Max-Planck-Institut
für Plasmaphysik

IPP

Development of Tungsten Coatings for the ITER-like Wall of JET

H. Maier

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T. Hirai (formerly), V. Philipps, A. Schmidt & more, FZJ

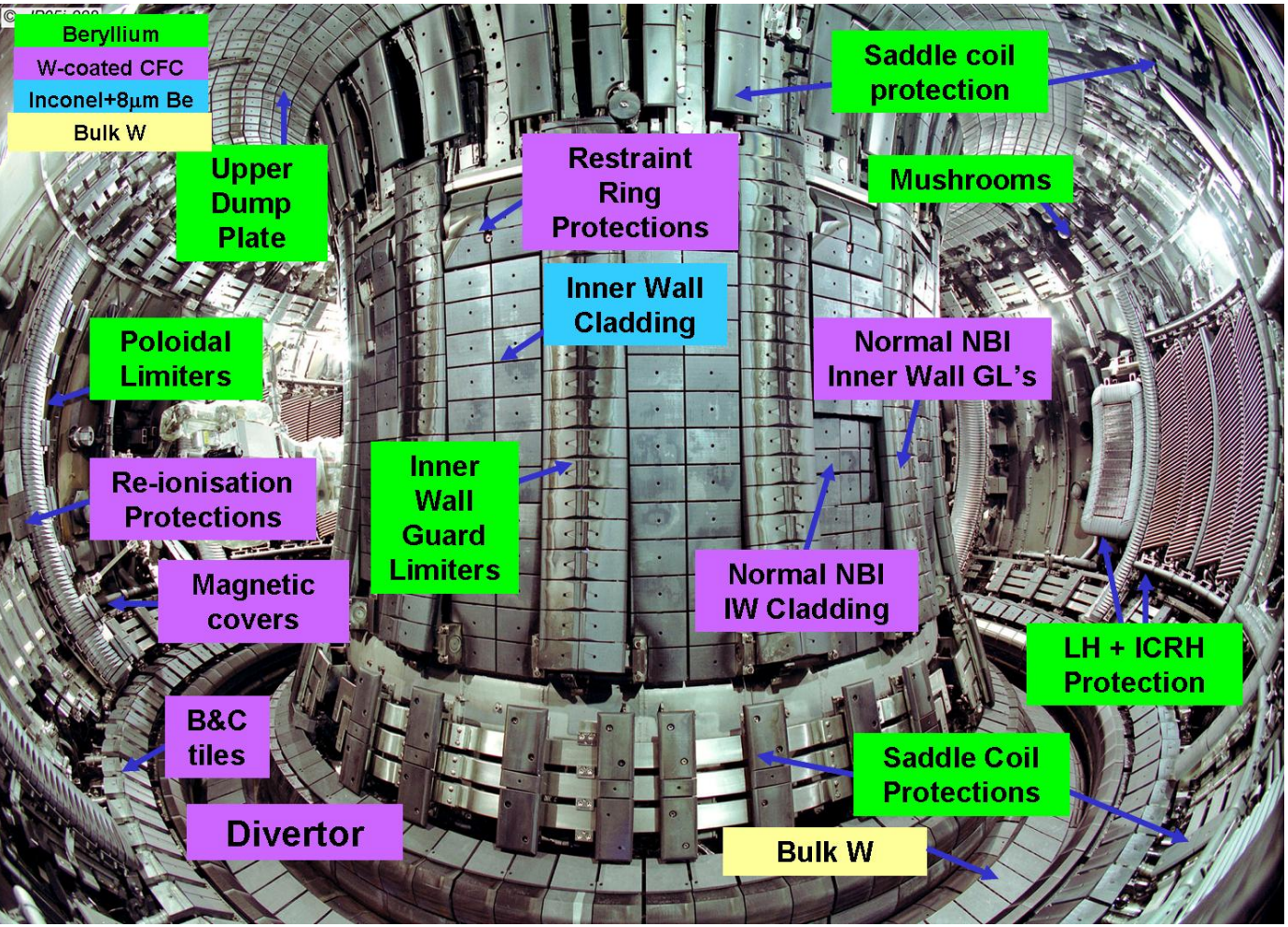
+ colleagues from several more Euratom associations: CCFE (UKAEA), FZJ, CEA, ENEA, TEKES

Brief (and incomplete) review of the past 6 years:

- **Research & Development phase 2005/2006**
- **Upscaling to industrial process 2007/2008**
- **(Quality assurance testing 2008-2010)**
- **Recent investigations (& future):**

Lifetime limitation due to carbide formation

The ITER-like Wall Project



JET is currently equipped with the ITER materials combination

Be

W

Tungsten coatings on CFC required:

