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Experimental modeling of film growth on diagnostic mirrors in ITER-relevant conditions

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NRC "Kurchatov institute"

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ITER project

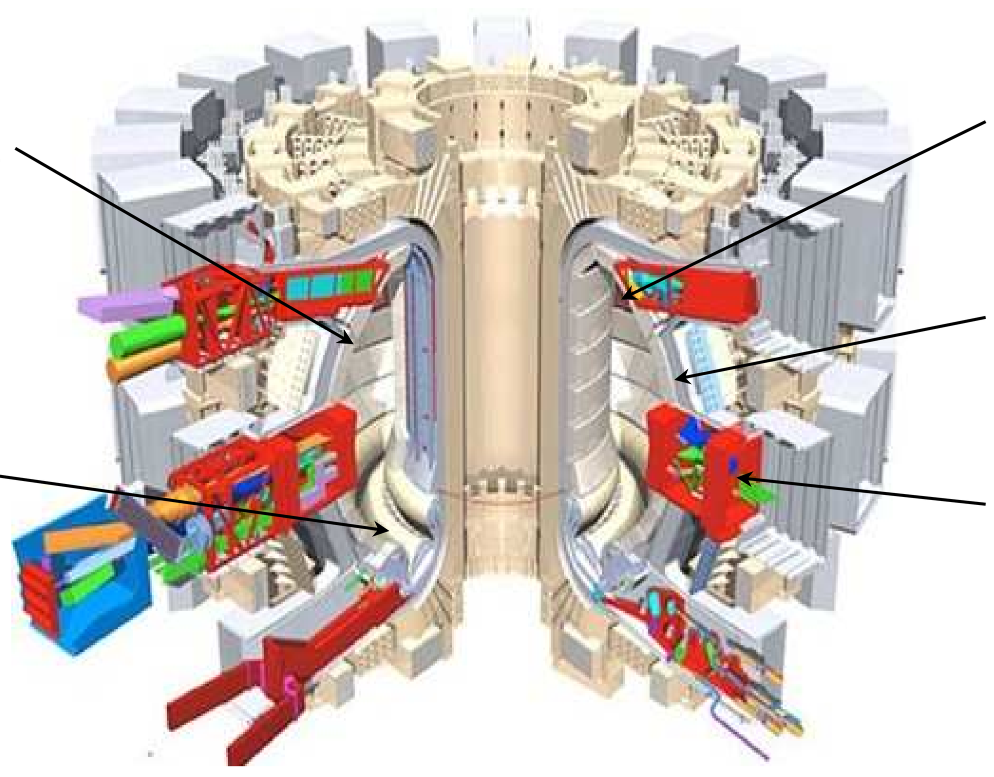
Particle flux on the first wall [1] :

- hydrogen isotopes ~$10^{20}…10^{21}$ $m^{-2}s^{-1}$;
- admixtures ~ $10^{18}…10^{19}$ $m^{-2}s^{-1}$; mainly C, Be, W;
- particle energy: 1…1000 eV.

Gas pressure in vacuum vessel [3]:

- Divertor: 1…10 Pa.
- There is no precise information in other regions. Estimations give the value **≤ 1 Pa**.

Inlet water temperature will be 100 ºC and outlet will be 150 ºC. [4]

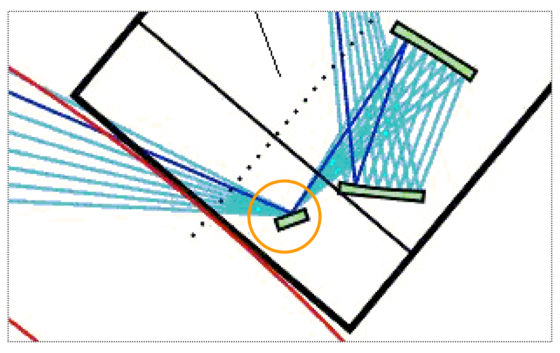


Radiation flux [2]:

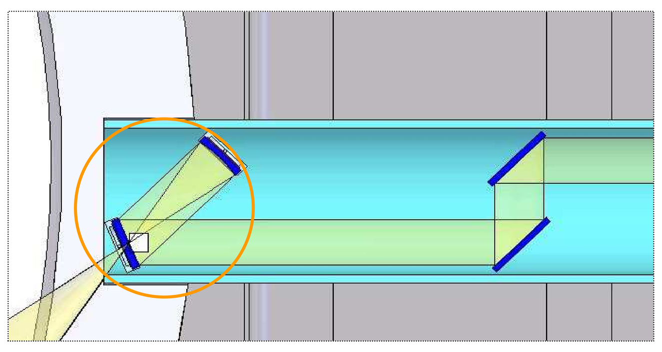
- First wall
  ^{1}n: $3·10^{18}$ $m^{-2}s^{-1}$;
  γ-ray: $2·10^3$ Gy/s.
- Blanket:
  ^{1}n: $0.2…1·10^{17}$ $m^{-2}s^{-1}$;
  γ-ray: 20…100 Gy/s.
- Port exit
  ^{1}n: $2·10^{13}$ $m^{-2}s^{-1}$;
  γ-ray: ~10^{-2} Gy/s.

Over 50 diagnostic systems. About a half of them are optical.

Each optical system include the first mirror or the first mirror assembly for collecting plasma radiation, e.g.



CXRS



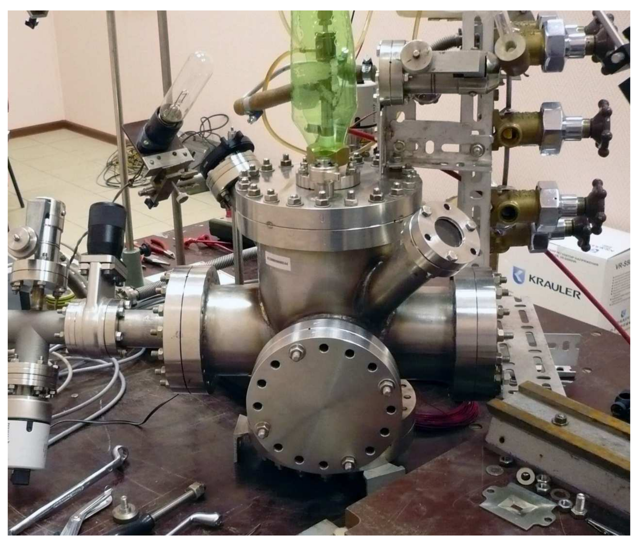
H-alpha

For all optical diagnostics one of the main problems is the estimation of the the first mirror's lifetime!

Main goal is to assess experimentally the impact of ITER-relevant conditions on the lifetime of diagnostic mirrors.

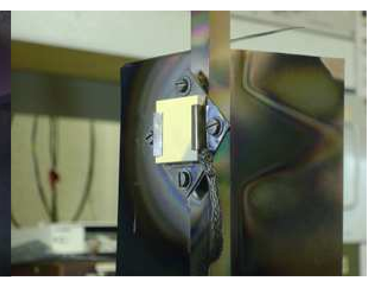
Research installations with magnetron sputtering device

