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PLANSEE

Tungsten as Structural Material

for Power Plant High Heat Flux Components

Michael Rieth & Andreas Hoffmann

Thanks for contributions and discussions to:
S. Baumgärtner, C. Bichler, B. Dafferner, C. Grubich, S. Heger, U. Jäntsch, M. Klimenkov, W. Krauss, P. Lukits, E. Materna-Morris, A. Möslang, P. Norajitra, J. Reiser, M. Rohde, W. Schulmeyer, R. Ziegler, H. Zimmermann

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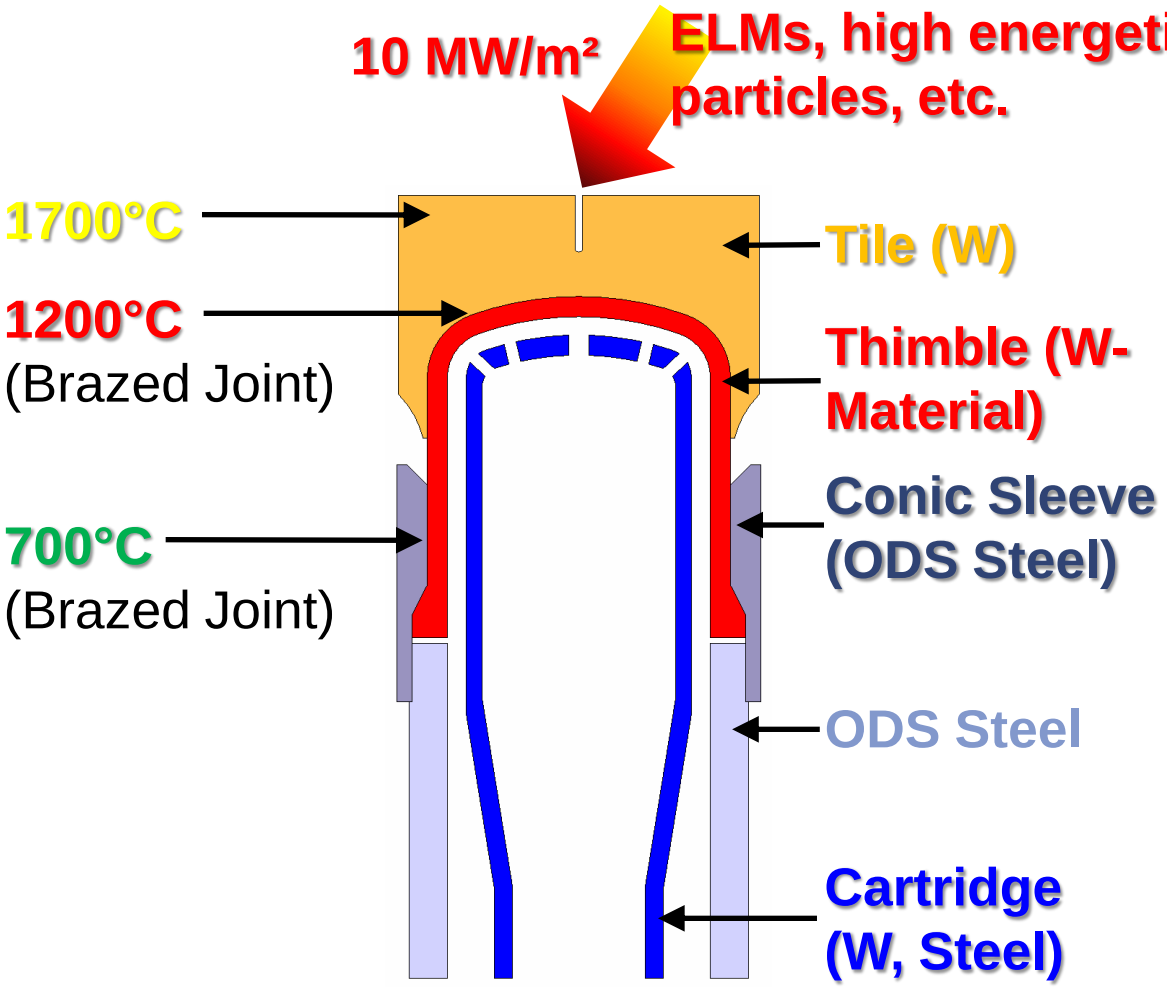
Contents

Overview, DEMO Divertor Design



→ P. Norajitra, this workshop

Materials

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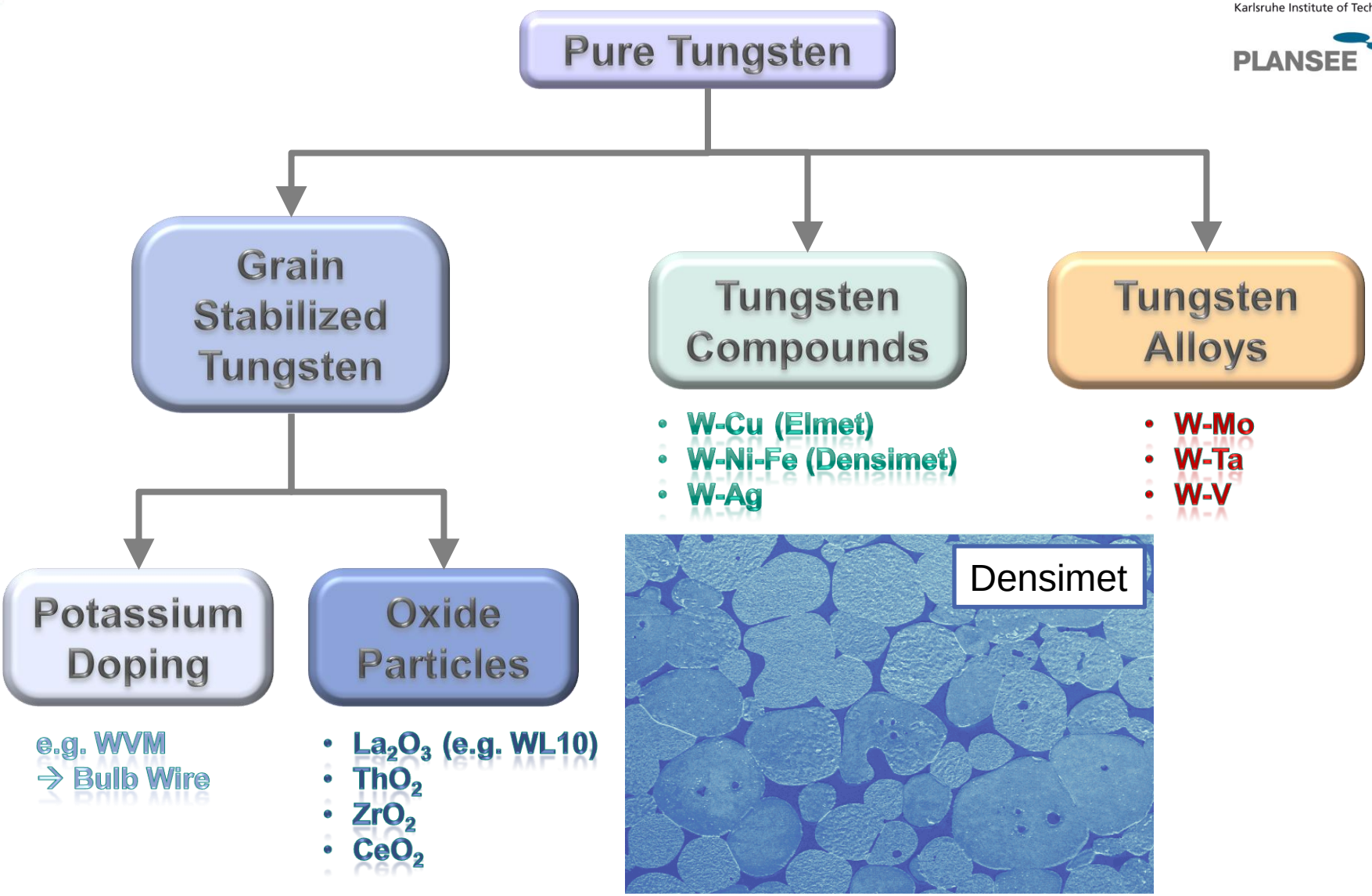
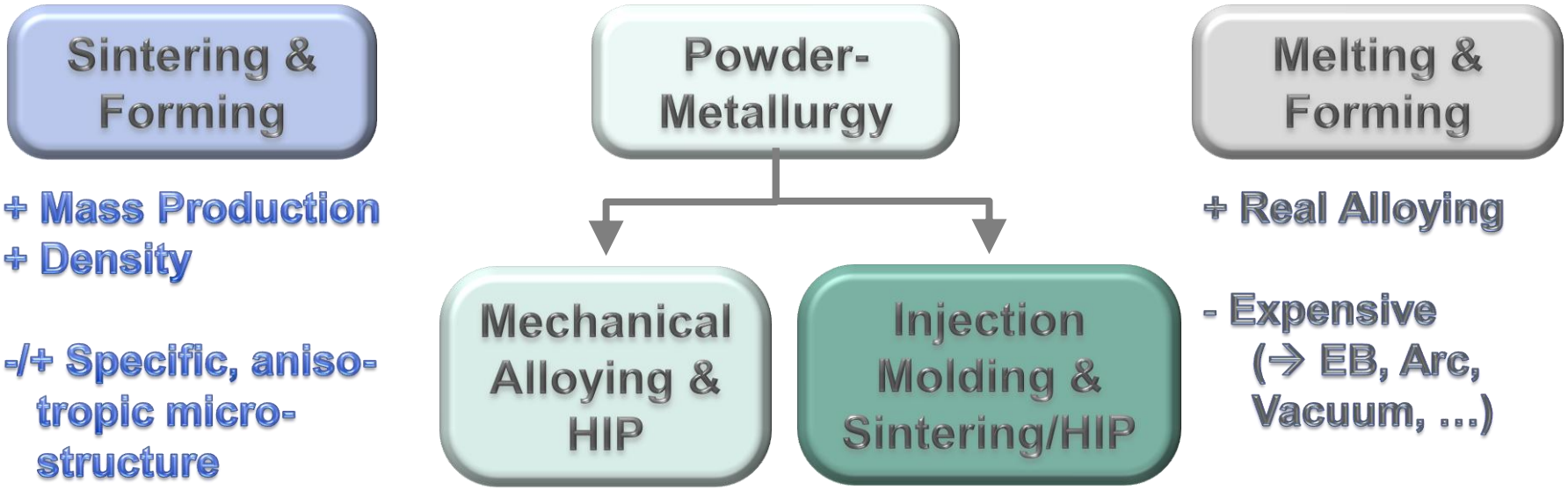
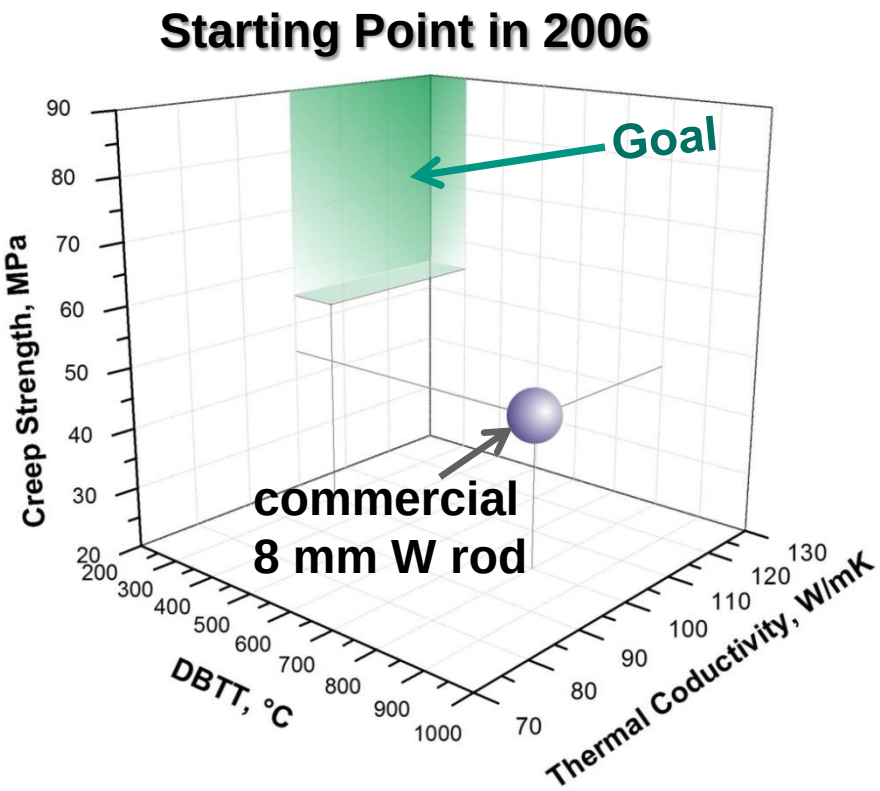


