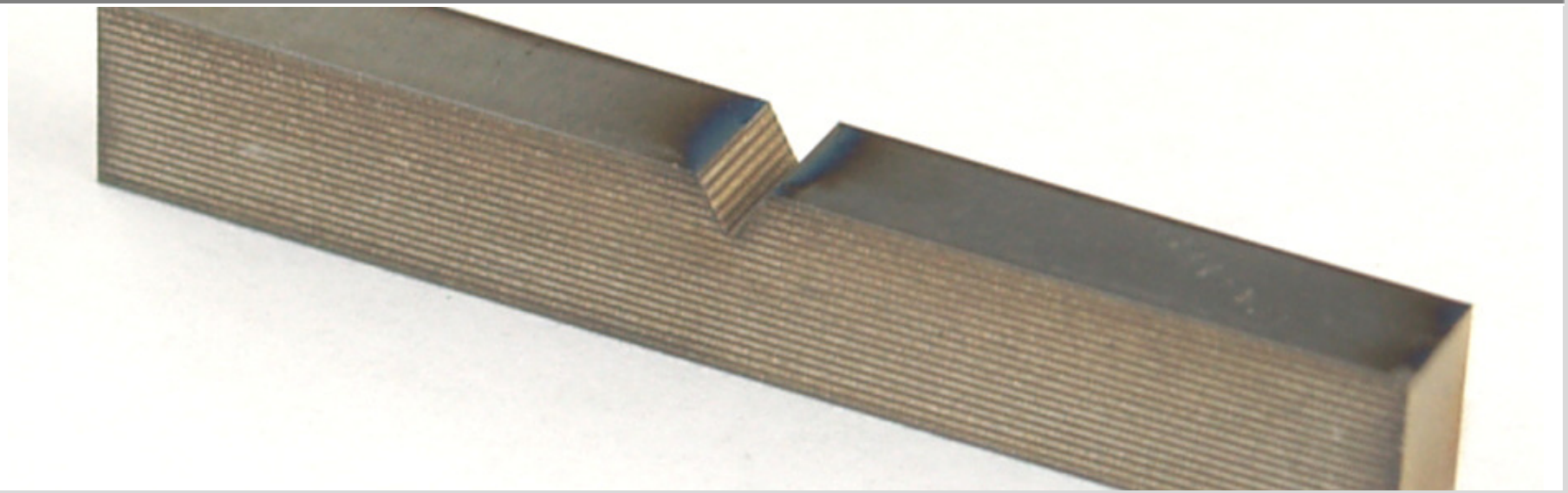
Ductilisation of Tungsten: Tungsten Laminate

J. Reiser[1], M. Rieth[1], B. Dafferner[1], A. Hoffmann[2]

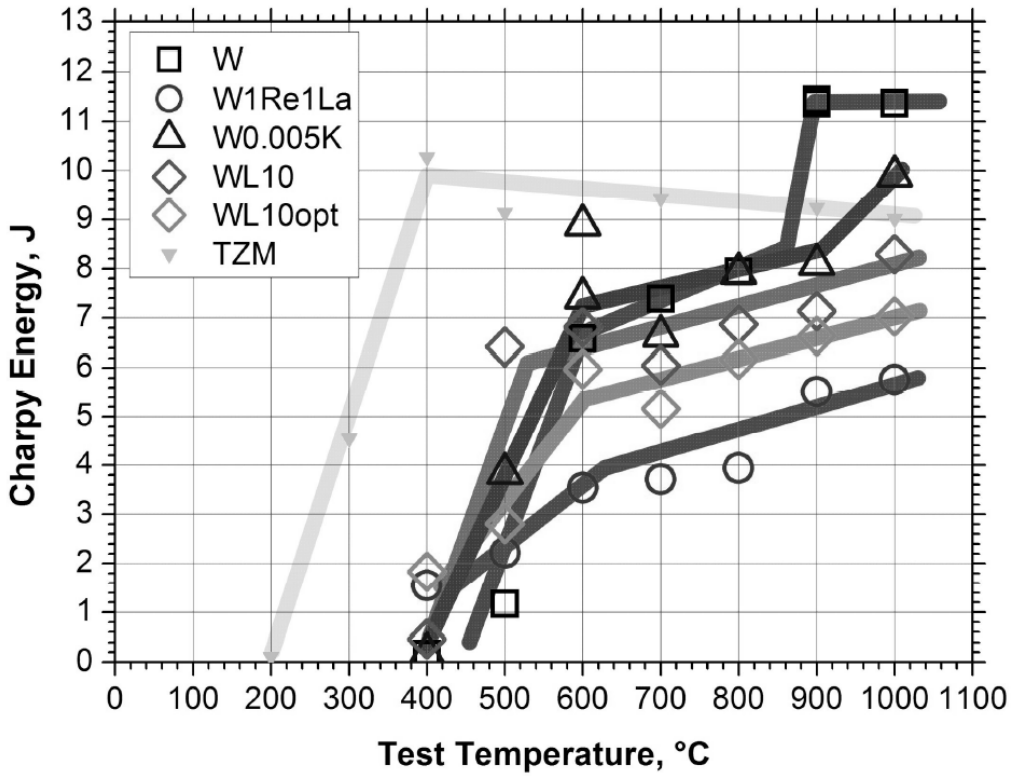
01.02.2012

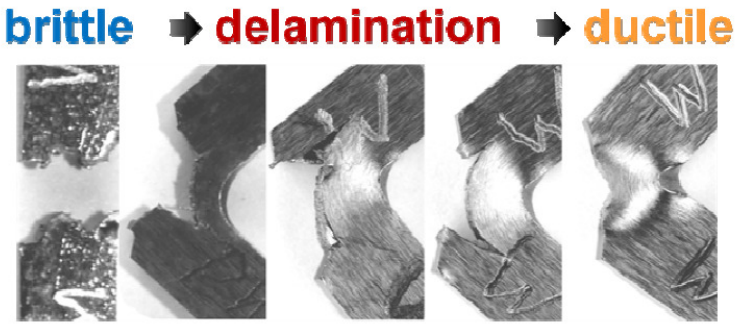
Kyoto

1: Karlsruhe Institute of Technology, Institute for Applied Materials, IAM-AWP, 76021 Karlsruhe, Germany
2: PLANSEE SE,6600 Reutte, Austria



The problem: brittle-delamination-ductile





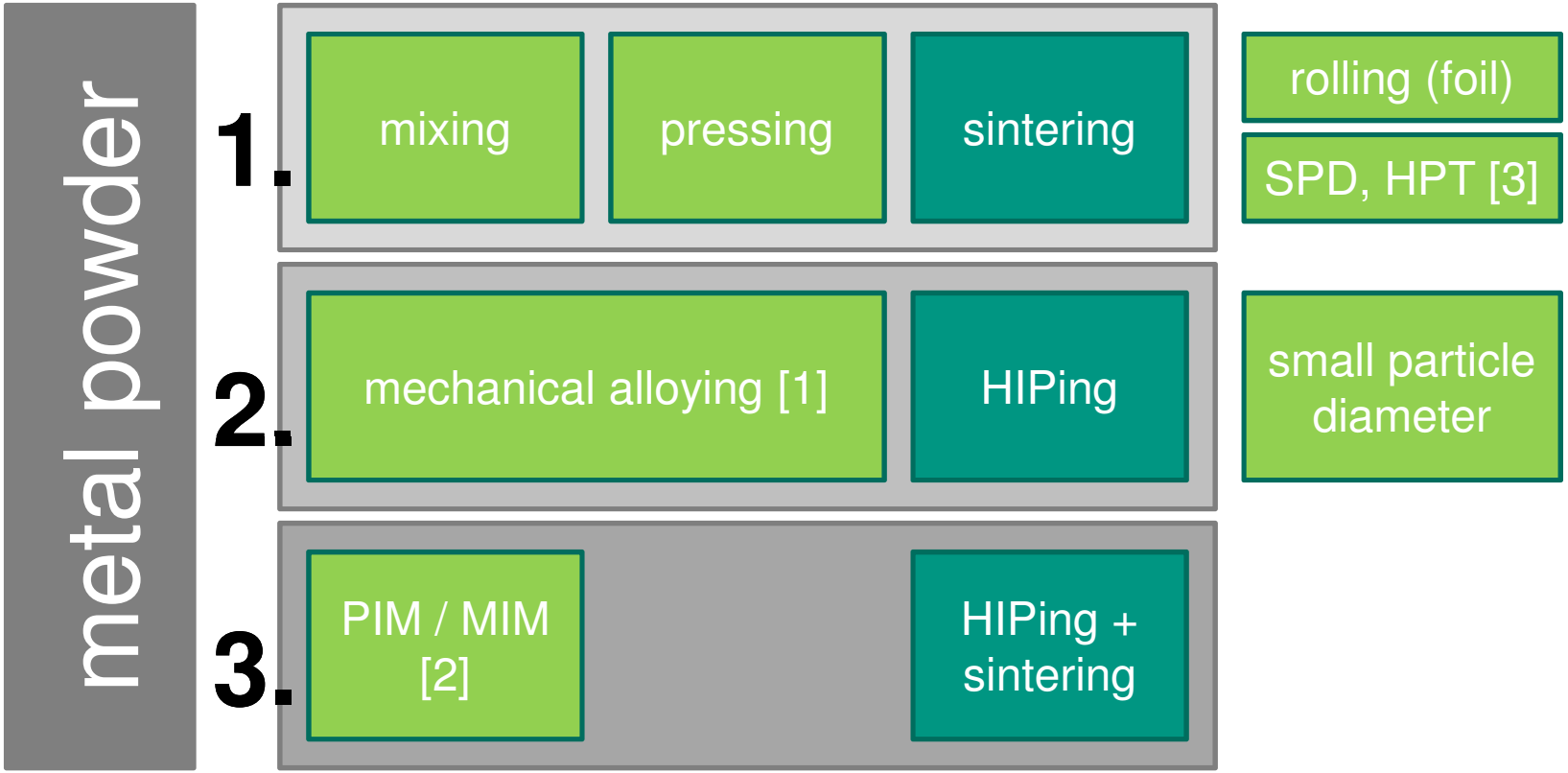
M. Rieth, KIT [1,2]