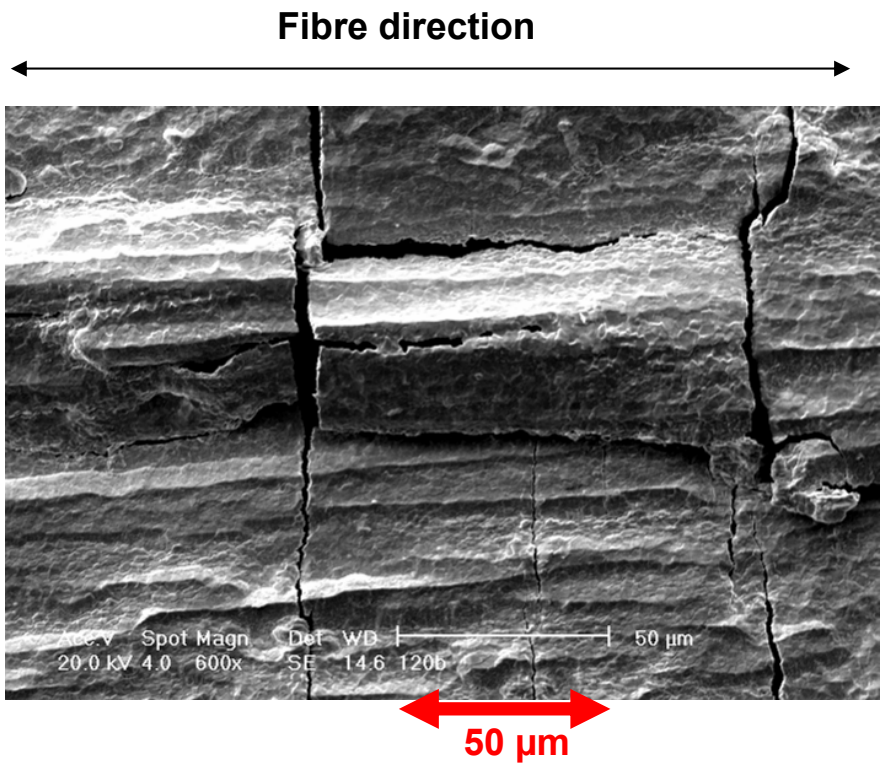
-parts of main chamber

-complete divertor

Installation of W coatings on CFC required

Thermal expansion mismatch
⇒ no solution at hand

H. Maier et al., J. Nucl. Mater. 363-365 (2007) 1246

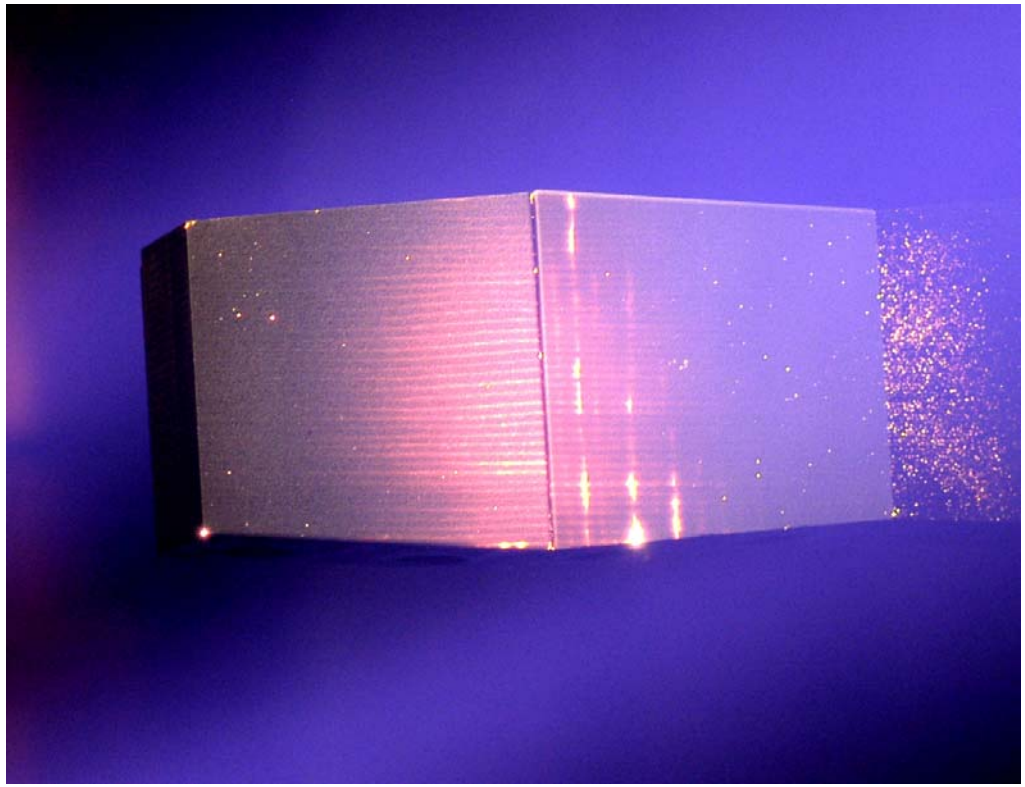


Research and Development:
Risk minimisation by test of several coating techniques and thicknesses:
Collaboration of 5 Associations
CEA
ENEA
IPP
MEdC
TEKES
- 3 different techniques:
  PVD, CVD,VPS
- 3 thicknesses:
  4, 10, 200 µm

⇒ **14 types**

High heat flux testing in GLADIS:

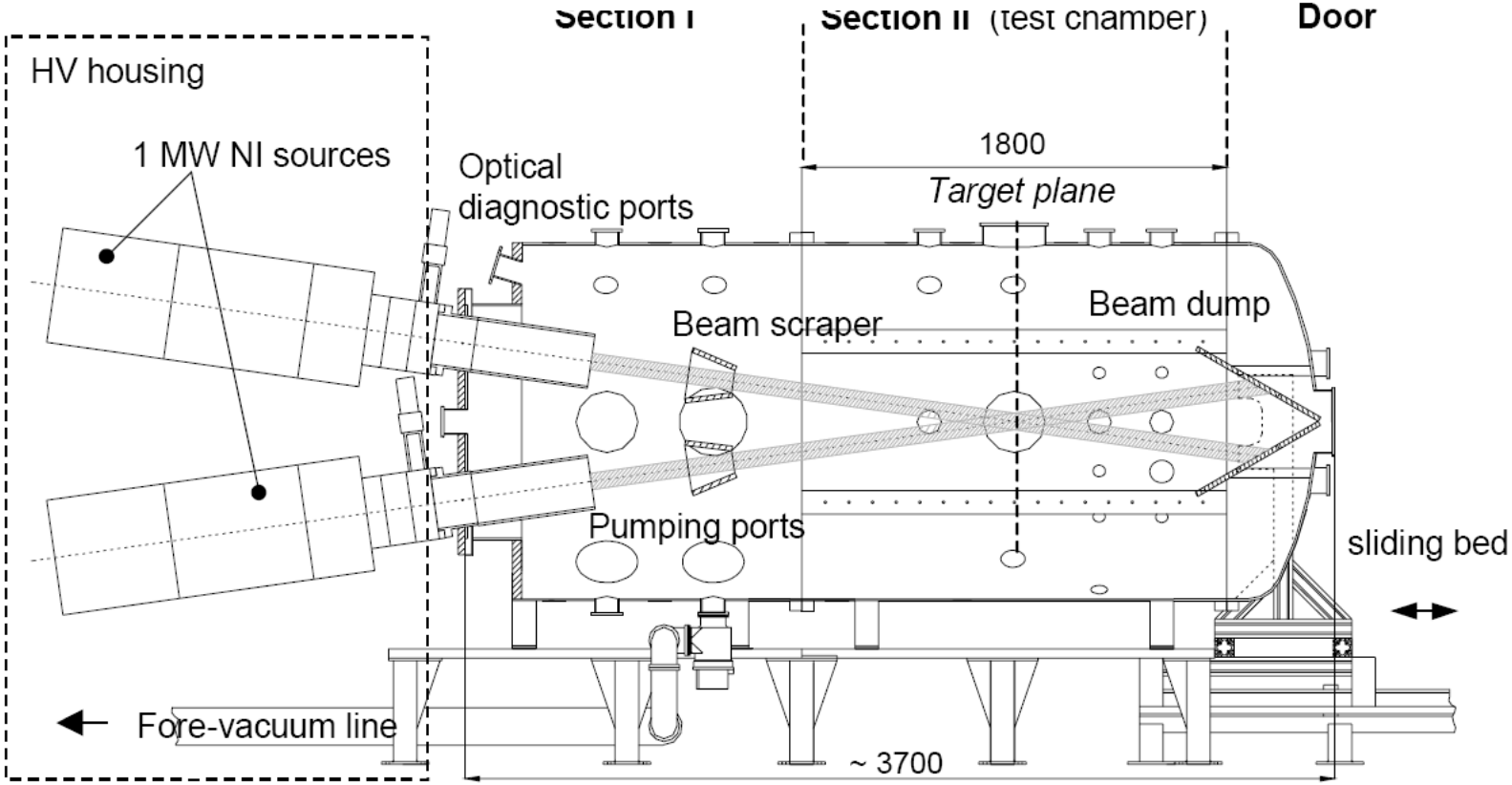
H/He neutral beam facility



H beam: power absorption same for C and W

High heat flux testing in GLADIS:

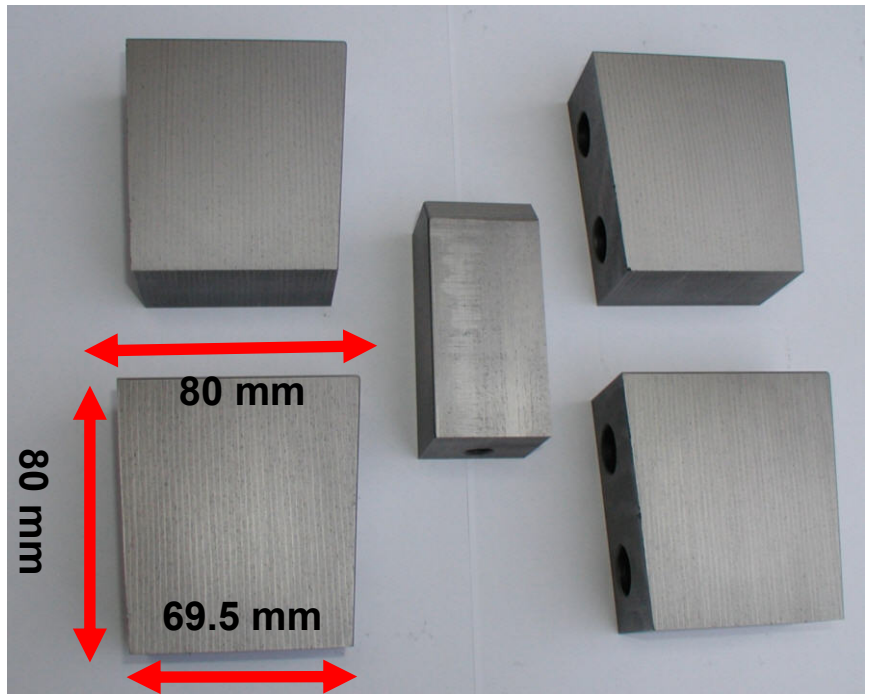
Neutral beam facility with 2
1 MW ion sources



Three-stage high heat flux test program

- thermal screening 5 steps (GLADIS)
  6.6 – 23.5 MW/m²
- cyclic loading (GLADIS)
  200 pulses, 10.5 MW/m²
- thermal shocks (JUDITH)
  1000 pulses, 0.35 GW/m²

all 14 types
best 6 types
best 3 types
layout of CFC test tiles



Further investigations

- stress analyses
- metallographic analyses
- adhesion tests (generally high)
- impurity content (generally low)

Upscaling

Best two selected:

- **VPS coating from Plansee**
- **CMSII coating from NILPRP**

Upscaling problems:

- **Plansee: facility existing, process upscaling required**
- **NILPRP: only small experimental facility existing**

  facility must be designed, optimised, constructed, and commissioned

Best two selected:

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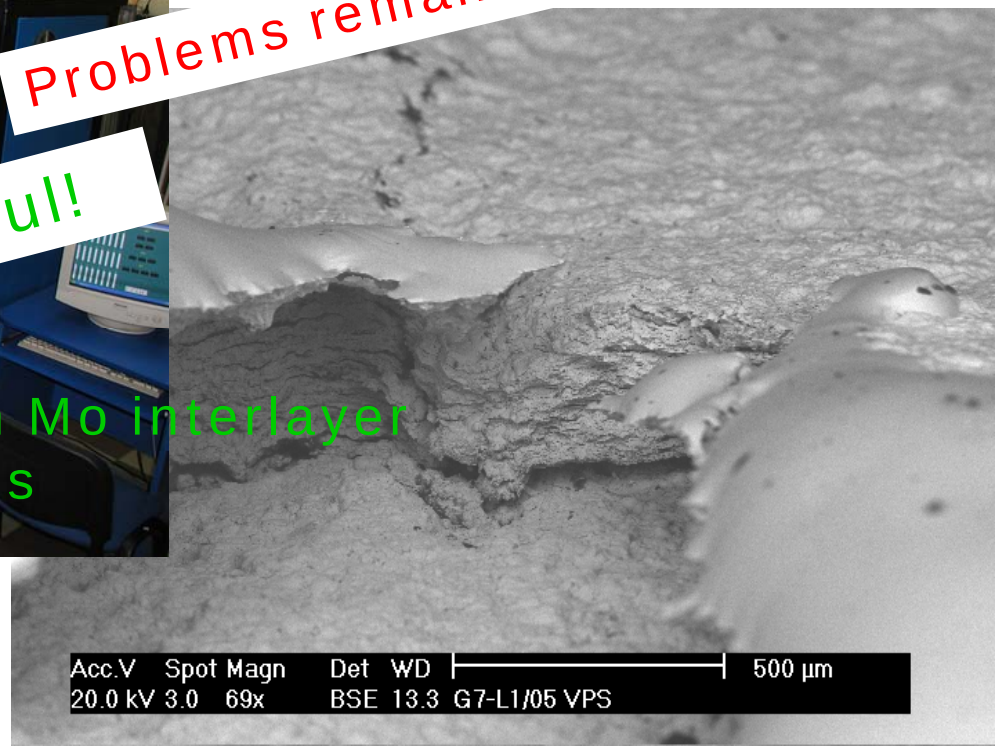
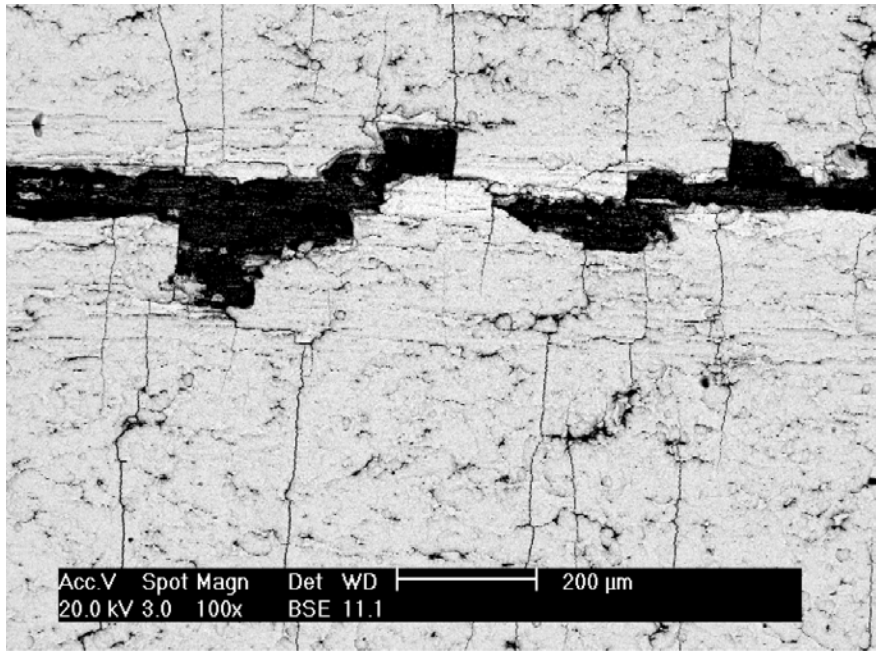


