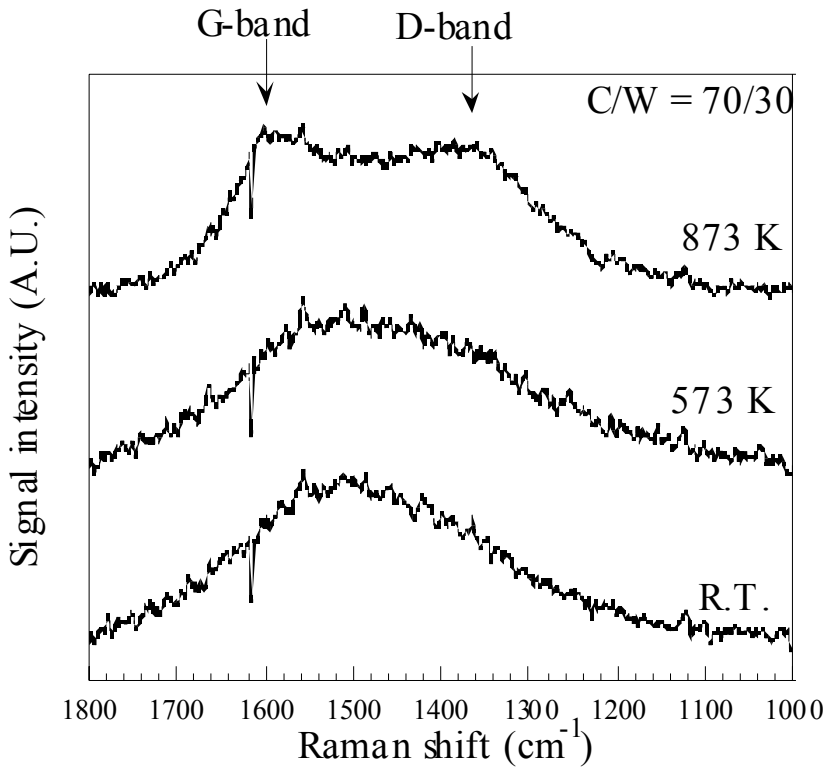


↕ 1 μ m

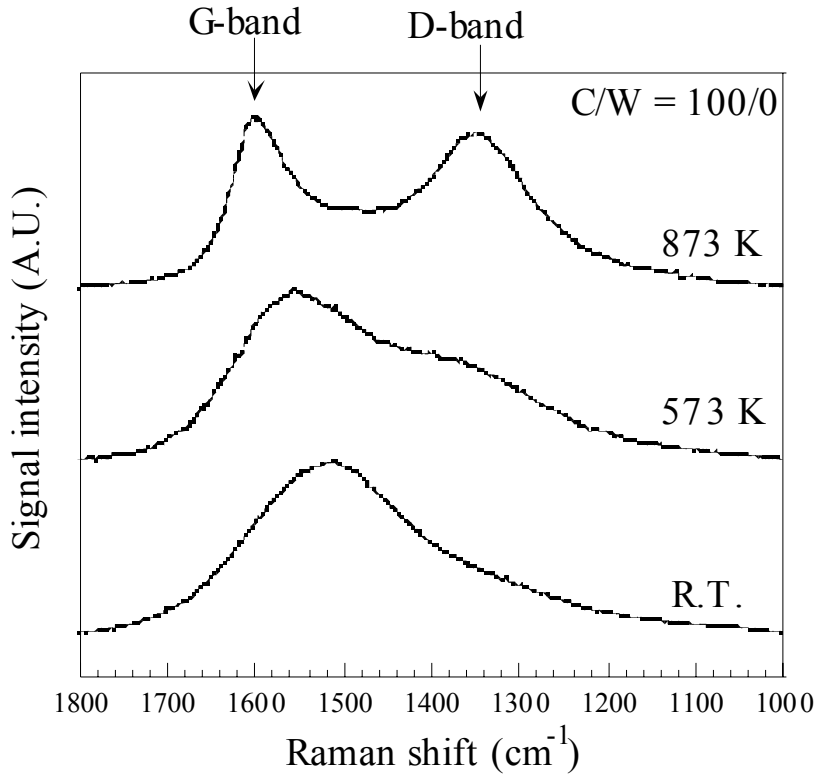
Dense film with 0.5μm thickness was obtained in both case.