Material Production Routes

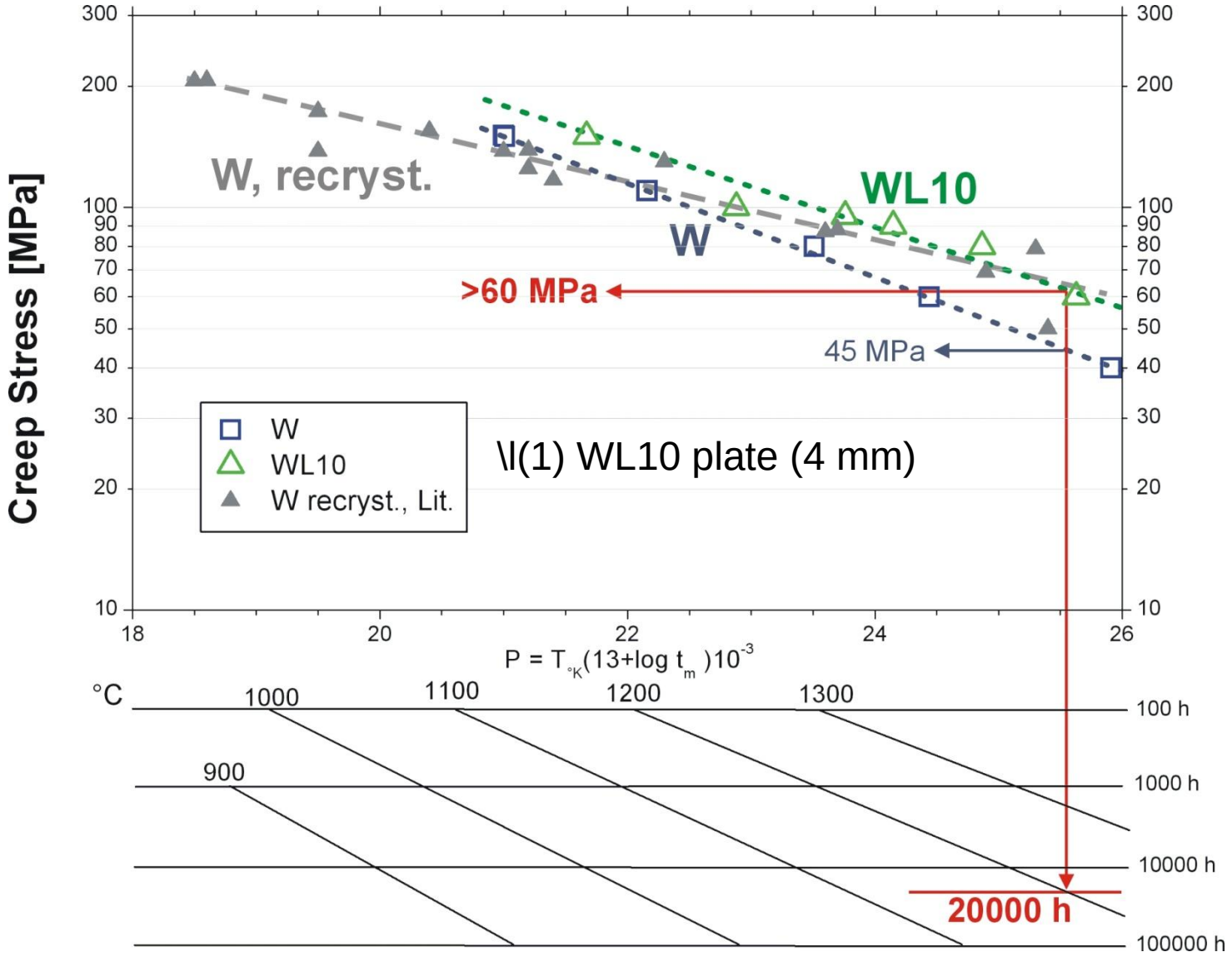


Important Design Criterions

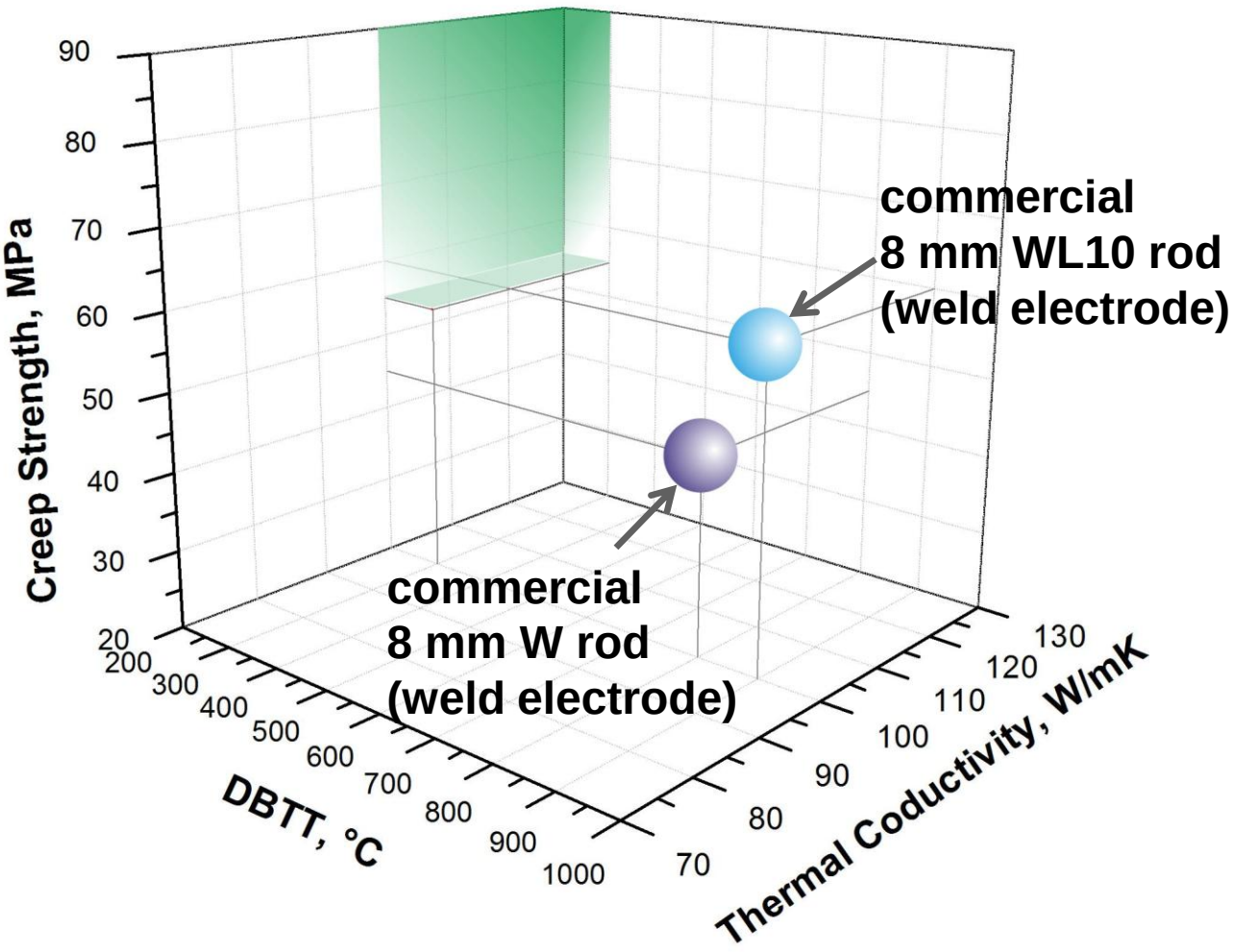
Thermal Conductivity	100 W/mK @ 1200 °C
Creep Strength	55 MPa, 20 kh @ 1200 °C
DBTT (EU Mini Charpy)	300 °C, un-irradiated
Recrystallization Temperature	1300 °C, for 20 kh



Present Knowledge: Creep



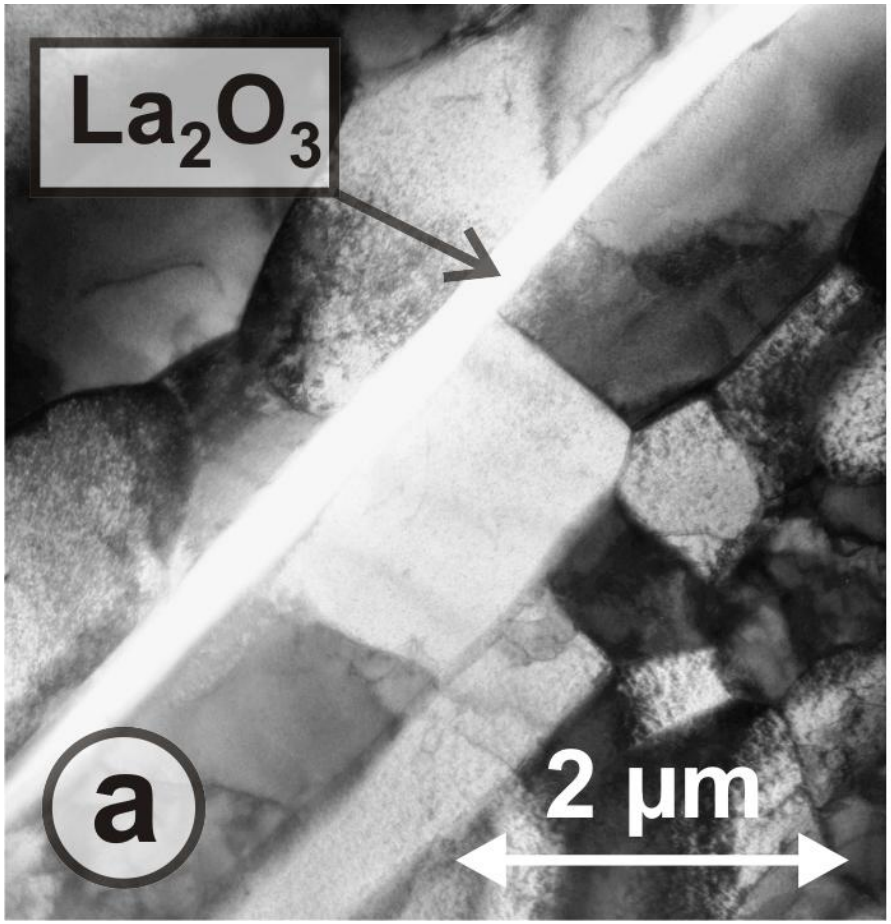
Present Knowledge: Creep



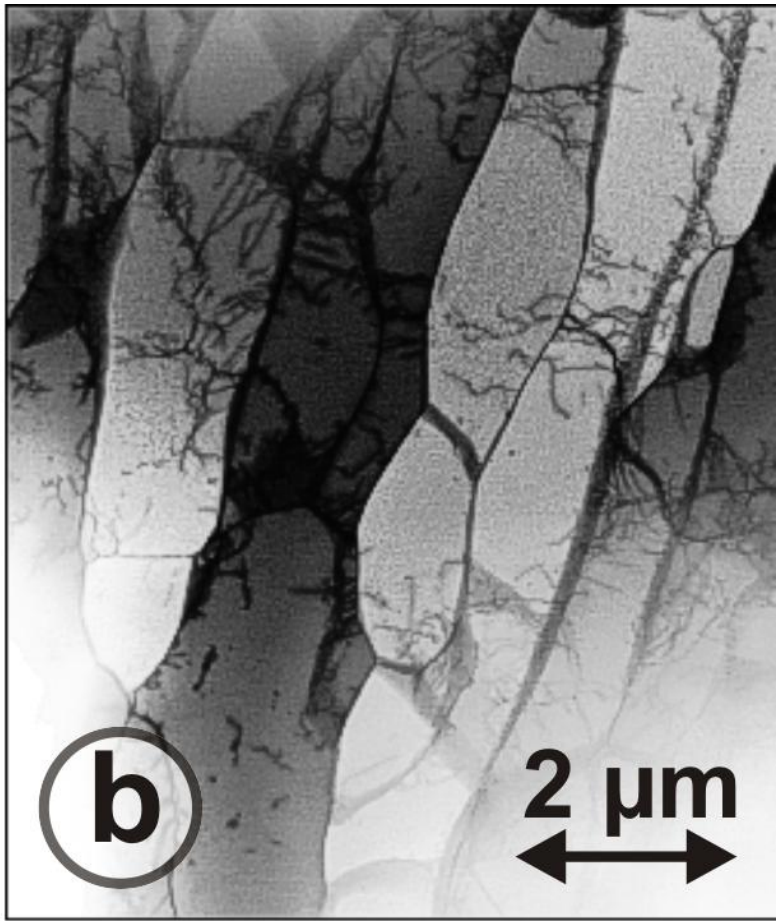
Present Knowledge: Recrystallization

Microstructure in the condition as delivered (by TEM)

