Brazing \ Mockup Fabrication \ Deep Drawing

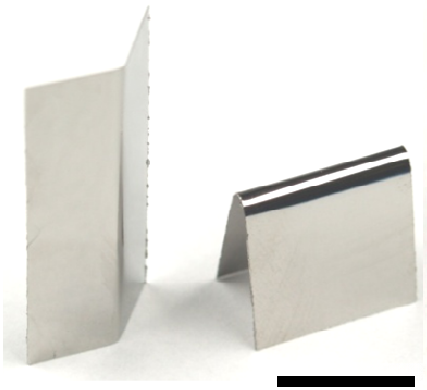
J. Reiser[1], M. Rieth[1], B. Dafferner[1], A. Hoffmann[2]

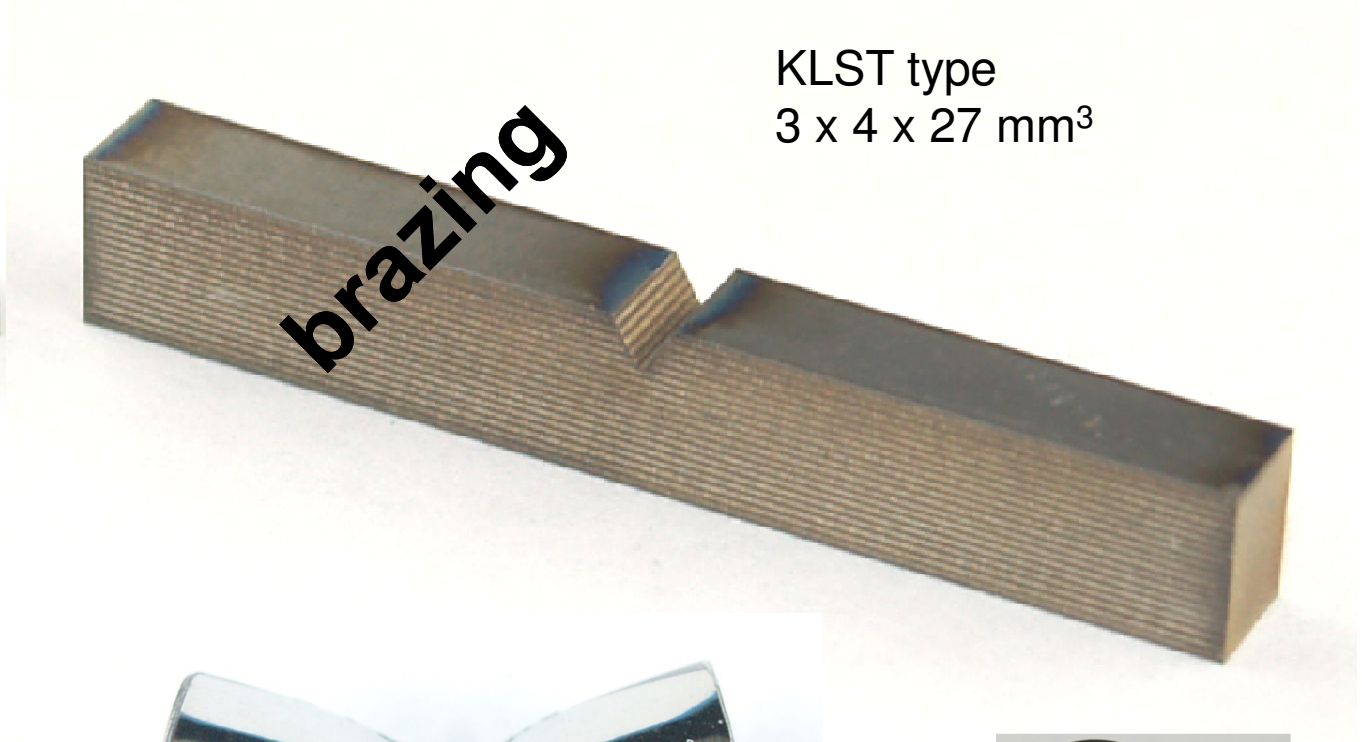
W workshop, Santa Barbara, 13.02.12 – 15.02.12

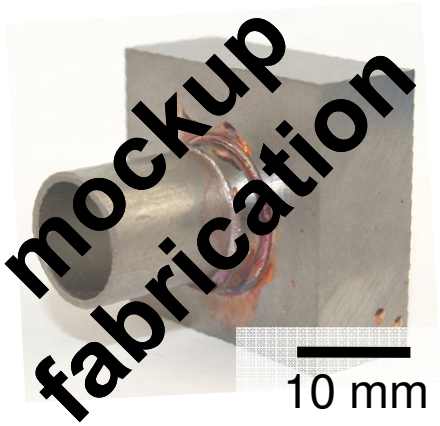
[1] Karlsruhe Institute of Technology, Institute for Applied Materials, IAM-AWP, 76021 Karlsruhe, Germany
[2] PLANSEE Metall GmbH, 6600 Reutte, Austria