- Result of Raman spectroscopy -

C-W mixed material



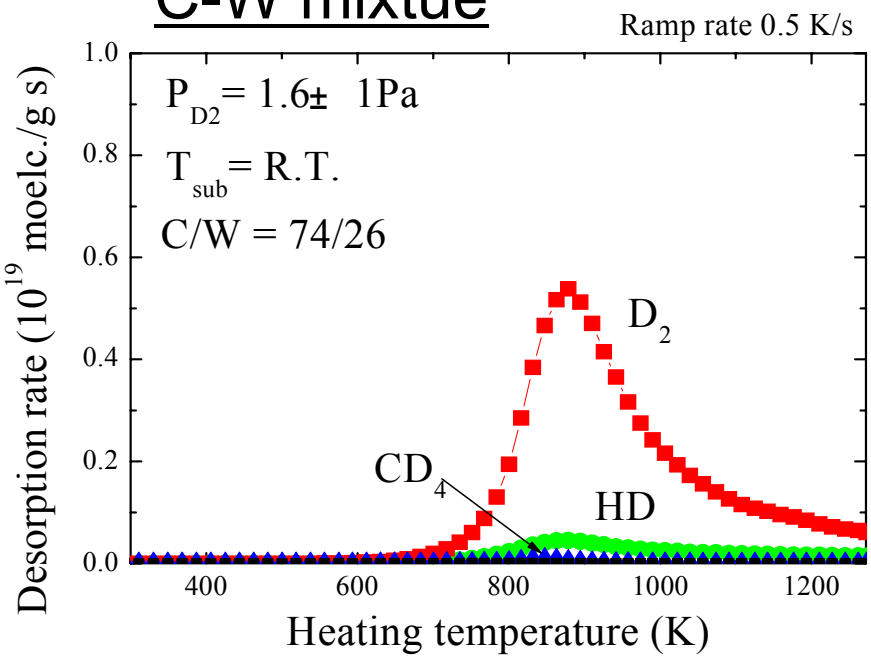
Carbon dust



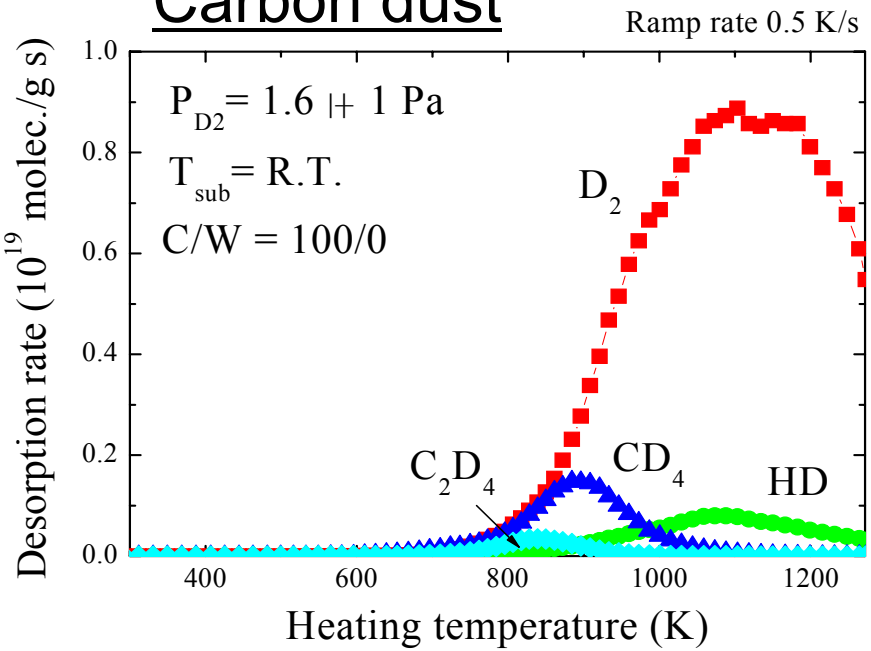
- The higher substrate temperature causes more graphitization in both materials.
- D-band of the C-W mixed material is broader than the carbon dust, which means that there is more defect structure in the C-W mixed material.