WL10 Rod, Ø7 mm



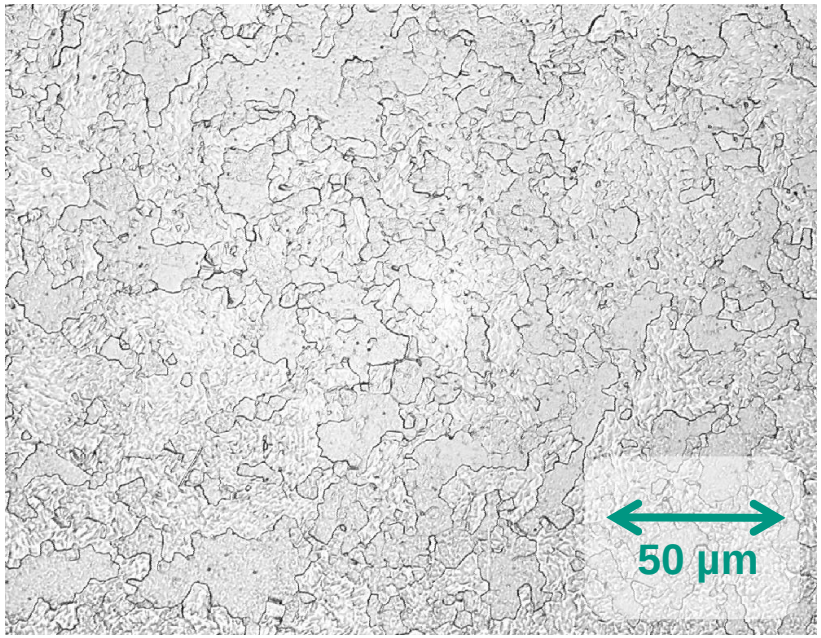
W Rod, Ø7 mm



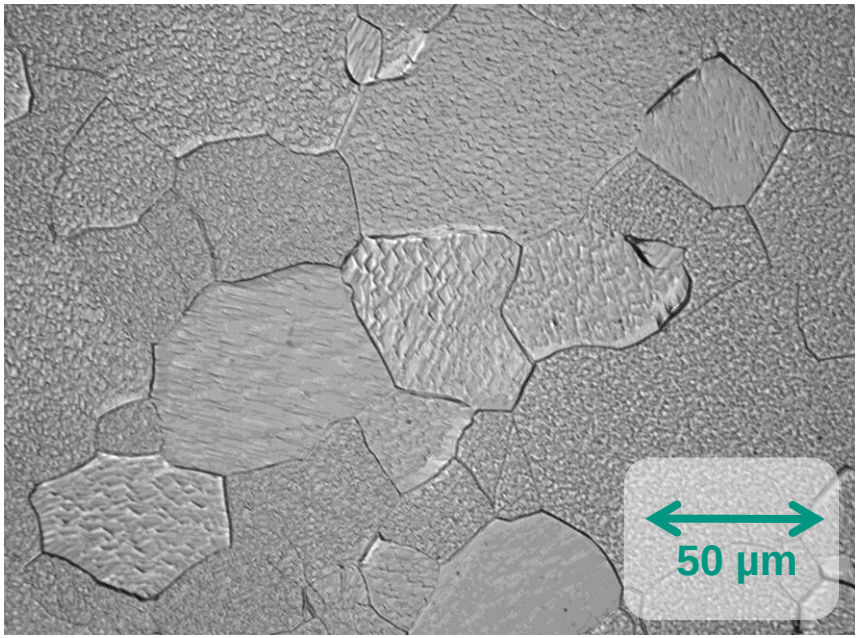
Present Knowledge: Recrystallization

Microstructure perpendicular to rod axis (by optical microscope)

W Rod, Ø10 mm, as delivered



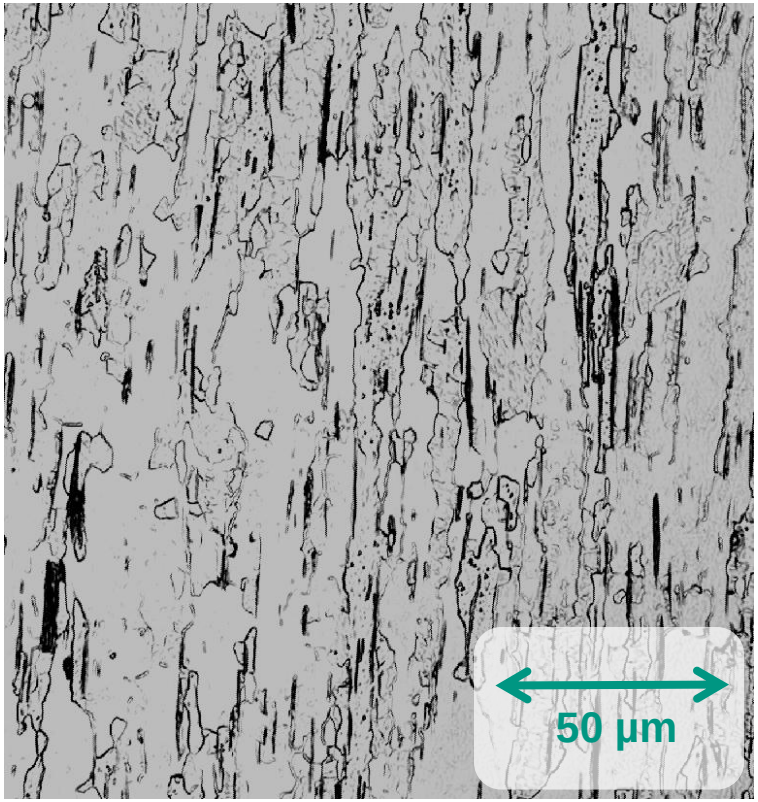
W Rod, Ø10 mm, 1300 °C/343 hours



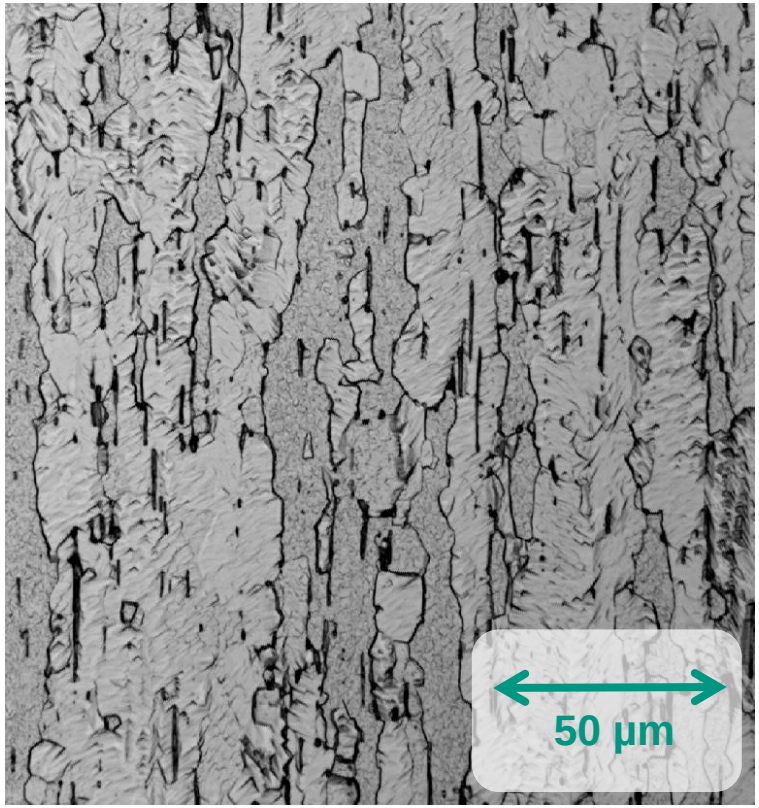
Present Knowledge: Recrystallization

Microstructure parallel to rod axis (by optical microscope)

WL10 Rod, Ø10 mm, as delivered

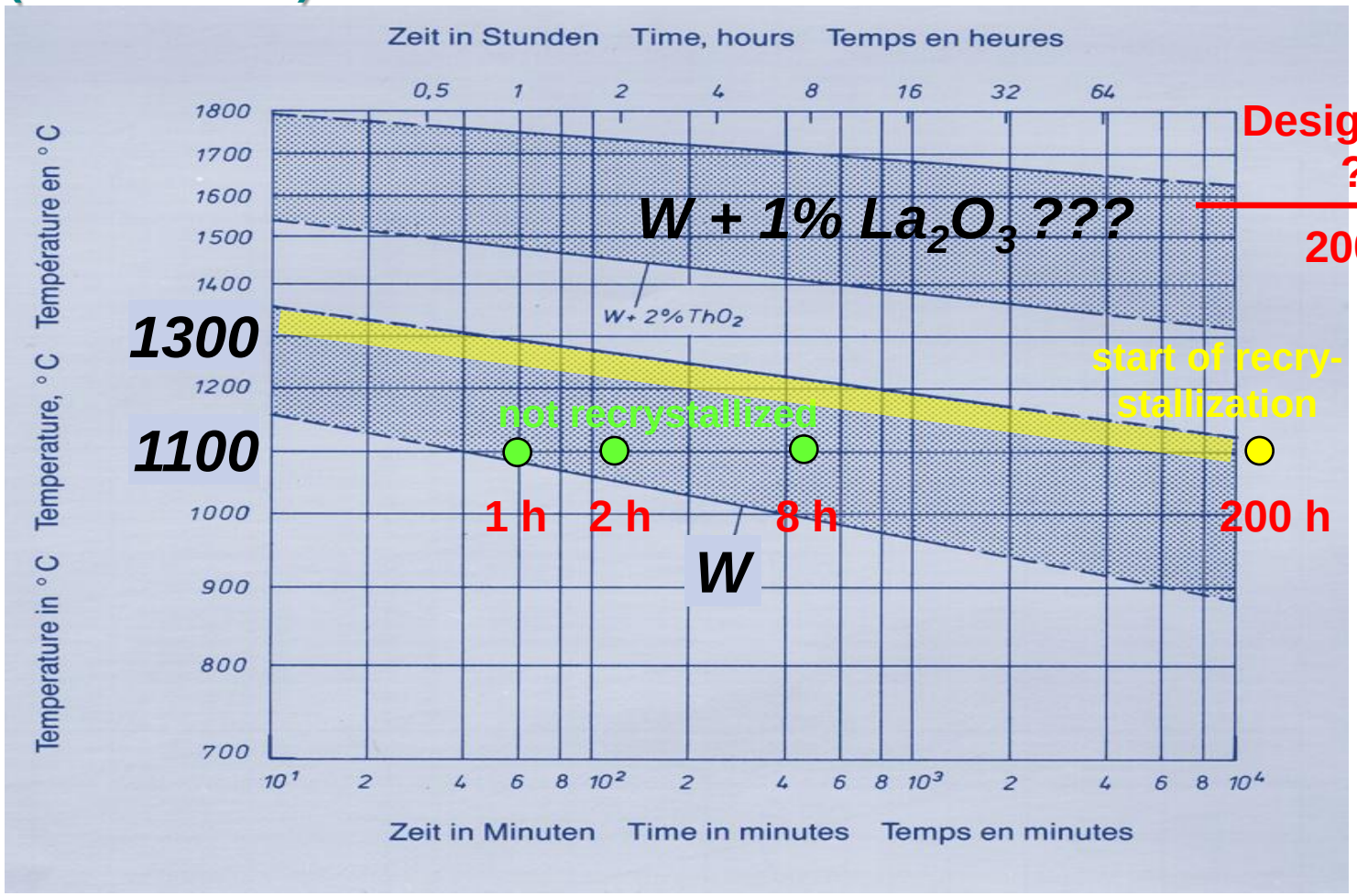


WL10 Rod, Ø10 mm, 1300 °C/1966 hours

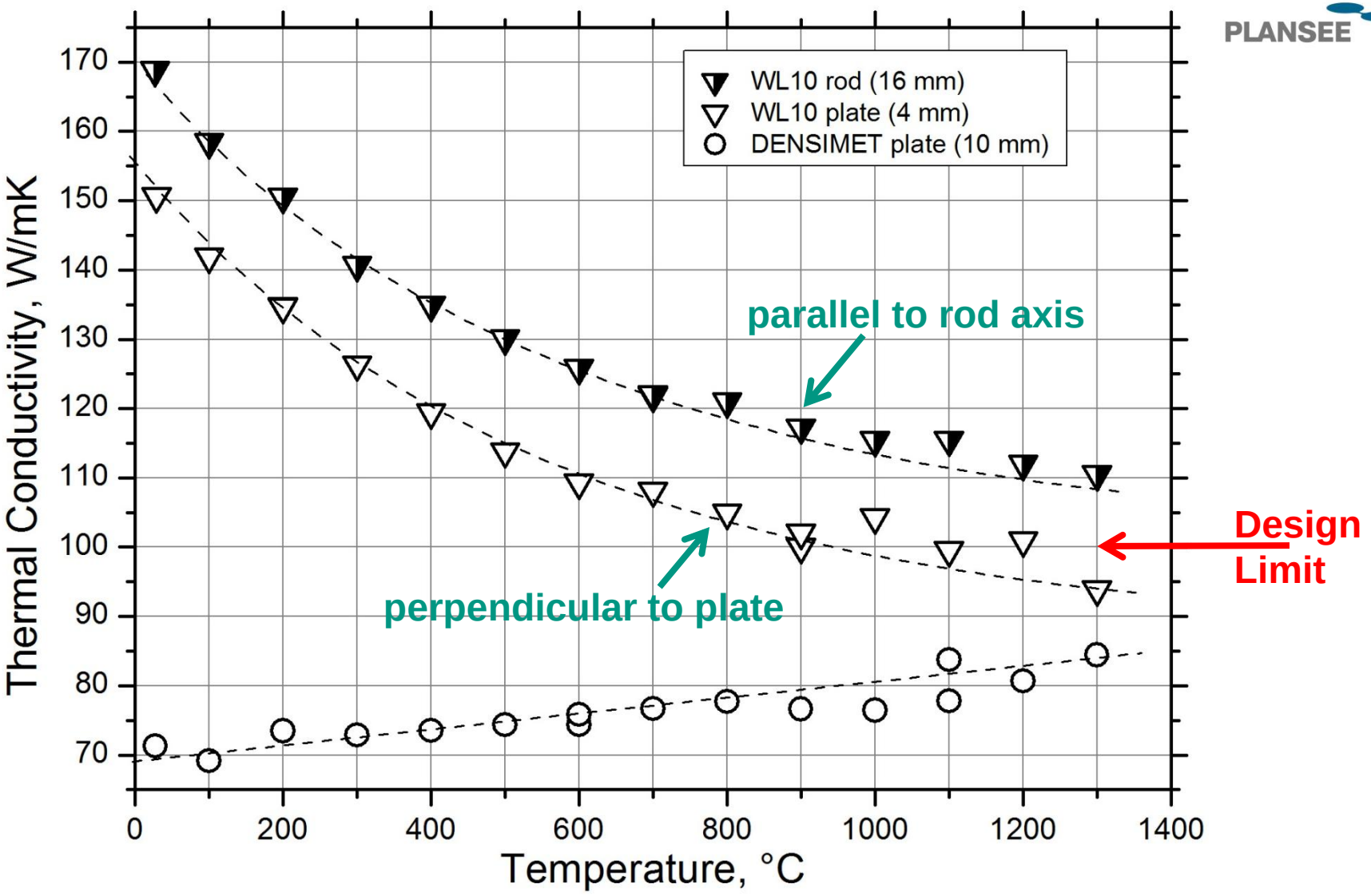


Present Knowledge: Recrystallization

Observed recrystallization compared to existing results (Ref.: Plansee)

