NILPRP

National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania
EURATOM Association - MEdC

W coatings for nuclear fusion

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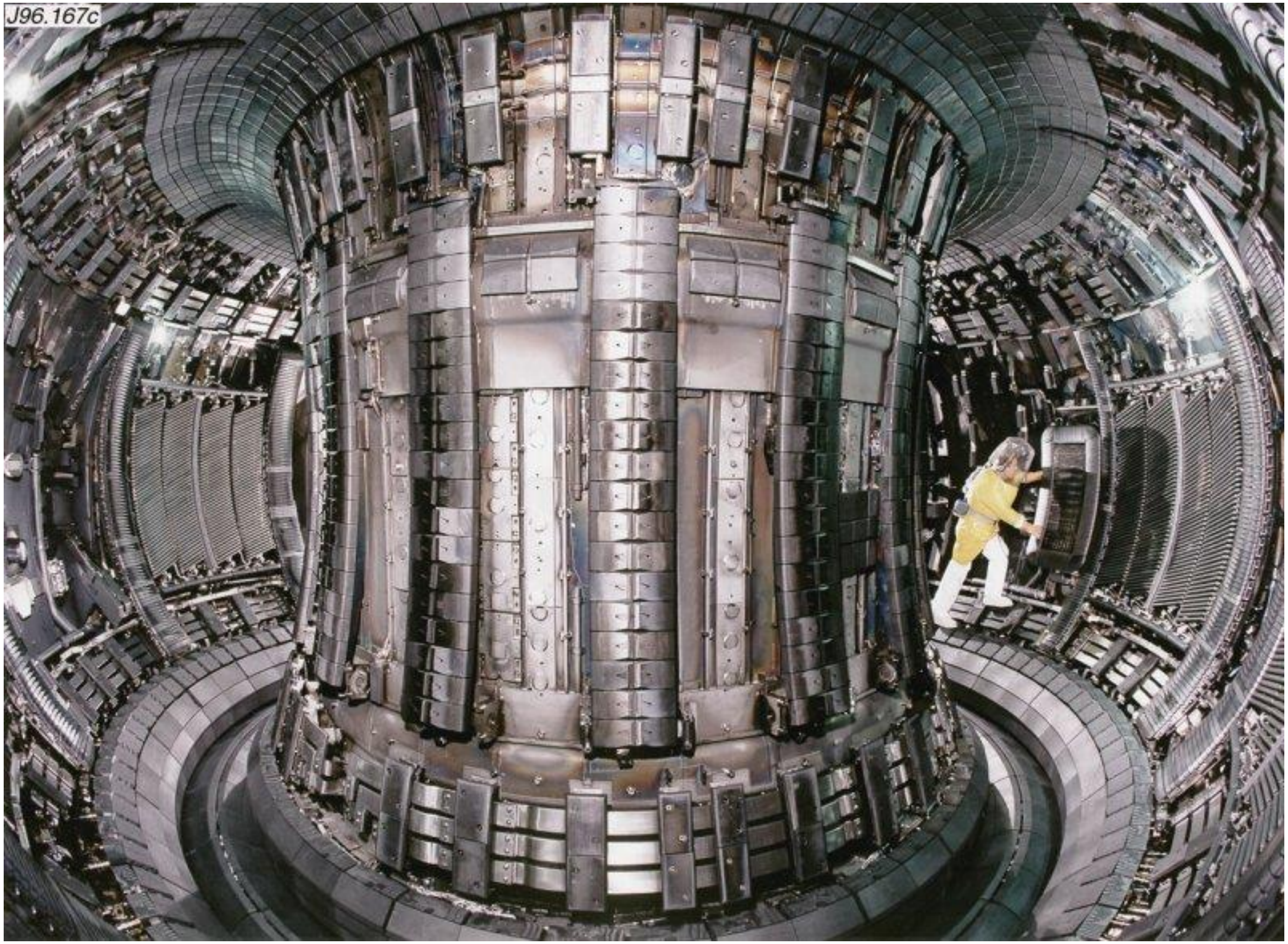
Outline

