Warsaw University of Technology, Faculty of Materials Science and Engineering

Thermal stability of W/Mo JET divertor coatings on CFC substrate

M. Rasinski[1a], H. Maier[2], C. Ruset[3], M. Lewandowska[1], K. J. Kurzydlowski[1]

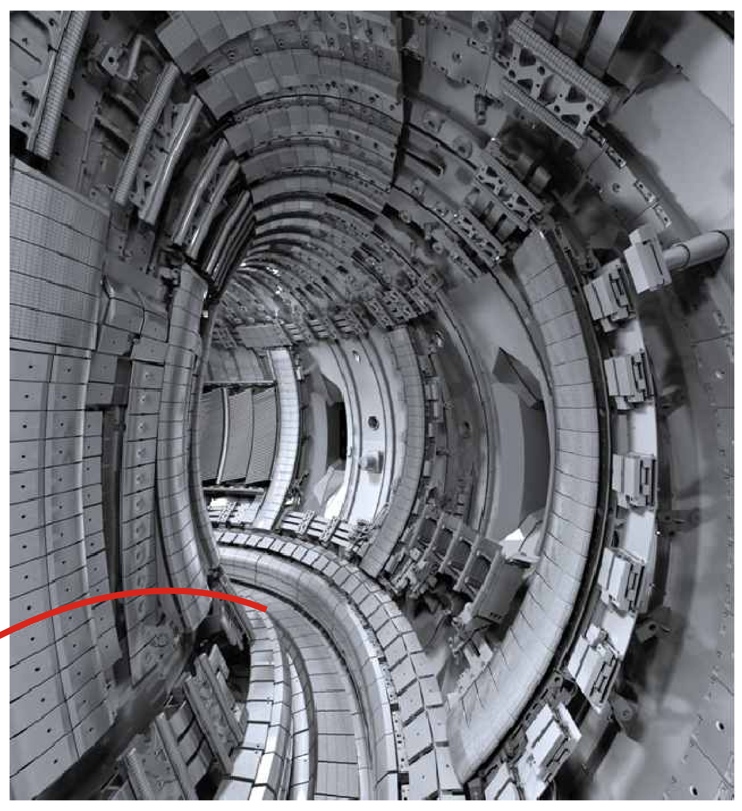
[1] *Warsaw University of Technology, Faculty of Material Science and Engineering, Warsaw*
[2] *Max-Planck-Institut für Plasmaphysik, EURATOM Association, Garching*
[3] *National Institute for Laser, Plasma and Radiation Physics, EURATOM-MEdC Association, Bucharest*

Introduction

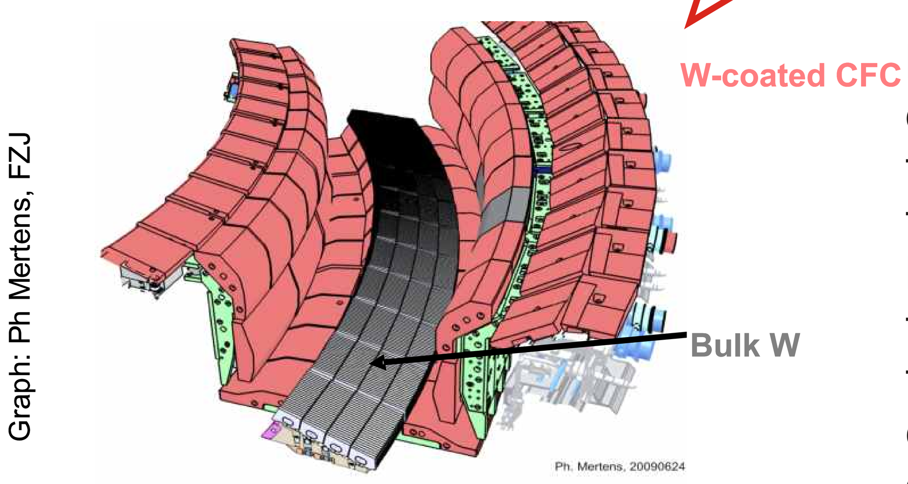
The JET reactor first wall material in the ITER-like wall project:
- Beryllium
- Carbon
- **Tungsten**

In the bottom part of the inside of the reactor - **divertor**

Divertor made of full carbon tiles together with **carbon tiles coated with tungsten.**



The inside of the JET reactor



Scheme of the divertor section in JET

During the operation of the reactor, diffusion of carbon from the substrate to the W layers is expected. Due to the fact that tungsten easily form carbides, brittle carbide phases may be created at the interface, strongly affecting the thermo-mechanical performance of the coatings. For the prediction of the operation time of such coated tiles, carbon diffusion and carbide formation need to be determined.

