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TEM investigation of W in the double forged and re-crystallized condition

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Introduction

Tungsten is a primary candidate for use as first wall material and other plasma facing components in future tokamaks, because of its high melting temperature, high temperature strength and low erosion rate. On the downside are the poor mechanical properties, in particular the fracture toughness and the high ductile-to-brittle transition temperature. During long-term exposure to the plasma, a recrystallization of the material takes places, altering its properties. The optimal production parameters and the full characterisation of the material is still under investigation. Here, transmission electron microscopy was applied to investigate the defect structure of the double forged tungsten and to assess the influence of the recrystallization.

Experimental

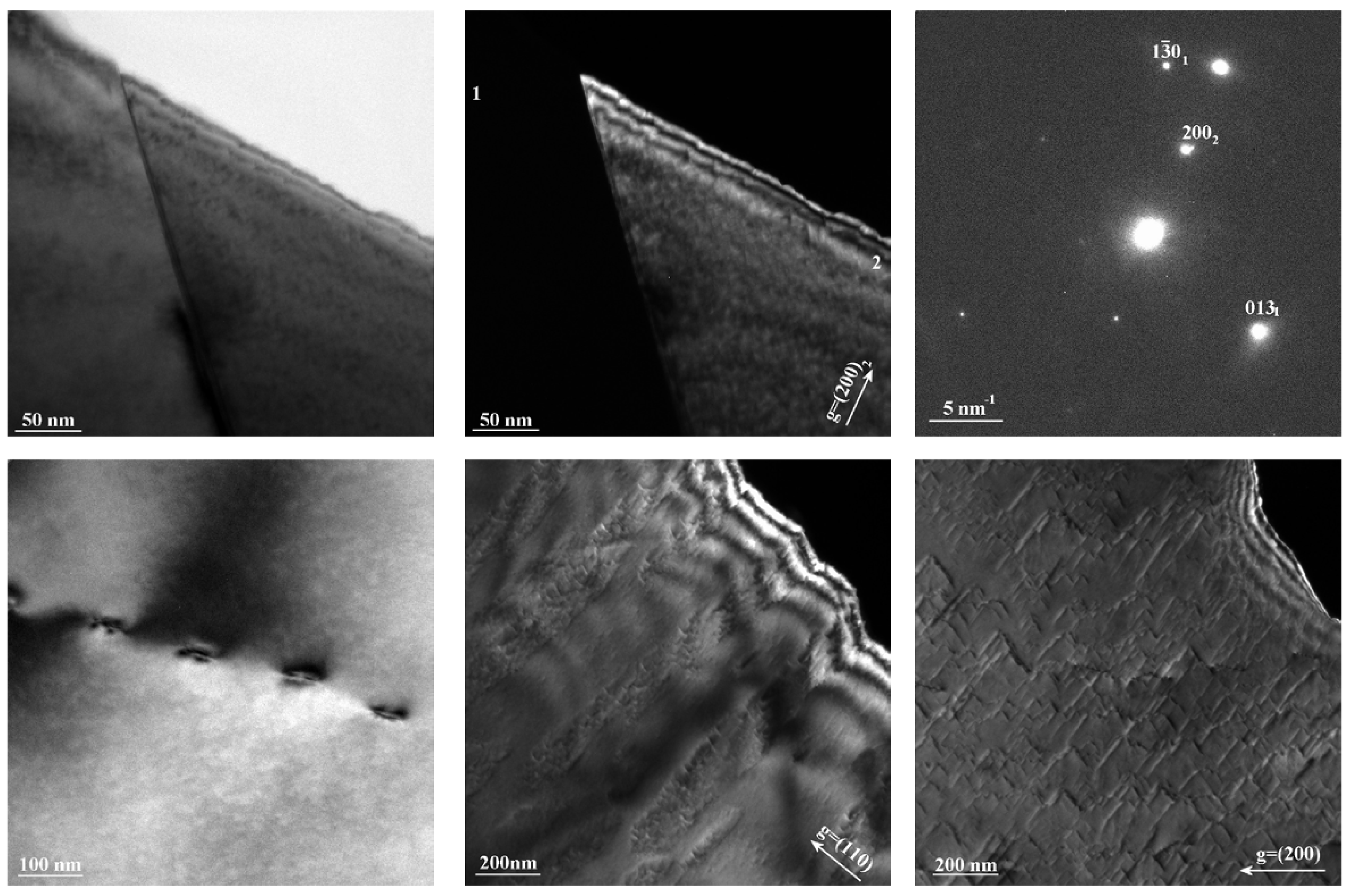
Pure tungsten blocks were produced by Plansee AG, Austria, including:
- Isostatic pressing and sintering to cylindrical block
- Double forging in the radial and a cylindrical direction
- Stress relief at 1000 °C.
- Recrystallization at 1600 °C for 1 hour.