Deuterium retention - TDS spectra -

C-W mixtue

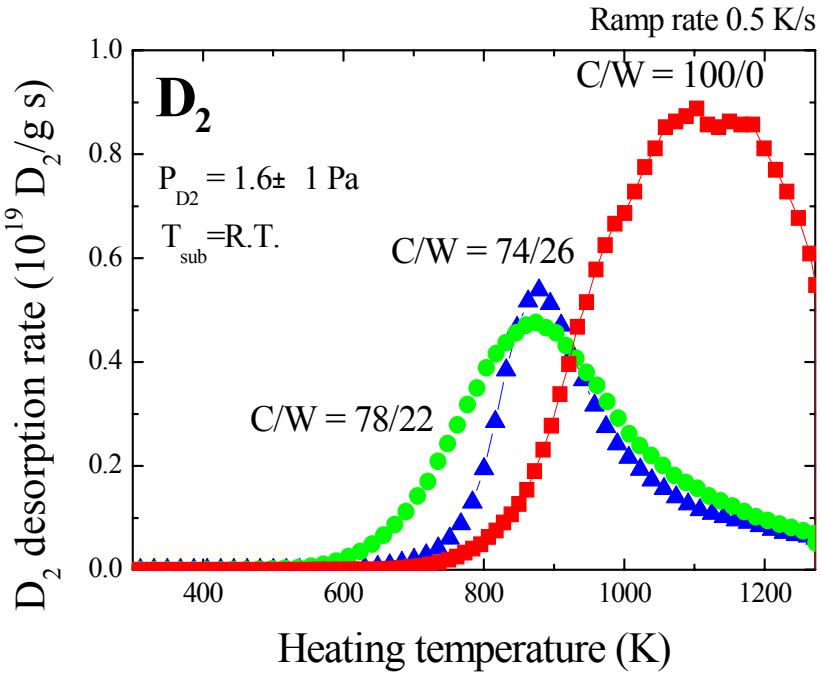


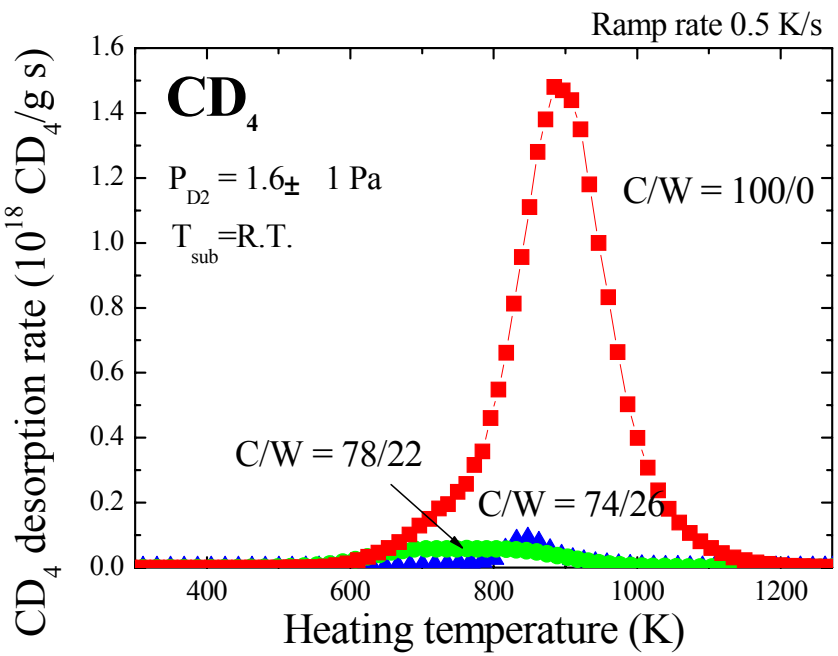
Carbon dust



1. The C-W mixed material has lower peak desorption temperature than the carbon dust. (1100 K → 850 K)
2. The hydro-carbon desorption of the C-W mixed material is about 1/10 of the carbon dust.