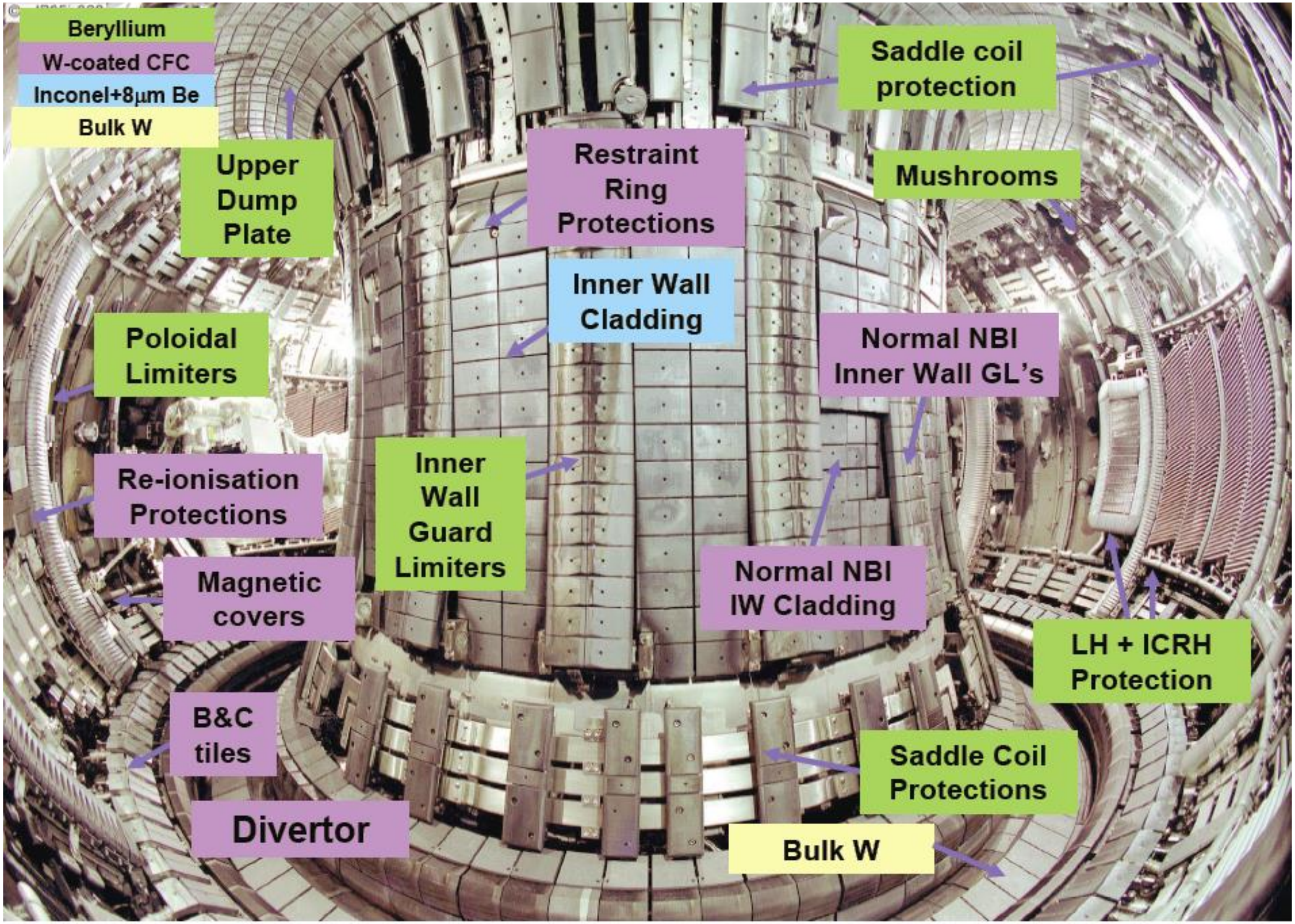
- Introduction
- CMSII – Equipment, technology and performances
- W coated tiles for JET and ASDEX Upgrade tokamaks
- Conclusions

W coating technology for JET (1)



Main disadvantages of CFC: high fuel retention and high chemical sputtering rate

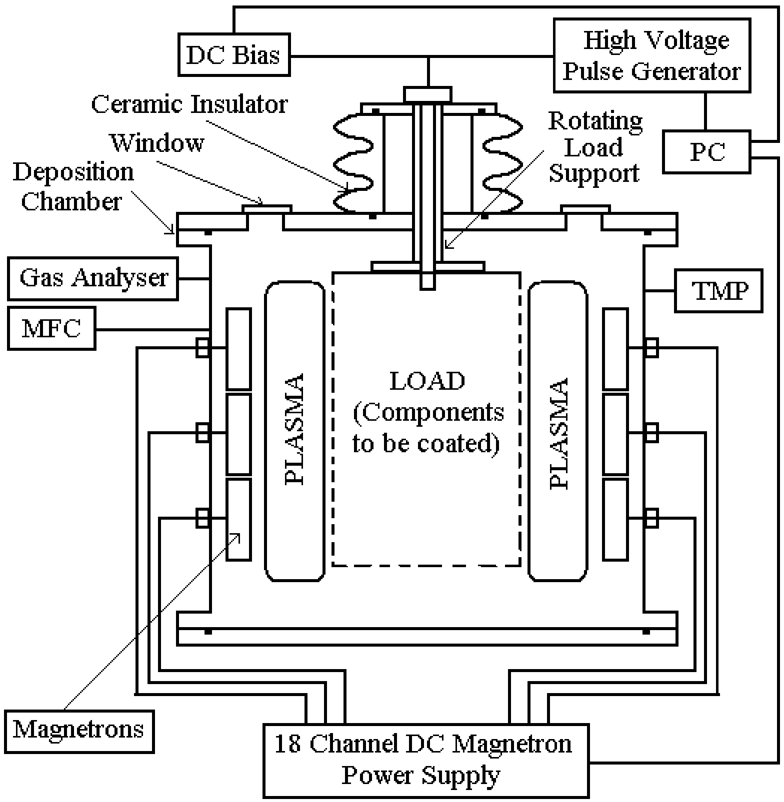
W coating technology for JET (2)