Vacuum vessel in BMSTU

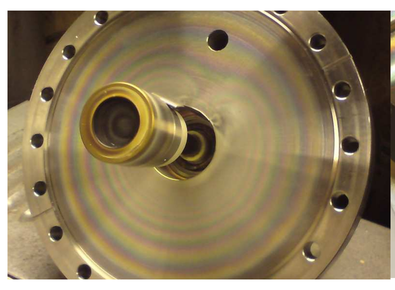


Vacuum vessel in Kurchatov institute

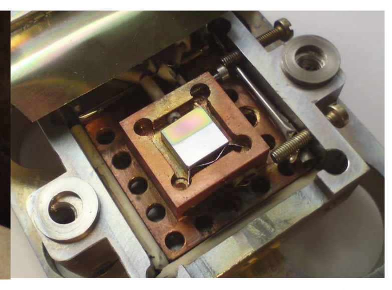
Magnetron device



Mirror 22x22x4 mm³

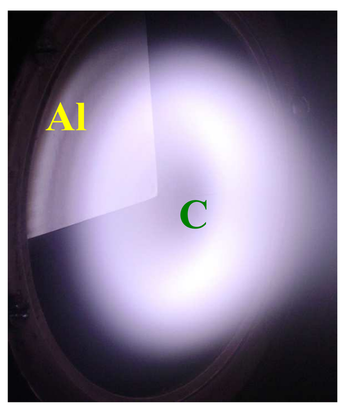


Magnetron device



Mirror 10x10x4 mm³

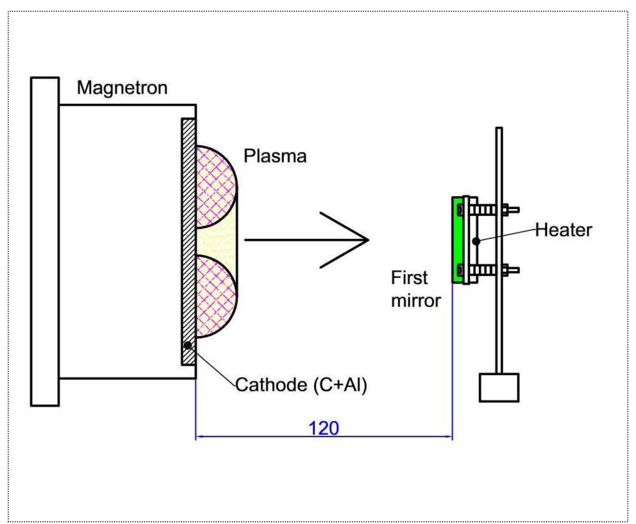
Combined C+Al flux with mirror's shielding (BMSTU)