Deuterium retention
- Dependency on C/W ratio 1 -



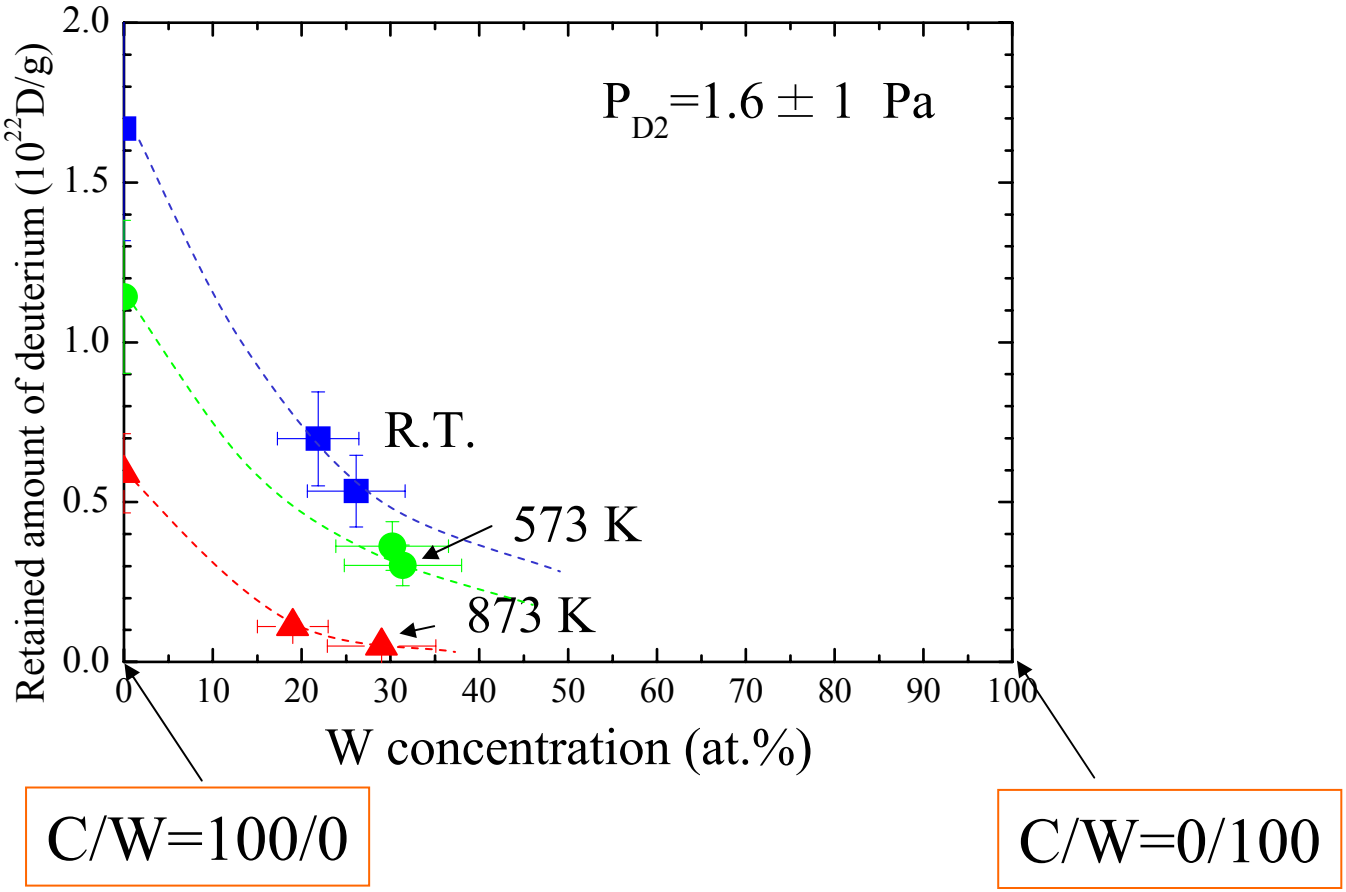


The more the tungsten ratio,

1. the less the FWHM of D_2 peak.
2. the lower the desorption temperature of D_2.
3. the less the desortion of CD_4.

