W Laminate

J. Reiser[1], M. Rieth[1], B. Dafferner[1], A. Hoffmann[2]
W workshop, Santa Barbara, 13.02.12 – 15.02.12

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[2] PLANSEE Metall GmbH, 6600 Reutte, Austria

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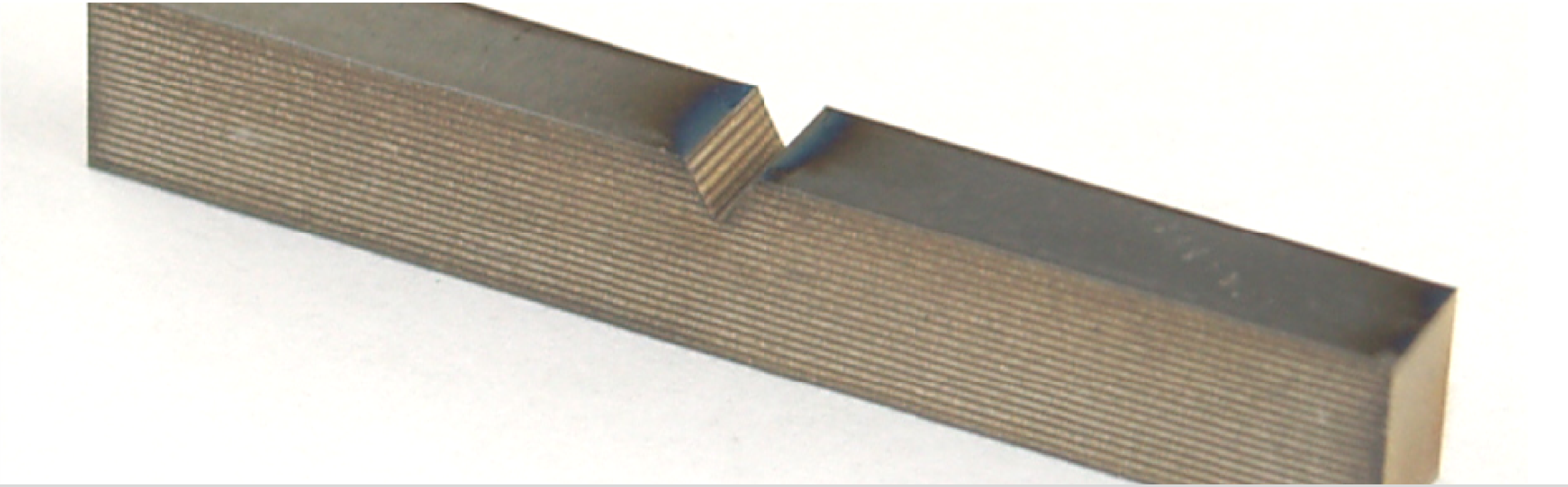
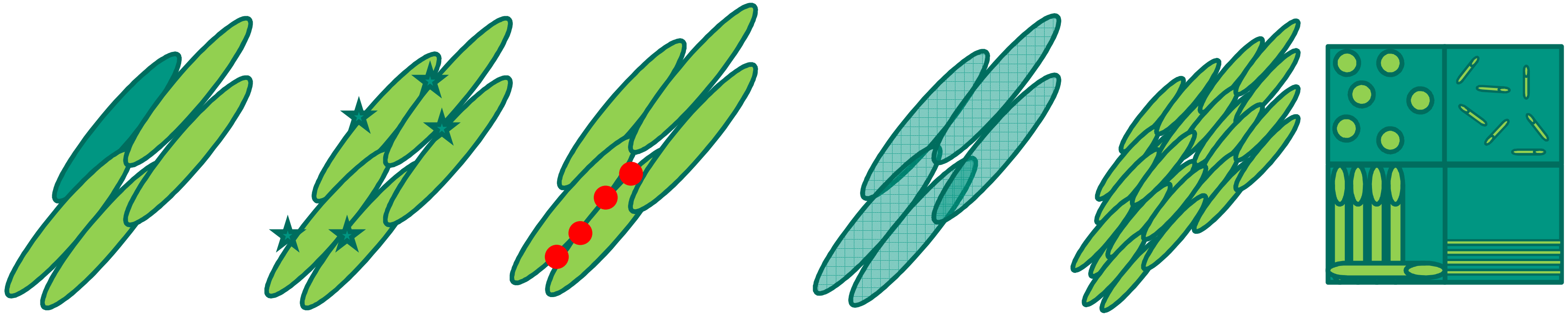


How to make tungsten ductile?

oxides	insoluble metals	roll of impurities	1. alloying	2. nano structuring	3. composite

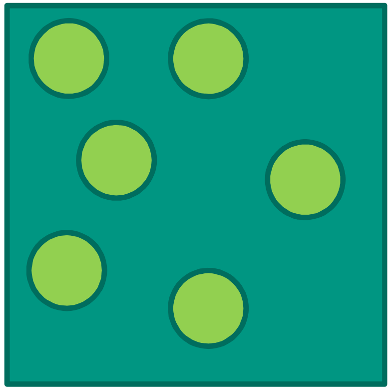


oxides? • La_2O_3 (WL10) • Y_2O_3 → NO!	insoluble metals? • K (WVM) → NO!	decrease of impurities? → NO!	WRe (WIr) is ductile • WTa • WV → NO!	mass production • SPD • mech. alloying → NO!	• particle • short fibre • long fibre • <u>laminate</u>

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

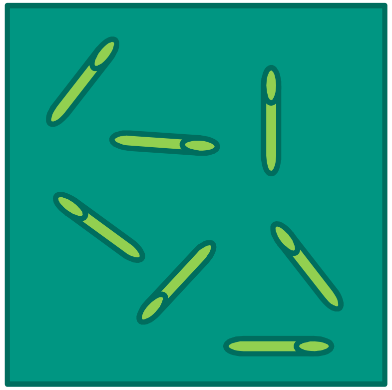
How to make tungsten ductile?

particle reinforced MMC [1]



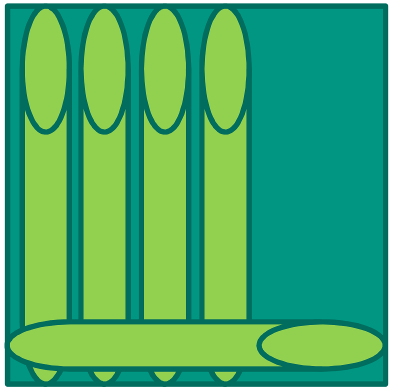
J. Hohe, IWM, Fraunhofer-Institut, Freiburg

short fiber reinforced (random) MMC [2]



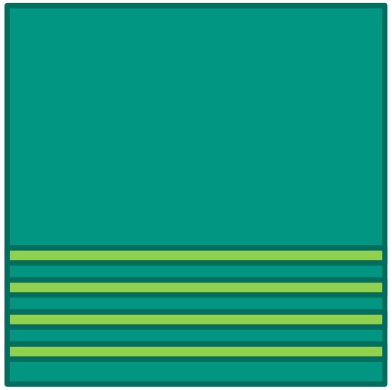
J. B. Correia, IST, Portugal

unidirectional fiber reinforced MMC [3]



J.-H. You, IPP, Garching

multi-layer MMC laminate material



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

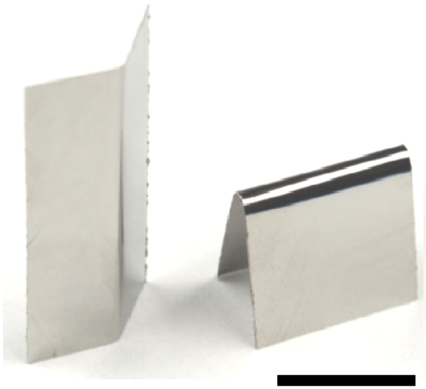
- Literature:

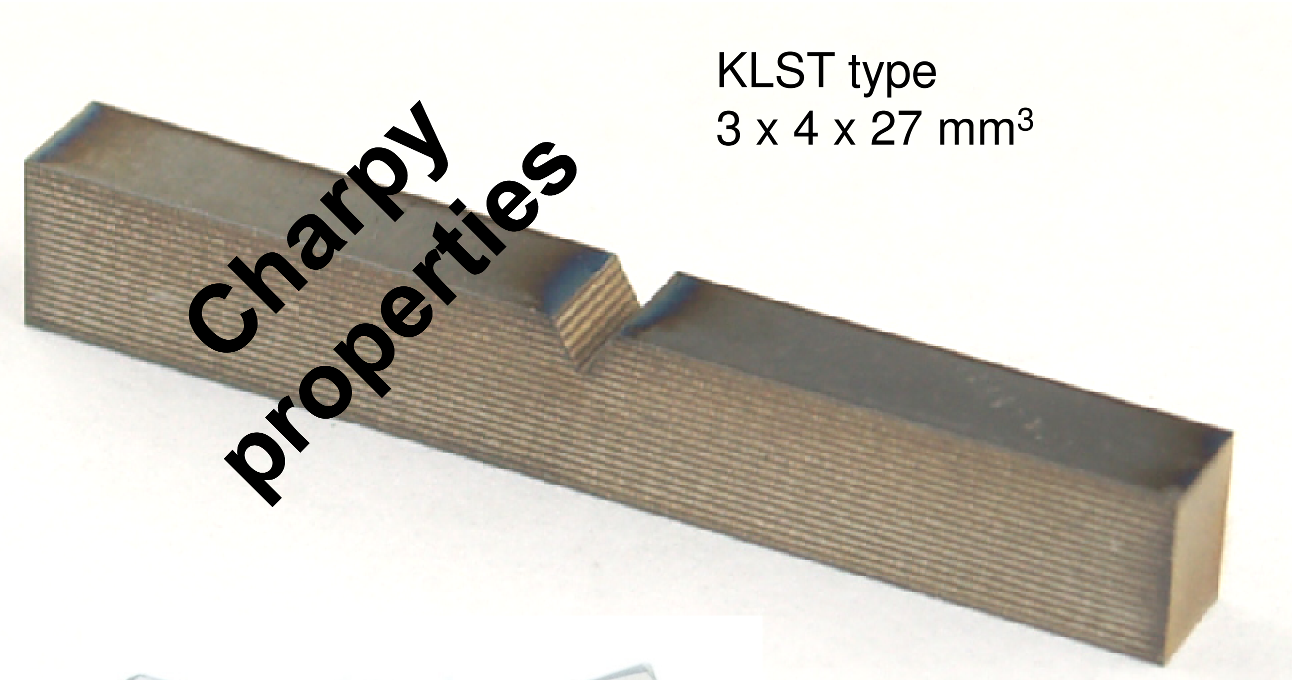
[1] J. Hohe, P. Gumbsch, J. Nucl. Mater. 400 (2010) 218.