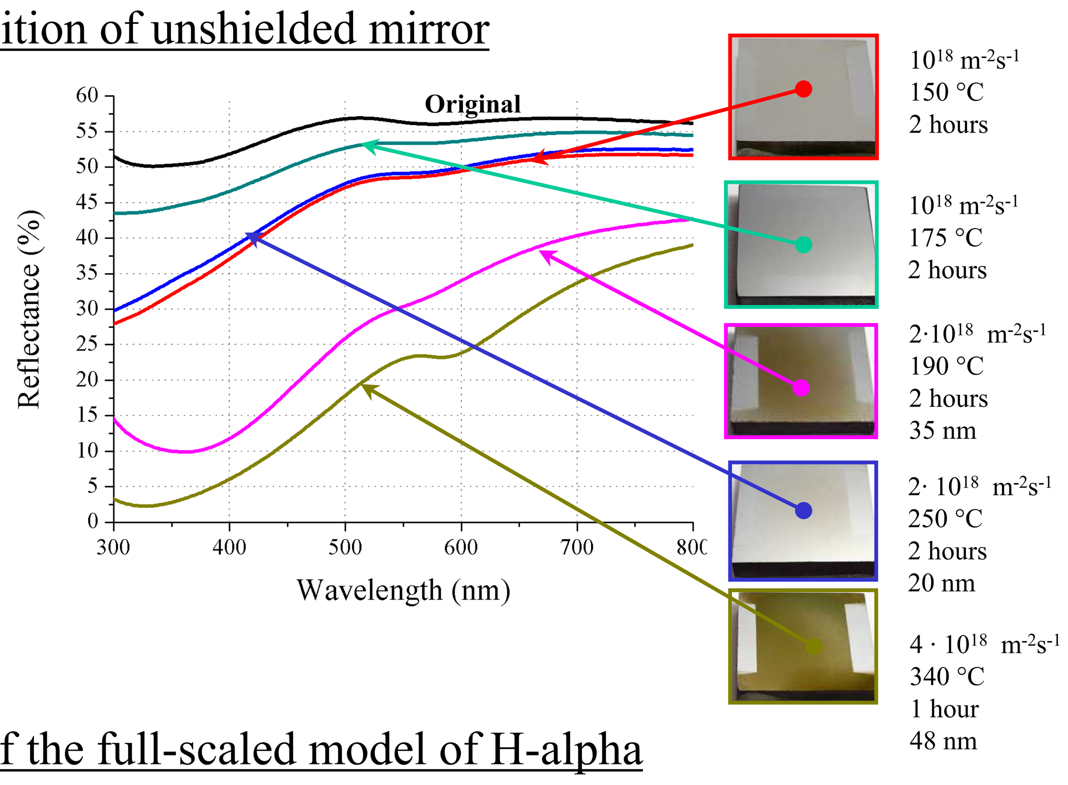


Gas mixture 100% D_2
Pressure 0.4 – 1 Pa
Magnetron discharge
I = 1 - 2 A, U = 300 – 400 V;
Cathode materials – *C(75%)+Al(25)%*
Exposition period: 2 hours; 8 hours.

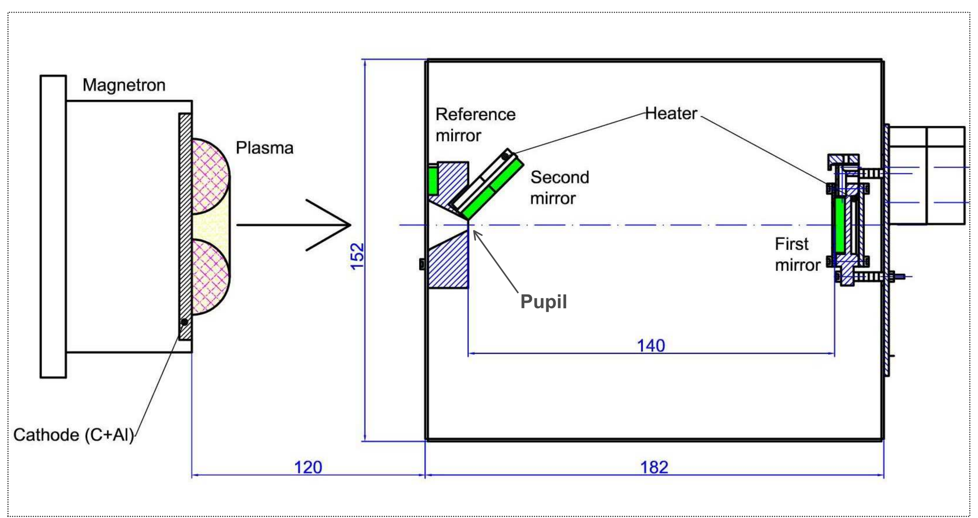
Mirrors:
material: *Mo*, 22x22x4 mm³;
temperature 100…250 ºC.
Particle flux on the mirror was estimated to be **$2-4·10^{18}$ $m^{-2}s^{-1}$** with average energy **10 eV** per atom (C 75%, Al 25% for combined flux)