Lifetime investigation

Problem: - W and Mo form brittle carbides

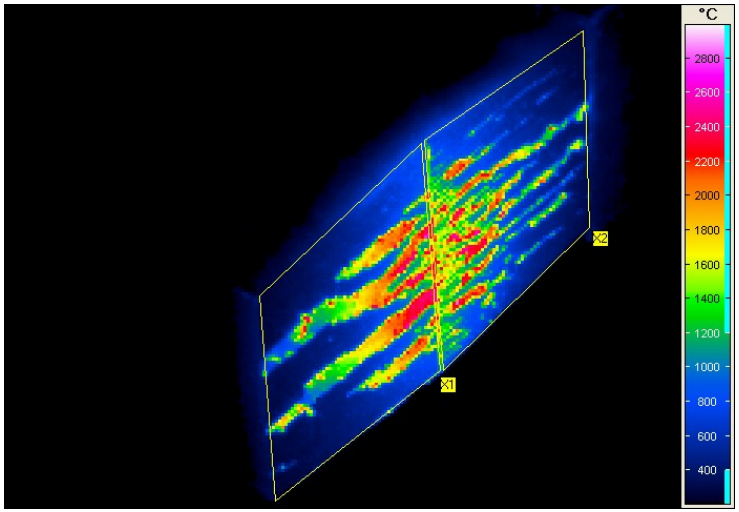
- There is no diffusion barrier



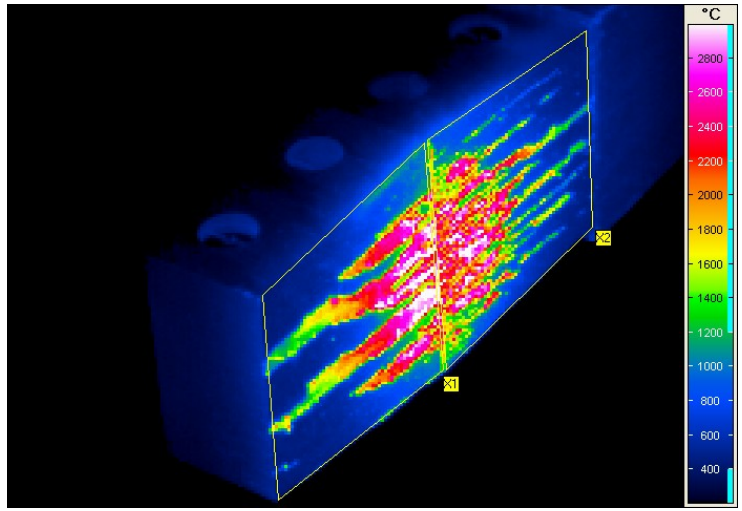
After carbide formation also the CMSII coatings with Mo interlayer show delamination failure on a very small scale

High heat flux testing in GLADIS of heat treated tiles (1350°C):

- Tests performed at 16.5 MW/m², 1.5 s, 25 to 200 pulses
- Pulse by pulse growth of delaminated surface area fraction: Averaged **apparent IR surface temperature**