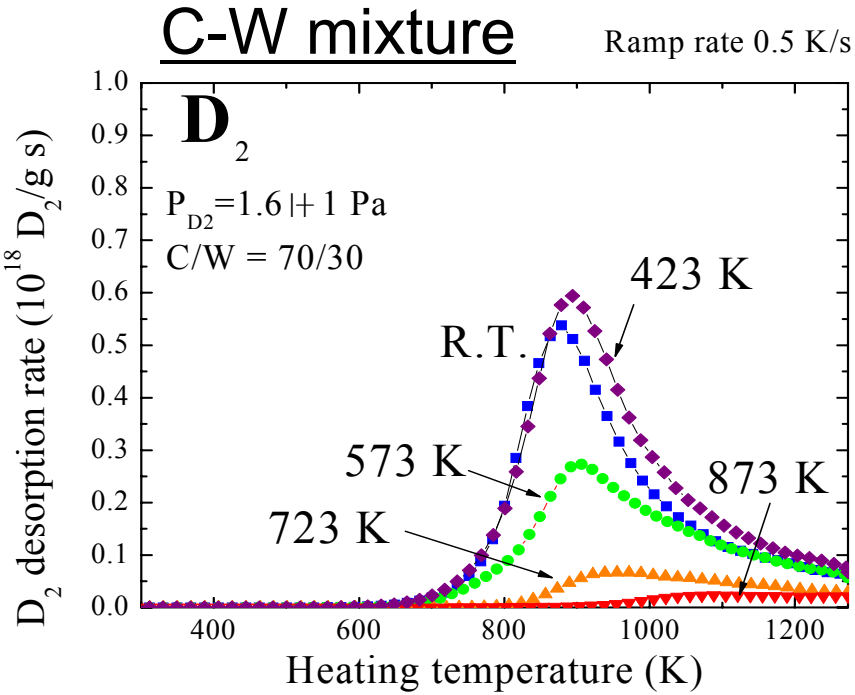
It shows that the effective recombination factor and the diffusion factor of D_2 increase with the increase of the tungsten ratio.

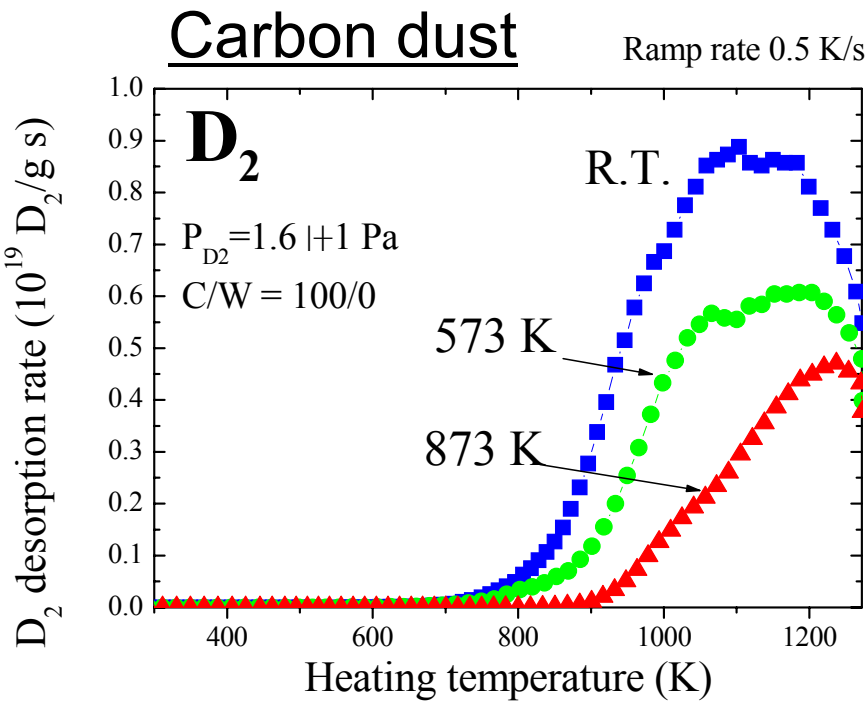
Deuterium retention
- Dependency on C/W ratio 2 -



The deuterium retention of the C-W mixed material exponentially decreases with the increase of the tungsten ratio, which means that deuterium is mainly captured by carbon.