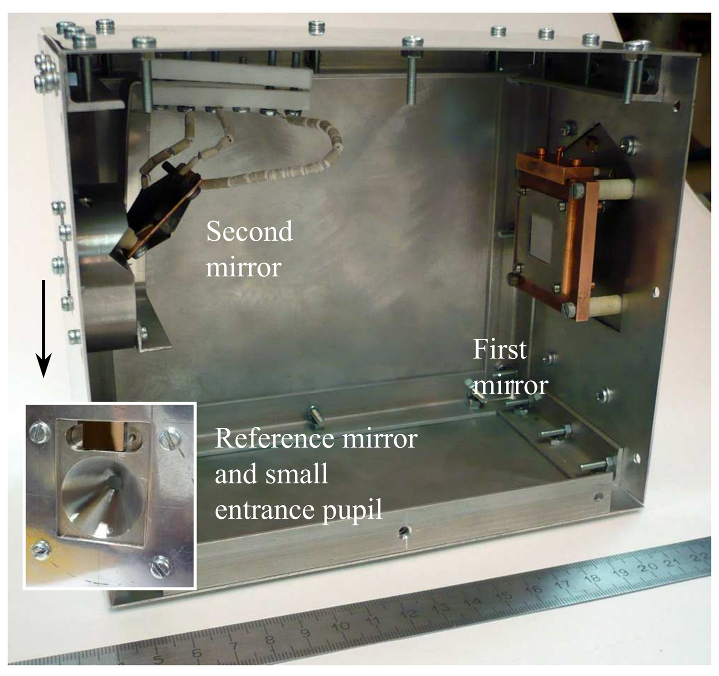
Exposition of unshielded mirror

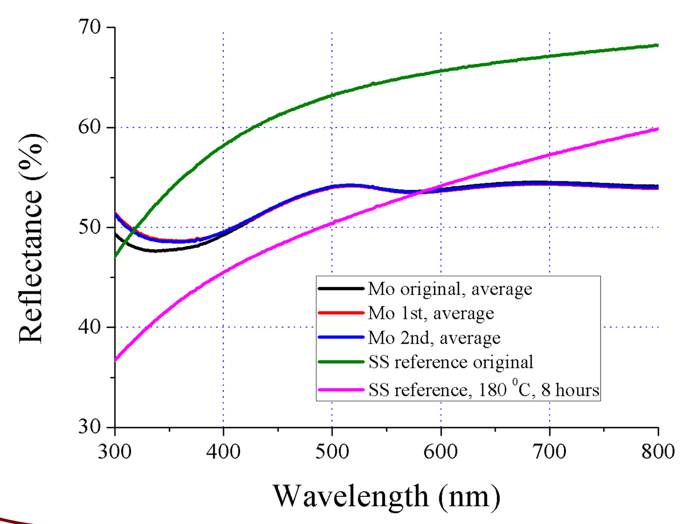




Exposition of the full-scaled model of H-alpha first mirror assembly with small pupil (Ø4 mm)







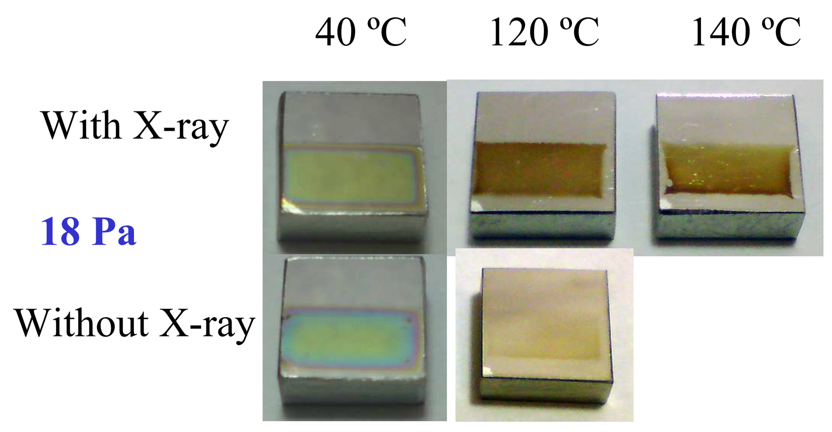
Reflectance of the first and the second Mo mirrors IMPROVED in UV.
Reflectance of the RM mirror (SS) reduced by 10%.

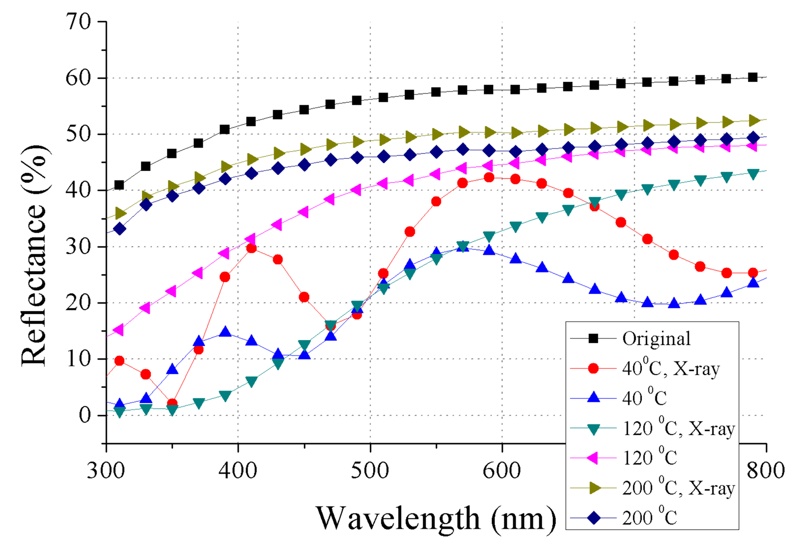
Exposition under X-ray irradiation (Kurchatov institute)