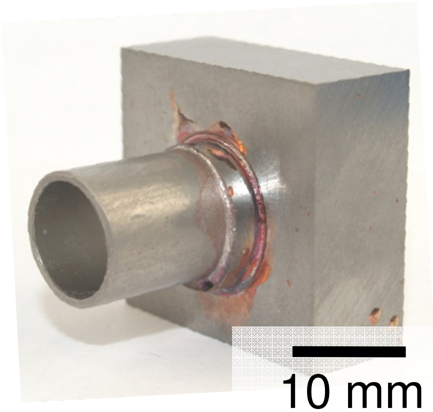
[2] V. Livramento, D. Nunes, J.B. Correia, P.A. Carvalho, R. Mateus, K. Hanada, N. Shohoji, H. Fernandes, C. Silva, E. Alves, Tungsten-tantalum composites for plasma facing components, Materials for Energy 2010, ENMAT2010, 4-8 July 2010, Karlsruhe, Germany.

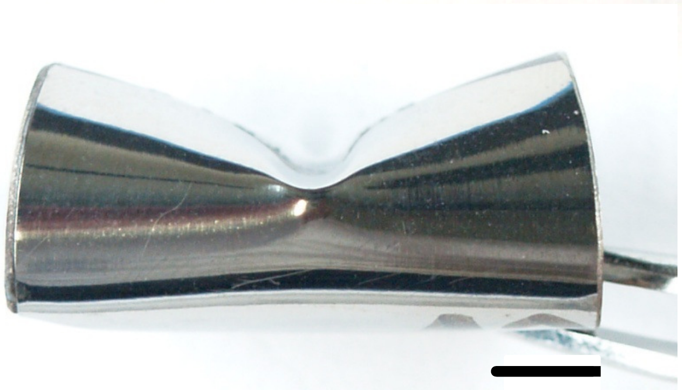
[3] J. Du, T. Höschen, M. Rasinski, S. Wurster, W. Grosinger, J.-H. You, Comp. Sci. Tech. 70 (2010) 1482.

Introduction



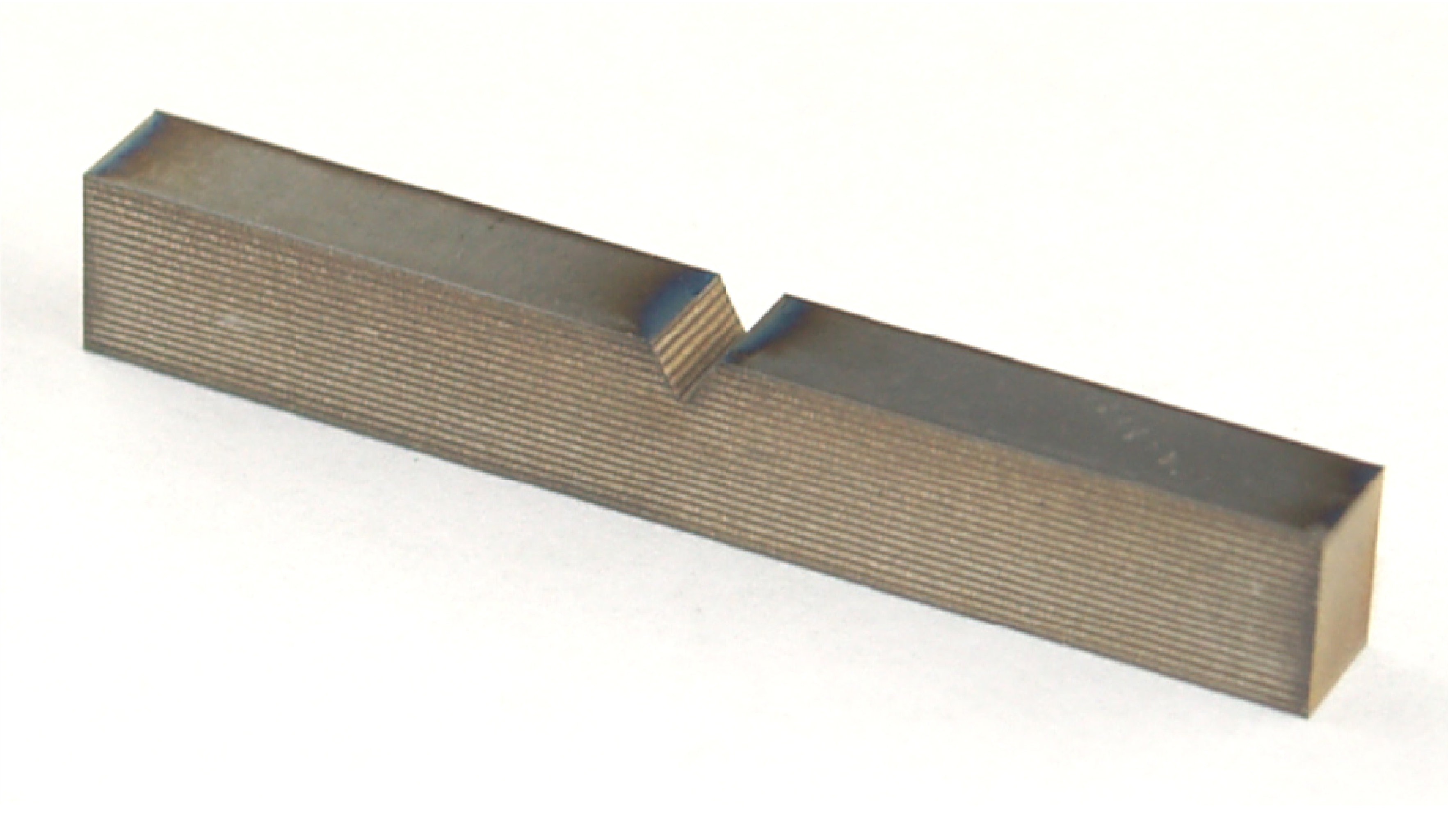




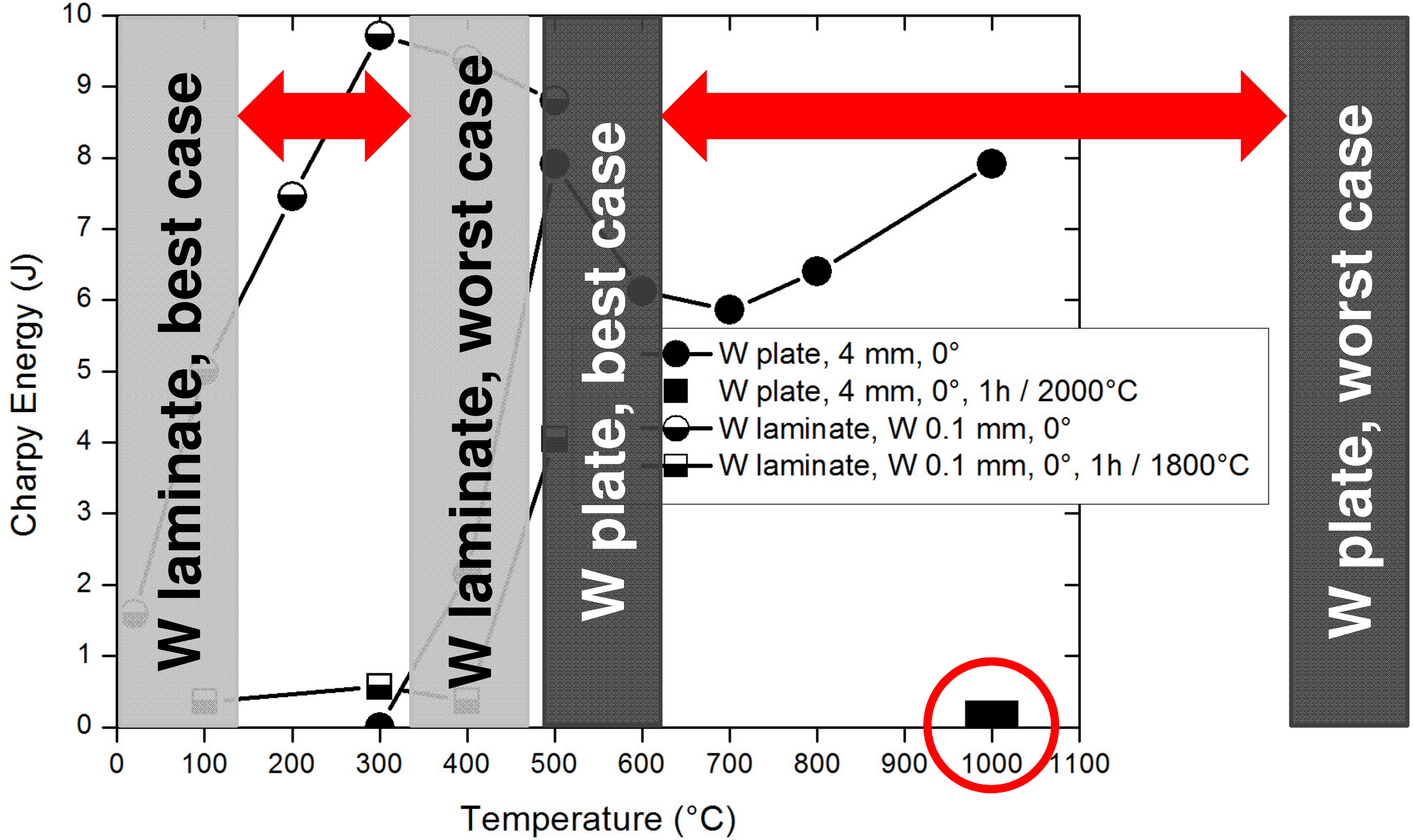


Charpy impact properties

Charpy test: W0.1(rxx) AgCu0.1, 3*4*27 mm^3



Charpy test: W0.1(rxx) AgCu0.1, 3*4*27



J. Reiser, IAM-AWP, KIT
W workshop, Santa Barbara

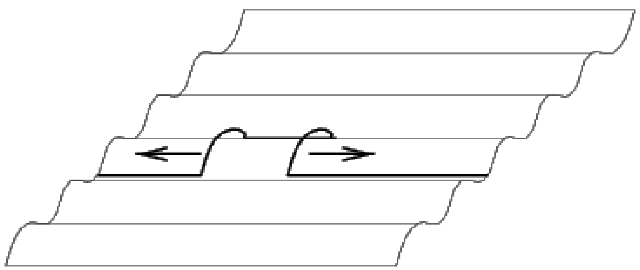
Source of ductility!