More than 5000 tiles to replace – 2 tons of Be

4

Combined Magnetron Sputtering and Ion Implantation (CMSII)



Specific characteristics of CMSII coatings (1)

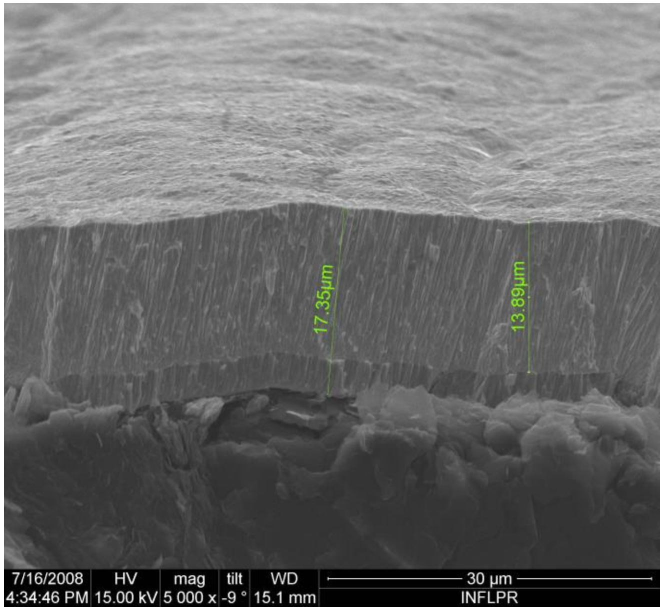
- High energy ion bombardment
  U_{HV} = 30-70 kV; τ ~ 20 μs; f = 25 Hz

r = 2 nm/s $\Rightarrow$ for 40 ms $\rightarrow$ d_{calc} = 0.08 nm
- increase the surface mobility
- high densification of the coating

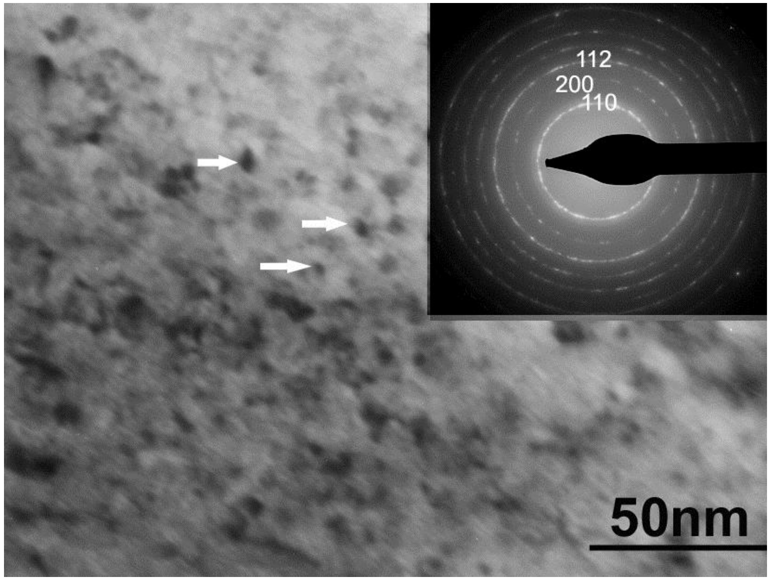
- Nano-crystalline structure

- A Mo interlayer is used to adjust the mismatch of thermal expansion coefficients between CFC ($\alpha_{CFC} = 10 \cdot 10^{-6}$ K^{-1} perpendicular to fiber and 0-$1 \cdot 10^{-6}$ K^{-1} parallel to fiber plane) and W (α_W $4.5 \cdot 10^{-6}$ K^{-1}). α_{Mo} is $7.2 \cdot 10^{-6}$ K^{-1}.

- Due to the high energy ion bombardment a stress relief occurs into the coating and consequently relative thick coatings (10-30 μm) can be produced.