Deuterium retention
- Dependency on Mo substrate temperature -

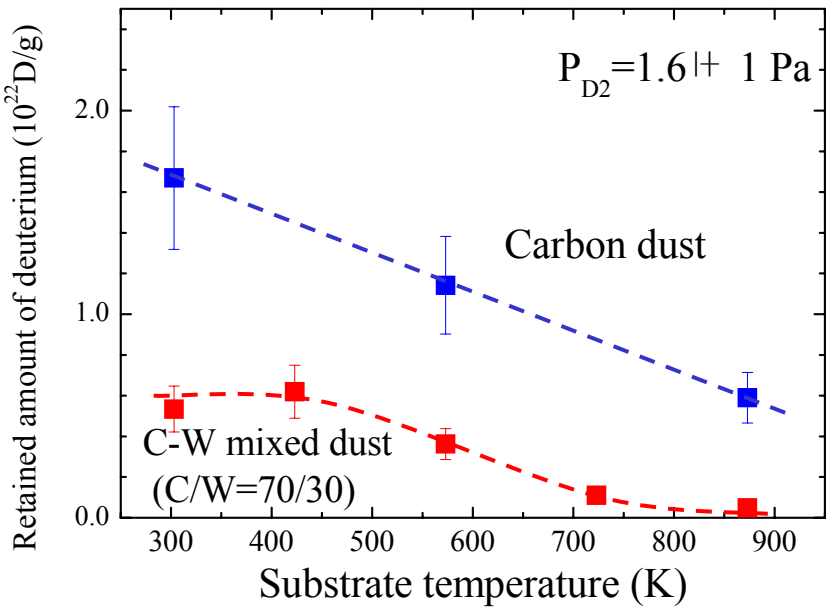




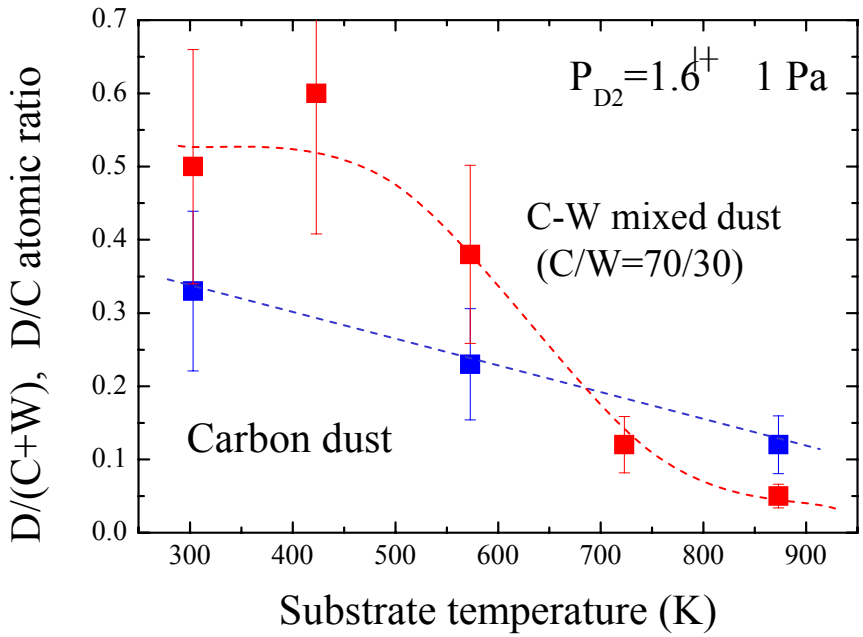
- The higher substrate temperature gives lower desorption of deuterium.
- The effect of the substrate temperature is more remarkable in the C-W mixed material than in the carbon dust.