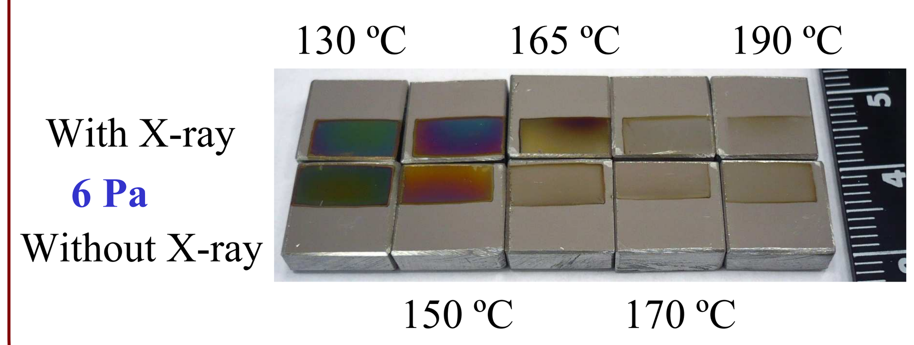
Gas mixture 40% Ar, 55% D_2, 5% CHD_3
Pressure 6 Pa; 18 Pa
Magnetron discharge
I = 100 mA, U = 400…500 V,
Cathode material – ***carbon.***
Exposition period: 2 hours.

Mirrors:
material: ***SS316***, 10x10x4 mm³
temperature 40…200 ºC.
X-ray tube:
U = 40 kV, I = 800 μA, W-cathode
Radiation level 0,1 Gy/s

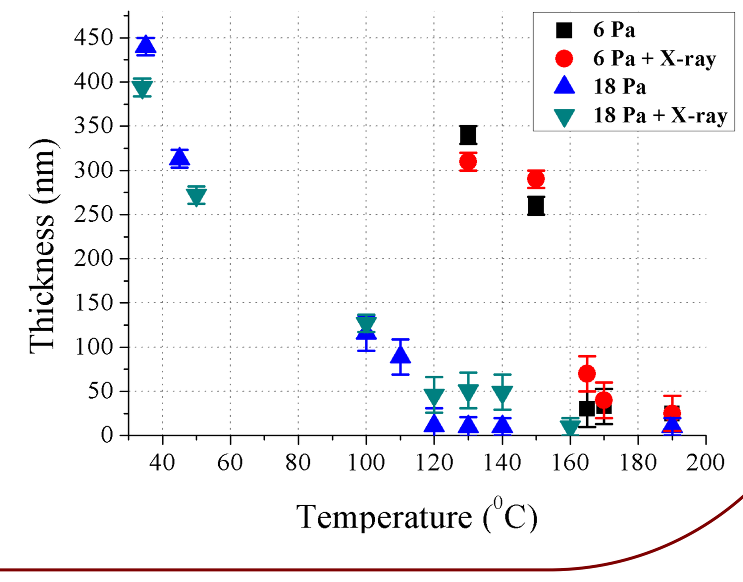
Particle flux on the mirror was estimated to be **$4·10^{18}$ $m^{-2}s^{-1}$** with average energy **10 eV** per atom.