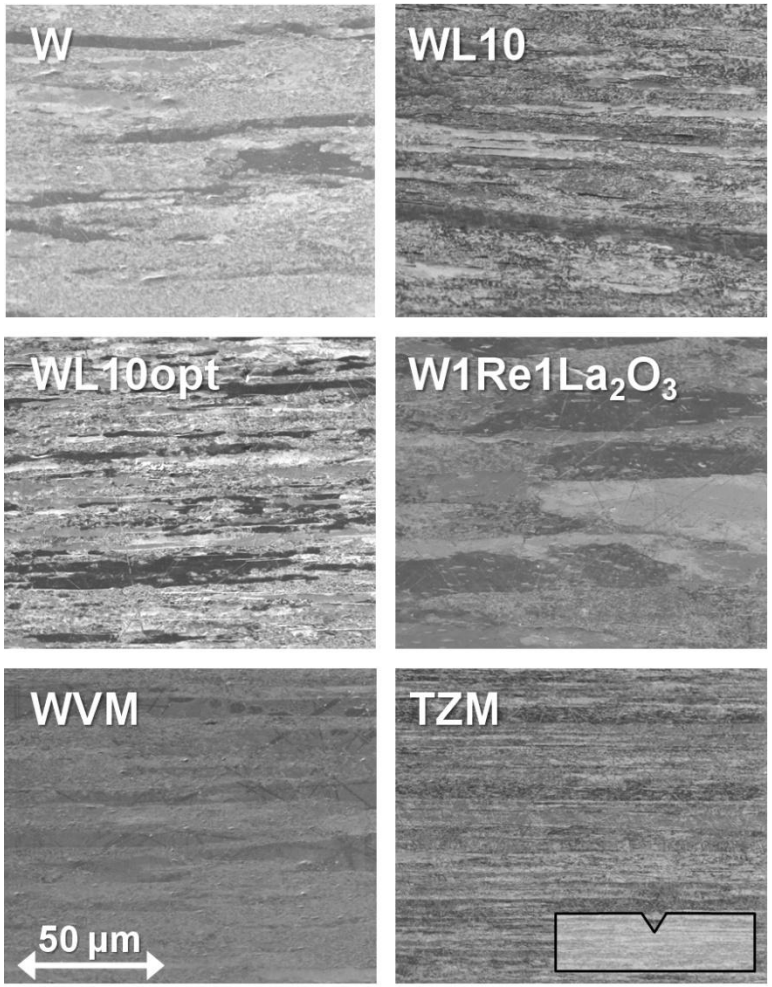


Present Knowledge: Th. Conductivity

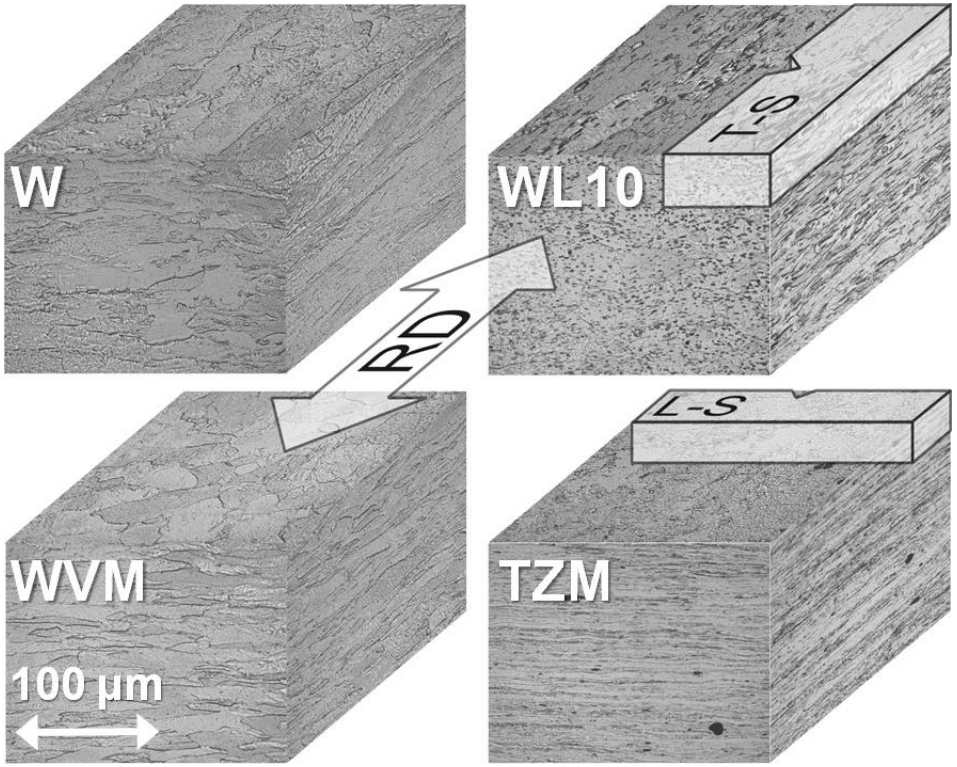


Materials, Rolling Texture

6 RODS

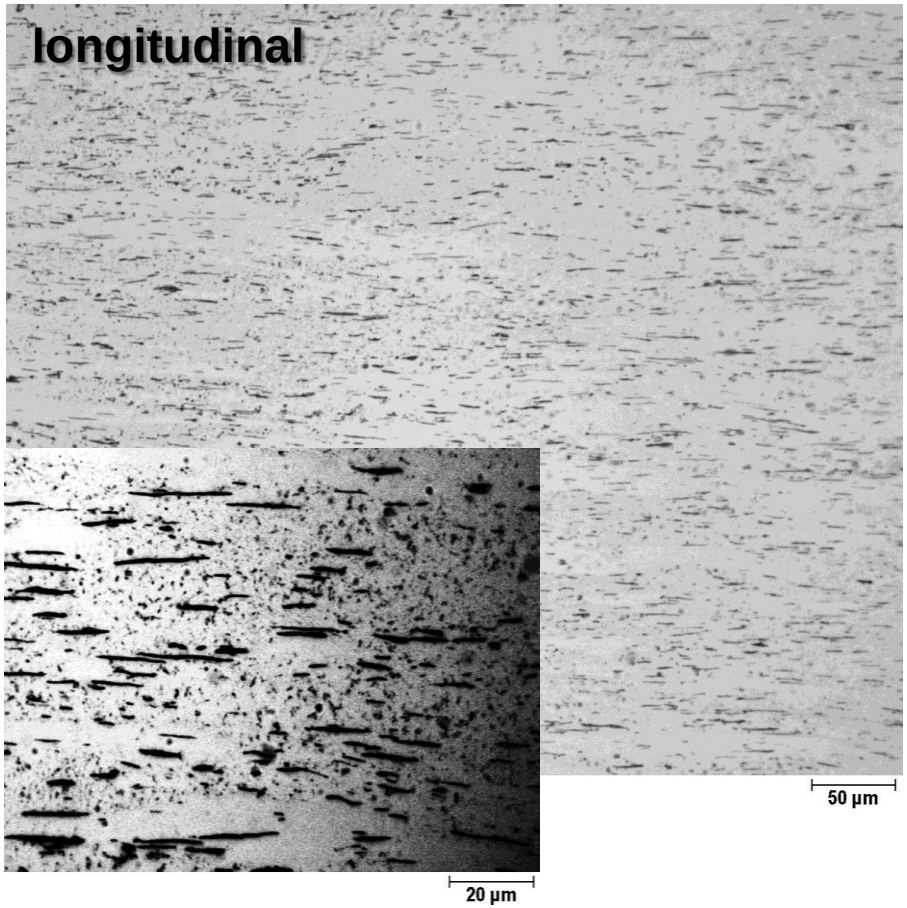


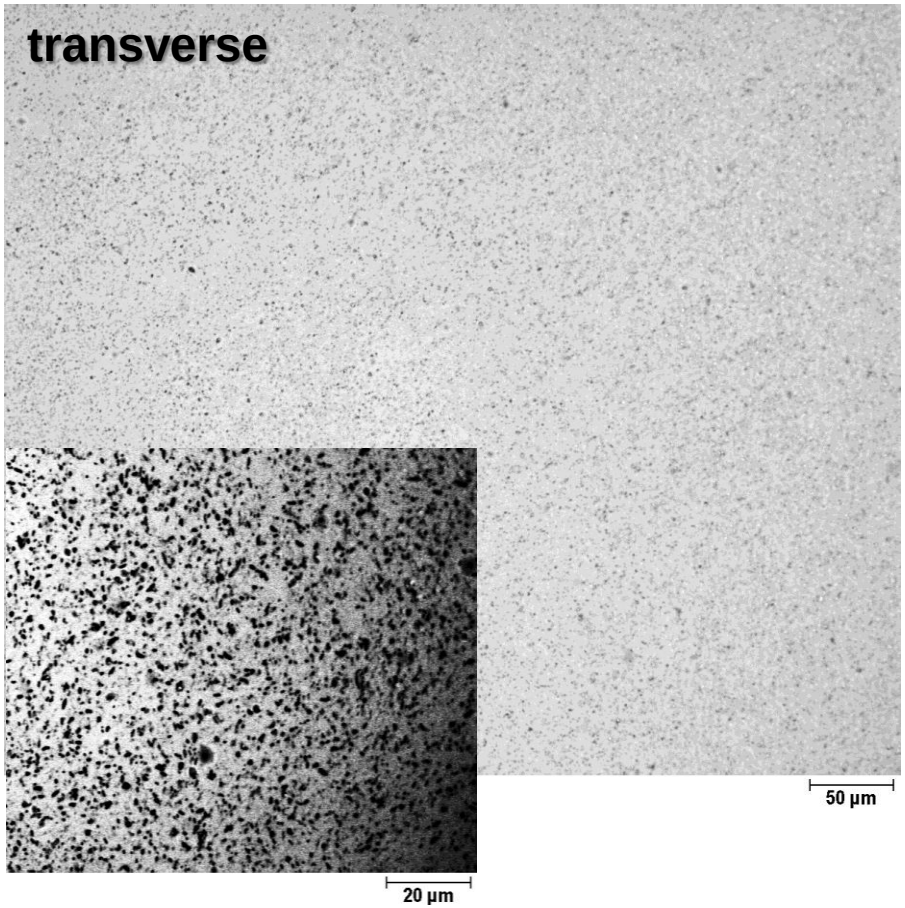
4 PLATES



Microstructure

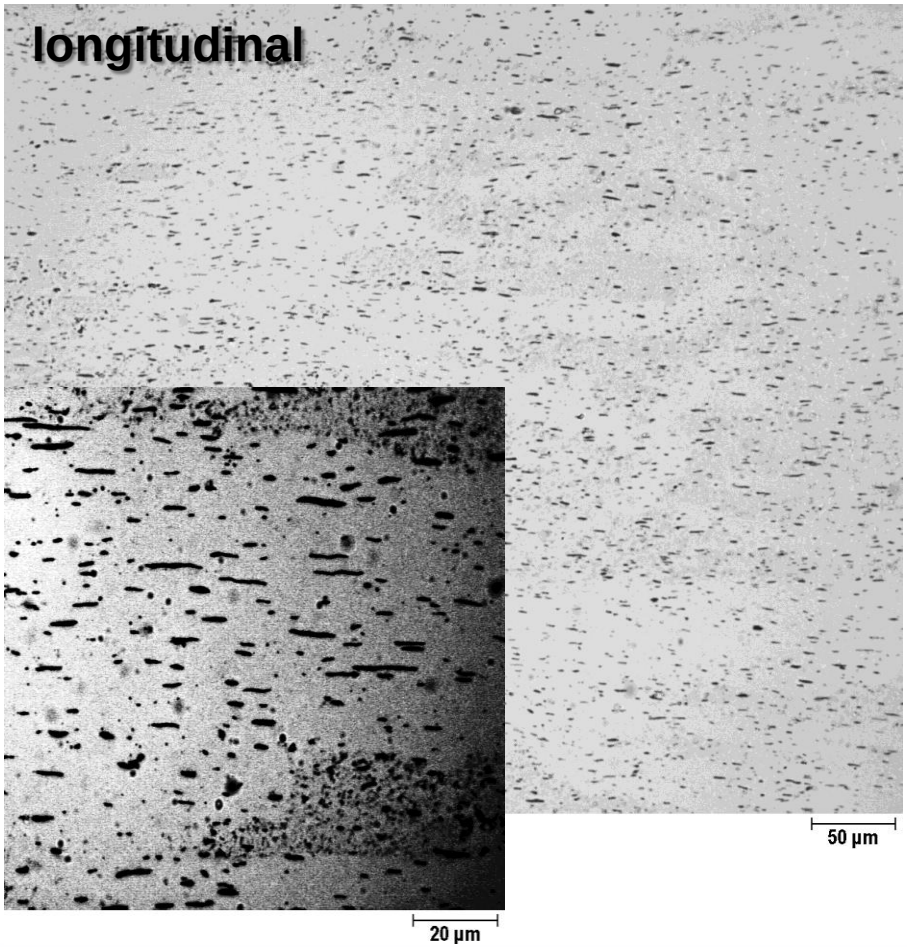
WL10 Rod, Ø7 mm

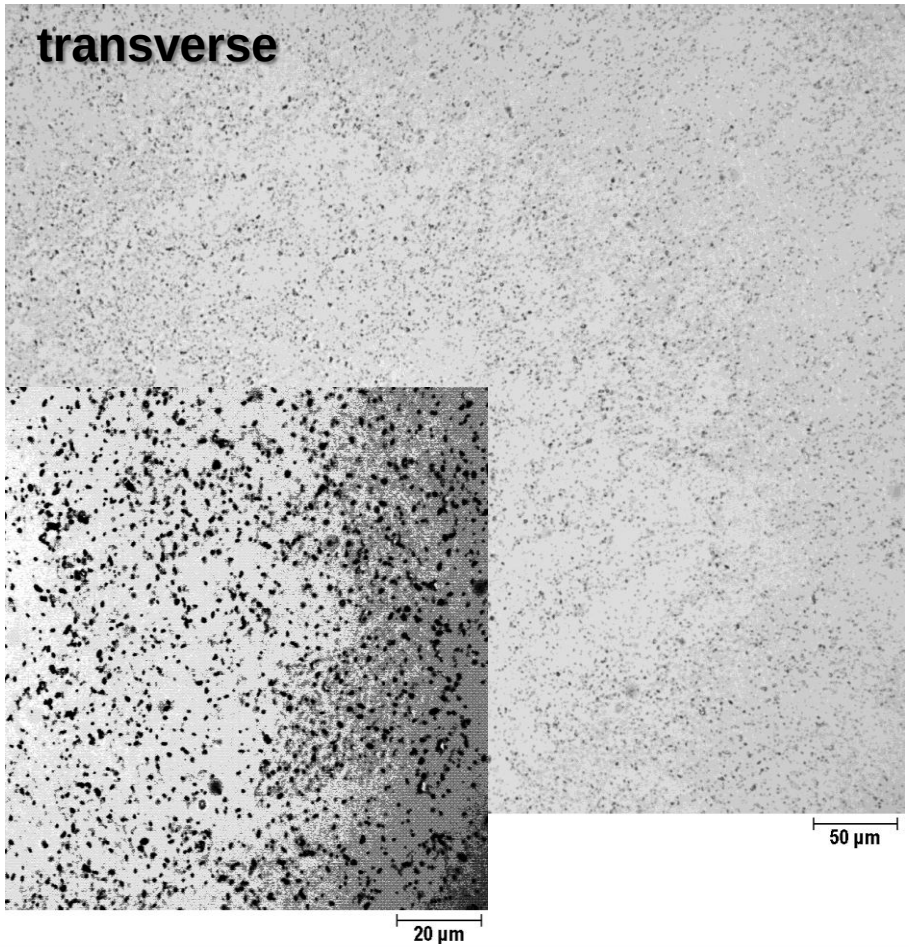




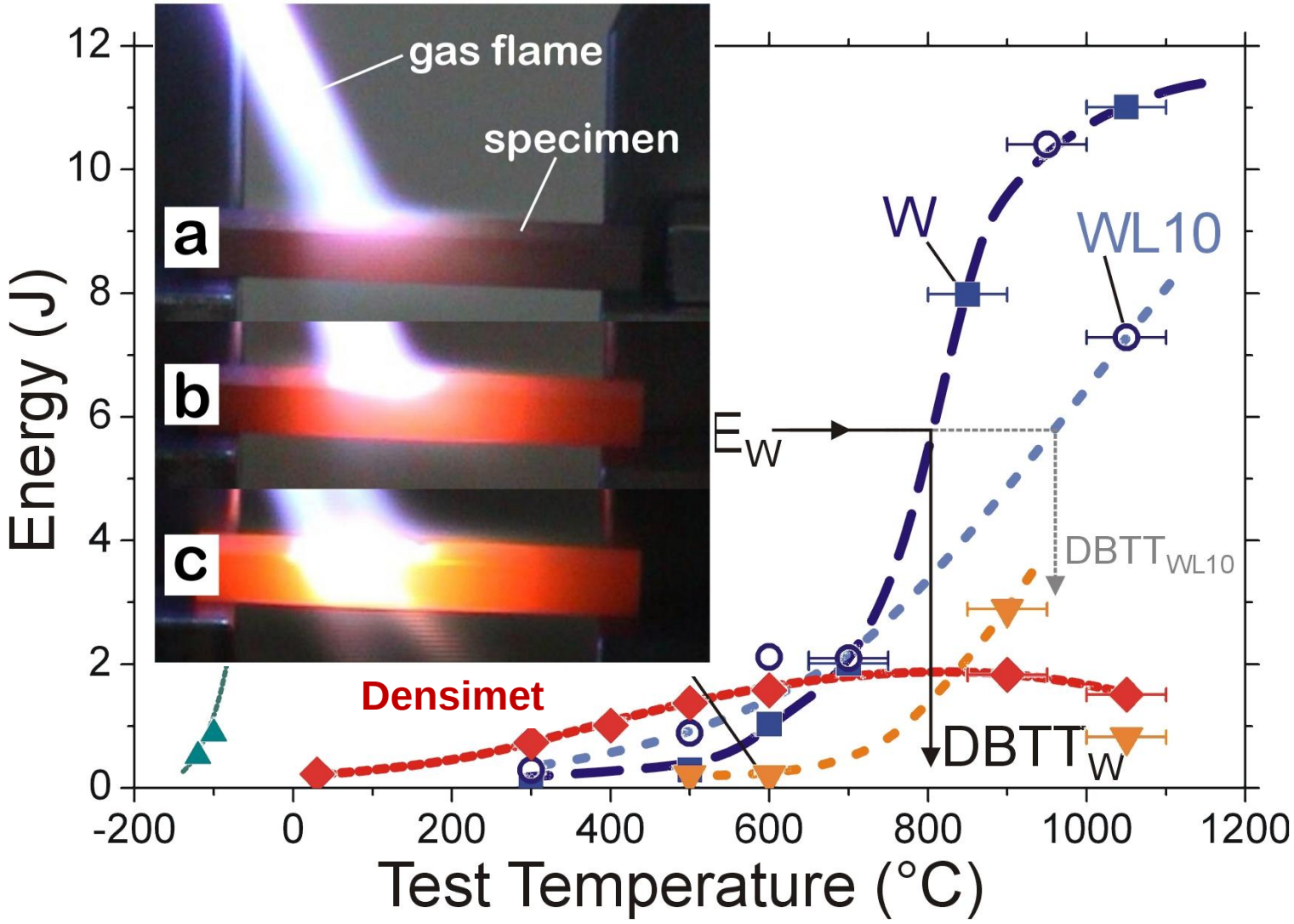
Microstructure