- Literature:

[1] M. Rieth et al., Adv. Sci. Tec. **73**, 11, (2010).

[2] M. Rieth, A. Hoffmann, Adv. Mater. Res. **59**, 101 (2009).

How to synthesize nano tungsten?



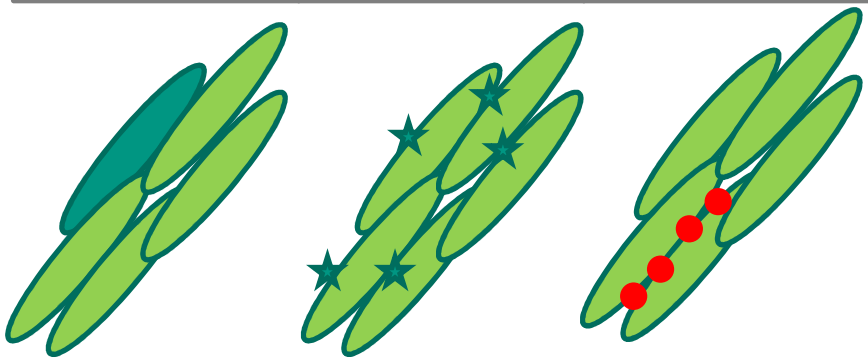
- Literature:

[1] H. Kurishita et al., J. Nucl. Mater. 398, 87 (2010).

[2] S. Antusch et al., J. Nucl. Mater. 417, 533 (2011).

[3] M. Faleschini, H. Kreuzer, D. Kiener, and R. Pippan, J. Nucl. Mater. 367-370, 800 (2007).

How to make tungsten ductile?

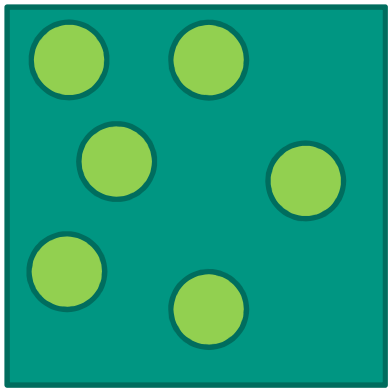
oxides	insoluble metals	roll of impurities
		
oxides? • La_2O_3 (WL10) • Y_2O_3 → NO!	insoluble metals? • K (WVM) → NO!	decrease of impurities? → NO!

1. alloying	2. nano structuring	3. composite
		
WRe (WIr) is ductile • WTa • WV → NO!	mass production • SPD • mech. alloying → NO!	• particle • short fibre • long fibre • <u>laminate</u>

→ pure W is the best W (in terms of ductility measured by Charpy)

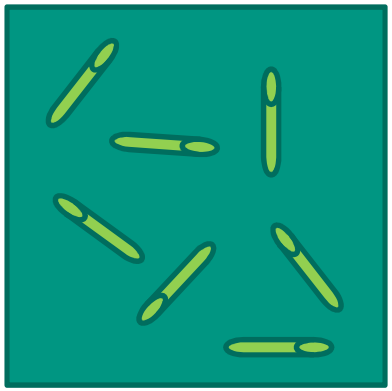
How to improve tungsten?

particle reinforced MMC [1]



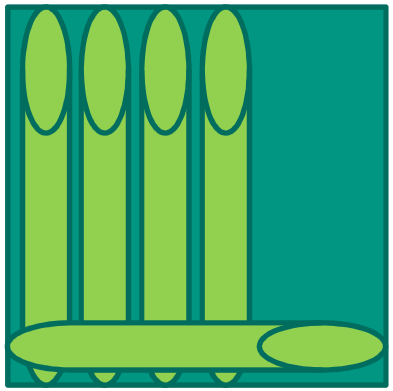
J. Hohe, IWM, Fraunhofer-Institut, Freiburg

short fiber reinforced (random) MMC [2]



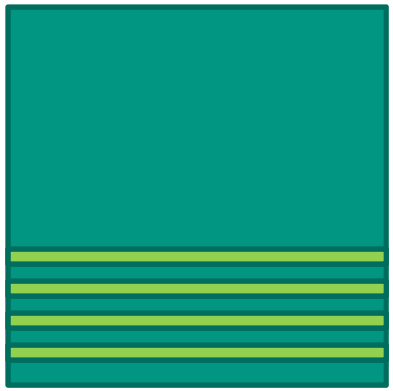
J. B. Correia, IST, Portugal

unidirectional fiber reinforced MMC [3]



J.-H.You, IPP, Garching

multi-layer MMC laminate material



M. Rieth, *J. Reiser*, IAM, KIT

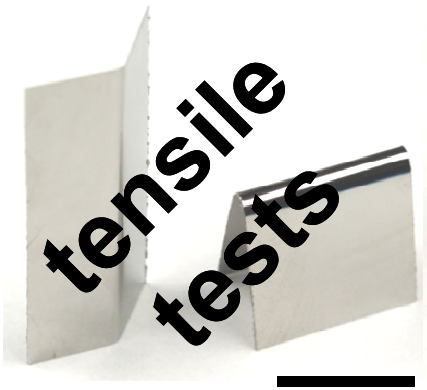
Literature:

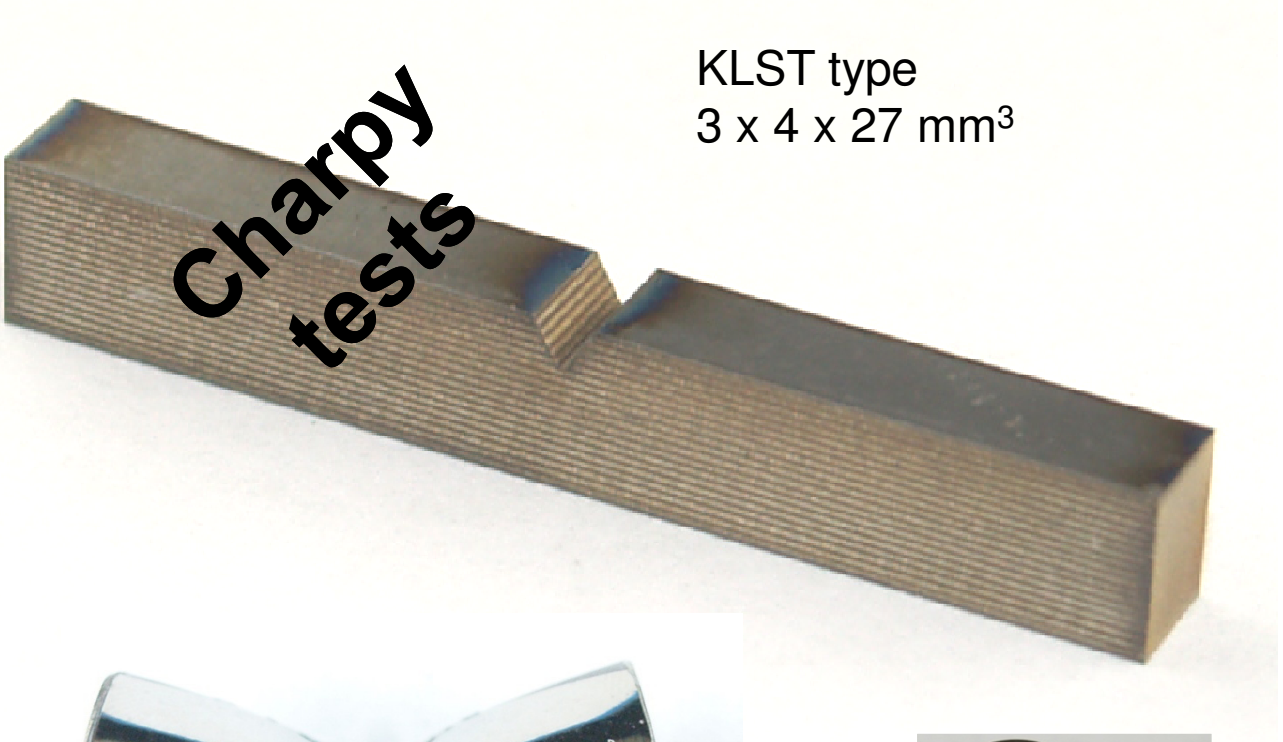
[1] J. Hohe, P. Gumbsch, J. Nucl. Mater. 400 (2010) 218.

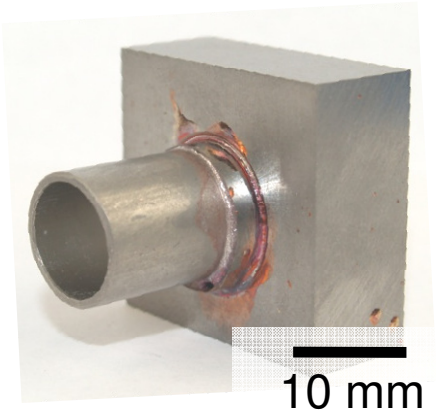
[2] V. Livramento, D. Nunes, J.B. Correia, P.A. Carvalho, R. Mateus, K. Hanada, N. Shohoji, H. Fernandes, C. Silva, E. Alves, Tungsten-tantalum composites for plasma facing components, Materials for Energy 2010, ENMAT2010, 4-8 July 2010, Karlsruhe, Germany.

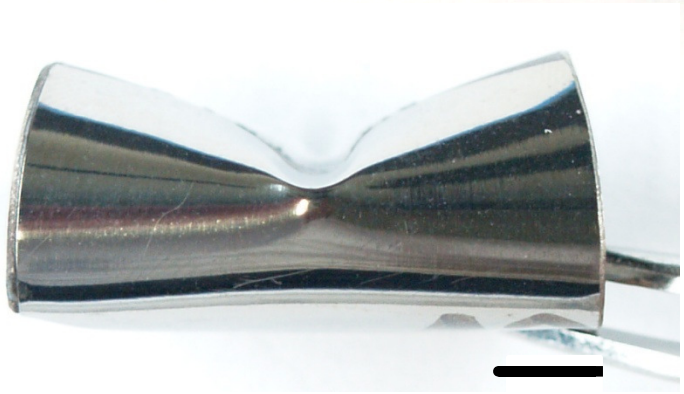
[3] J. Du, T. Höschen, M. Rasinski, S. Wurster, W. Grosinger, J.-H. You, Comp. Sci. Tech. 70 (2010) 1482.