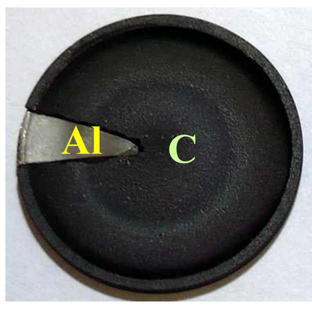




No film was deposited on the mirrors heated over 190ºC



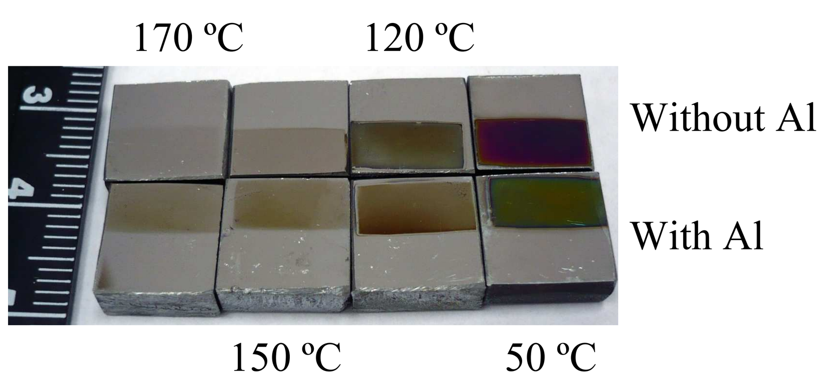
Exposition under pure C and combined C+Al fluxes (Kurchatov institute)

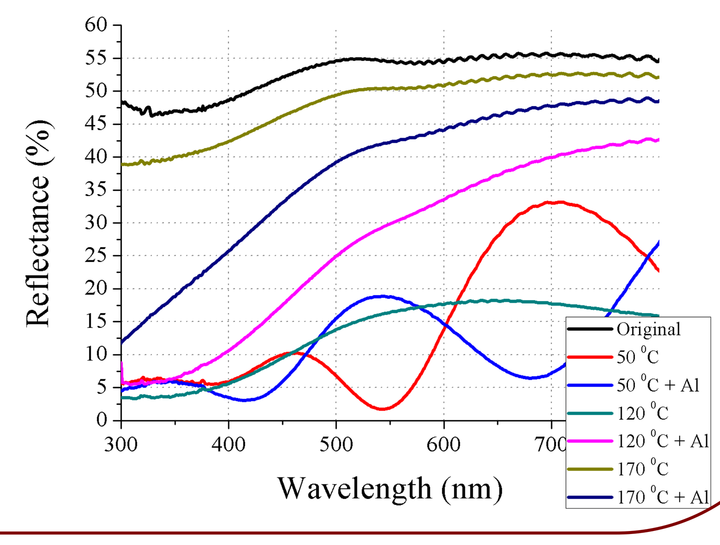


Gas mixture
40% Ar, 55% D_2, 5% CHD_3
Pressure 6 Pa
Magnetron discharge
I = 70 mA, U = 520 V;
Cathode materials – *C*,
C(92 %)+ Al(8%)
Exposition period: 2 hours.

Mirrors:
material: ***Mo***, 10x10x4 mm³;
temperature 50…170 ºC.

Estimated total particle flux on the mirror was **$4·10^{18}$ $m^{-2}s^{-1}$** with average energy **10 eV** per atom (C 75%, Al 25% for combined flux).





Conclusions

Experiments show that X-ray irradiation can stimulate film growth though its influence becomes insignificant at low pressure expected in diagnostic ports.

Combined H(D), C and Al flux leads formation of metalized CH films that cannot be prevented only by temperature elevation.

Small entrance pupil suggested for H-alpha and VIS-IR dramatically reduces deposition rate on diagnostic mirrors even under C+Metal particle flux.

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2. Sasao M. et al., Integration of Lost Alpha-Particle Diagnostic Systems on ITER, IAEA=TCM=EP9
3. Chiocchio S., Project Requirements (PR) ITER_D_27ZRW8 v4.6, 07 May 2010
4. (DDD)Diagnostic Generic Equatorial Port Plug Structures_ITER_D_3U8JU7

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