Experiment

Material production:
Full divertor tiles with 3-4 μm Mo and 10 - 25 μm W layer deposited on CFC substrate by combined magnetron sputtering and ion implantation technology (CMSII).

Machinining of samples with dimension 10 x 10 x 3 mm for further heat treatment analysis

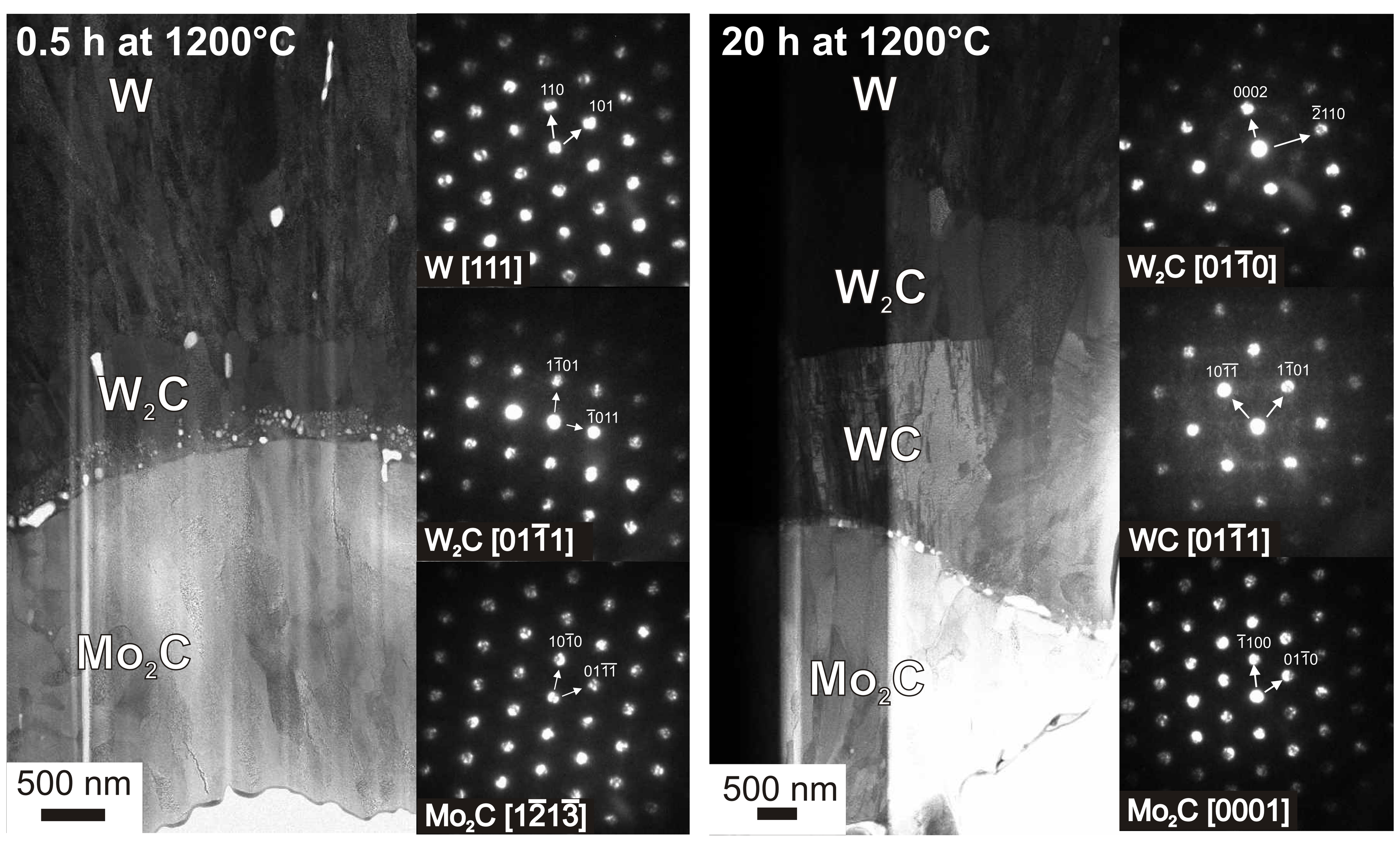
Annealing:
Ar flow/vacuum furnace at **1100°C, 1200°C, 1350°C** for **0.5h, 1h, 2h, 5h, 20h**

Electron microscopy observation:

Carbon diffusion measurement - Dual Beam FIB/SEM device:
=> FIB cross-section preparation
=> SEM observation