W-1%Re-1%La_2O_3 Rod, Ø10 mm

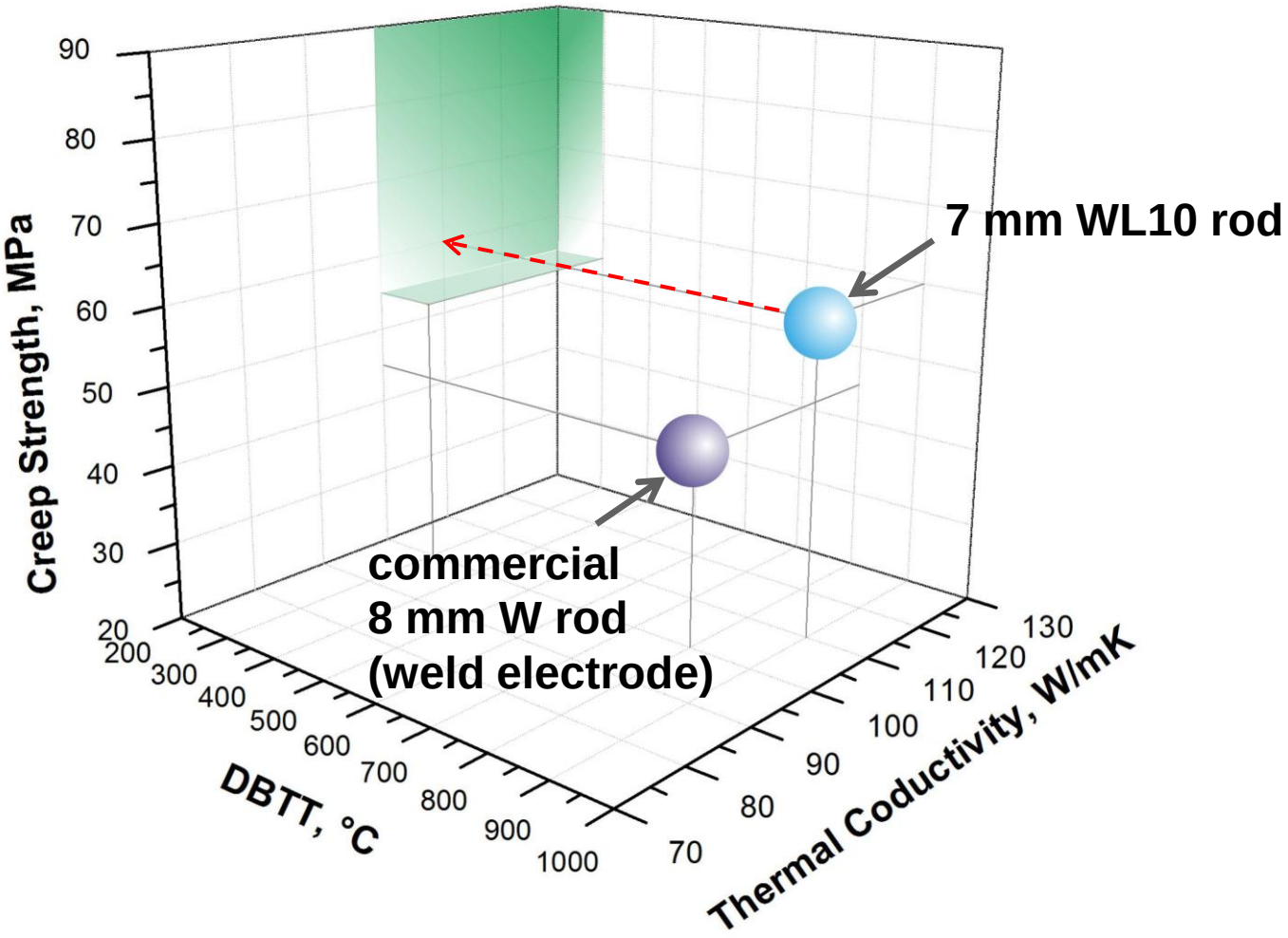




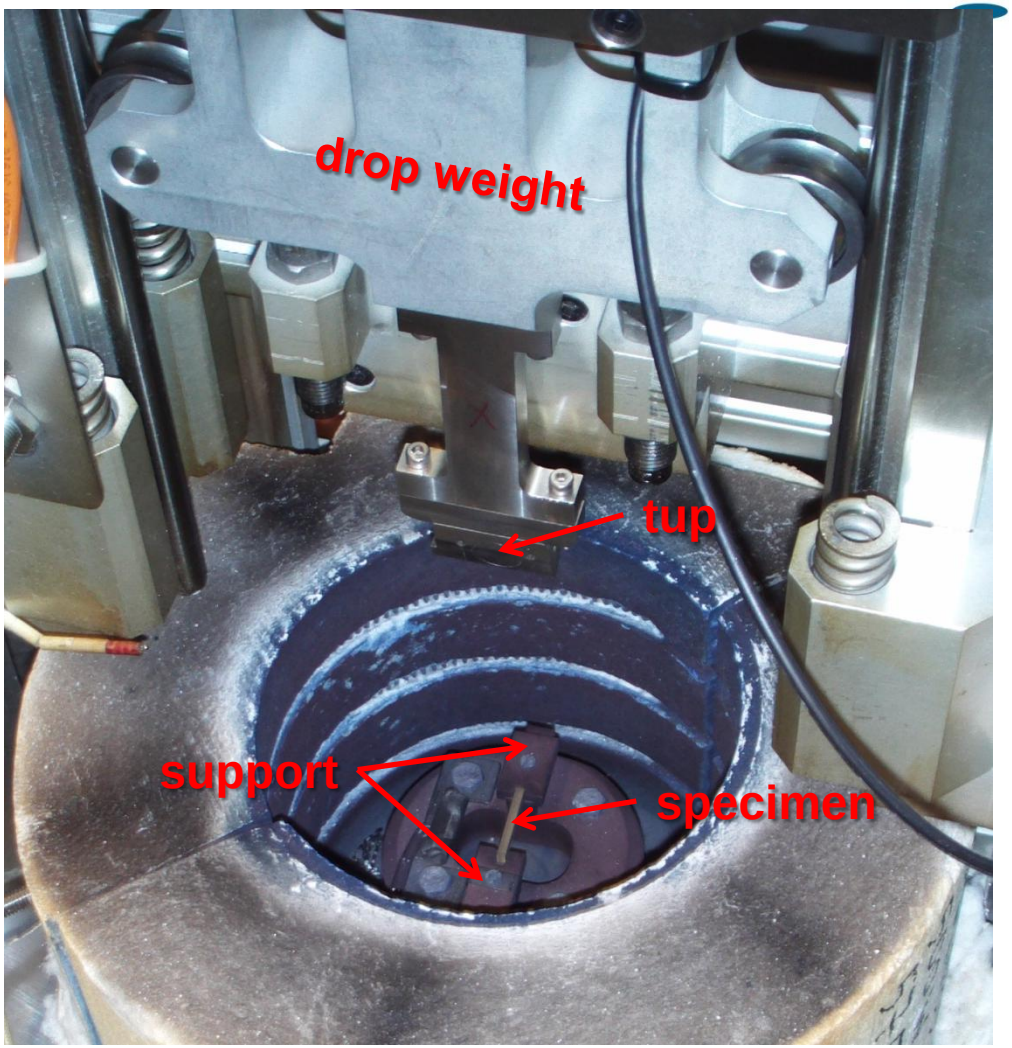
Present Knowledge: DBTT



Present Knowledge: DBTT



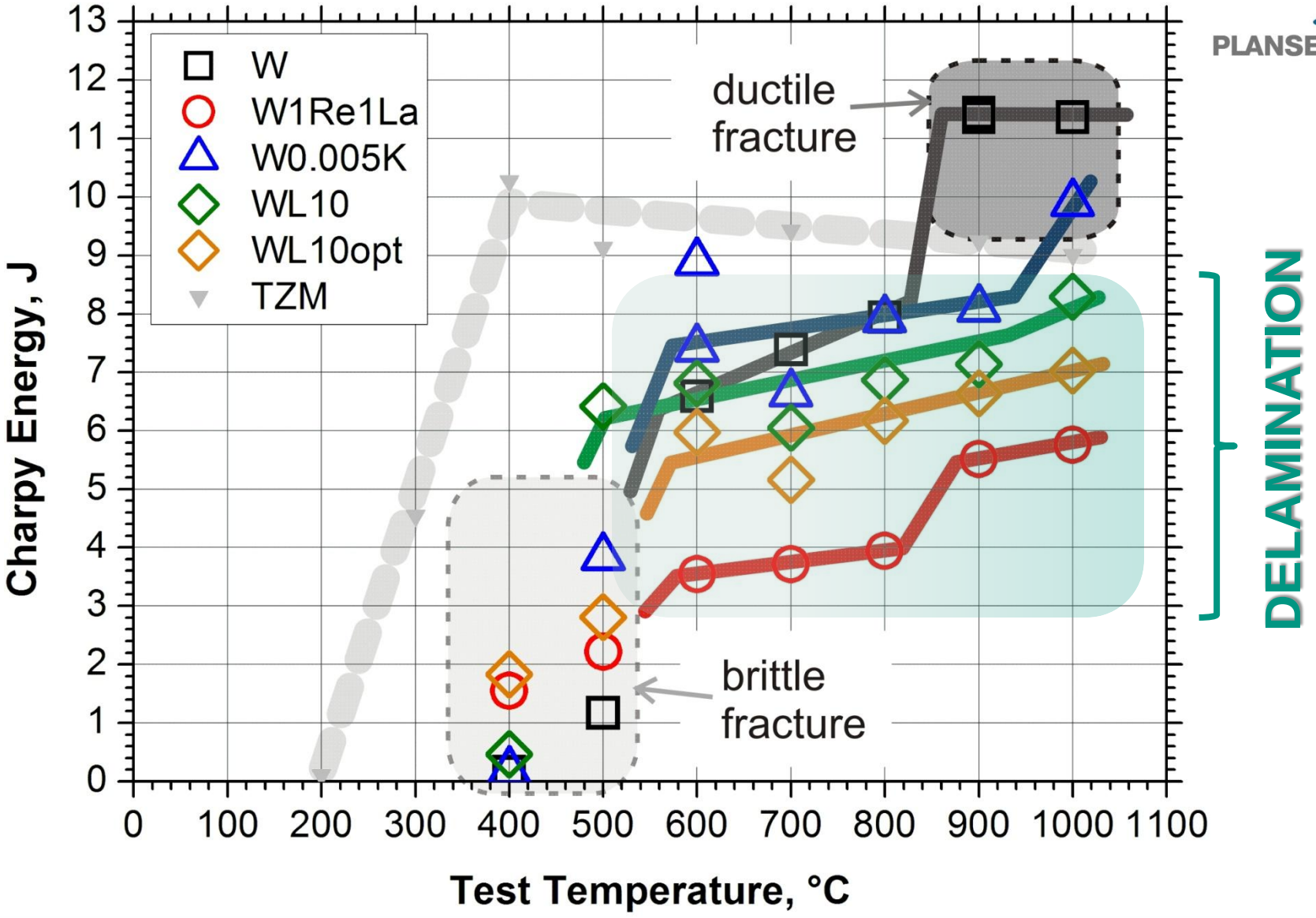
High Temperature Charpy Tests



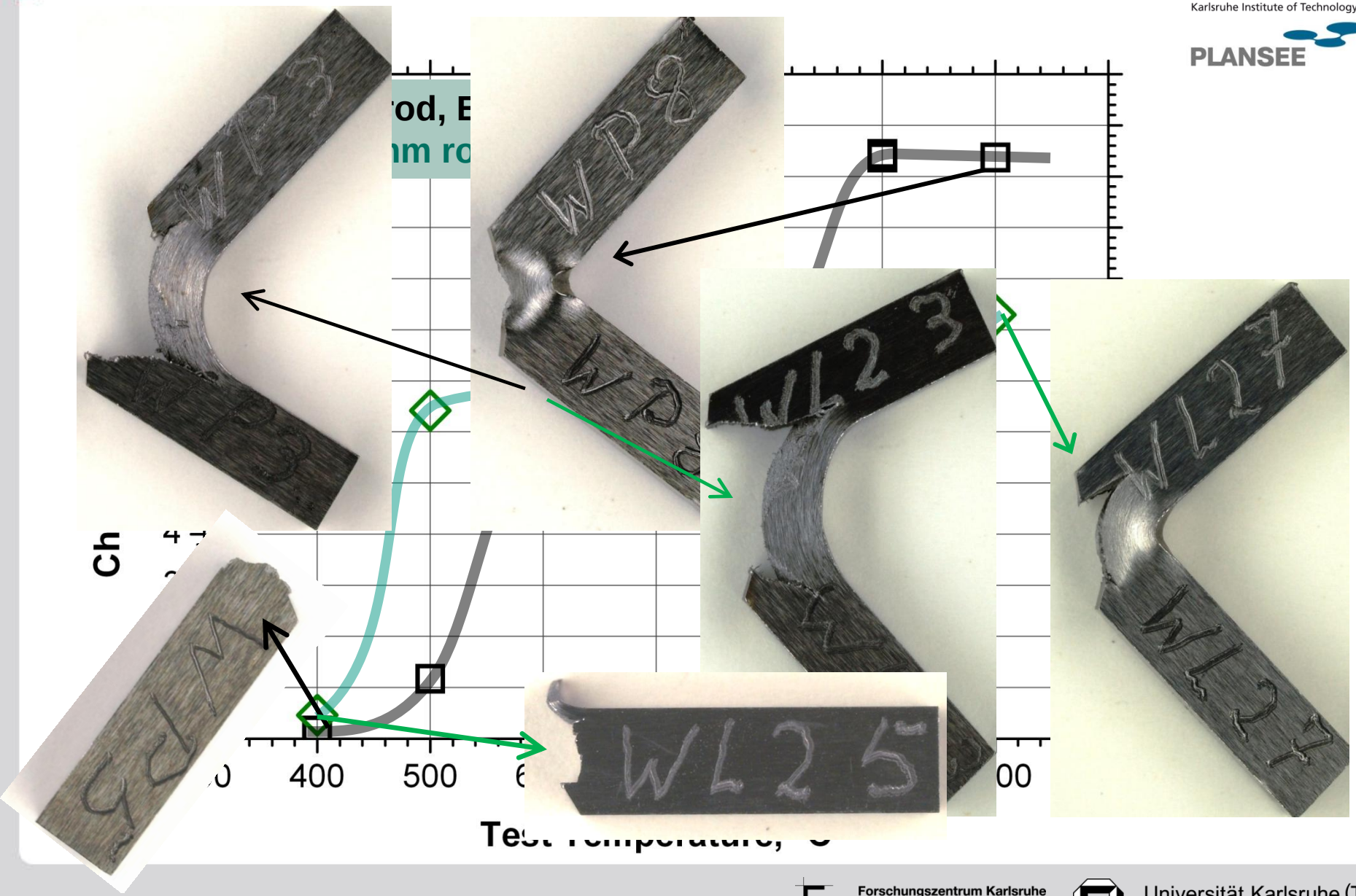
drop weight design, vacuum vessel

opened furnace: view on support

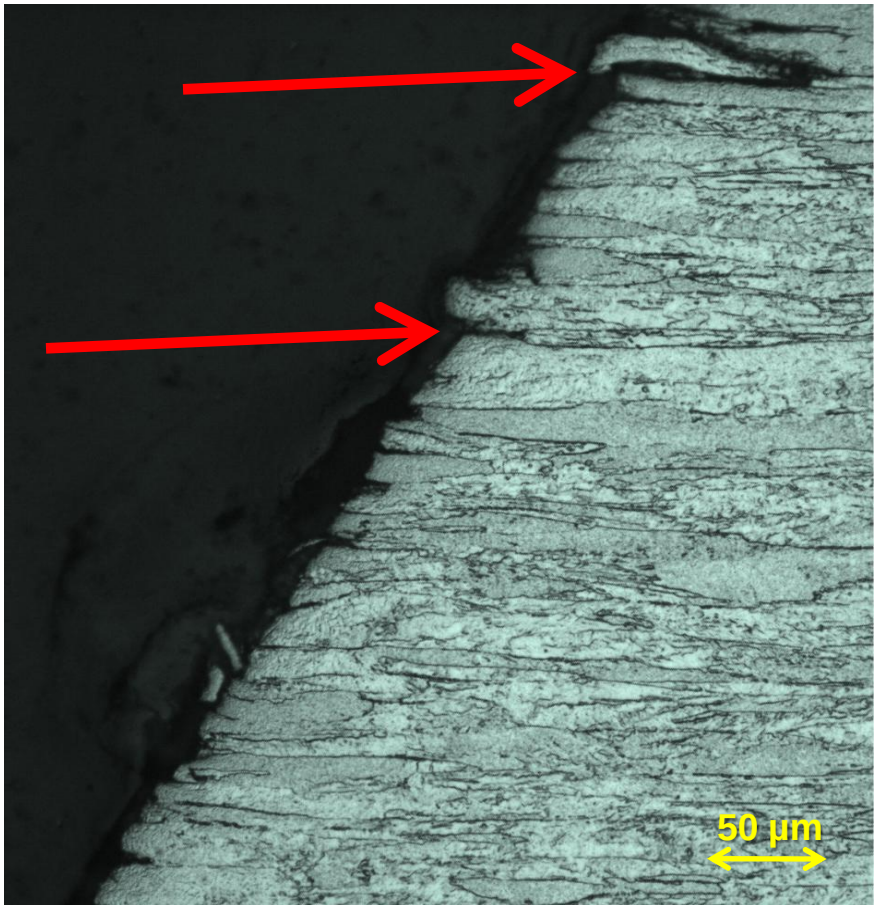
Results, Rod Materials



