

Deuterium retention in co-deposited C-W-D films formed in magnetron deuterium plasma discharge



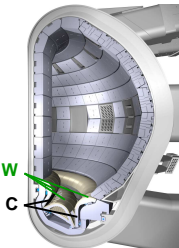
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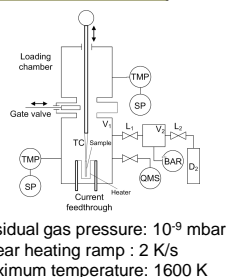
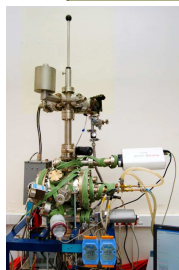
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Motivation

- Hydrogen isotopes retention and removal from co-deposited films is considered as a serious problem from safety reason.
- W/C divertor is planned for ITER. C-W-D films, therefore, should be formed in remote areas.



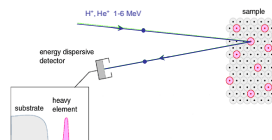
TDS



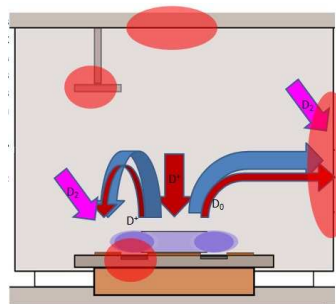
Ion Beam Analysis



- RBS with 2 MeV $^4\text{He}^+$ incident ions.
- NRA with 2.5 MeV $^3\text{He}^+$ incident ions gives total amount of D and C.
- NRA scan for D depth profiling.

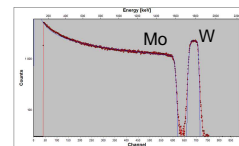
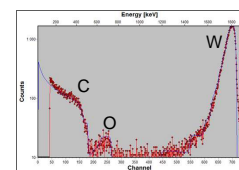


Experimental details



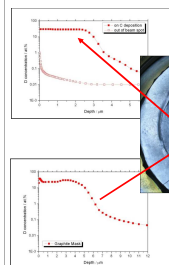
- All C-W-D films were deposited in magnetron plasma discharge.
- Main parameters of the setup:
 - Residual gas pressure - $< 10^{-5}$ mbar
 - Deuterium pressure - 10^{-2} mbar
 - Discharge voltage - 400 V
 - Discharge current - 100 - 350 mA
 - Bias voltage: 0-100 V
- Samples were placed on walls of the vacuum chamber, at the linear feedthrough with a bias potential, and on the cathode (red areas in the figure).

- Substrates:** C (fine grain graphite) and Mo substrate
- Cathodes:** C (PAPYEX paper) and W (polycrystalline)
- The film thickness was up to 200 nm.
- W amount was the same for both substrates
- D retention in all samples with carbon substrates was higher than with Mo substrate. Very likely, due to trapping in substrate. Therefore, C substrate was used only for impurities determination.
- RBS spectra for deposited films on C substrate showed few percents of O and negligible concentration of other impurities.

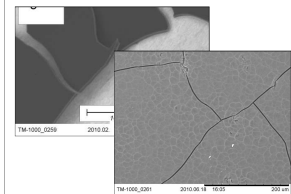


C-D films

- D content is about 40 at.% for grounded and biased (up to 60 V) samples, that is often observed in various experiments.
- Intensive growth of C-D film was observed also on the cathode!



- Growth of a C-D layer in the area of maximal plasma density was observed instead of erosion!!!
- The thickness of the film both on samples and on the mask achieved several micrometers with D content of 30 at.%.
- Growth of the film depends on the temperature of the substrate
 - It grows faster on "cold" surface (< 250 °C) and slower or don't grow on "hot" (> 300 °C)

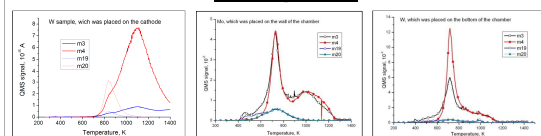


- The film thickness reached up to several microns
- Cracks appeared at the thickness of several microns or after heating.



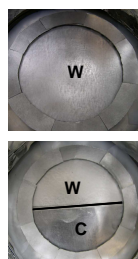
- We concluded that the middle area is a source of C as well as the place of deposition
- C_xH_y evaporation can be a mechanism of that

TDS spectra

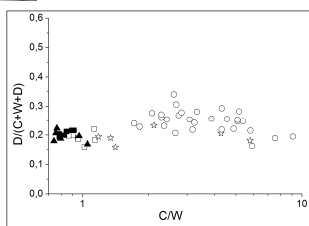


Deuterium desorption from the film deposited on the cathode occurs mostly at high temperature region.

C-W-D films



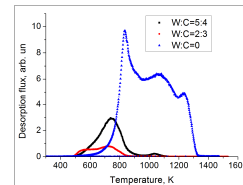
- Films deposited with W cathode contained a lot of C, up to 50 at.%!
 - This carbon could appear due to decomposition of C-containing molecules of residual gas in plasma.
- However, there was no difference in C content after improvement of vacuum from 10^{-4} to 10^{-5} mbar (pressure of D_2 - 10^{-2} mbar) and exchange of the pumping system to oil free pumps.



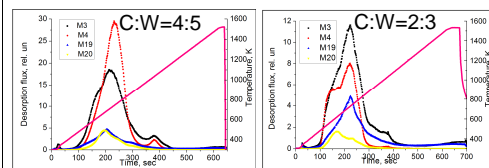
- Surprisingly, the deuterium content is only slightly less than that in free-of-tungsten C:D films deposited in similar conditions. All data lie in the range $\text{D}/(\text{C}+\text{W}+\text{D}) = 0.15-0.30$
- This data are close to [1,2], but not to [3].

8.09.09.10	D	C	W	C/W	D/(D+C+W)
Pre-TDS	0.76	1.21	1.35	0.90	0.23
Post TDS	0	0.22	1.31	0.17	0
5.06.09.10	D	C	W	C/W	D/(D+C+W)
Pre-TDS	0.28	0.65	0.50	1.29	0.19
Post TDS	0.001	0.41	0.36	1.14	0.001

TDS of D_2 from the C-W-D films deposited on the Mo substrate under the bias of -62V



- TDS spectra of deuterium from C-W-D films differ from C-D films deposited in the same conditions. They are shifted to low temperatures, and have no high-temperature peaks.
- There is no also a low temperature part typical for bulk tungsten irradiated by D^+ ions.



NRA measurements for C-W-D surprisingly gave a higher D content than TDS. This is probably connected with a large amount of hydrocarbons with a high sticking probability, which can not reach the mass-spectrometer.

[1] H. Yoshida et al. / Journal of Nuclear Materials 329-333 (2004) 790-794.
[2] K. Katayama et al. / Thin Solid Films 506-507 (2006) 188-191.
[3] V.Kh. Alimov, D.A. Komarov, J. Nucl. Mater. 313-316 (2003) 599..

Summary

- C-D and C-W-D films deposited in magnetron sputtering device were investigated.
- Intensive growth of C-D films was observed also on the cathode in the area of maximal plasma density!
- Deuterium content in C-W-D films was only slightly less than that in free-of-tungsten C:D films deposited in similar conditions. $\text{D}/(\text{C}+\text{W}+\text{D}) = 0.15-0.30$.
- TDS peaks for C-W-D films are shifted to low temperatures comparing to C-D films and have no high-temperature peaks.