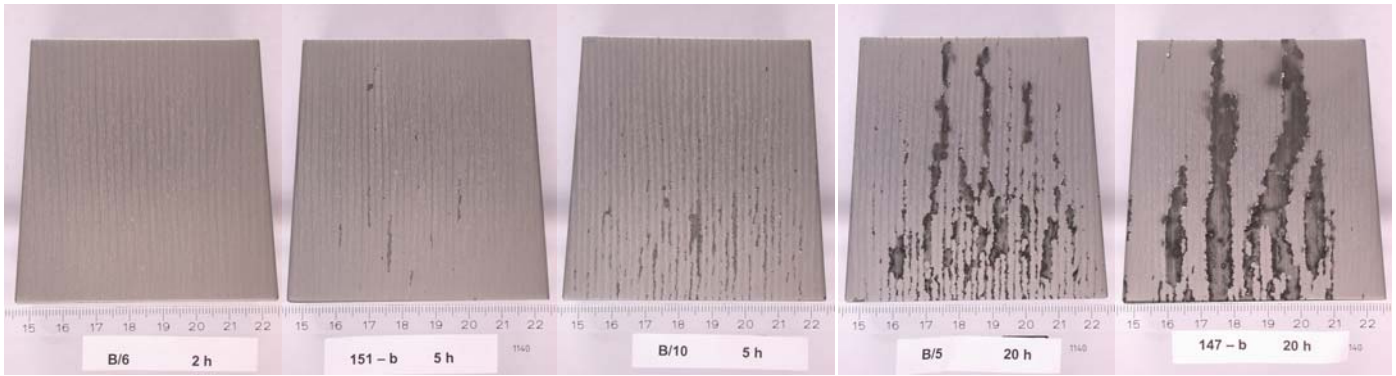
Pulse 1



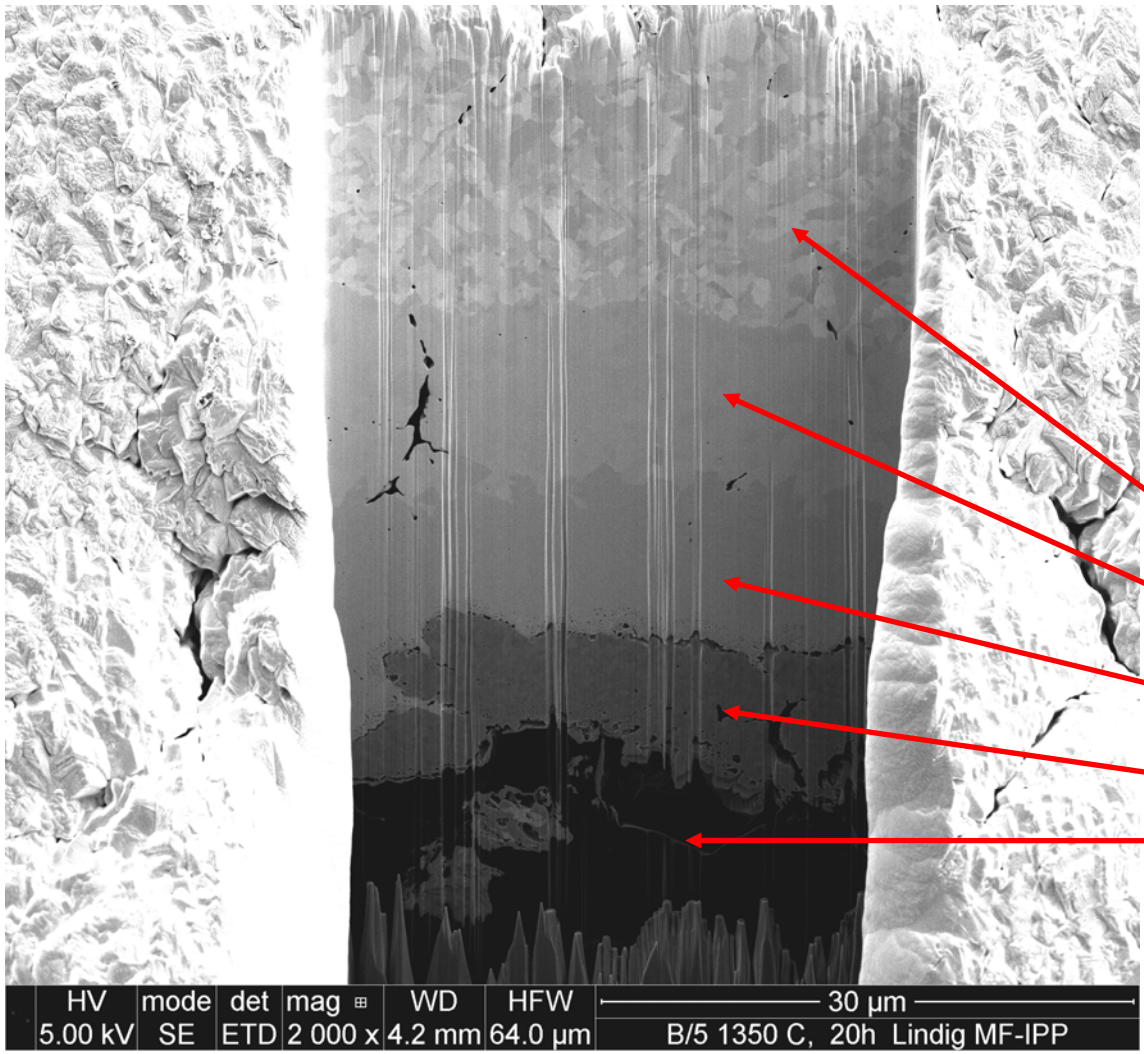
Pulse 25

High heat flux testing in GLADIS of heat treated tiles (1350°C):

- Tests performed at 16.5 MW/m², 1.5 s, 25 to 200 pulses
- Pulse by pulse growth of delaminated surface area fraction: Averaged **apparent IR surface temperature**
- Clear **threshold behaviour**



Dwell time	2 hours	5 hours	20 hours
Delaminated fraction	0.02%	1%, 5%	17%, 29%



Reason:

Formation of brittle carbides

Tungsten

Tungsten subcarbide W_2C

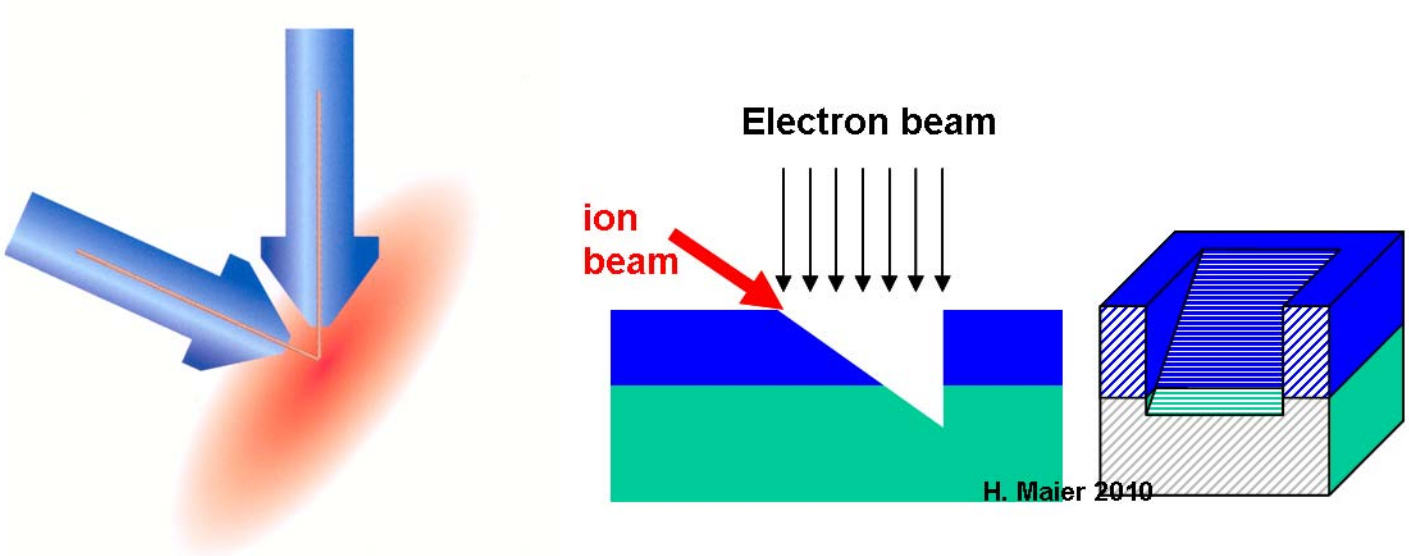
Tungsten carbide WC

Molybdenum carbide

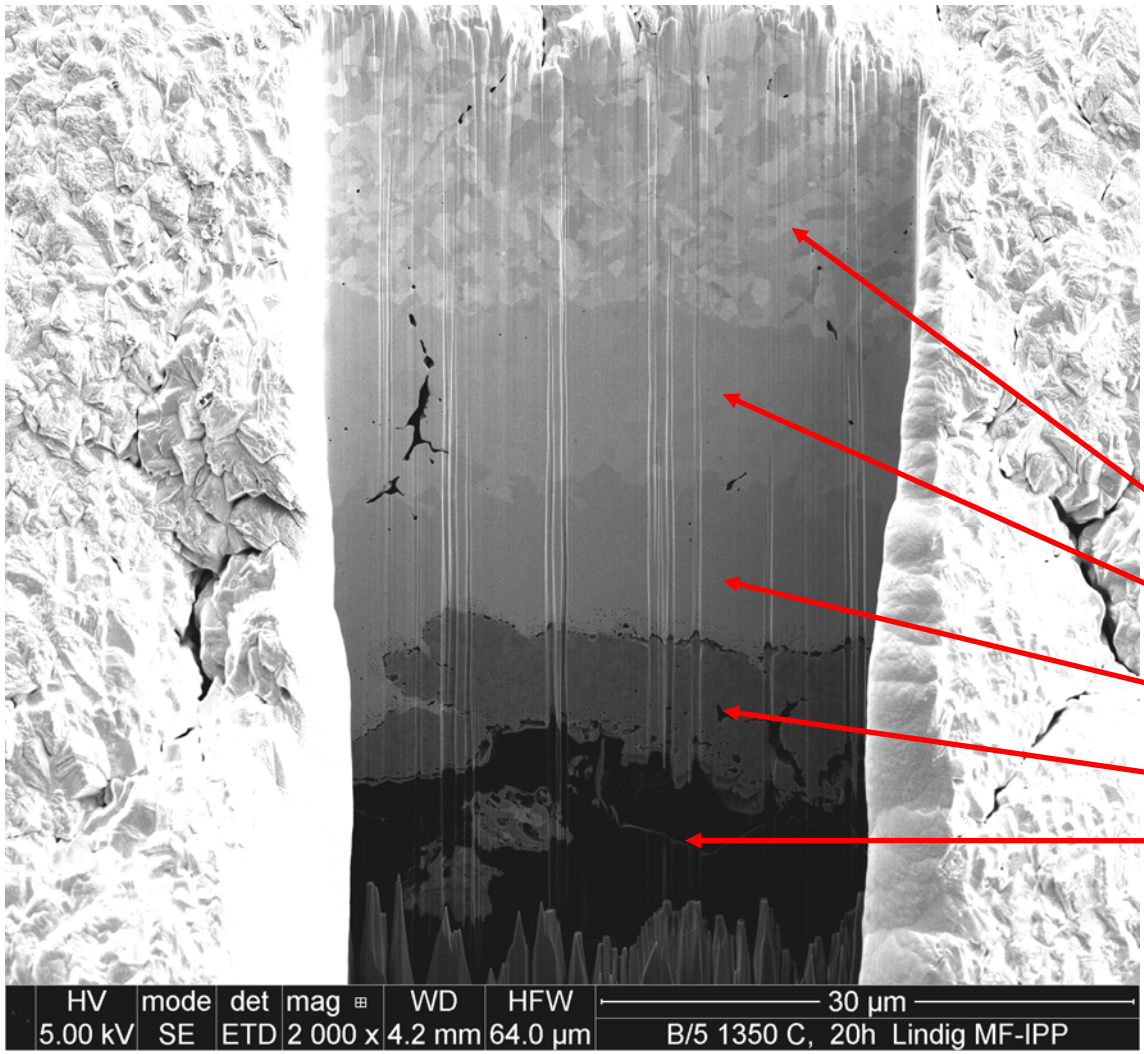
CFC substrate

SEM investigation combined with focussed ion beam preparation

(M. Rasinski, M. Balden, S. Lindig)



Dual beam device
(FEI “HELIOS”)