The tungsten foil project



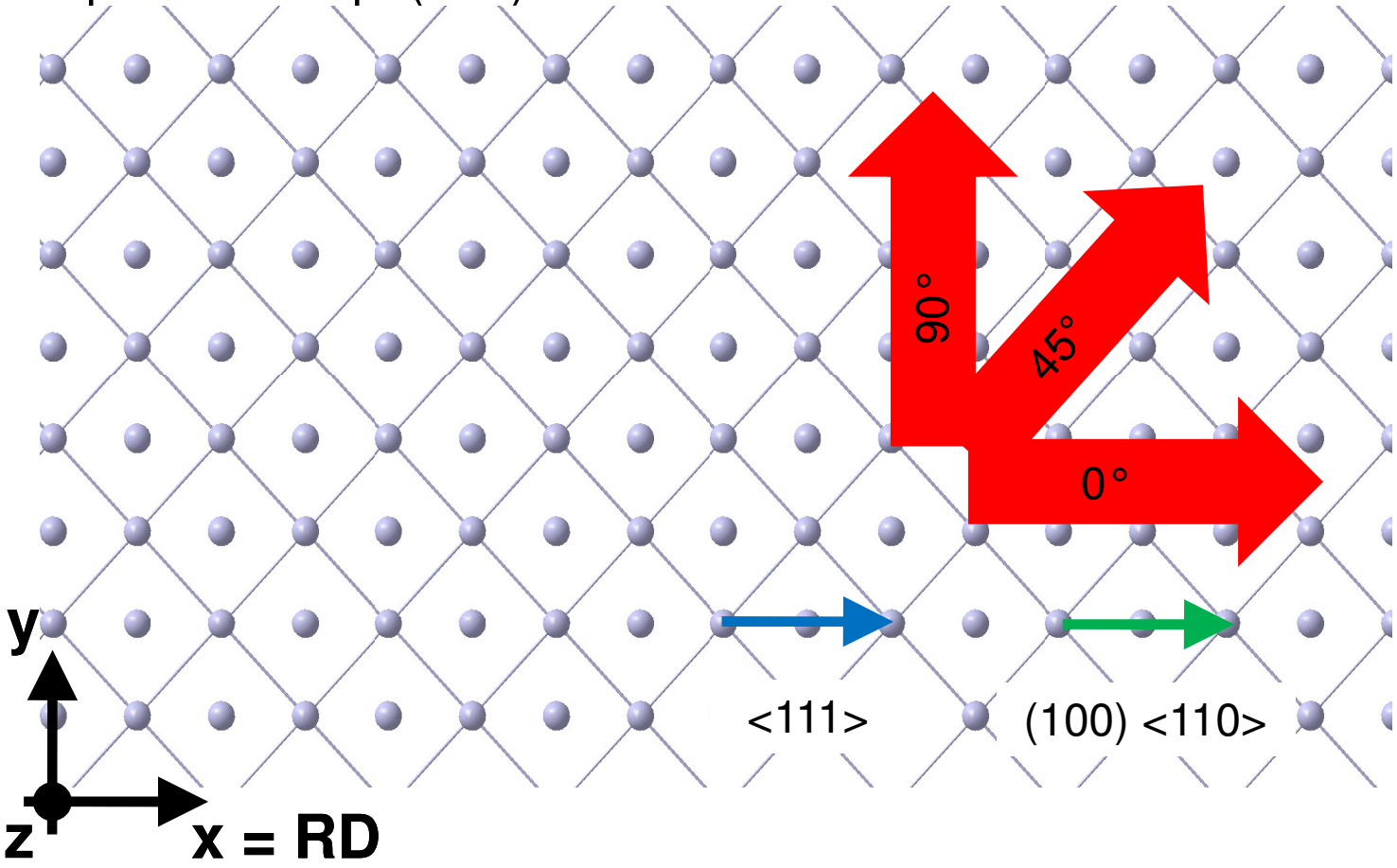






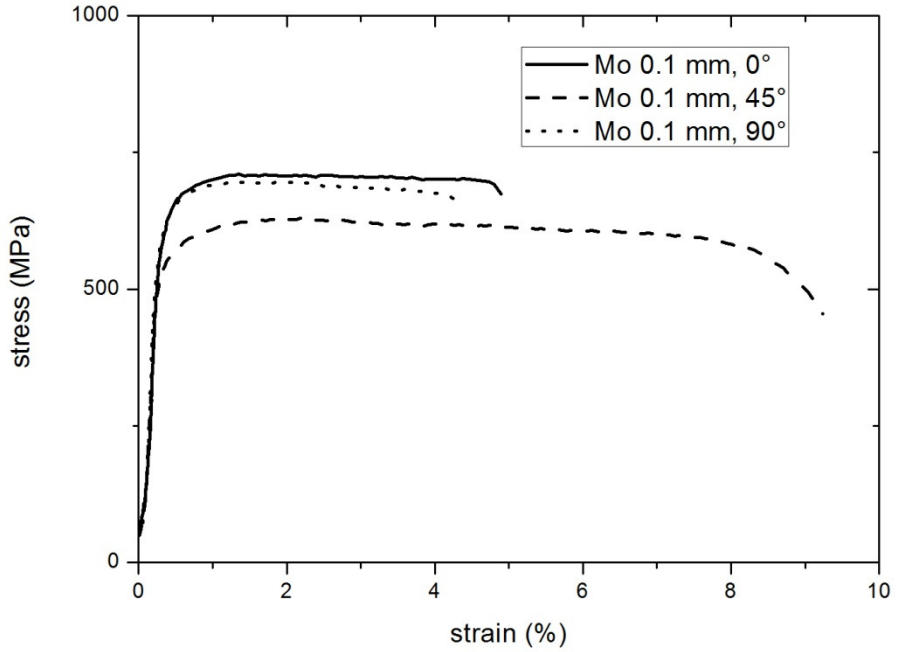
Tensile test properties: W 0.1 mm

- texture: (100) <110>
- preferred slip: (110) <111>

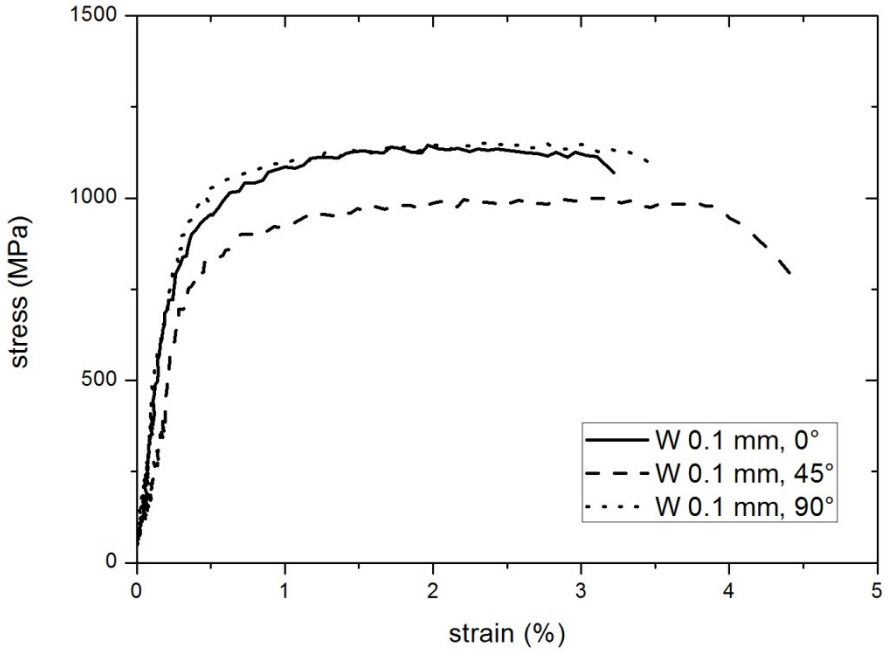


Tensile test properties: W 0.1 mm

Mo foil, 0.1 mm, RT



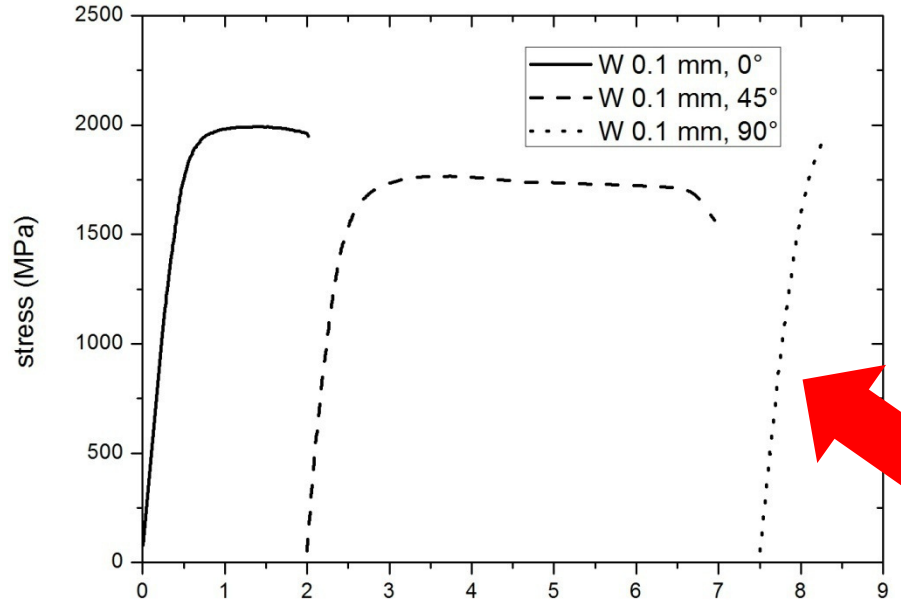
W foil, 0.1 mm, 600°C



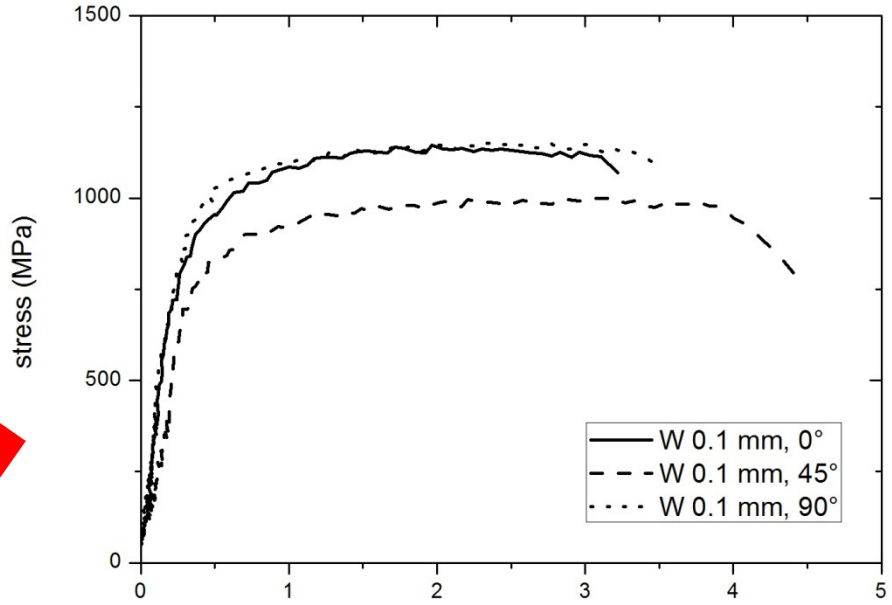
- anisotropic
- most ductility in 45° direction
- same material behavior in 0° and 90° direction