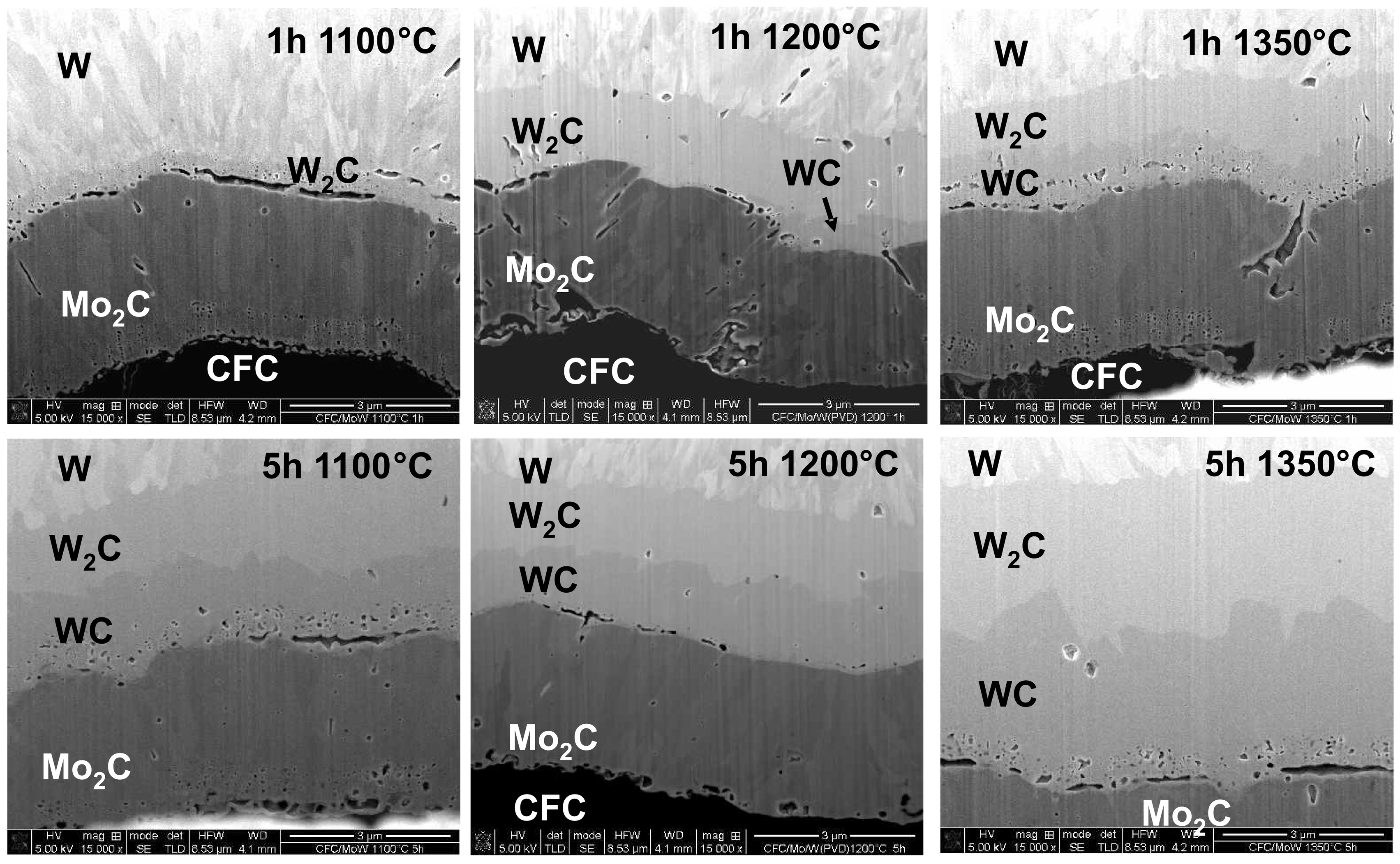
Phase determination
=> thin lamella preparation by single beam FIB device
=> TEM observation
=> local convergent beam diffraction analysis