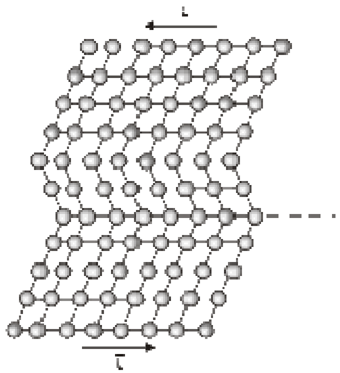
J. Reiser, IAM-AWP, KIT
W workshop, Santa Barbara

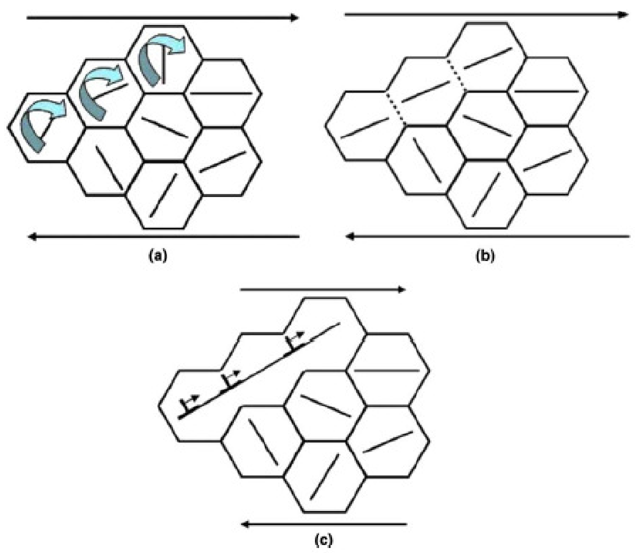
Source of ductility?

- movement of dislocations (edge (0.3 eV), screw (1.05 eV))
- twinning
- nano crystalline effects: grain rotation, grain boundary sliding, grain boundary dislocation interaction or grain rotation and alignment [1]

- dislocation annihilation







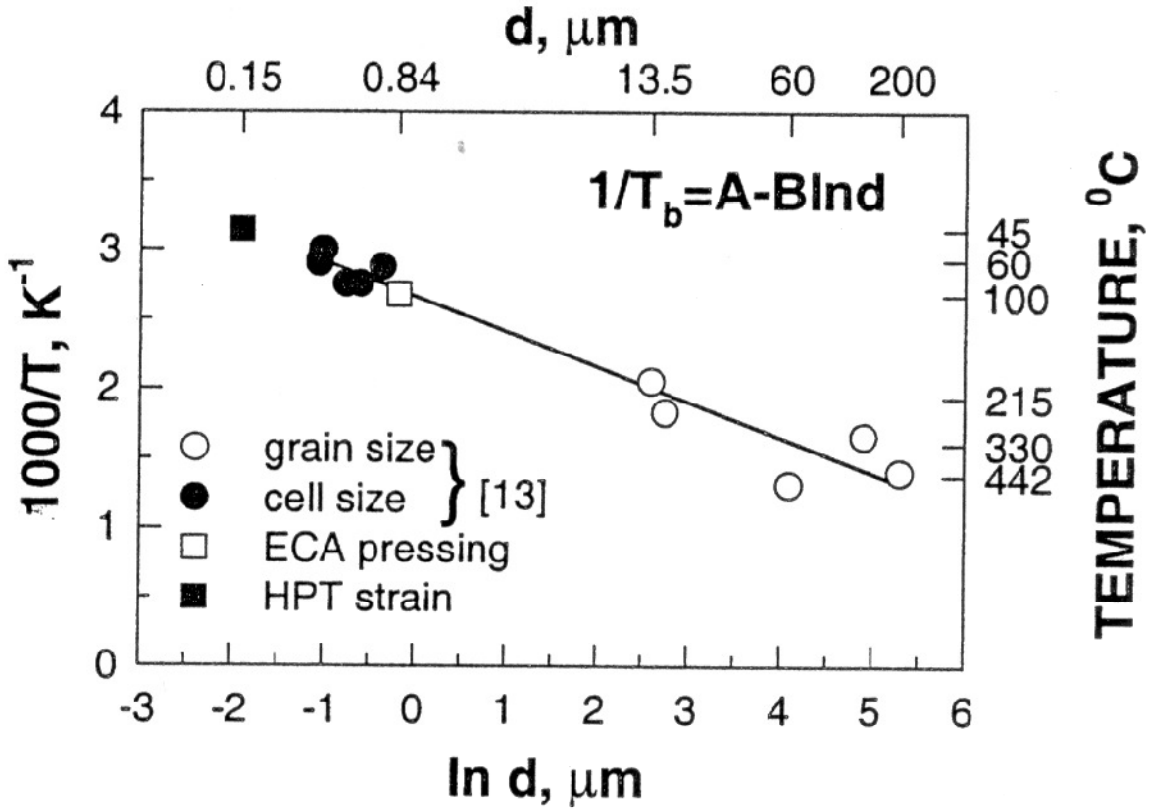
- Literature:

[1] M.A. Meyers, A. Mishra, D.J. Benson, Prog. Mat. Sci. 51 (2006) 427.

How to improve ductility?

How to improve ductility? Grain size

- the smaller the grain size, the higher the ductility



ECAP: equal channel angular pressing

How to improve ductility? Deformation

- the higher the degree of deformation, the higher the ductility

tion, and b.c.c. metals can be ductilised by prior plastic working. Ashby and Embury [9] have

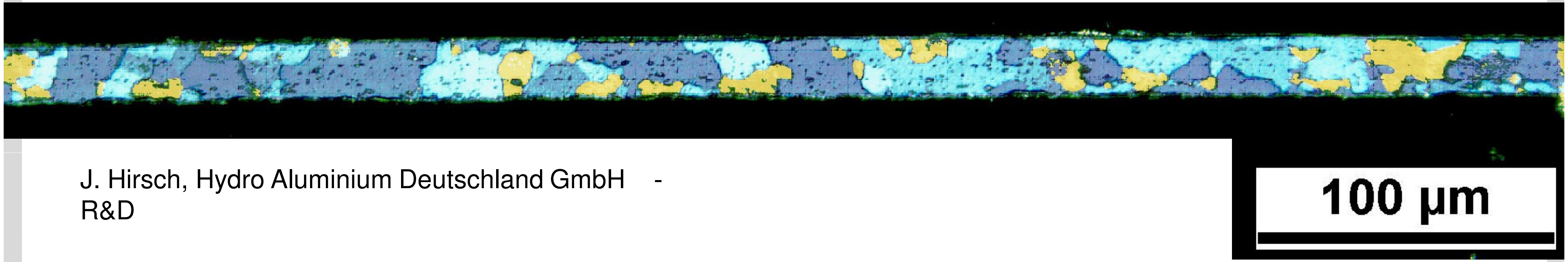
- Literature:

[1] P.B. Hirsch, S.G. Roberts, J. Samuels, *Revue Phys. Appl.* **23**, 409 (1988).

How to improve ductility? Foil effect

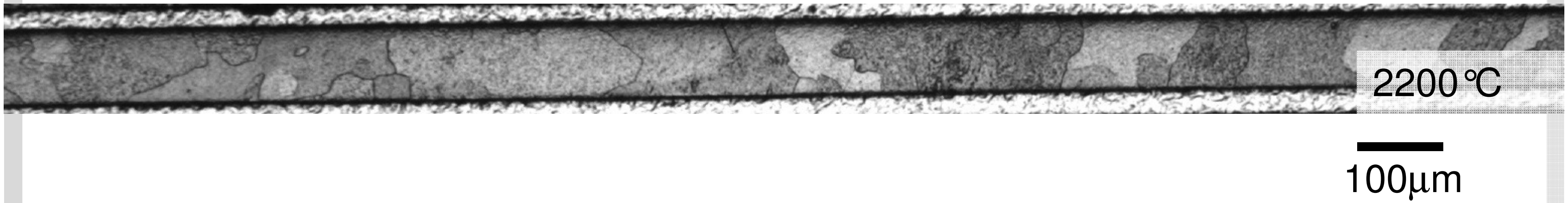
- the ‘foil effect’: dislocation annihilation on the free surface

20 µm aluminum foil



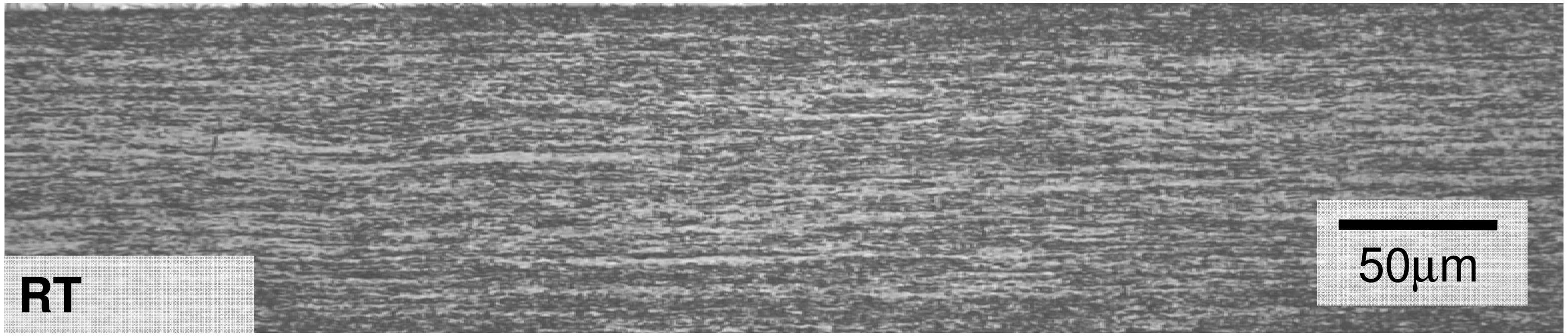
J. Hirsch, Hydro Aluminium Deutschland GmbH - R&D