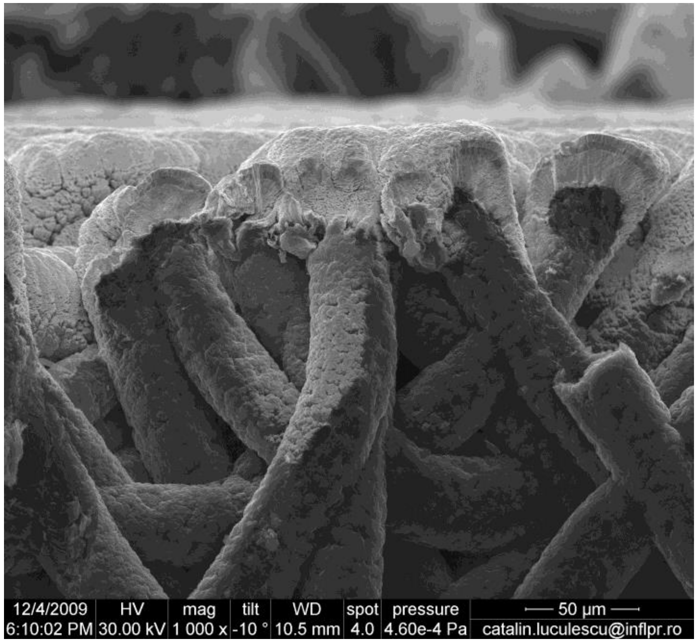
SEM micrograph

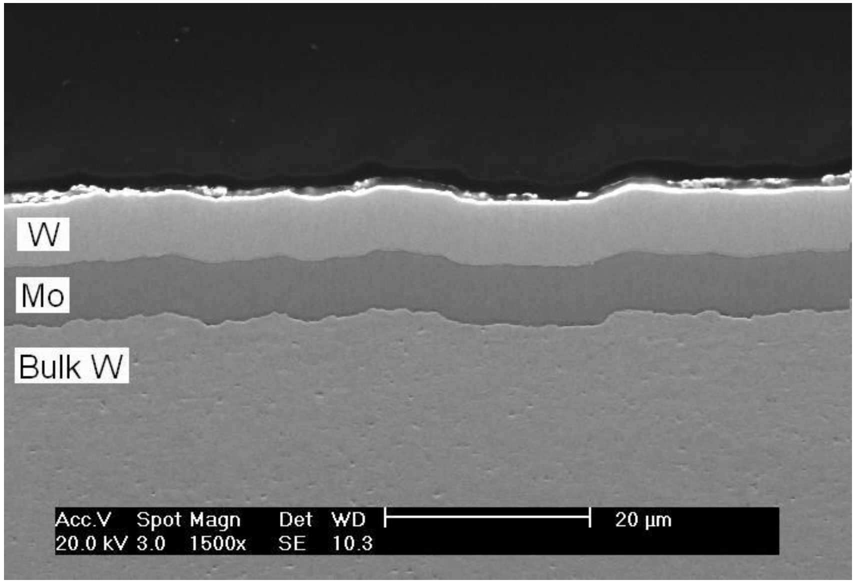


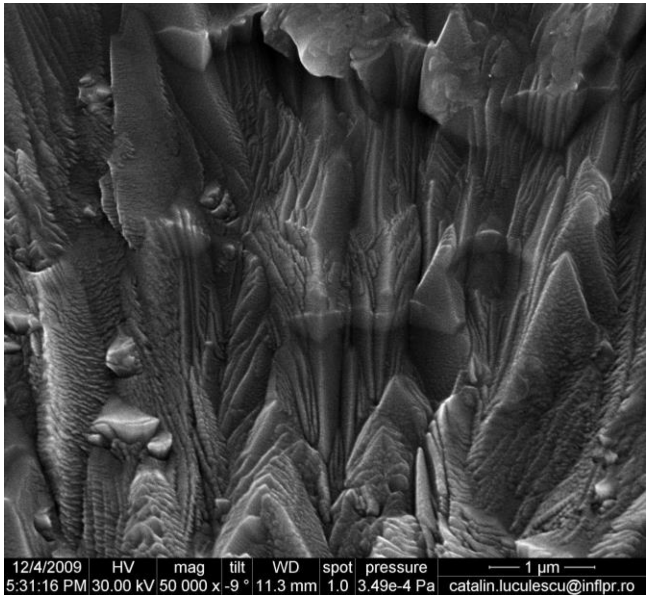
TEM micrograph

Specific characteristics of CMSII coatings (2)