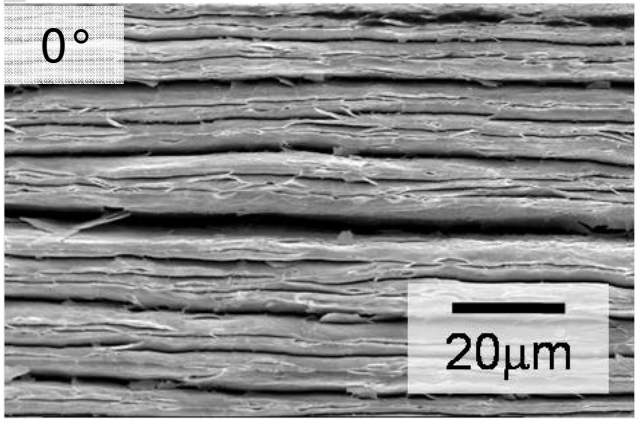
Tensile test properties: W 0.1 mm

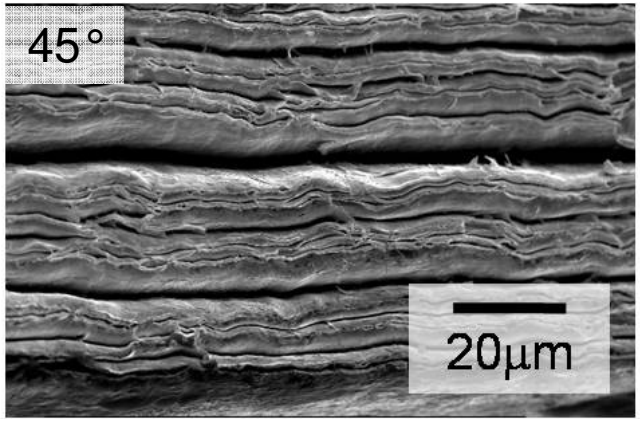
W foil, 0.1 mm, RT

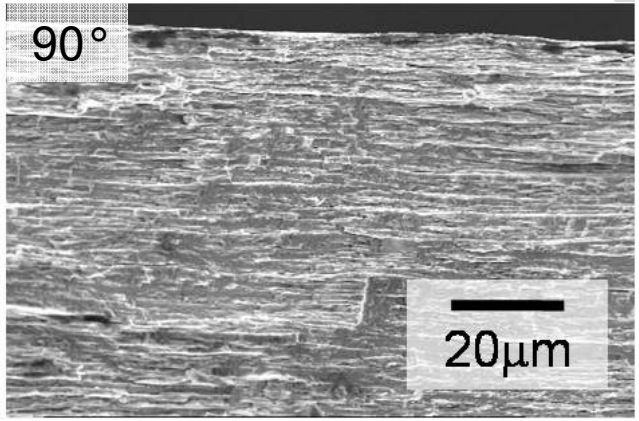


W foil, 0.1 mm, 600℃



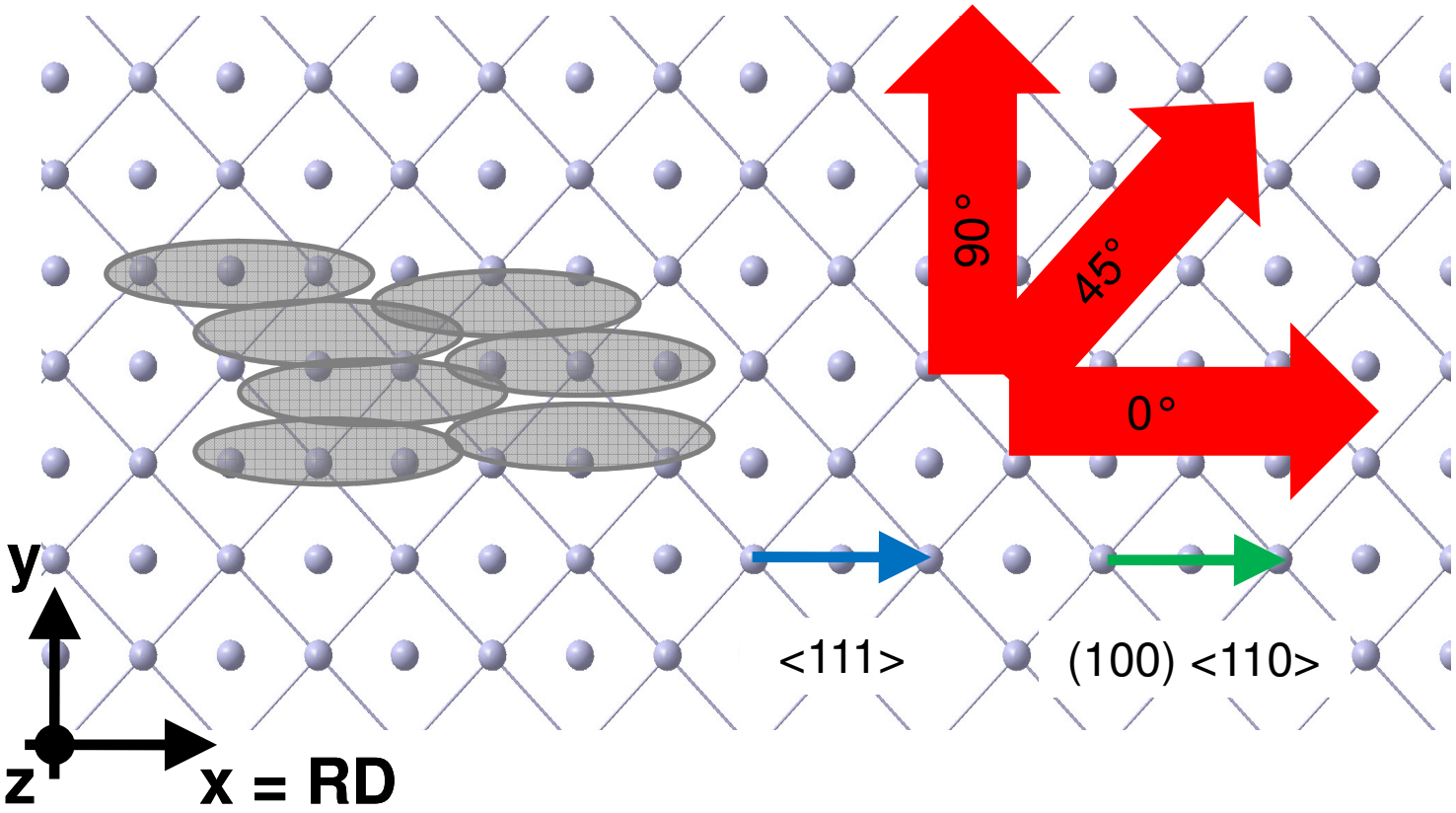






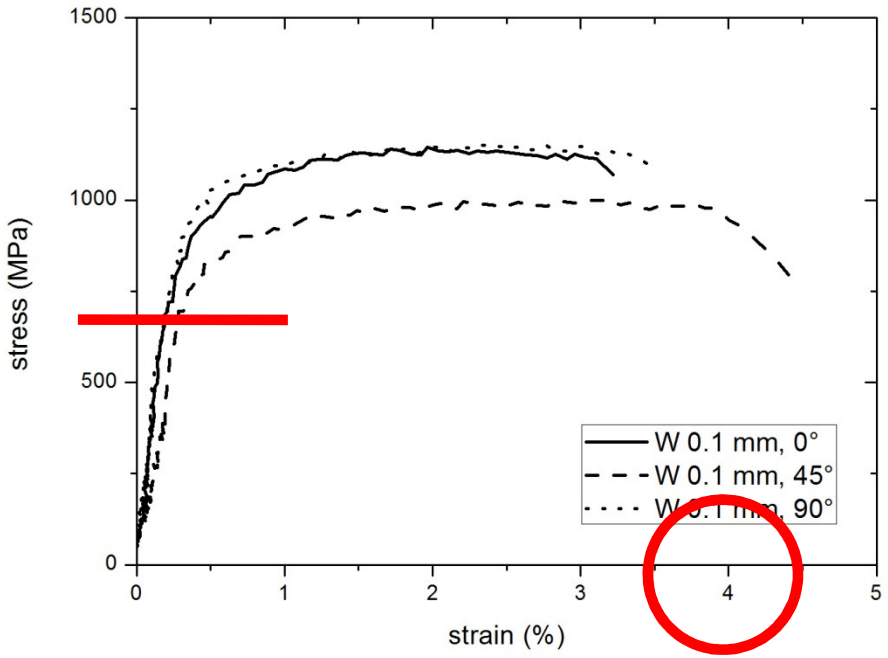
Tensile test properties: W 0.1 mm

- texture: (100) <110>
- preferred slip: <111>
- W foil, 0.1 mm, grain size: 0.5 x 3 x 15 µm³