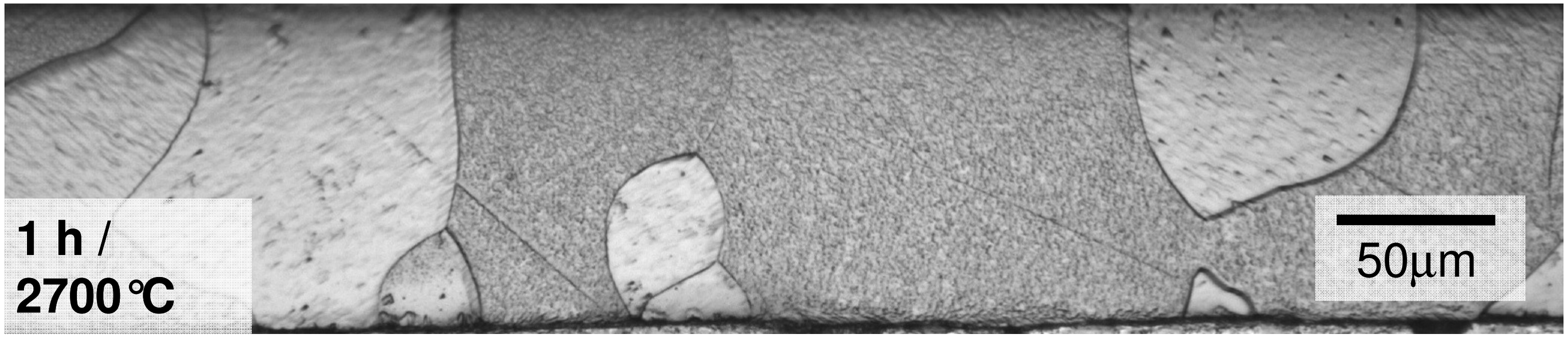
W0.1, 1h/2200°C



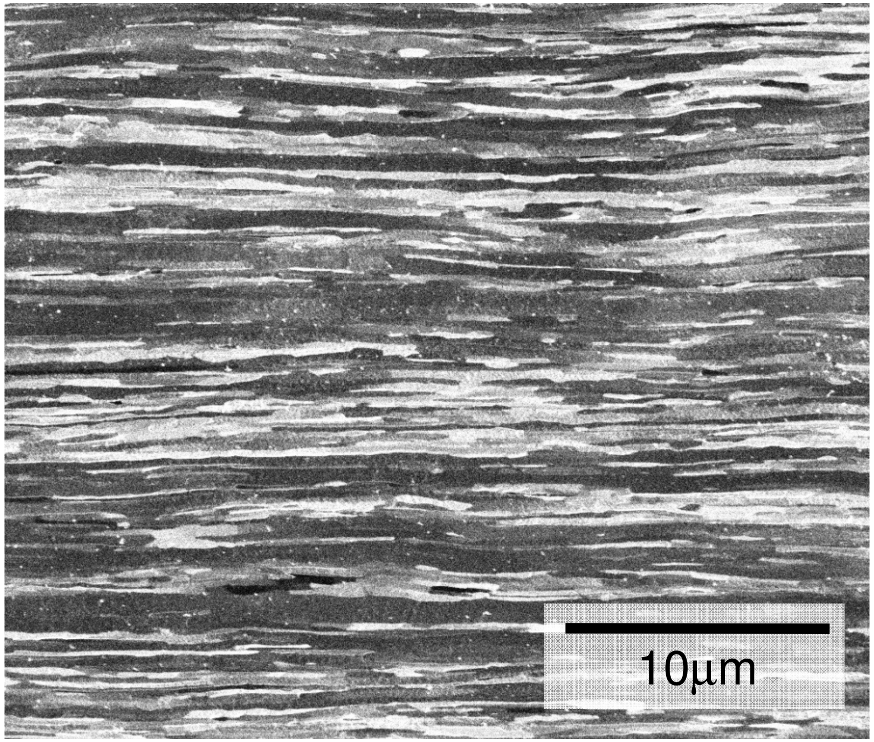
Assessment of W foil

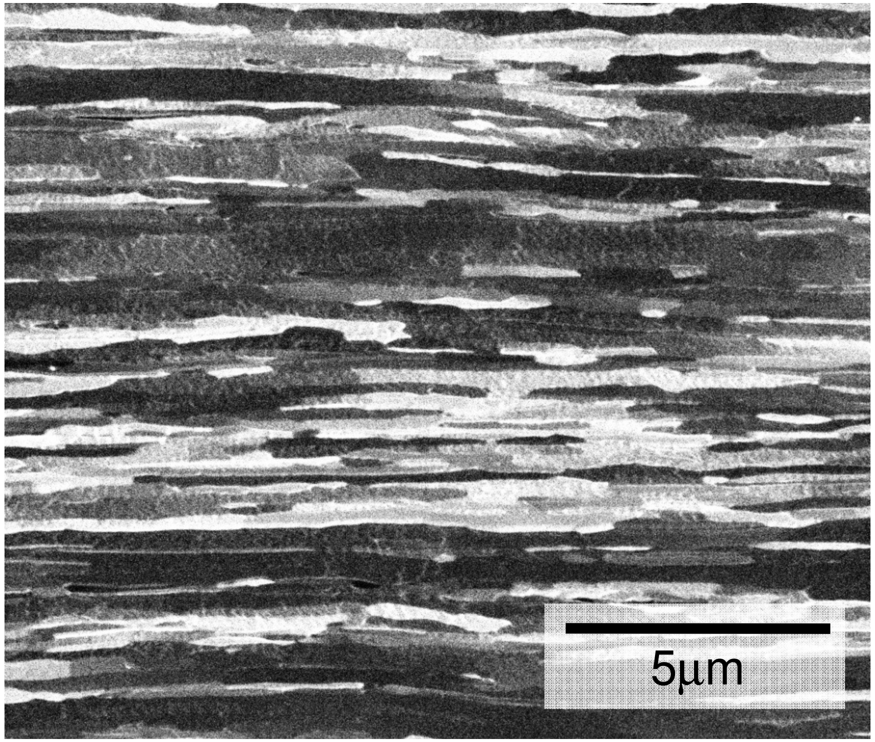
Analyses of W foil: grain size



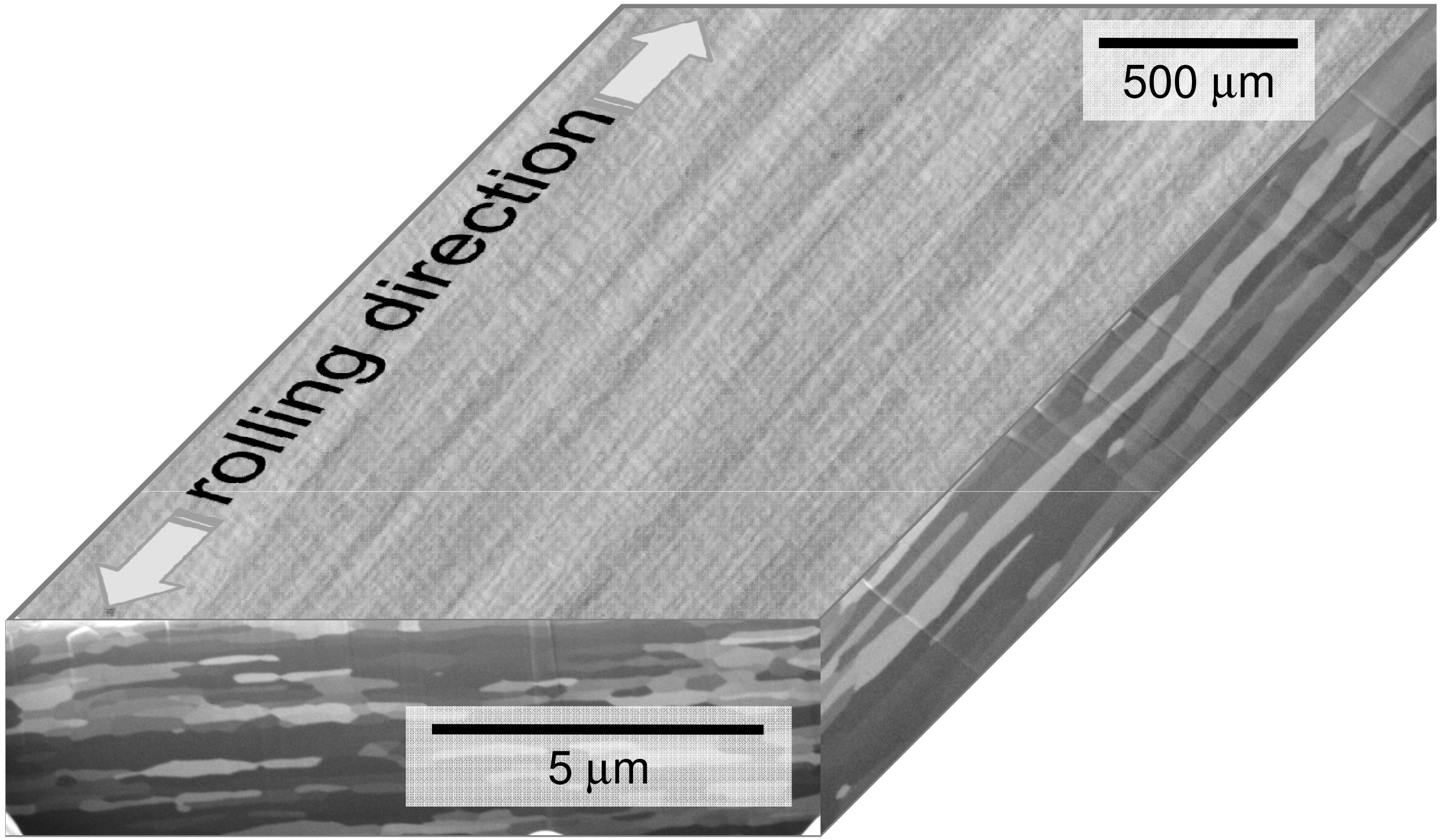


Analyses of W foil (as-received): grain size





Assessment of W foil: grain size

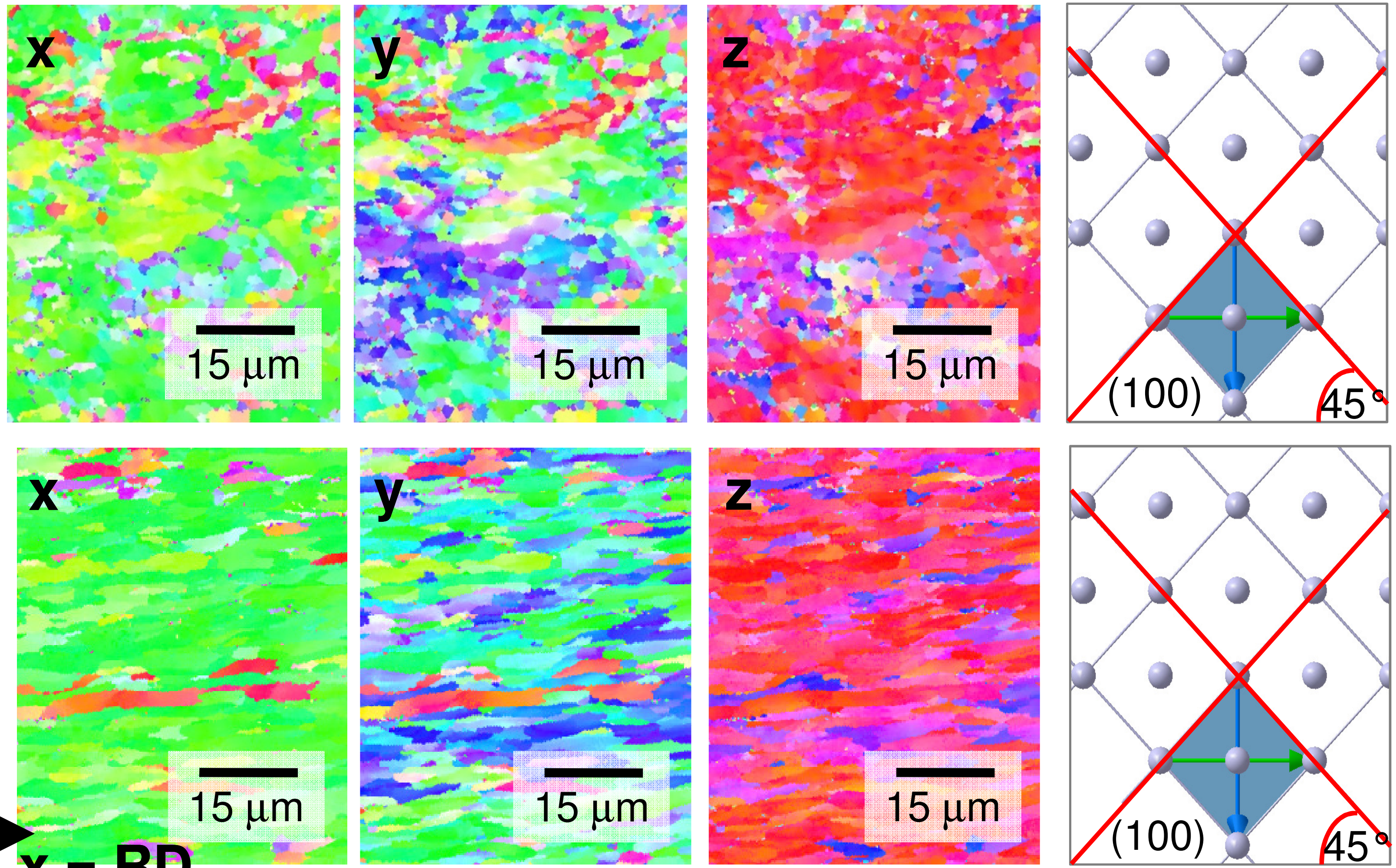


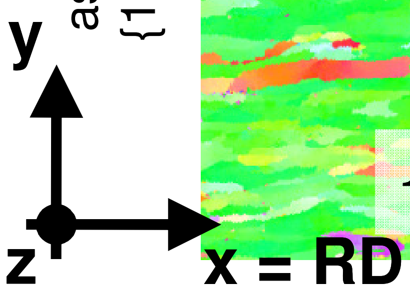
- grain size: 0.5 x 3 x 15 μm^3

Analyses of W foil: texture

W 0.1
1 h / 800°C
{100} <011>

W 0.025
as-received