Deuterium retention
- Dependency on Mo substrate temperature -

Normalized by unit mass

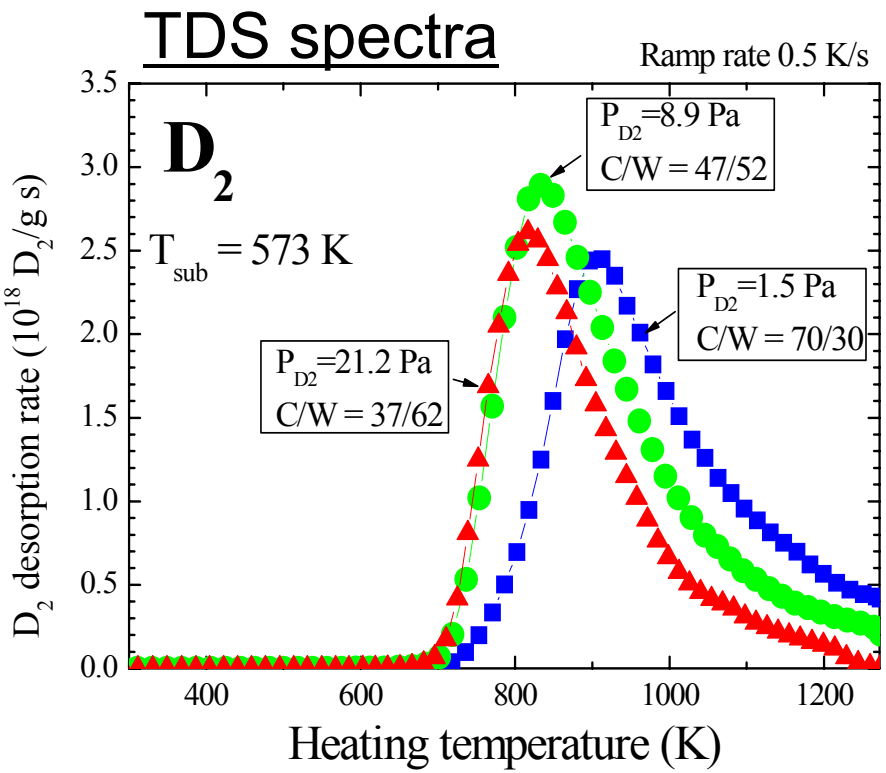


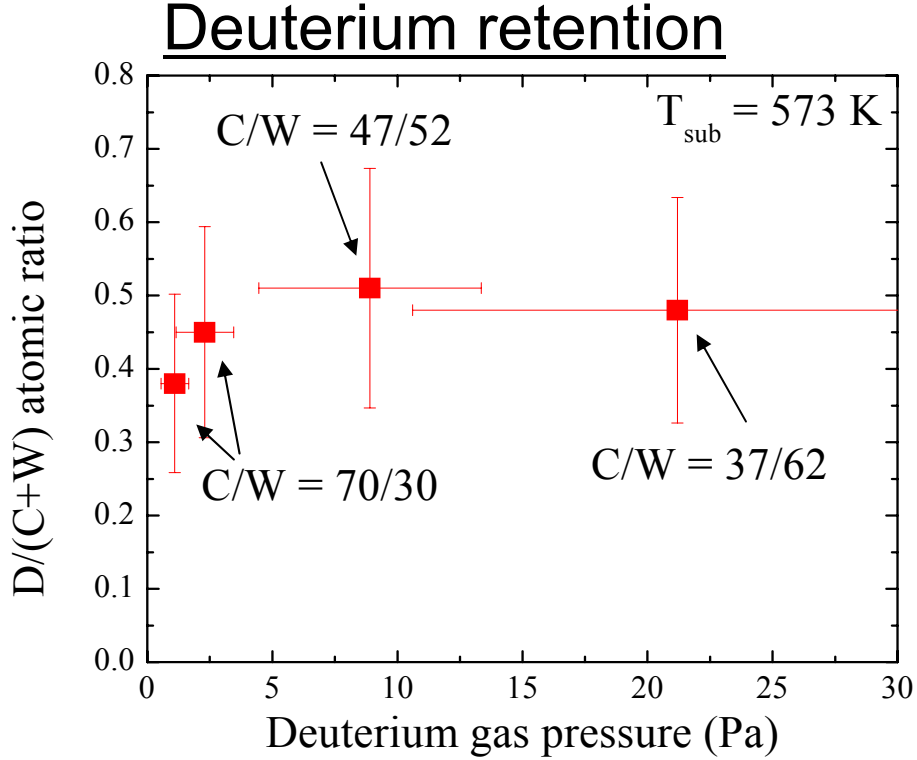
Normalized by atomic number



- Deuterium retention of the C-W mixed material is
  D/(C+W) : 0.4~0.5 @RT ~ 573 K
  D/(C+W) : ≤ 0.1 @573 k ~

Deuterium retention
- Dependency on D_2 gas pressure -





- The D_2 gas pressure strongly affects the C-W atomic ratio.

Summary

- Deuterium retention of the C-W mixed material simulating the in-vessel dust of ITER was investigated.
- The C-W mixed material has lower desorption temperature than carbon dust.
- The quantity of hydro-carbon desorption of the C-W mixed material is about 1/10 of carbon dust.
- Deuterium is mainly captured by carbon in the C-W mixed material.
- Deuterium retention of the C-W mixed material is

  0.4~0.5 @ RT~573 K

  $0.1 \geq$ @ 573 K~

Workshop Agenda