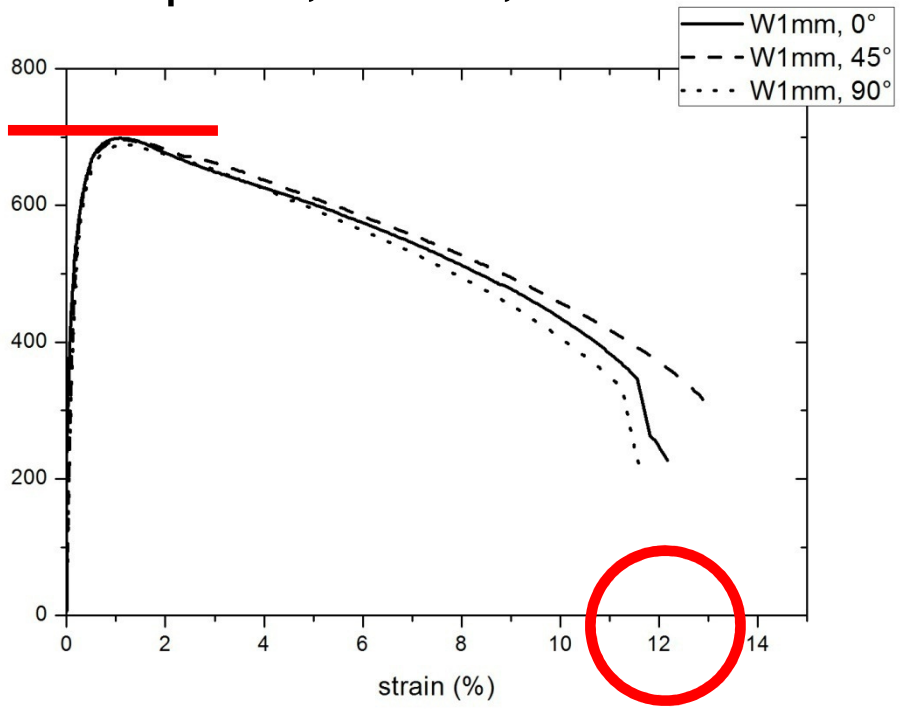


Tensile test properties: W 0.1 mm

W foil, 0.1 mm, 600 °C



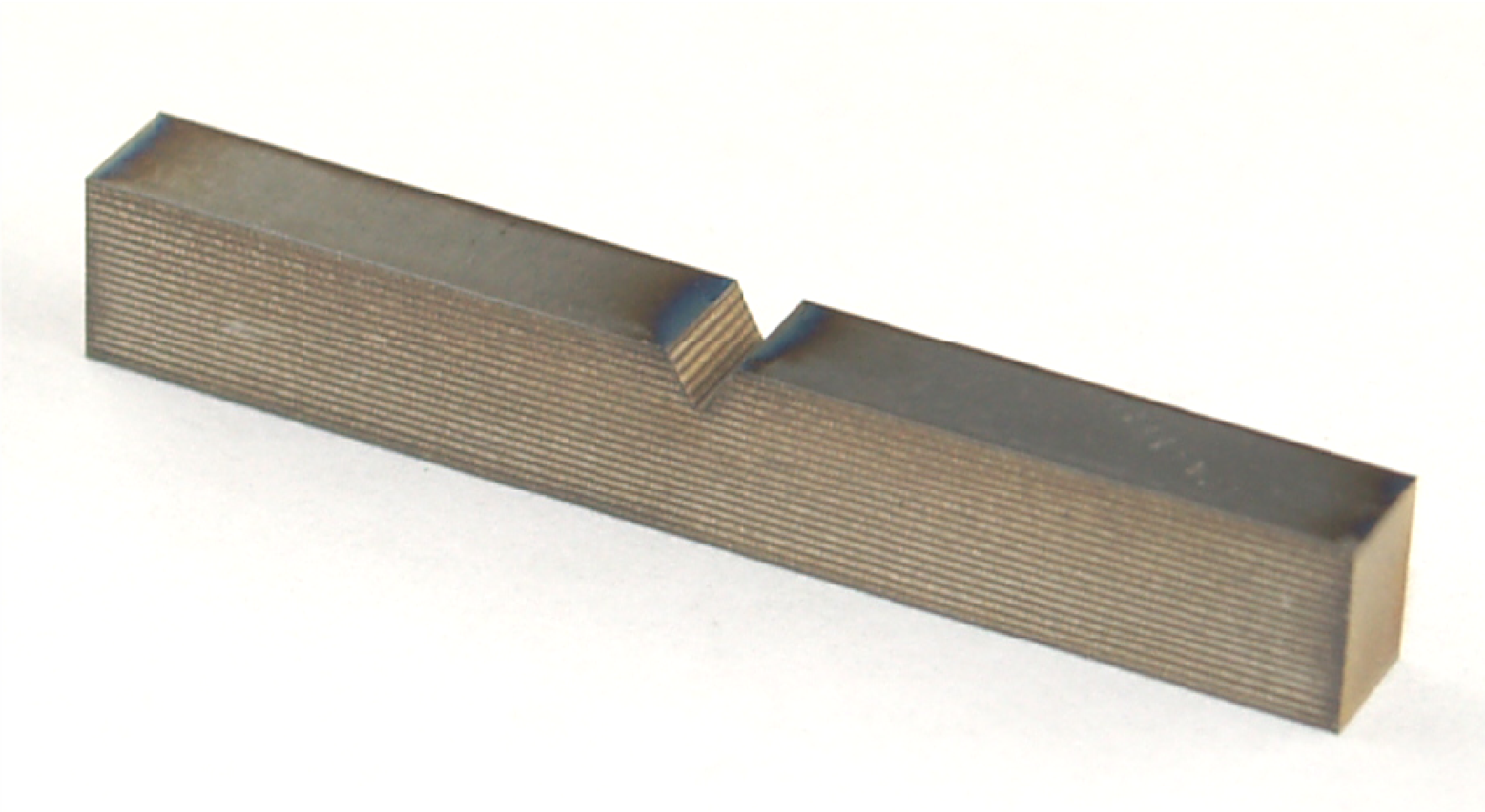
W plate, 1 mm, 600 °C



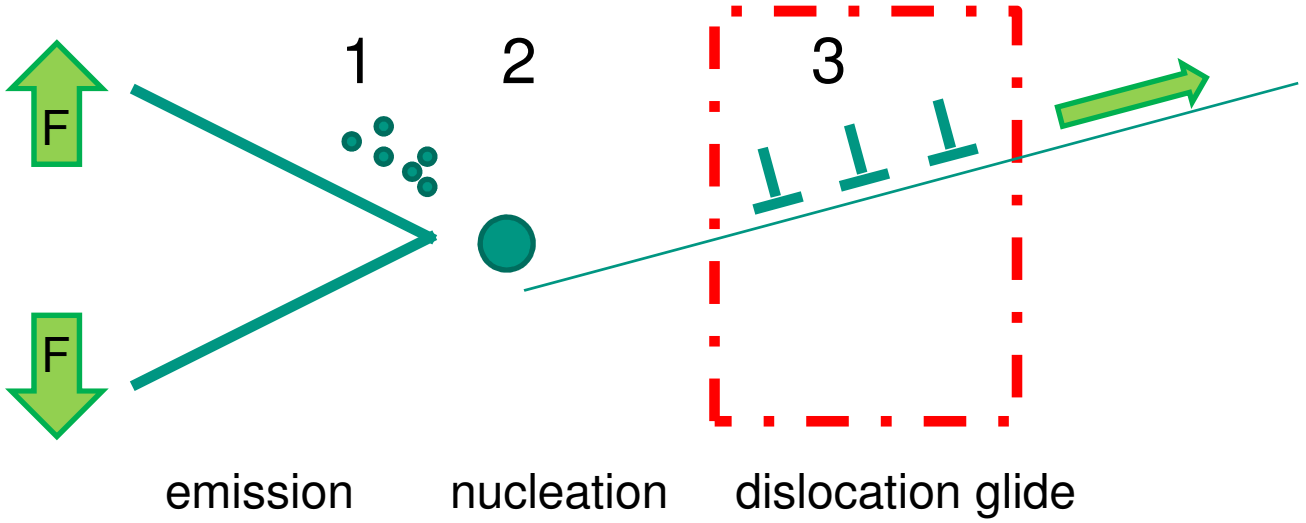
no necking
only 4 % total strain

extreme necking
12 % total strain

Charpy test sample: 3 x 4 x 27 mm³ (KLST)



Which mechanism controls the bdt?



- Literature:

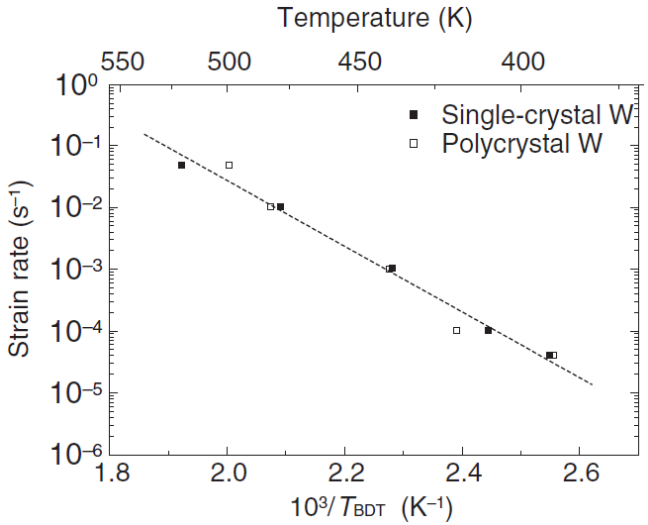
[1] S. G. Roberts, *Comp. Sim. in Sci.,* 409 (1996).