{100} <011>

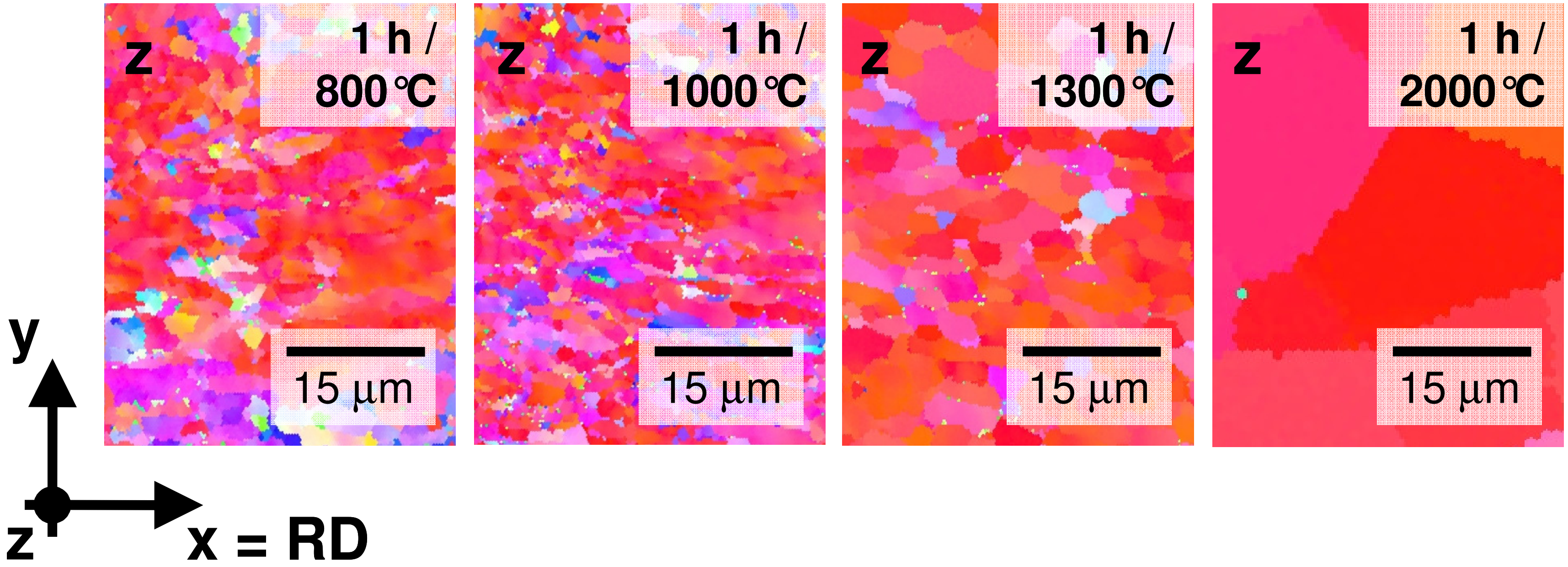




David Armstrong, Oxford

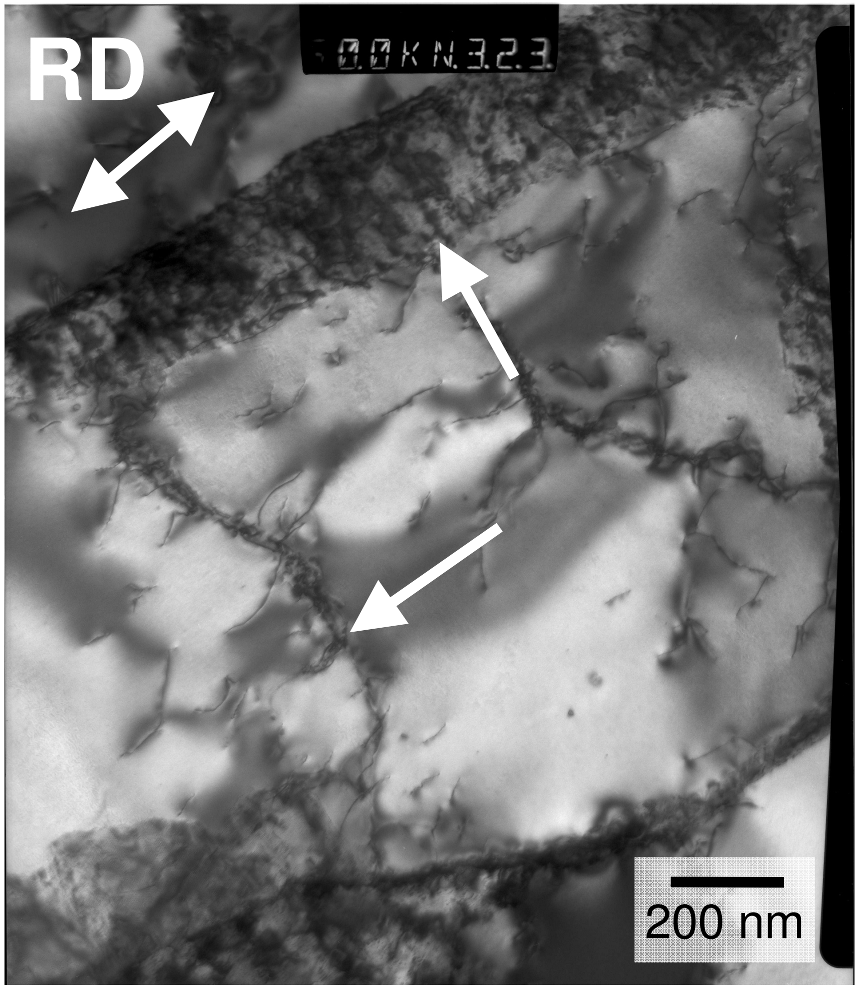
Analyses of W foil: texture

KIT Karlsruhe Institute of Technology

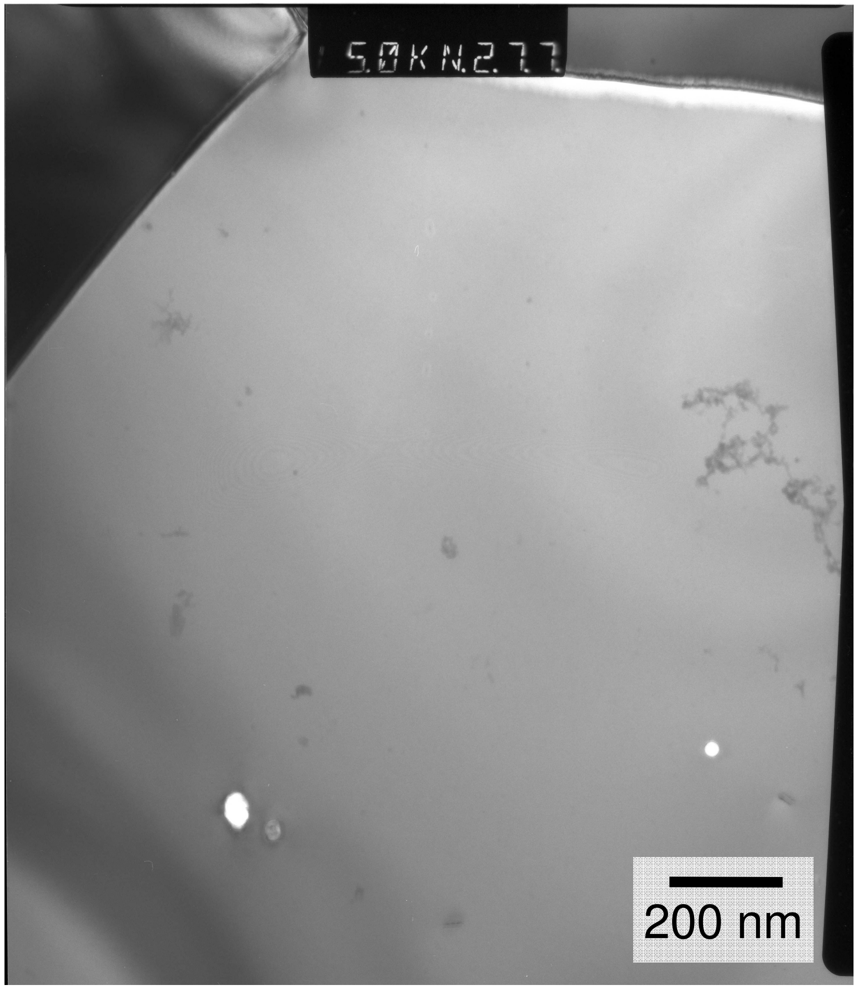


David Armstrong, Oxford

Analyses of W foil: TEM



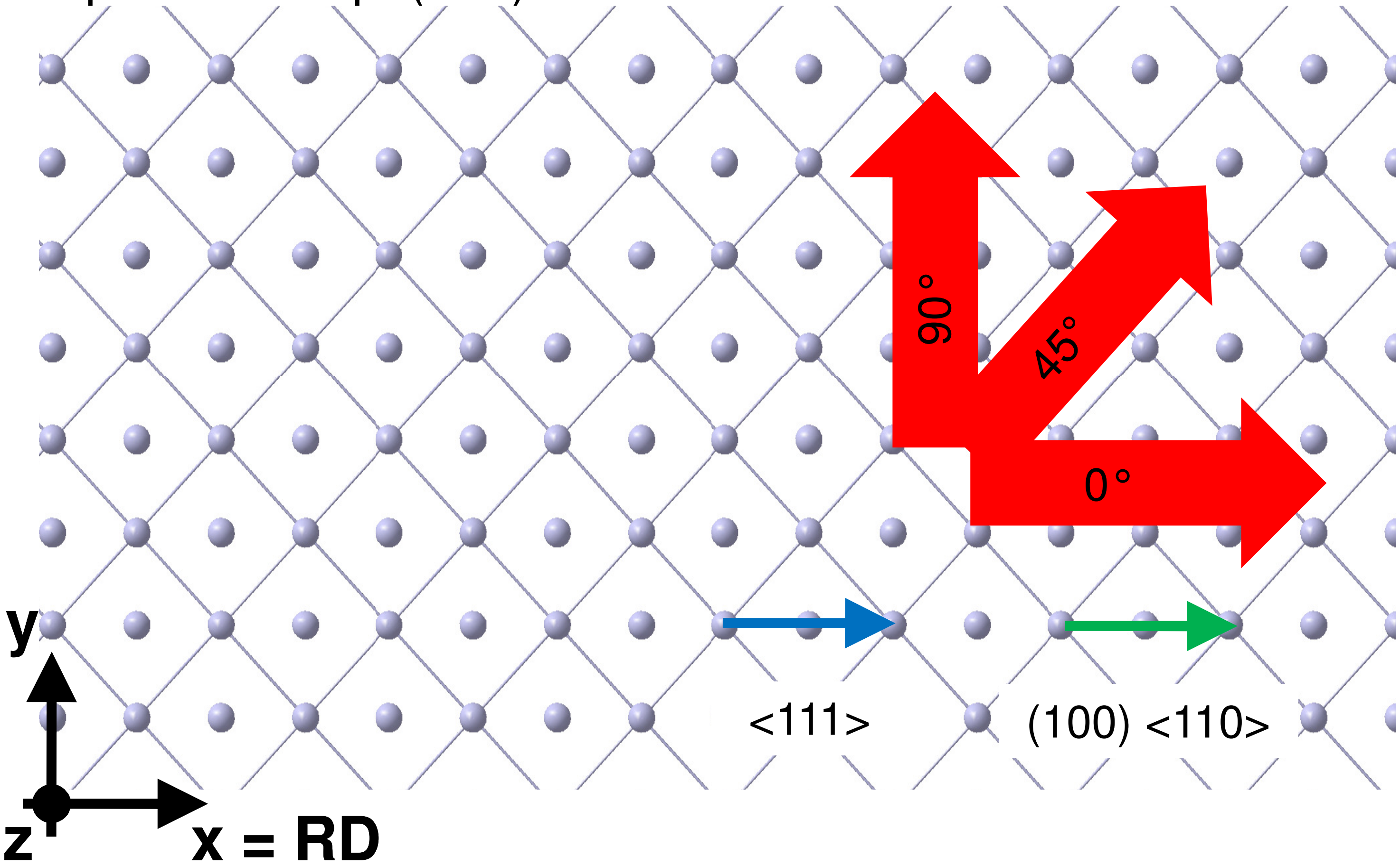
W0.1, as-received



W0.1, 20 h / 1400°C *Yi Xiauuo*, Oxford

Tensile test properties: W 0.1 mm

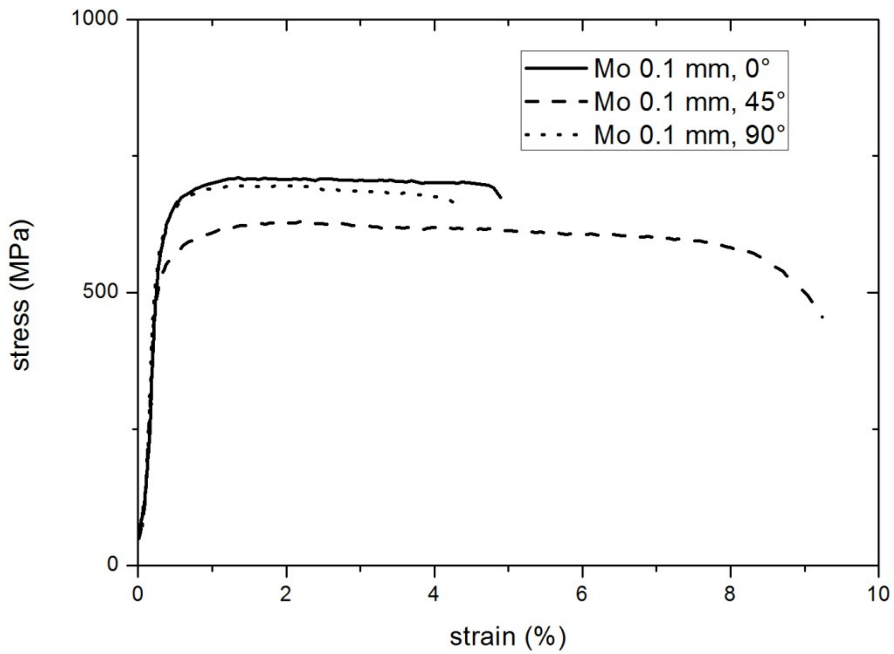
- texture: (100) <110>
- preferred slip: (110) <111>