Results - TEM analysis

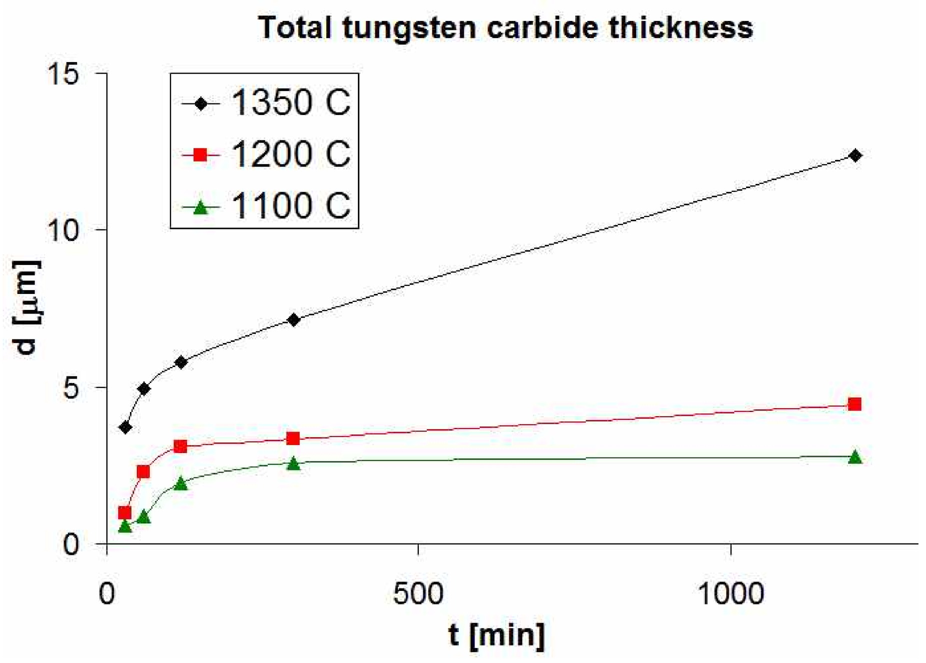


TEM images with diffraction analysis of multilayer systems after 0.5h and 20h annealing at 1200°C

Results



SEM images of FIB prepared cross-section of samples annealed at 1100°C, 1200°C and 1350°C

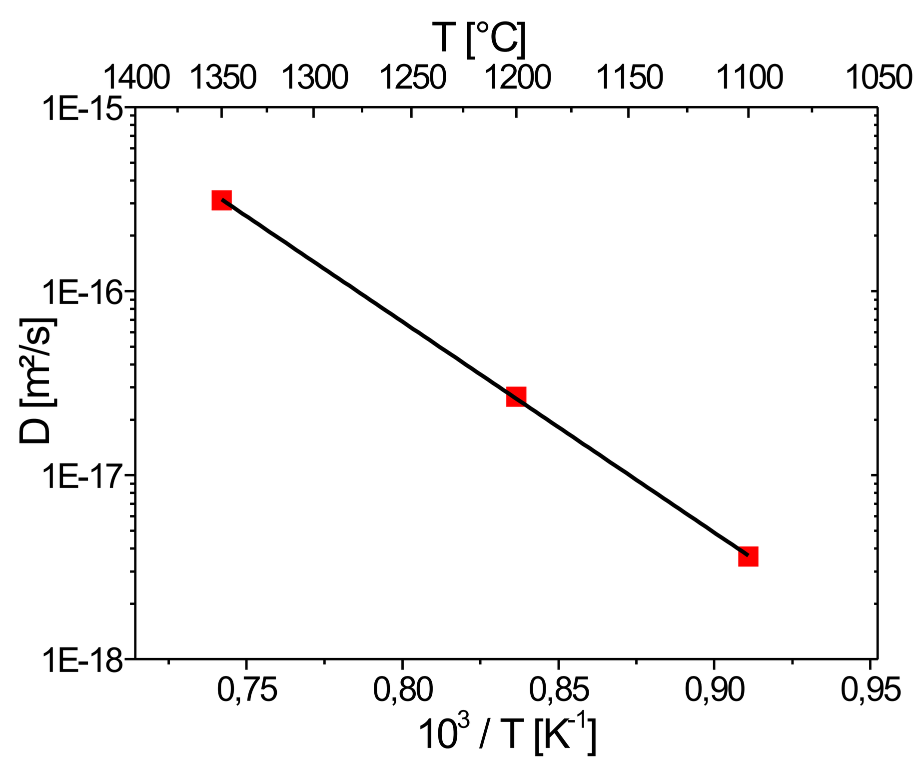


Total thickness of tungsten carbide versus growth time

TEM diffraction analysis enabled **Mo_2C** carbide identification in the initial molybdenum layer and two tungsten carbide phases - **WC** and **W_2C** in the initial tungsten layer after subsequent annealing.

SEM cross section investigation => average thickness of total tungsten carbide thickness measured and plotted versus growth time.

Growth of the total carbide thickness (W_2C phase) follow the parabolic law.



Arrhenius plot of total tungsten carbide growth rate

Assumption:
Movement of W_2C reaction front can be described by one single diffusion process, i.e.

$$d^2 = 6\,Dt$$

with a "diffusion coefficient" D.

Arrhenius plot of the "diffusion coefficient" versus annealing temperature =>
In the investigated temperature window the process can be described by one single "effective" activation energy:

E_A=3.4 eV

Conclusion

TEM diffraction analysis => **Mo_2C** carbide as well as **W_2C and WC** carbide identified.

Growth of the W_2C carbide phase follow the parabolic law => main process controlling the growth is carbon diffusion from the substrate to the reaction front.

Activation energy E_A can be employed to model the kinetics of the carbide layer growth for complex temperature-time history
=> Lifetime assessment of the coatings during JET operation

mrasin@o2.pl