Which mechanism controls the bdt?

$$\dot{\varepsilon} = A \exp\left(-\frac{\Delta H_{\mathrm{BDT}}}{k T_{\mathrm{BDT}}}\right), \qquad \text{with } A = \text{constant},$$

- ΔH_{BDT} = 1.05 ± 0.05 eV
- Kink-pair formation process: H_{kp} = 1.11 eV
- Edge dislocation mobility = 0.3 eV

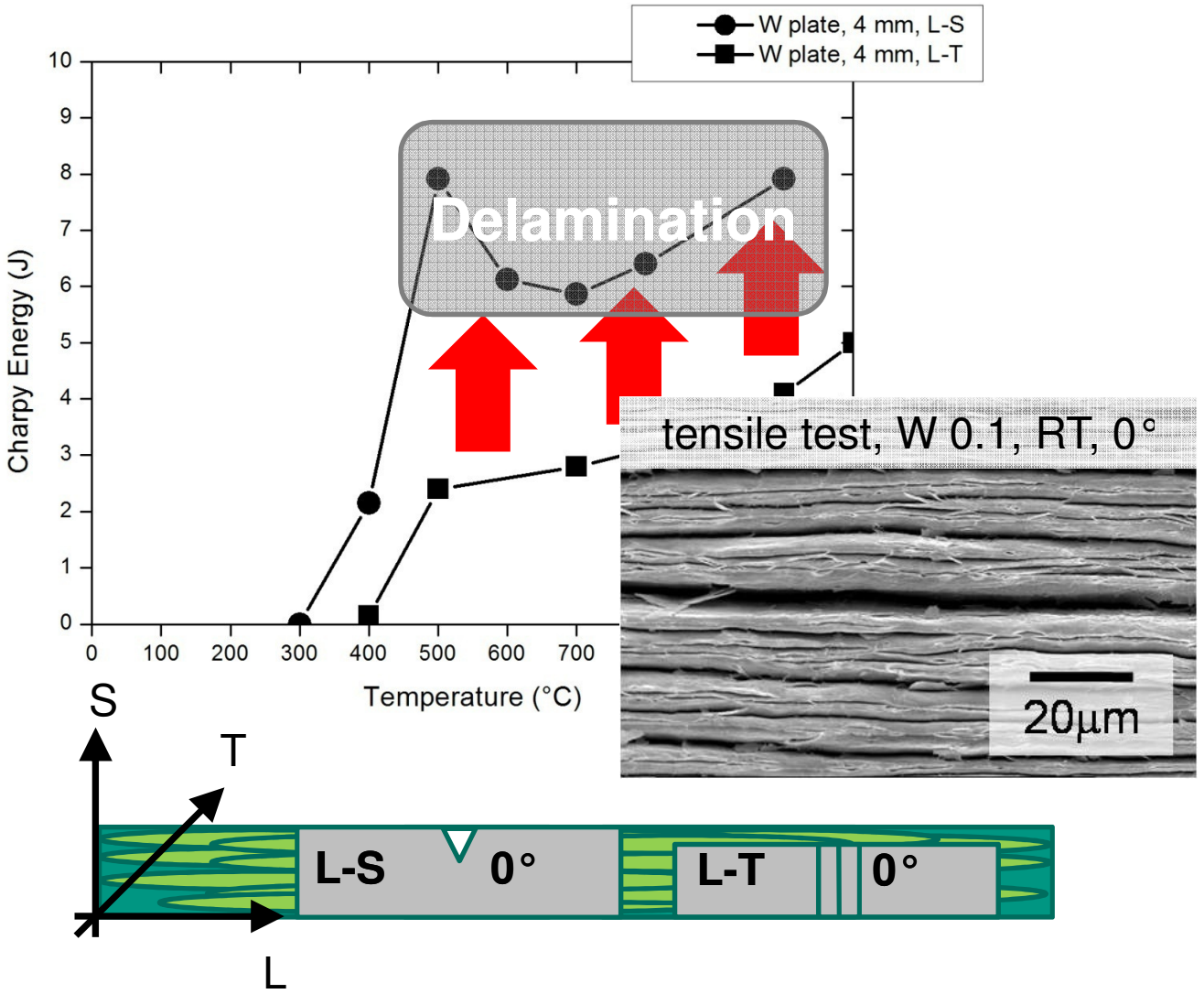
→ Dbt is controlled by screw dislocations



- Literature:

[1] A. Giannattasio, S. G. Roberts, *Phil. Mag.*, **87**, 2589 (2007).