TEM specimen preparation:
- Rods of ø 3mm machined from different areas of the cylindrical block.
- Cutting of thin slices and mechanical polishing to 0.1 mm.
- Electrochemical polishing using 1.5 g NaOH in 1 l water at 15 V.
- Specimens were investigated in a JEOL 3010 TEM.

Results

- The grain structure differs from the edge to the middle and an anisotropy occurred in the longitudinal and transverse direction[1,2].
- No differences in microstructure were found in different areas.
- Only the recrystallization treatment significantly changed microstructure.
- Specimens are characterized as double forged or recrystallized, no distinction is made for area.

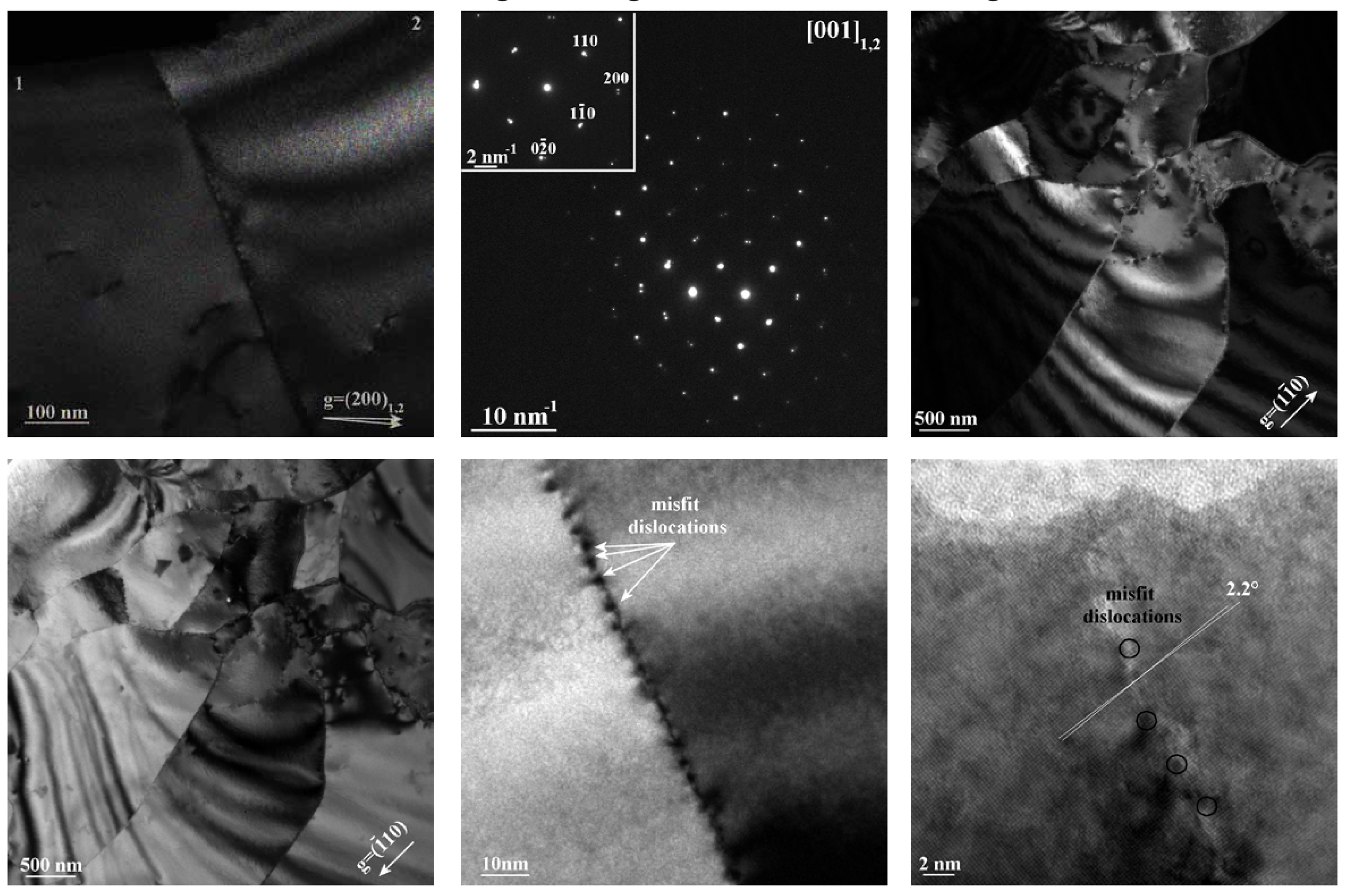
Defect structure after recrystallization