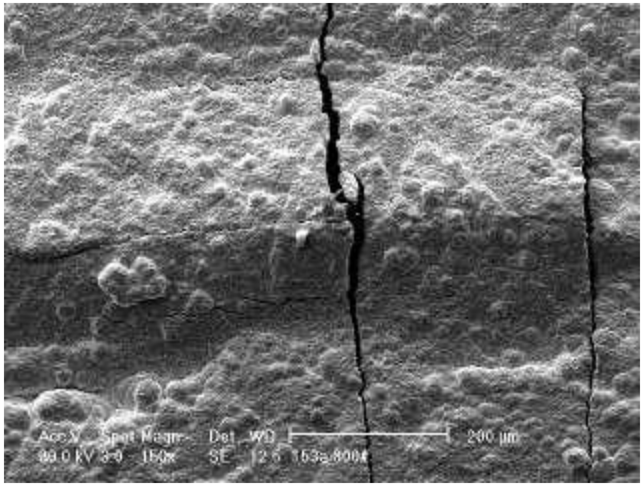
- W coating penetrates into the gapes between fibers, surrounding the fibers → adhesion
- The W coating appears to be more compact than bulk W

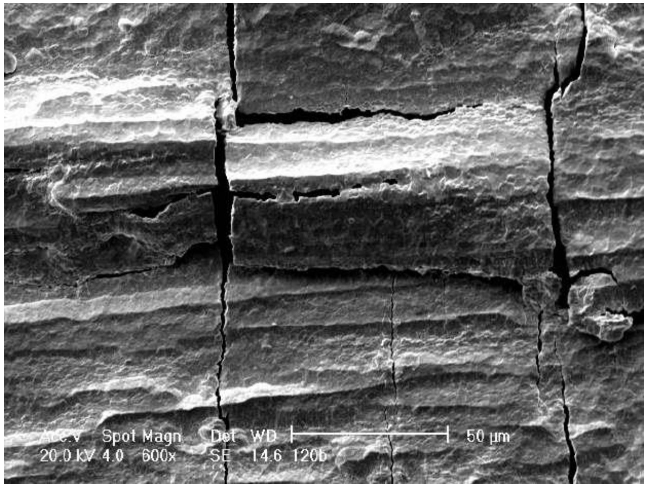




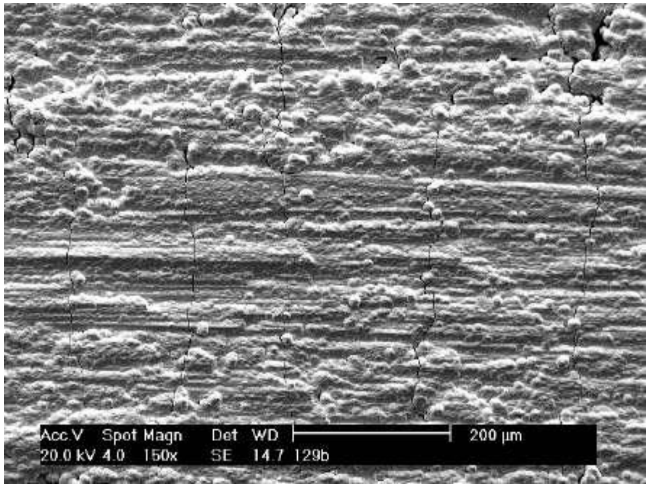