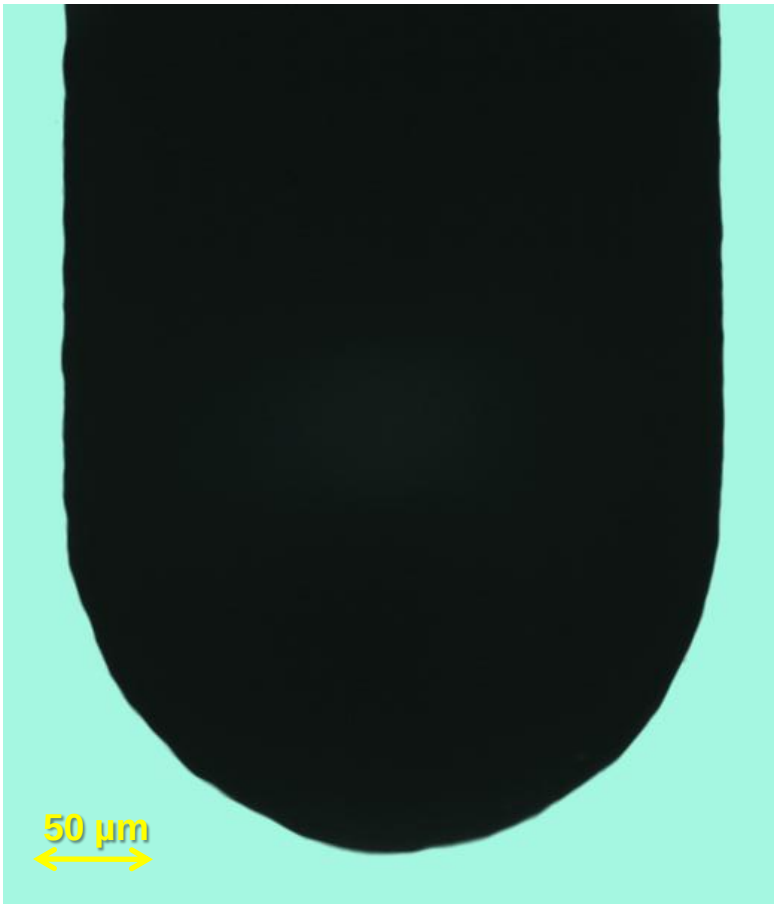
Fracture: W & WL10, 7 mm rods



Surface Fabrication

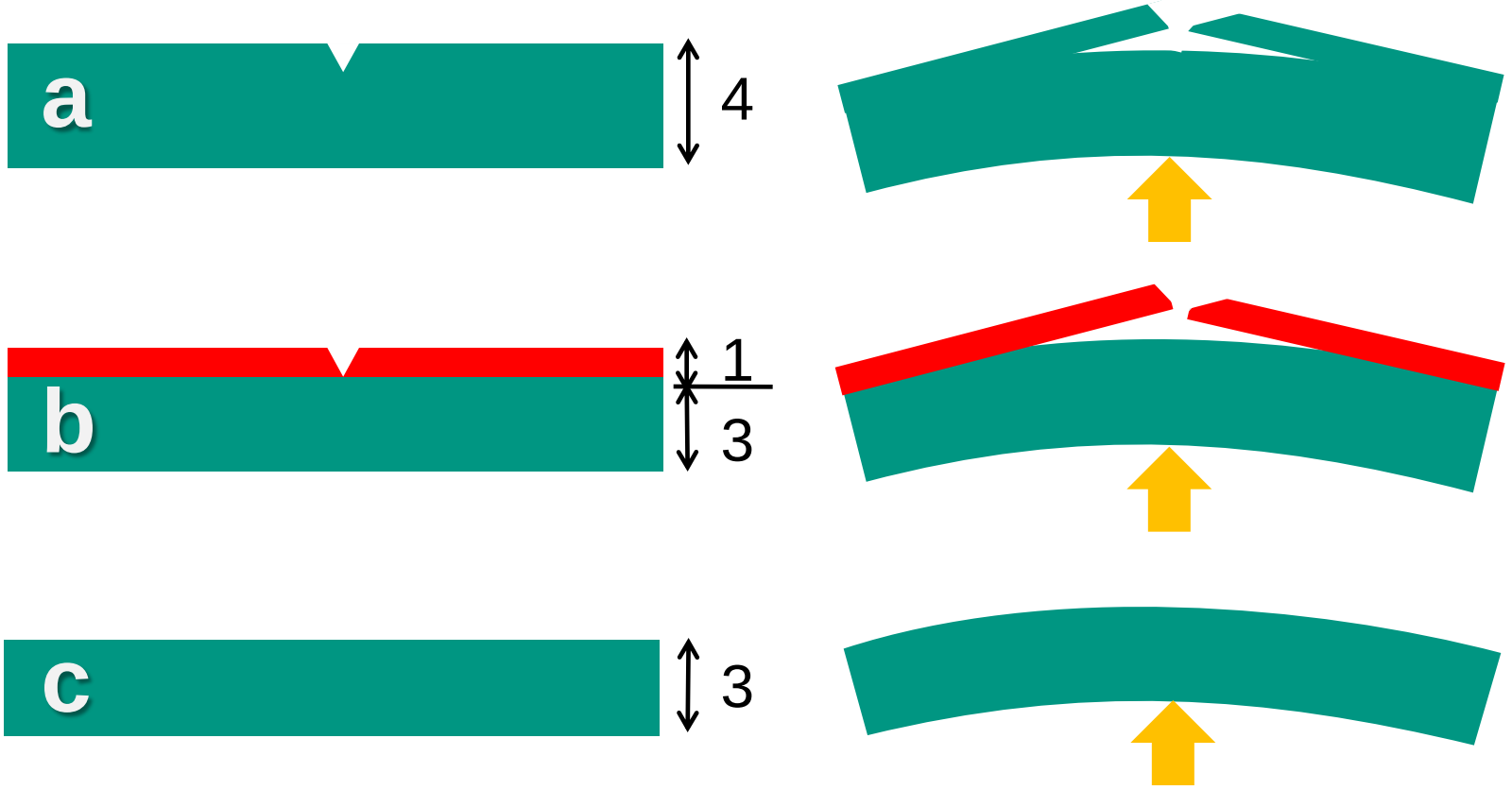


W Rod, EDM

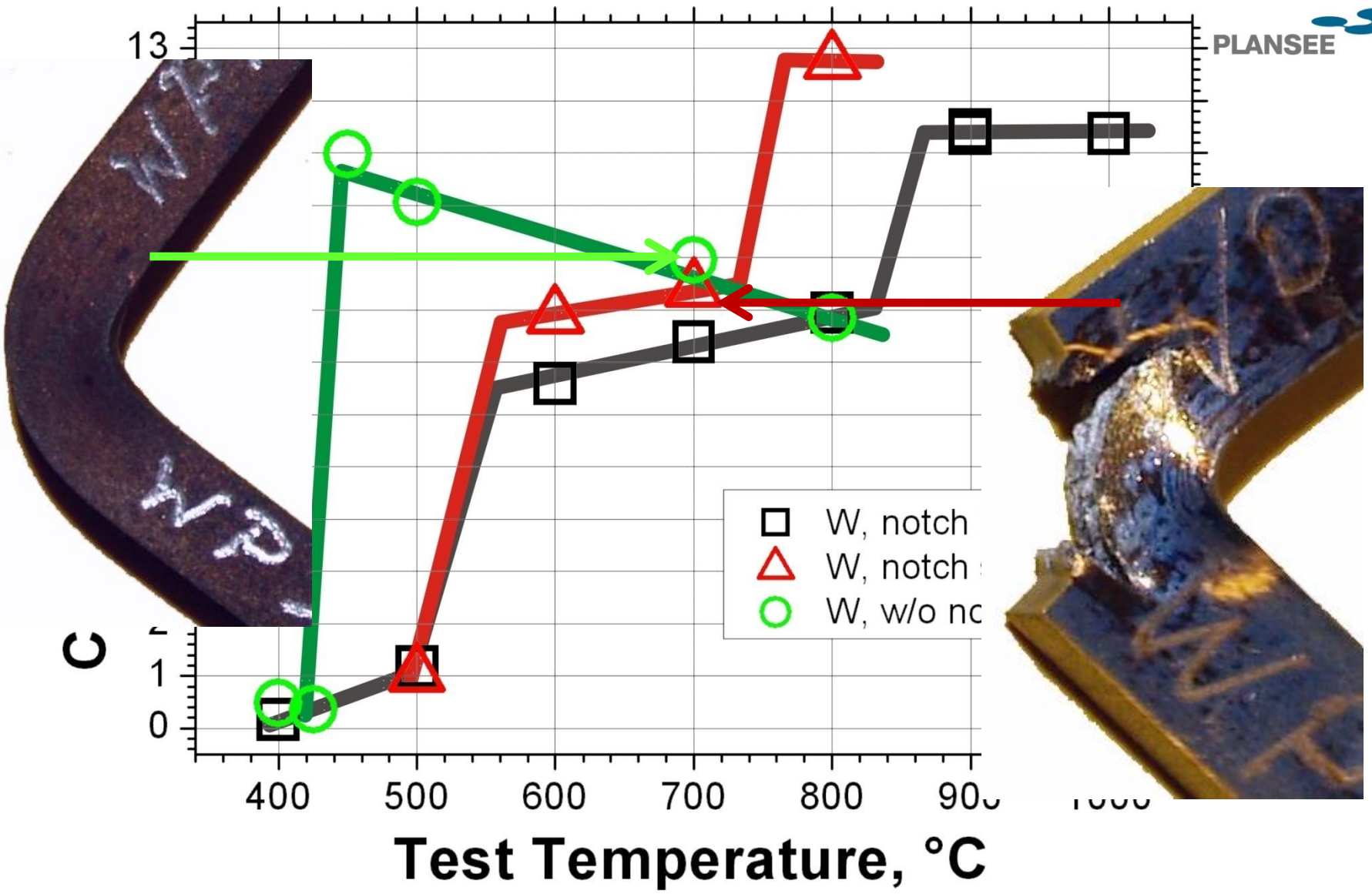


W Rod, Diamond Saw

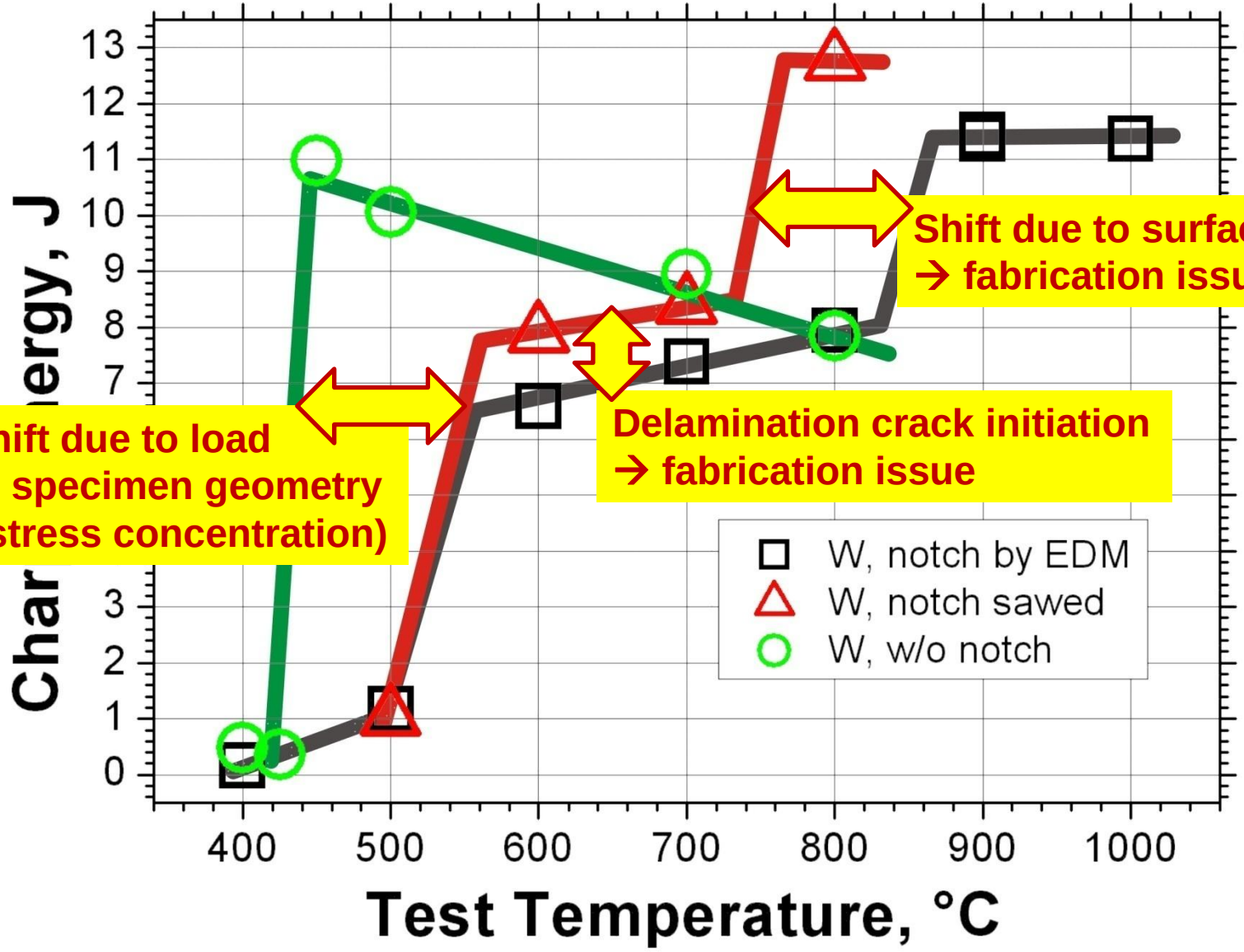
Delamination, Simple Analogy



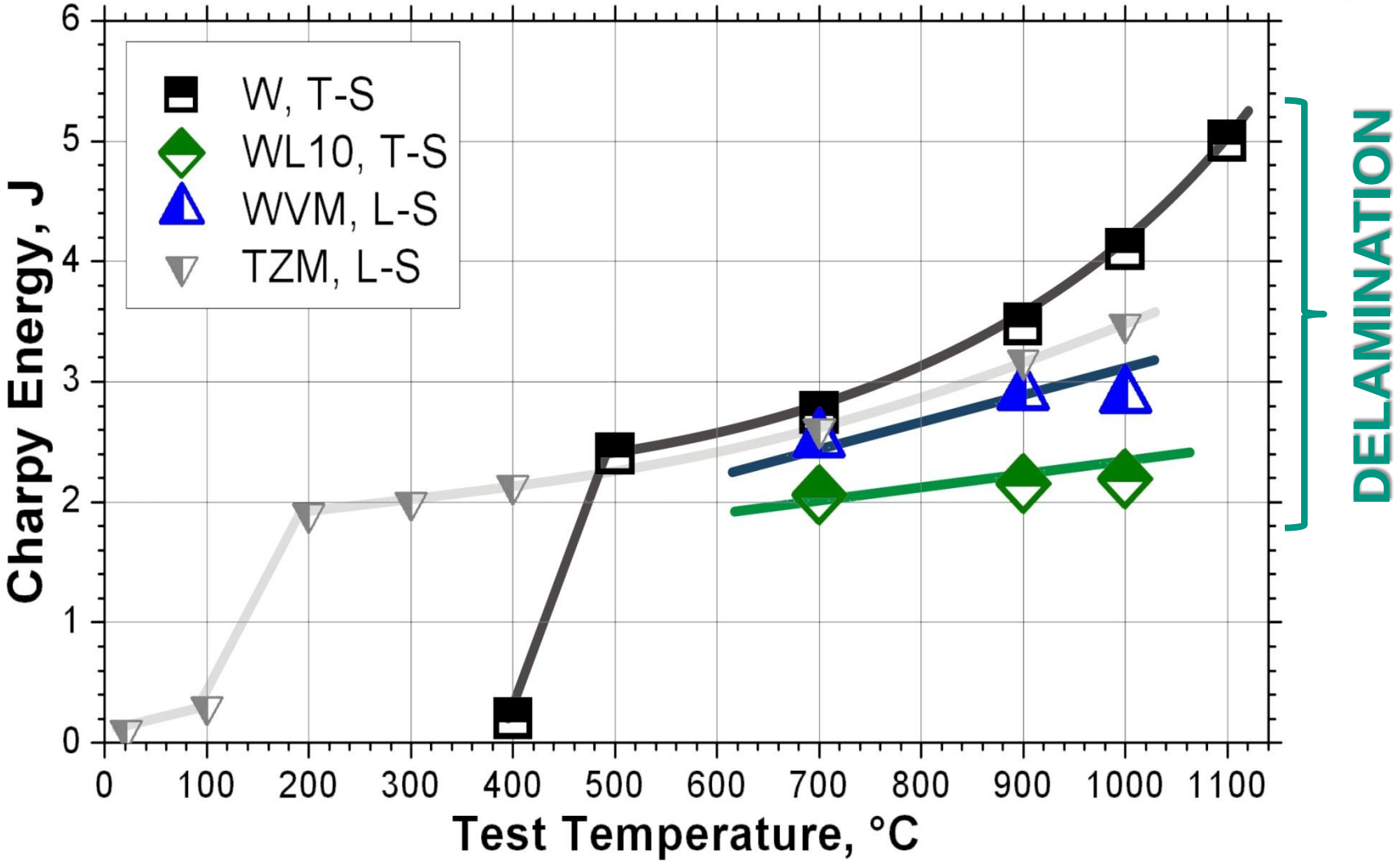
Results, Surface Fabrication



Discussion



Results, Plate Materials



Fracture: W & WL10, plates