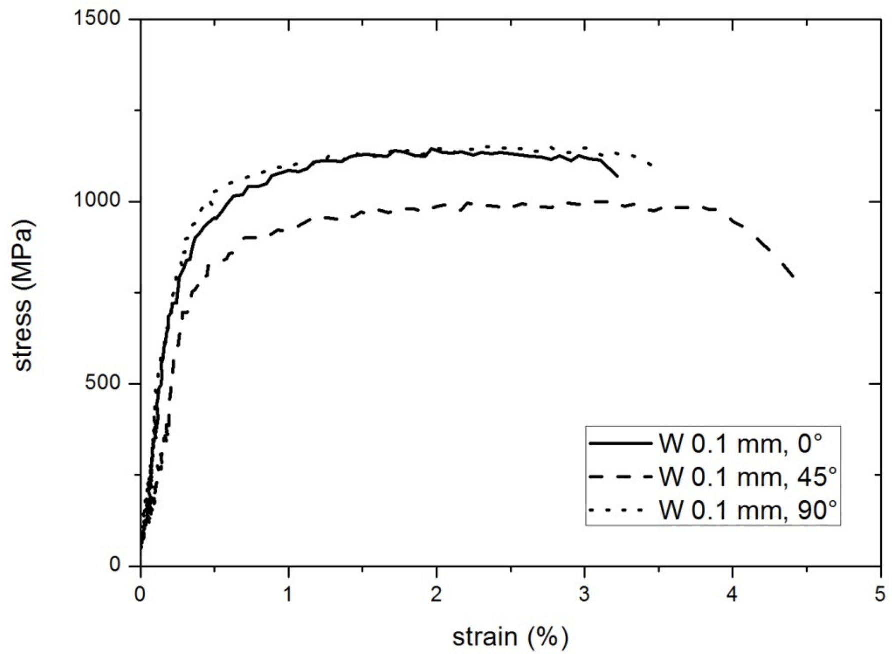
Tensile test properties: W 0.1 mm

Karlsruhe Institute of Technology

Mo foil, 0.1 mm, RT



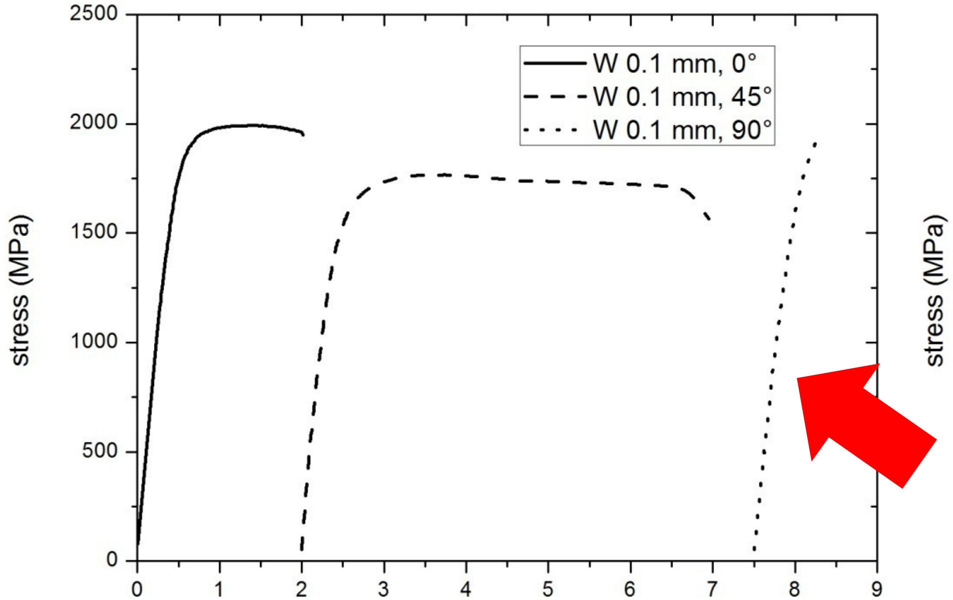
W foil, 0.1 mm, 600℃



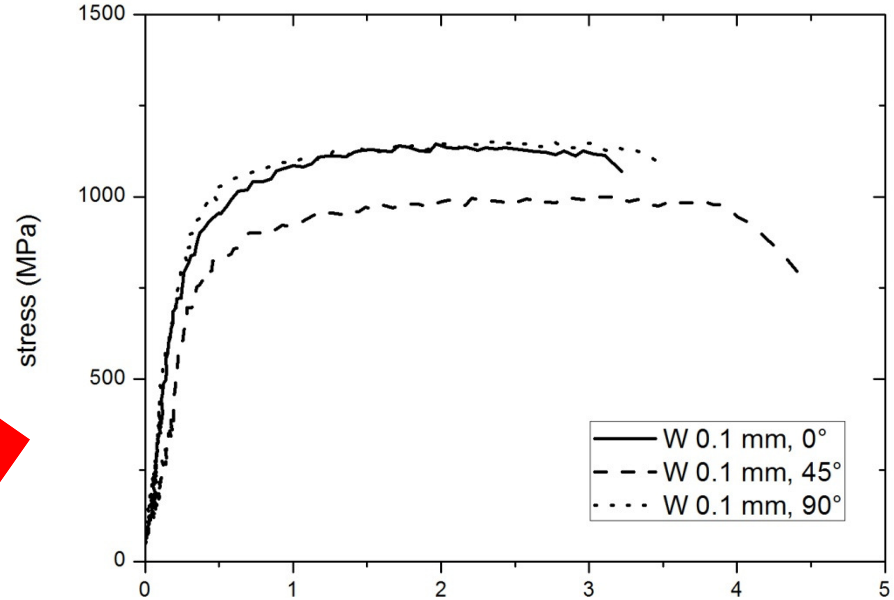
- anisotropic
- most ductility in 45° direction
- same material behavior in 0° and 90° direction