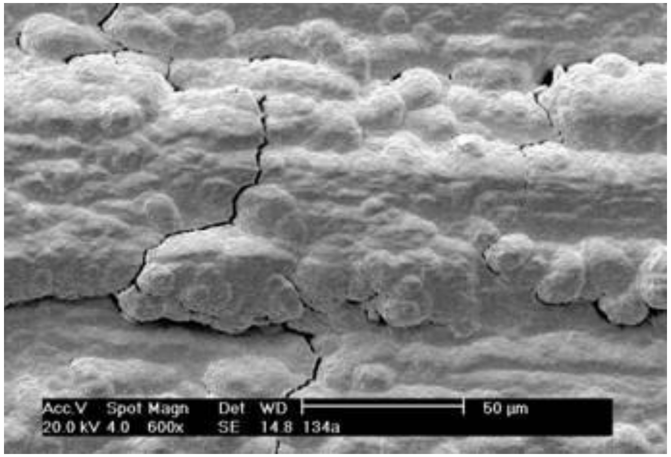
After HHF tests in GLADIS





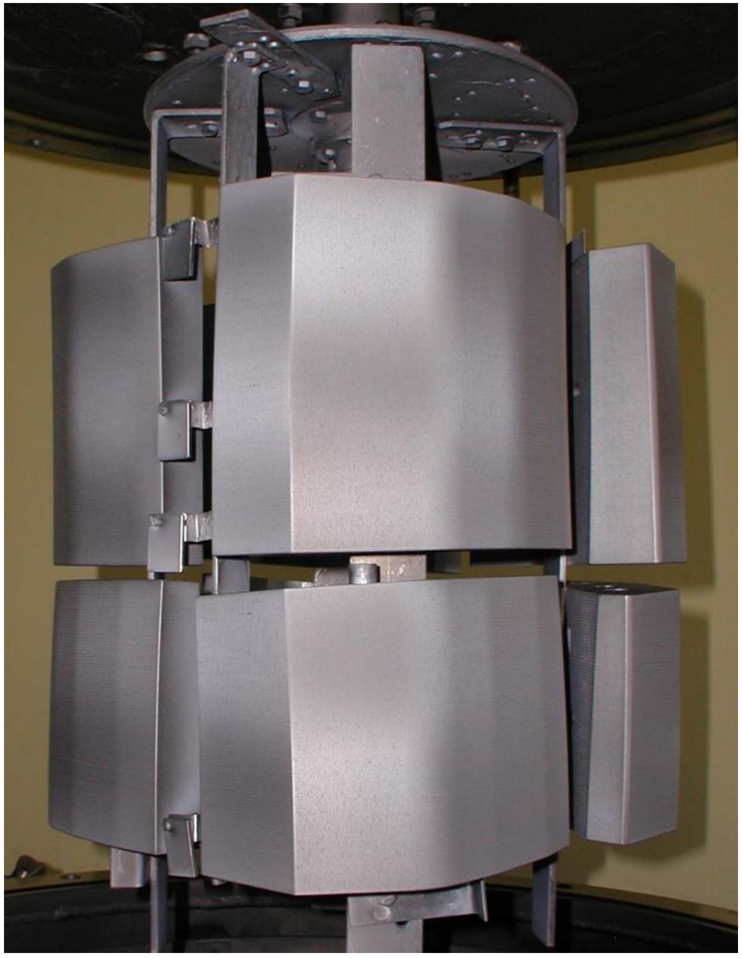
Coatings deposited by conventional PVD or CVD techniques





Coatings deposited by CMSII technique

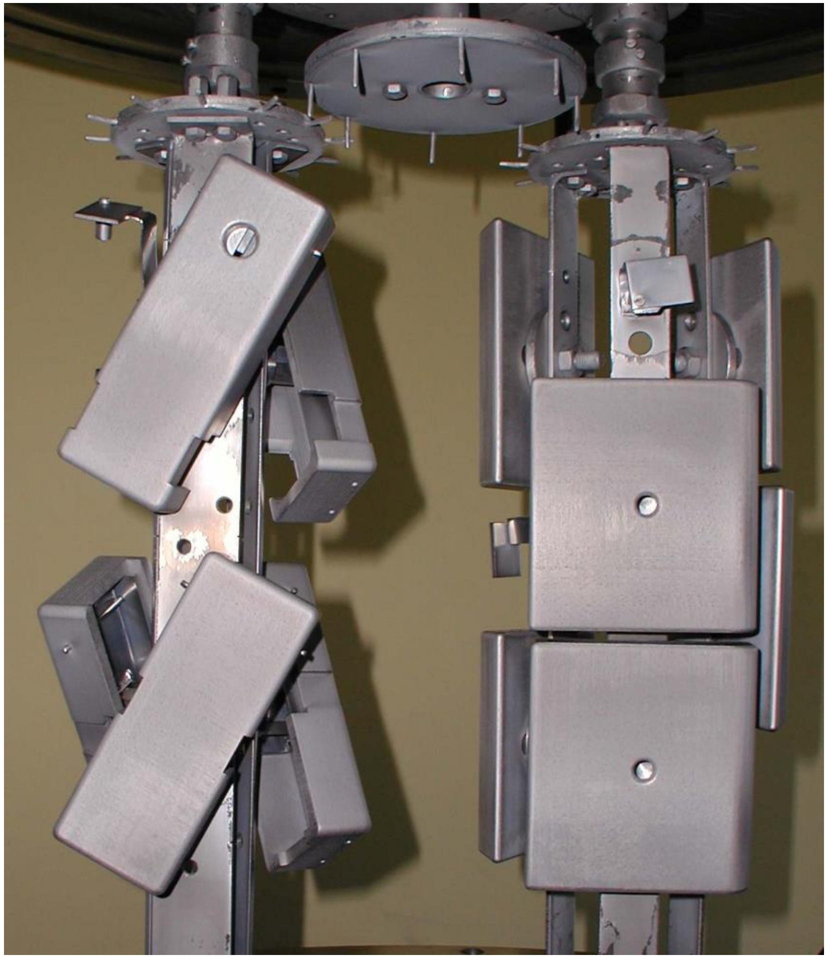
W COATED CFC TILES (1)