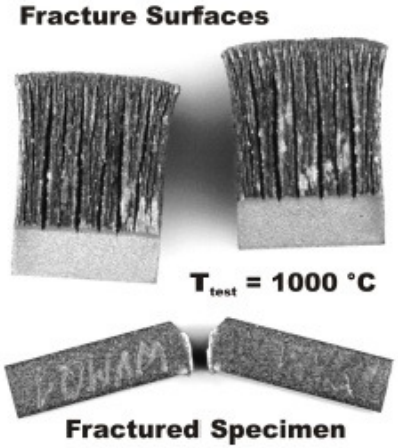
Charpy test results



L-S sample

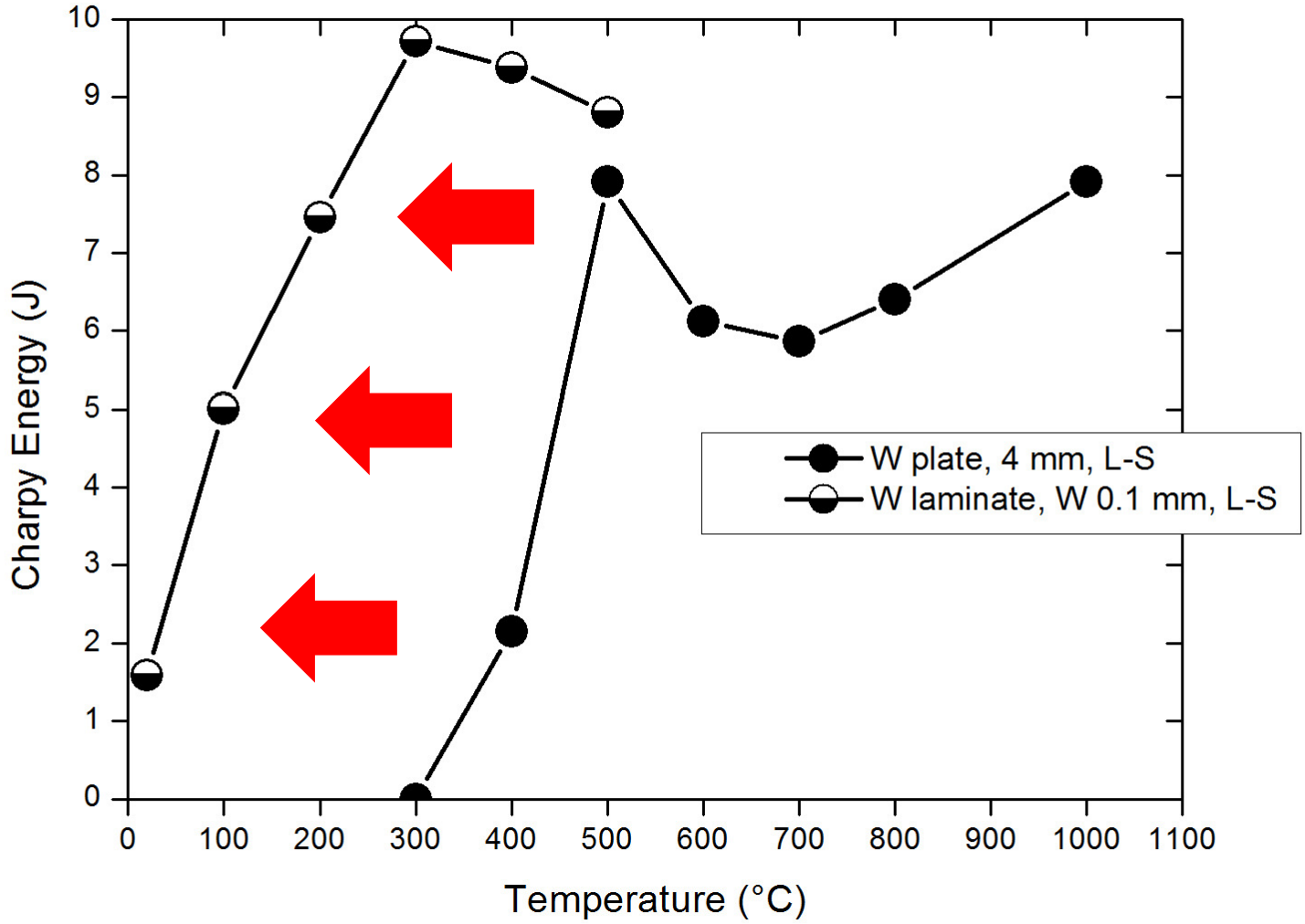
600 °C

L-T sample

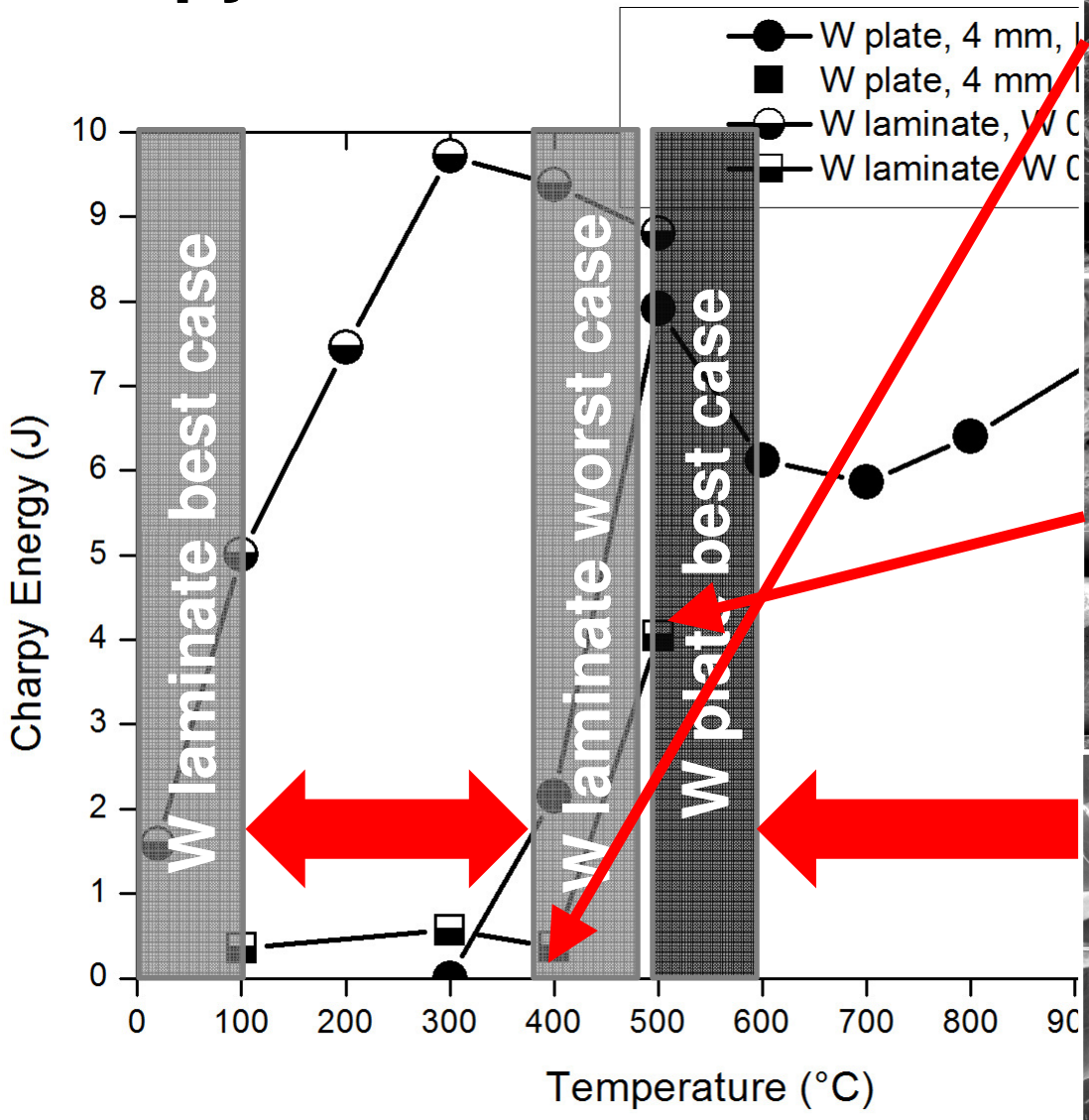


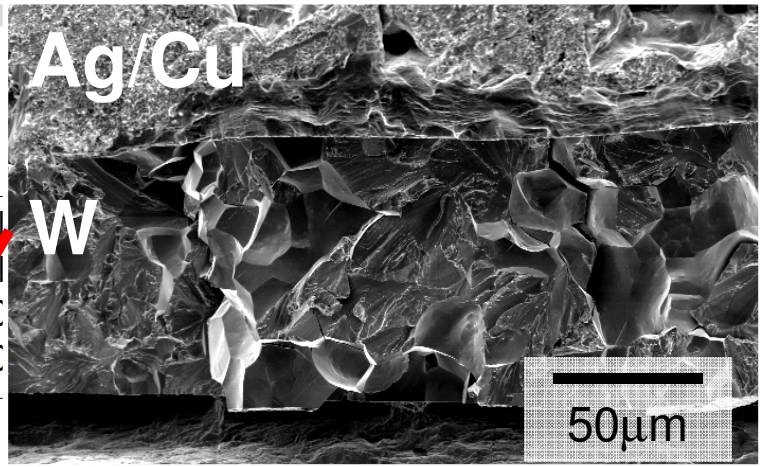
M. Rieth, KIT-IAM

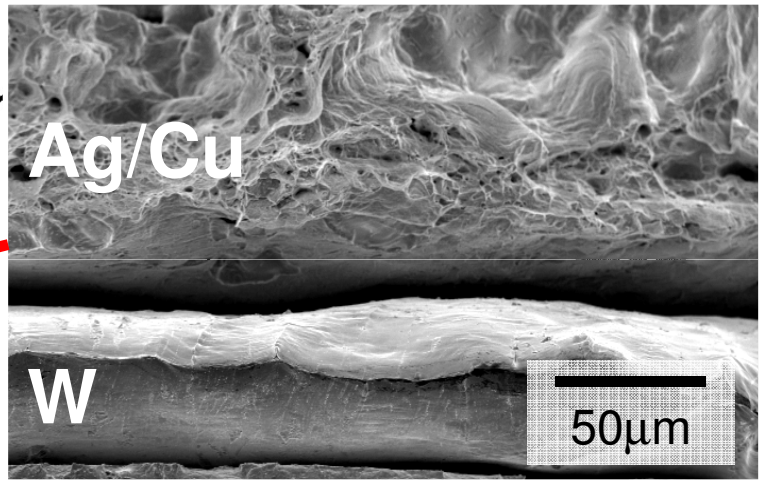
Charpy test results

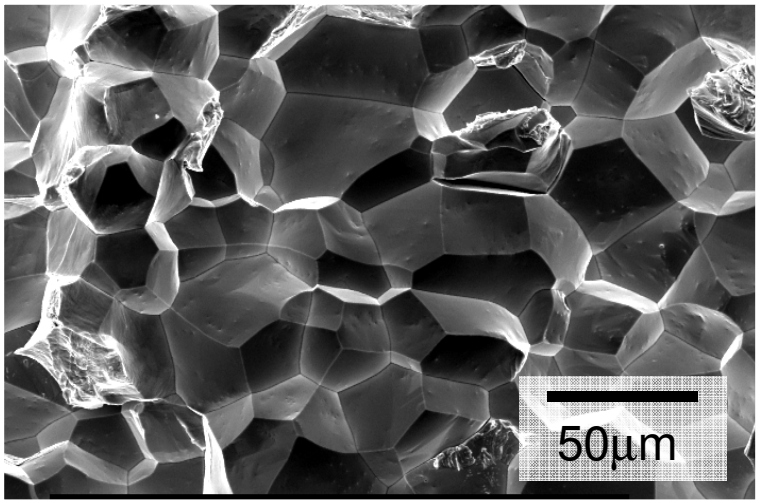


Charpy test results









Thank you for your attention

The authors are grateful to:

Plansee Metall GmbH
University of Oxford
our colleagues from IAM (KIT)