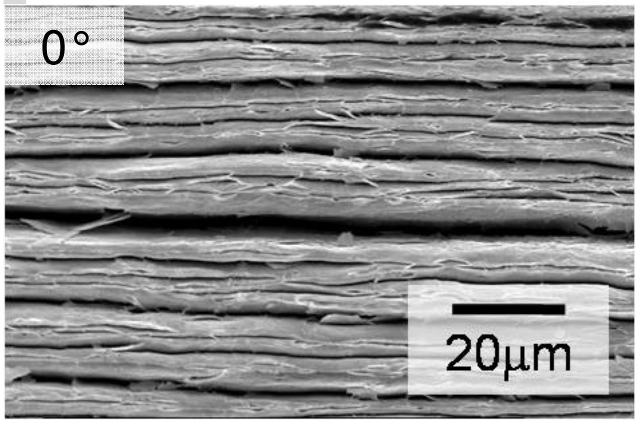
Tensile test properties: W 0.1 mm

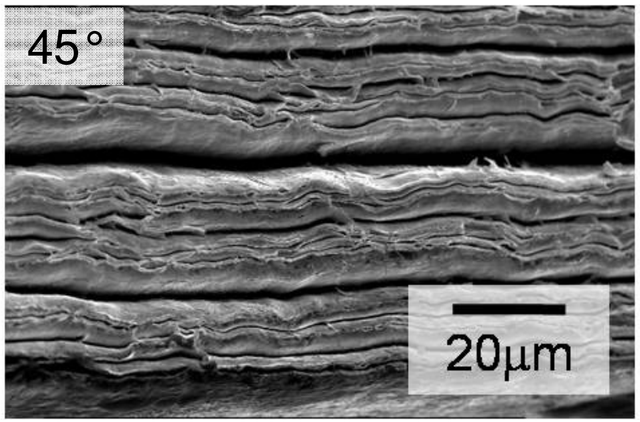
W foil, 0.1 mm, RT

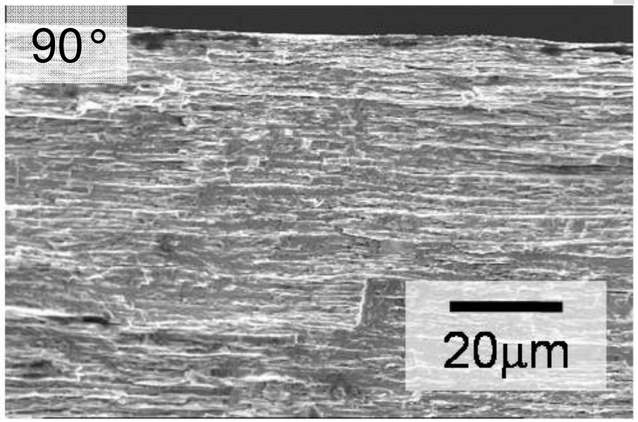


W foil, 0.1 mm, 600℃



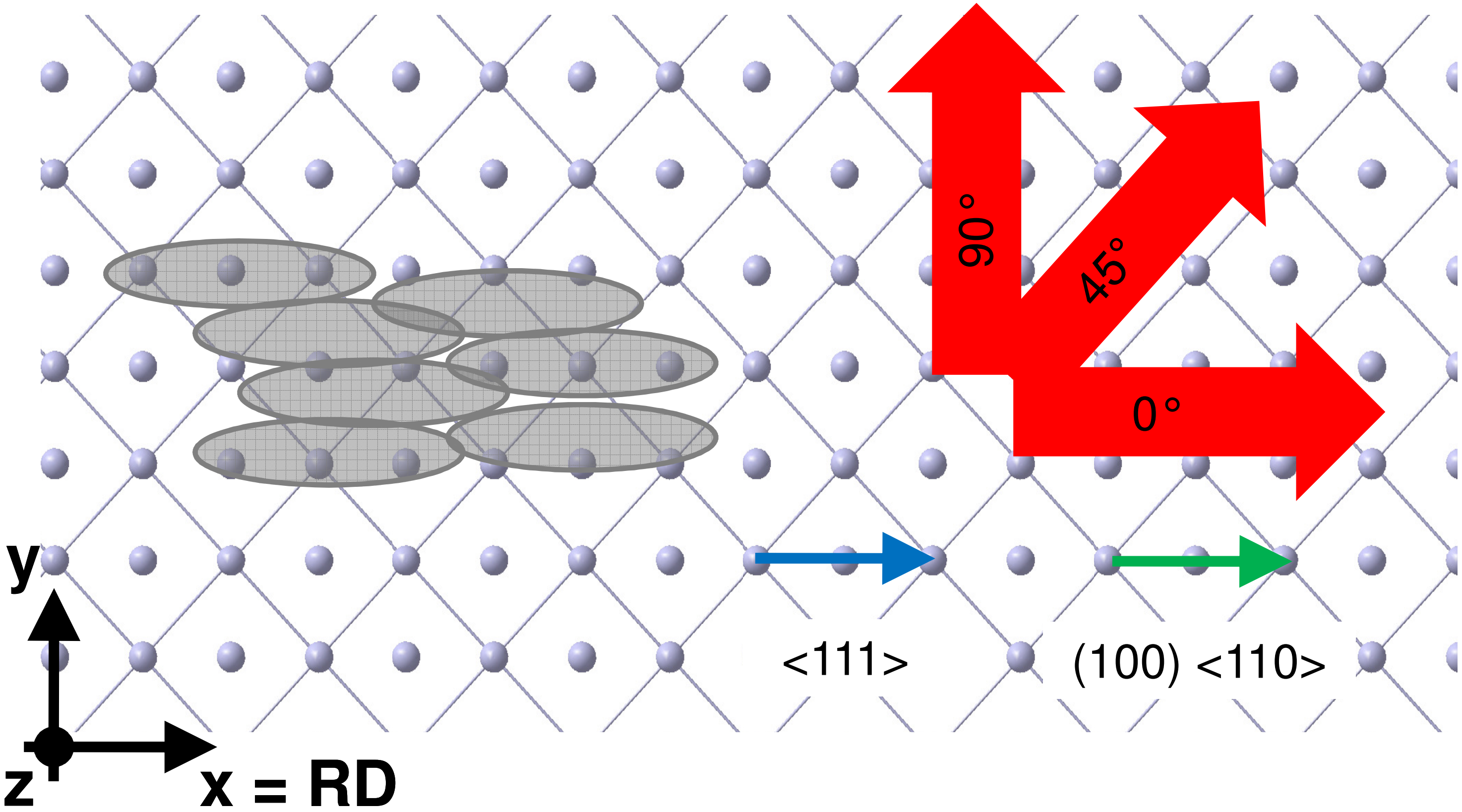




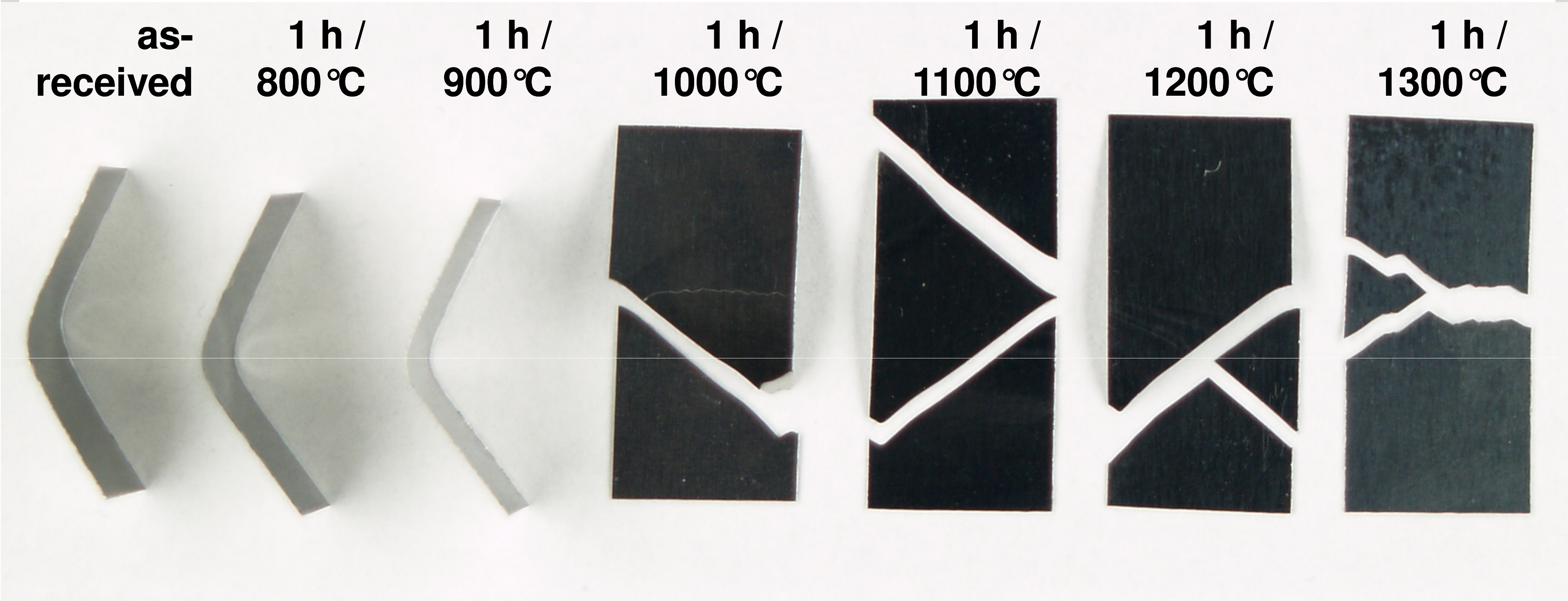


Tensile test properties: W 0.1 mm

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

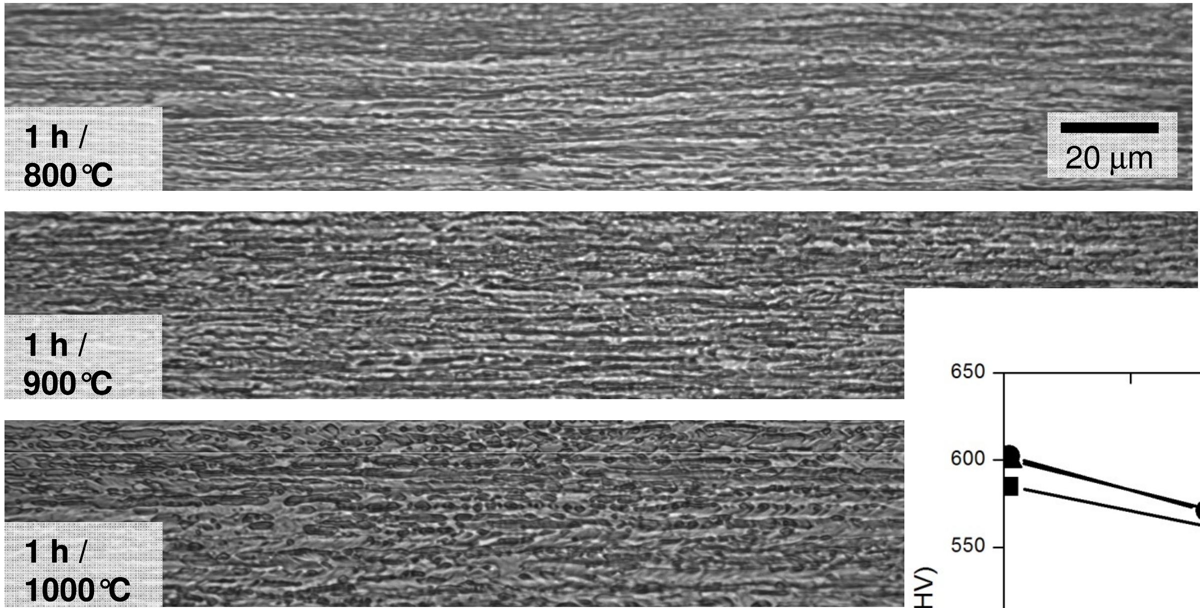


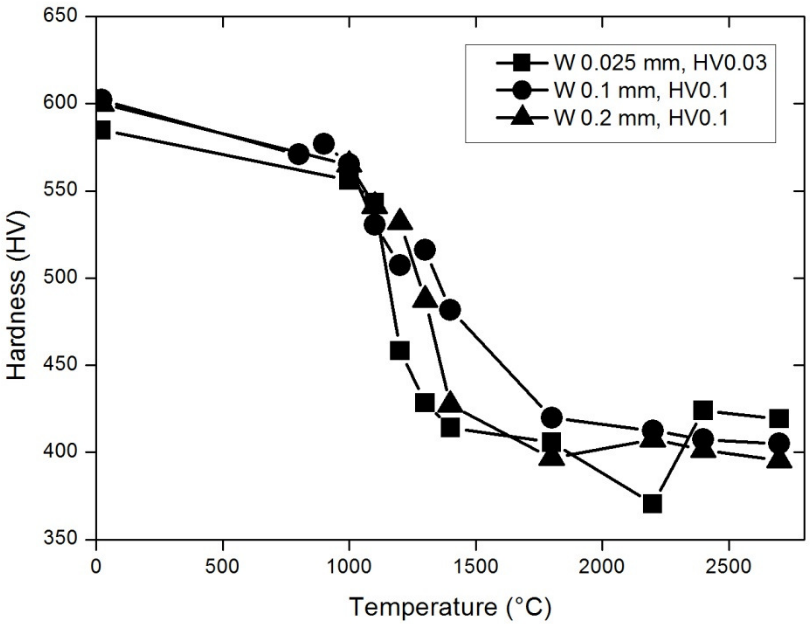
3PB test at RT: W0.1



annealing: 1h
3PB at RT
0°

3PB test at RT: W0.1