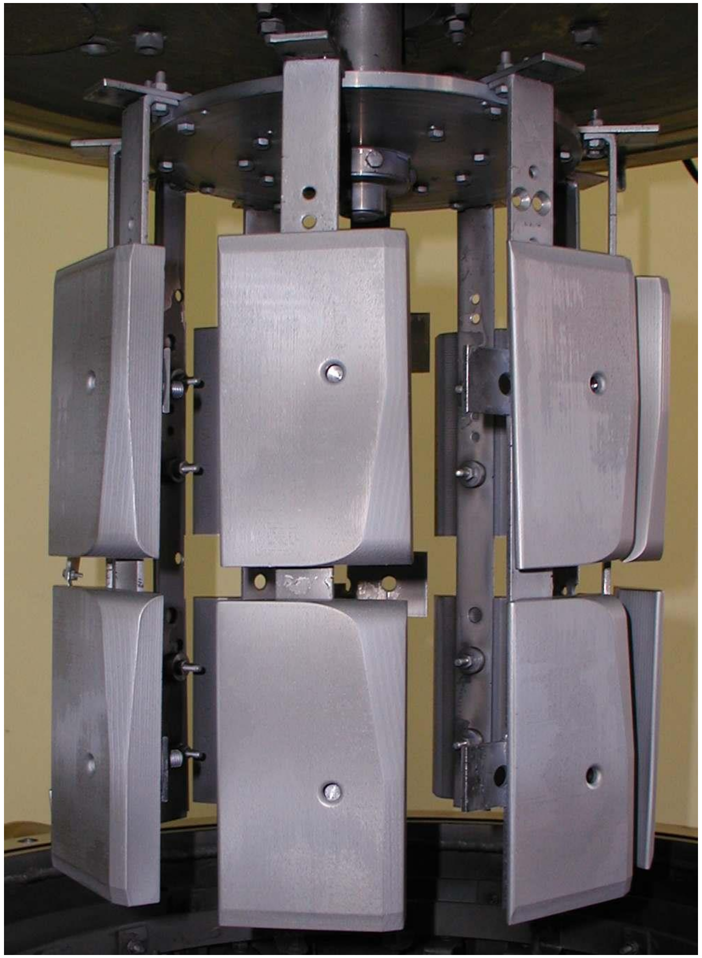
G 1 and G8 divertor tiles coated with 20-25 μm W in series production

G 6 and G7 divertor tiles coated with 20-25 μm W in series production

W COATED CFC TILES (2)



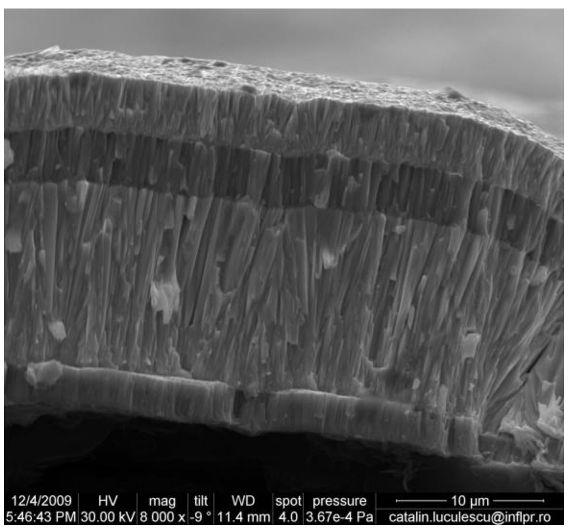
Diagnostic covers and shinethrough protection tiles from the main chamber; coating thickness 10-15 μm