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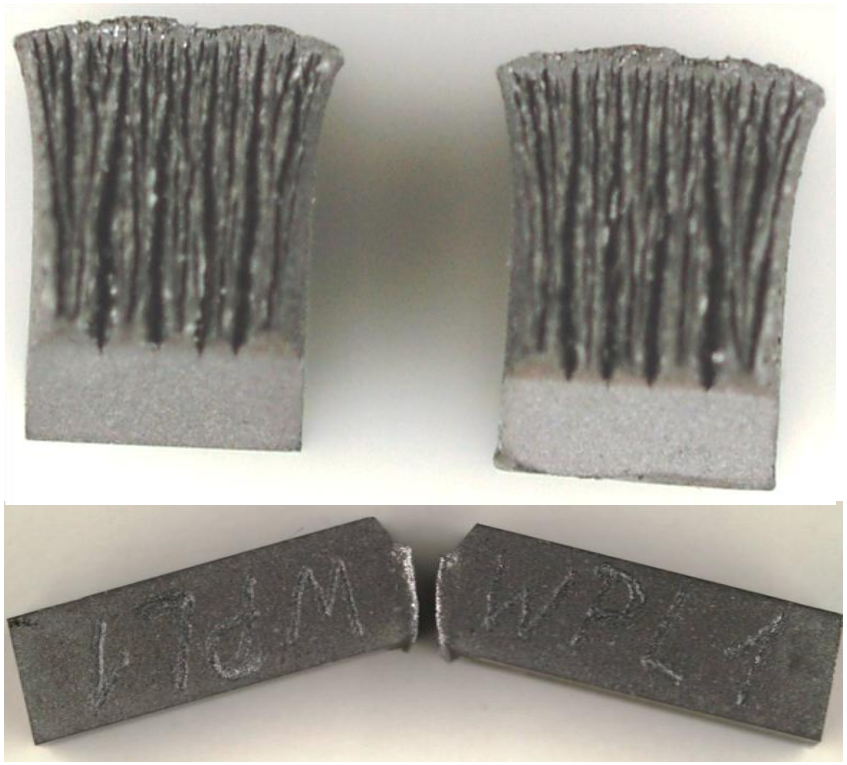
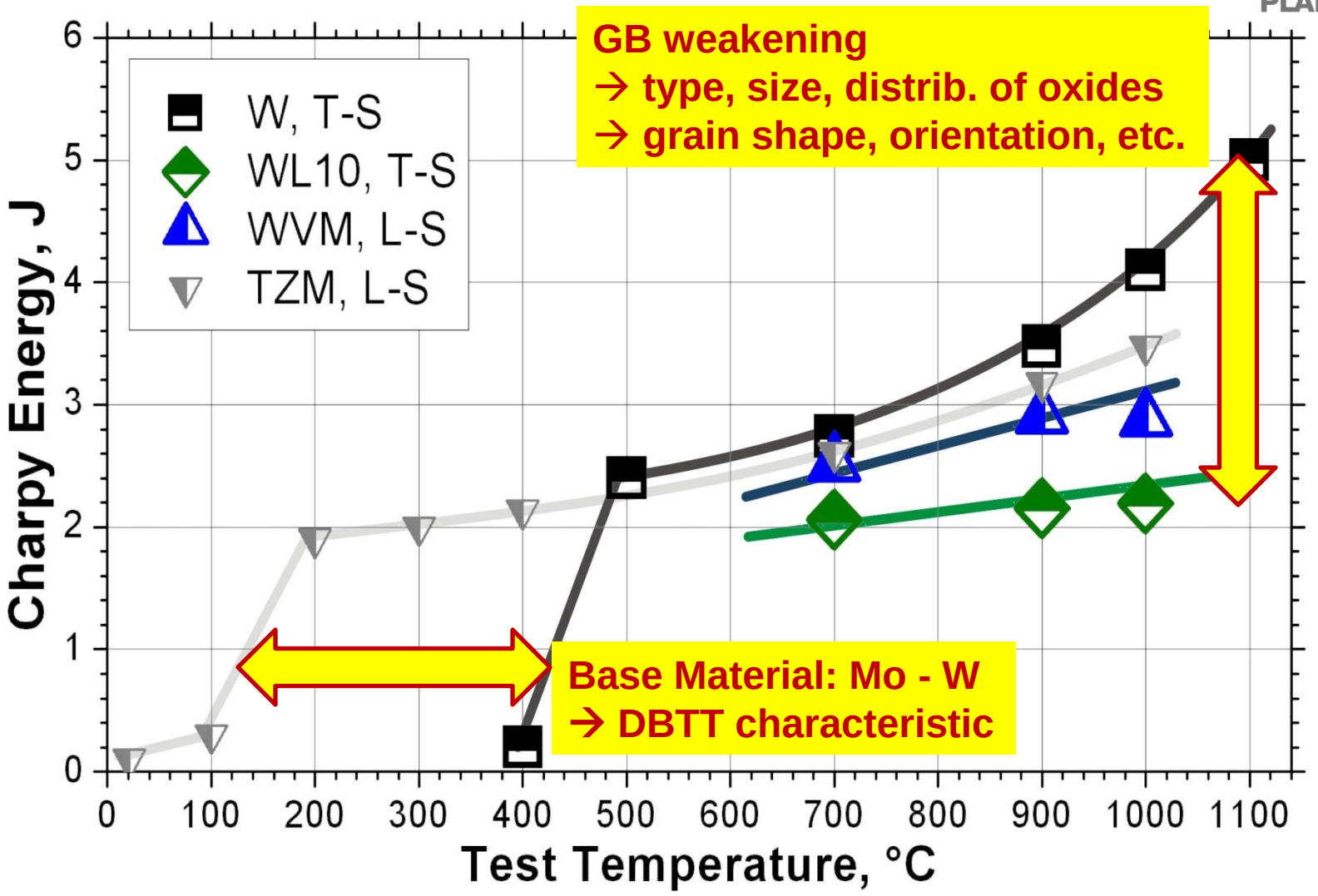
W

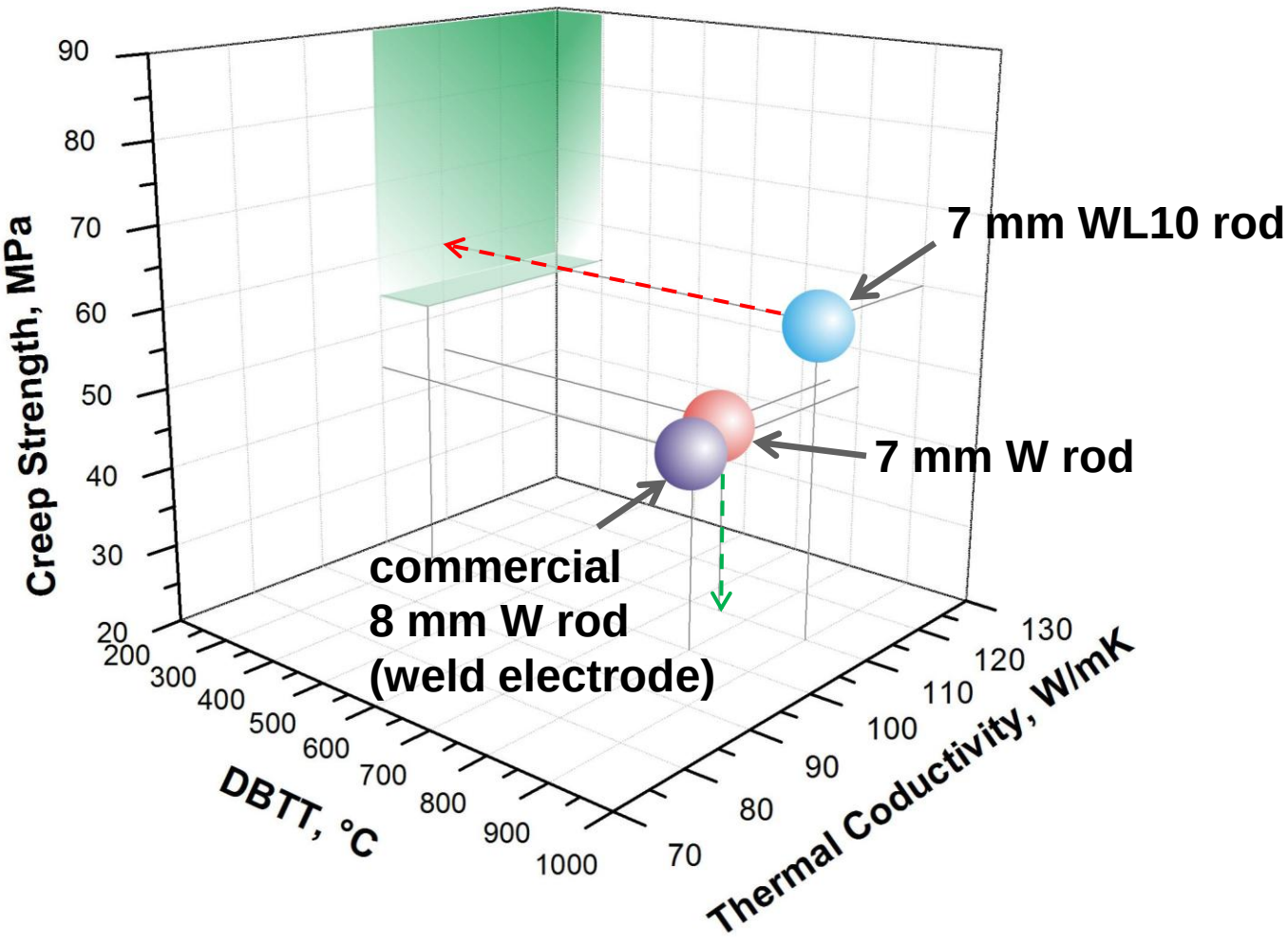


WL10

Discussion



Present Knowledge: DBTT



Conclusions

- Long-term creep strength and recrystallization behavior have still to be examined
- Microstructure significantly defines transition temperatures (rod texture more favorable than that of plates)
- Oxide particles (and also potassium doping) promote delamination (but they are necessary for stabilizing GB → suppr. re-crystallization)
- Tungsten materials have a DBTT limit of ≥400°C (when produced by sintering & deformation, tested according to DIN EN ISO 148-1, …)
- Notches/edges have to be avoided in structural parts
- Optimum fabrication probably only by aligning grains along the contour of the according part → deep drawing, twisting, pressing, …