Recrystallized material
No tilt-boundaries, only grain boundaries

Inhomogeneous defect structure
- Isolated a/2‹111› type dislocations
- No Dislocation networks
- Residual "network" contrast on specific crystallographic orientations preferentially ‹111› directions

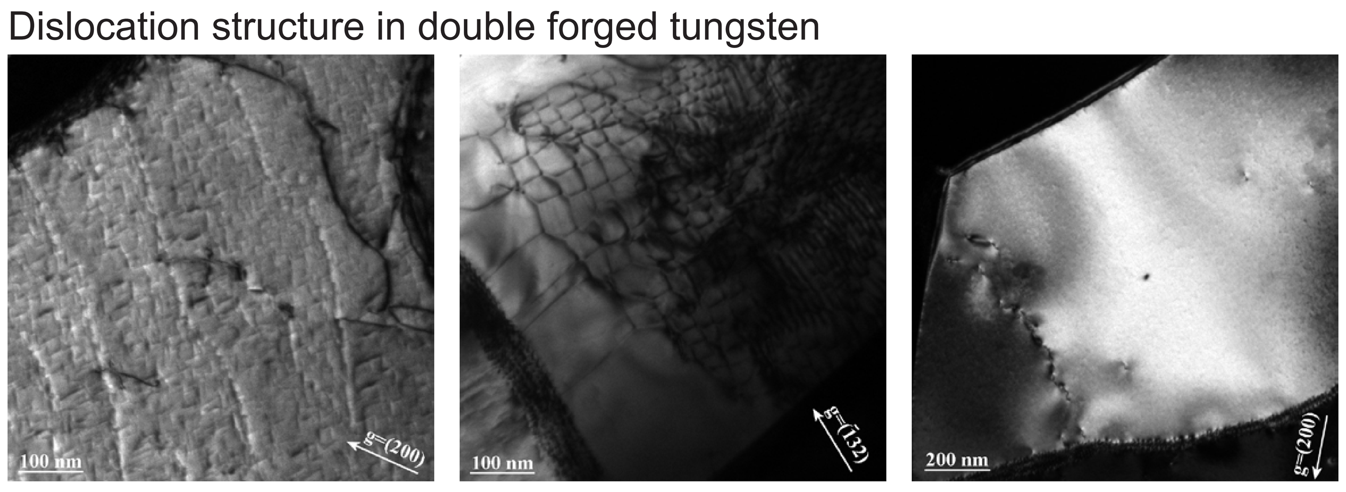
Tilt boundaries in double forged tungsten at different magnifications



Double forged material
Large amount of tilt boundaries
- boundary between two regions of small orientation difference
- misfit dislocations to accommodate orientation difference

Inhomogeneous defect structure
- Isolated a/2‹111› type dislocations
- Dislocation network
- Residual network contrast

Dislocation structure in double forged tungsten



Discussion

- Forging introduces high amount of stress resulting in dislocation networks and small angle tilt boundaries
- Subsequent stress relief insufficient to remove all defects: mainly tilt boundaries remain
- Recrystallization removes tilt boundaries
- Related to mechanical properties, recrystallization decreases flow stress, but increases ductility [2]
- Tilt boundaries are obstacles to dislocation movement, thereby increasing the hardness of the material.
- Residual strain fields: result of removal of dislocation networks or surface roughness?

Conclusions

The microstructure of double forged and recrystallized pure tungsten was investigated with TEM. In double forged material small angle tilt boundaries and dislocation networks were observed. These defects were removed during the recrystallization treatment resulting in a material of lower strength, but higher ductility. The anisotropy in the grain structure at different locations in the tungsten block did not show up in the microstructure.

References

[1] G. Pintsuk, A. Prokhodtseva, I. Uytdenhouwen, J. Nucl. Mater. (2011), doi:10.1016/j.jnucmat.2010.12.109
[2] I. Uytdenhouwen, PFMC-13/FEMaS-1, poster P67B