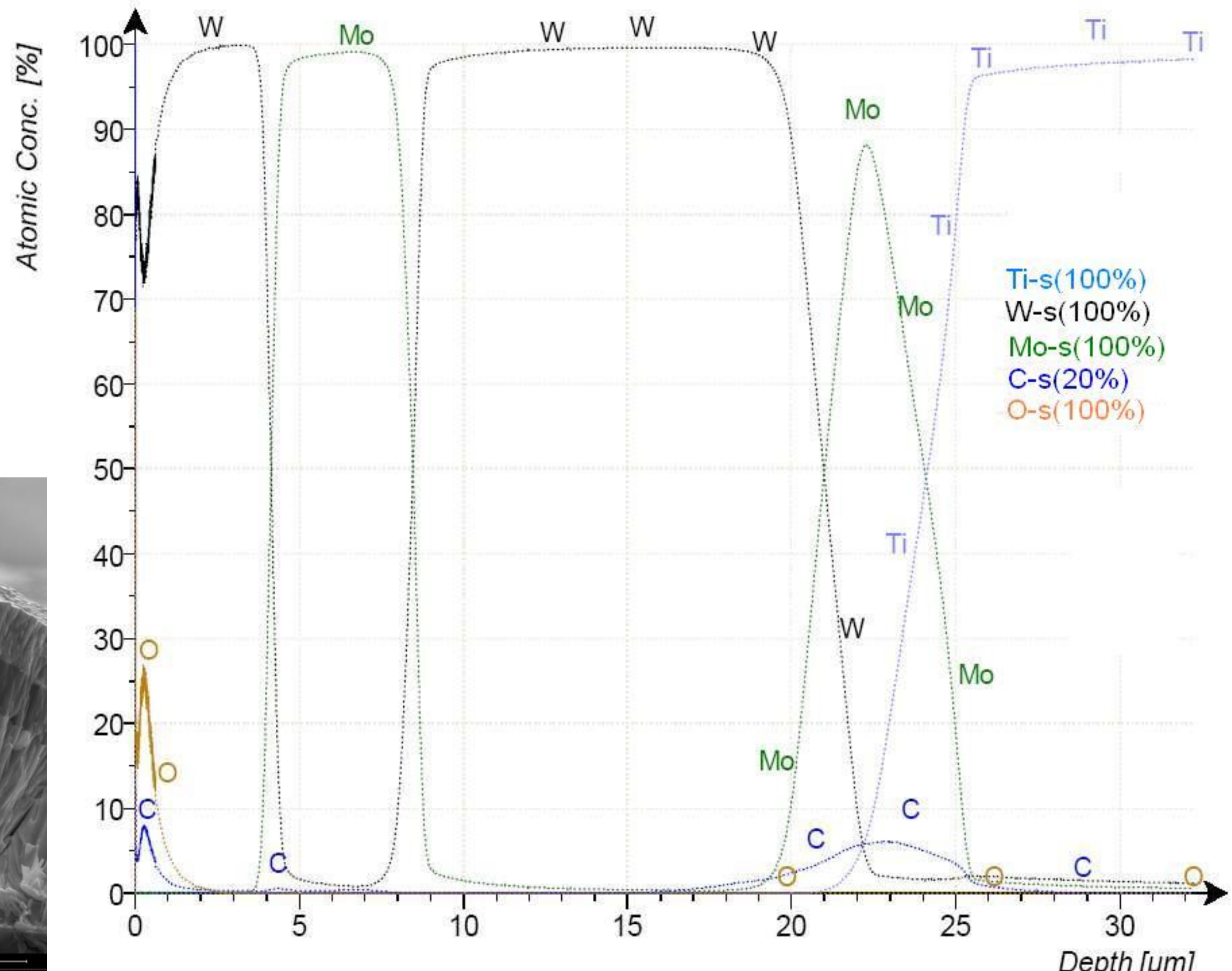


Tiles – C from the main chamber; coating thickness 10-15 μm

W/Mo markers for measurement of W erosion in JET divertor

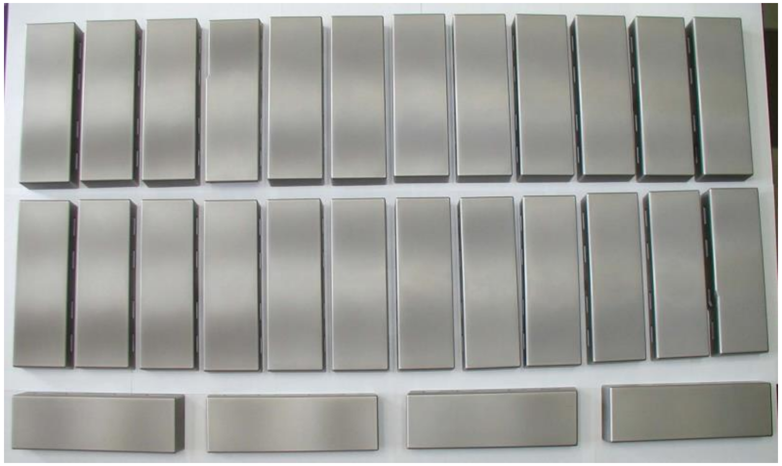
- Structure of markers:
  - 2-3 μm Mo
  - 12-14 μm W
  - 3-4 μm Mo
  - 3-4 μm W
- Applied on particular G6, G7, G1 and G8 tiles





W coating of FGG tiles for ASDEX Upgrade (1)

- About 1000 FGG components have been coated by CMSII technology and installed in tokamak.
- Coating thickness: 10-15 μm



W coating of FGG tiles for ASDEX Upgrade (2)

Conclusions

- CMSII technique has been developed from the laboratory to industrial scale and it has been successfully applied for W coating of carbon based materials for the first wall in fusion devices

- Coating thickness was in the range of 10 – 25 μm, but W/Mo coatings of ~ 50 μm were produced and successfully tested at high heat fluxes up to 23 MW/m^2 ($T \leq 2000$ °C)

Thank you for your attention!