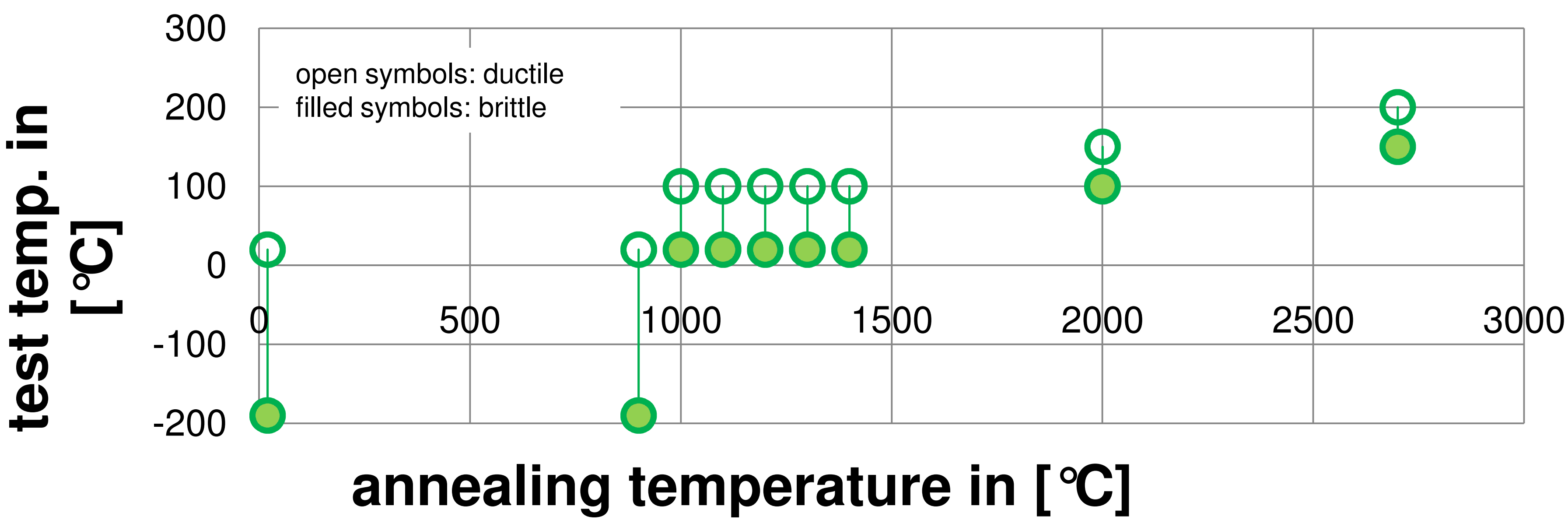
3PB: the barriers

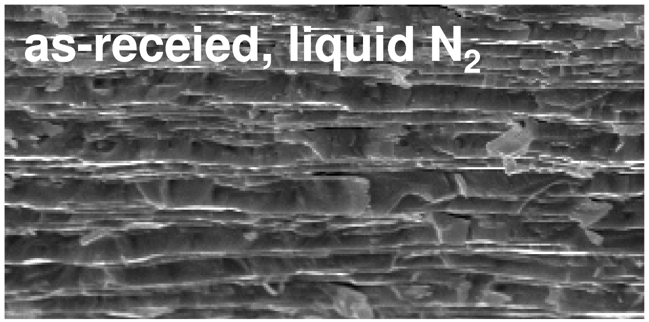
W 0.1 mm, as-received

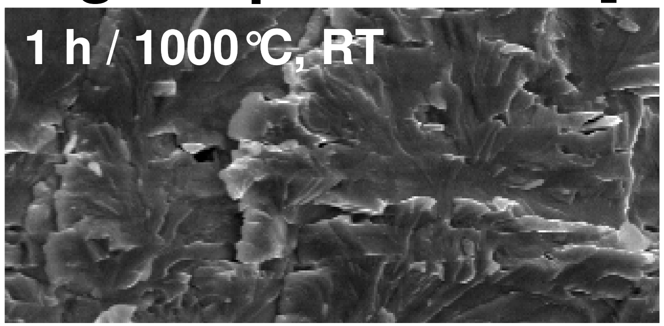
texture:	{100} <011>
grain size:	0.5 x 3 x 15 μm^3
dislocation density:	high
source of ductility:	edge, nano

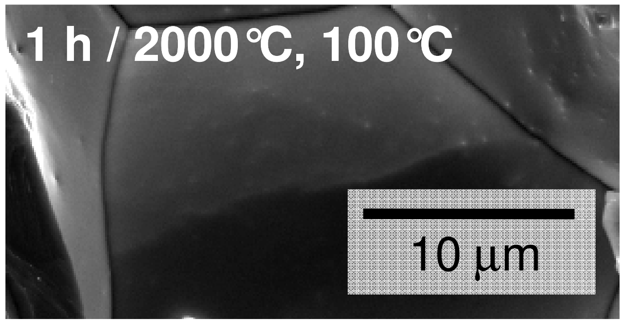
W 0.1 mm, annealed

texture:	{100} <011>
grain size:	100 x 100 x 100 μm^3
disl. density:	low
ductility:	screw, disl. annihil.









Thank you for your attention

The authors are grateful to:

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