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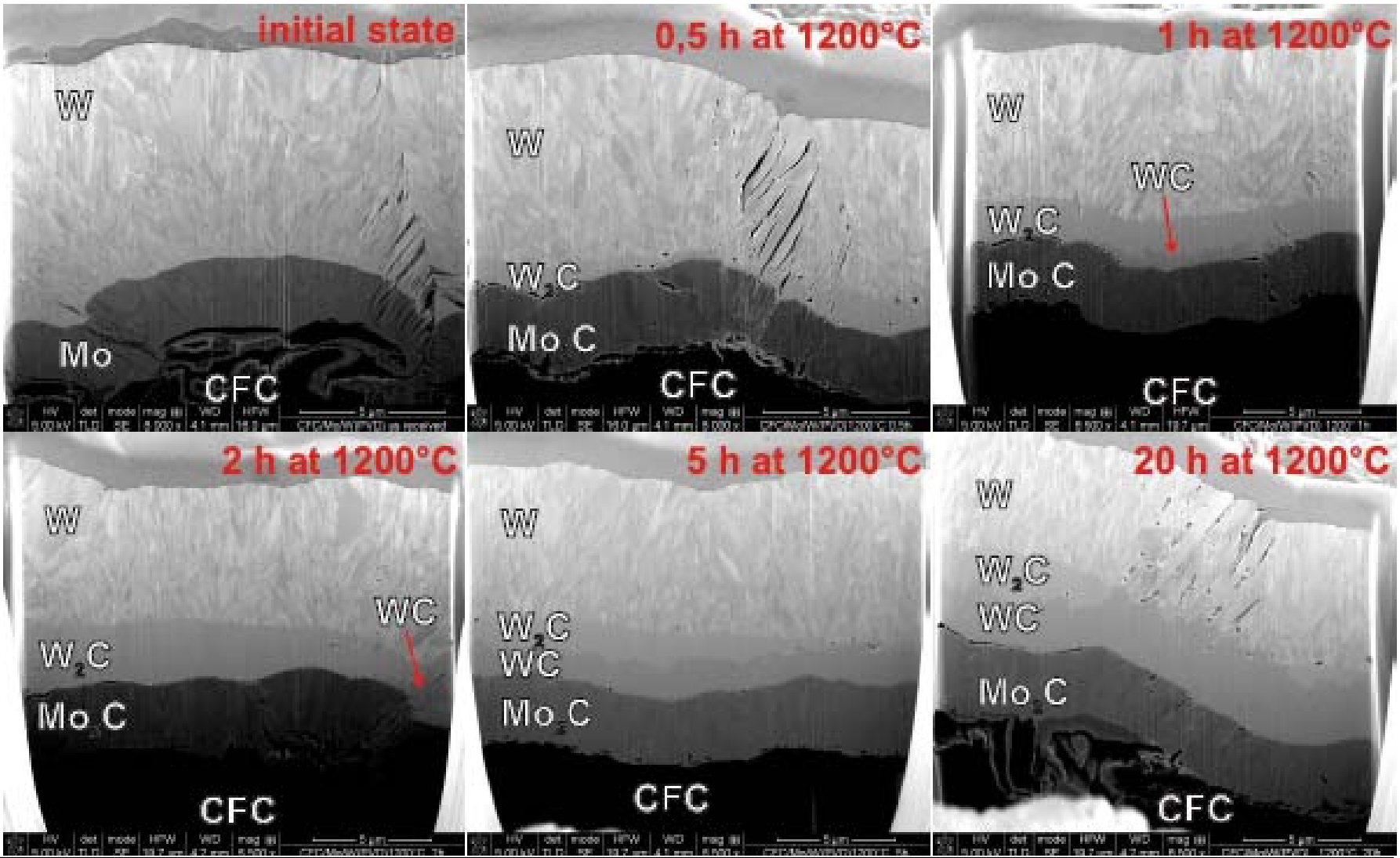
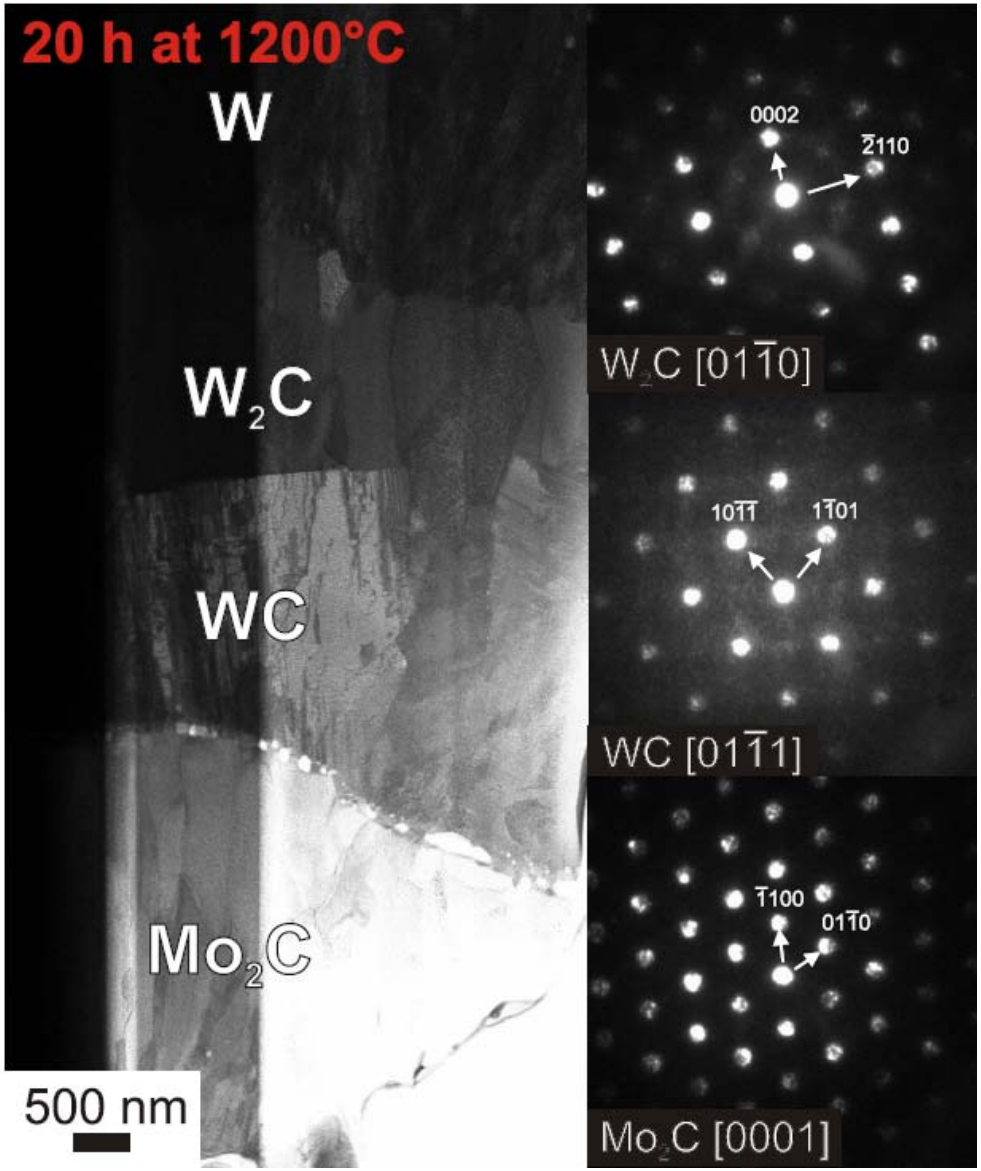


Lifetime investigation



Direct verification of phases by selected area diffraction and diffraction pattern analysis in a transmission electron microscope

(performed by M. Rasinski at Warsaw Technical University)

Conclusion

- After an extensive 6-year development programme JET is now upgraded with (4 tons of Be and) 1700 W-coated CFC tiles
- Due to the formation of carbides the performance of the coatings will have limits
- Therefore the allowed peak surface temperature will have to be controlled and monitoring will be essential
- A JET-EFDA Fusion Technology task was established for a detailed lifetime investigation