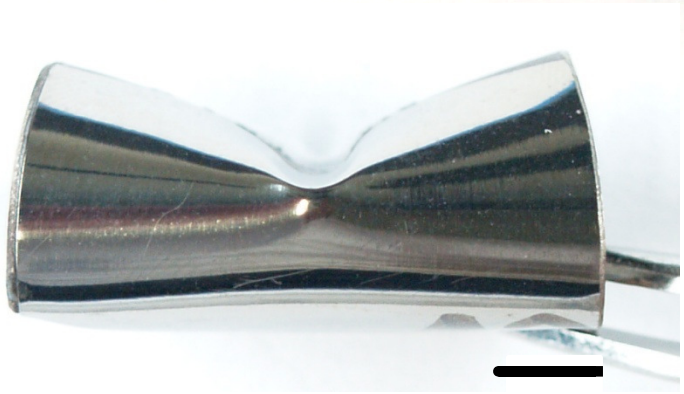
KARLSRUHE INSTITUTE OF TECHNOLOGY, INSTITUTE FOR APPLIED MATERIALS

Introduction

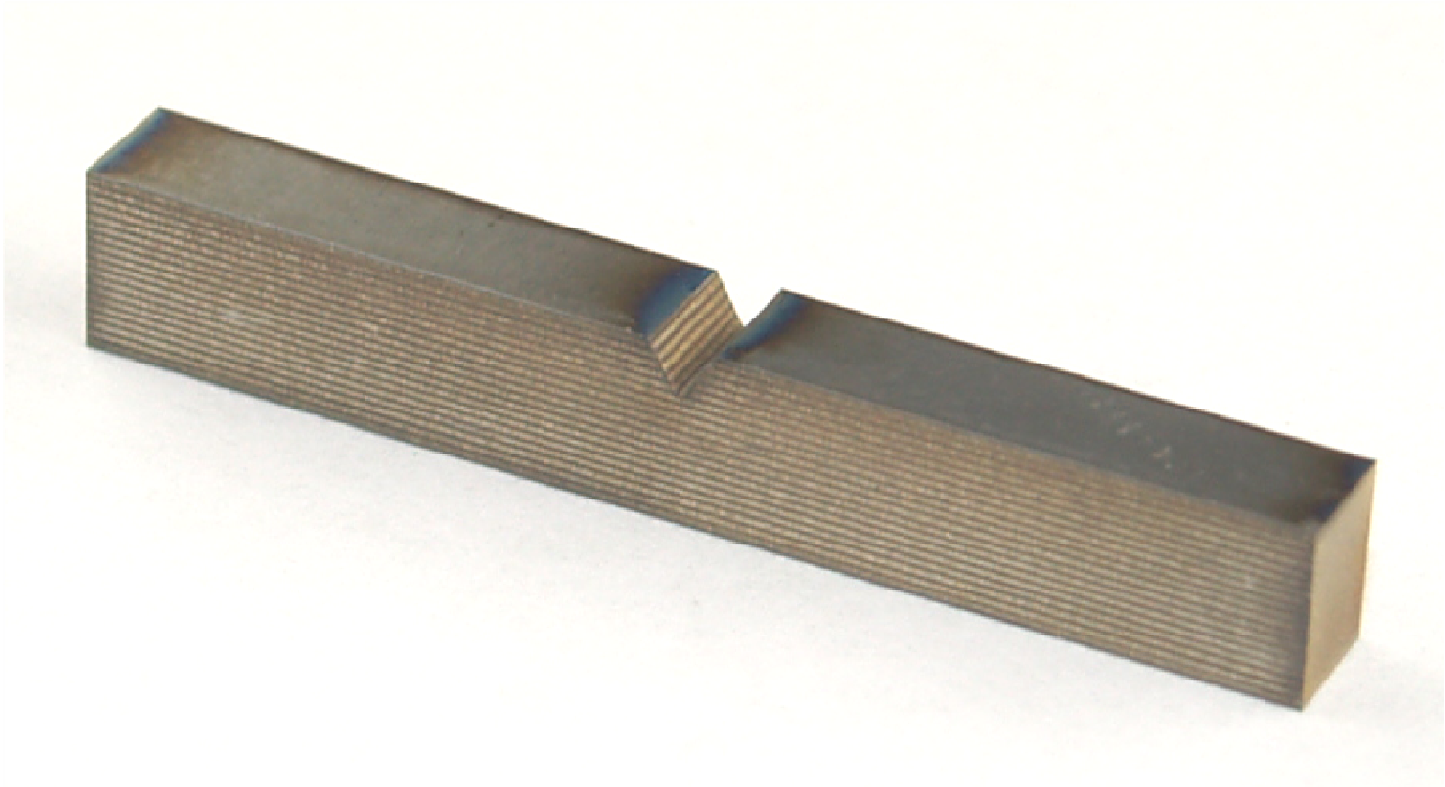








Brazing



Syntheses of a W laminate

best case combination of joining process and interlayer:

- save the nanocrystalline microstructure
  - interlayer: no diffusion into the W foil, no solid solution, no intermetallics
  - joining process: temperature below the rxx of W foil, as cold and as short as possible
- guarantee the dislocation annihilation on the interface W foil and interlayer → fcc metals are recommended
- high re-melting temperature

Syntheses of a W laminate

joining process	comment
brazing	
cold brazing	pressure required
diffusion bonding	high re-melting temp.
explosive welding	short time
explosive welding	joining of dissimilar mat.
electro pulse	not as fast as explosive welding
roll cladding	
HIPing	pressure

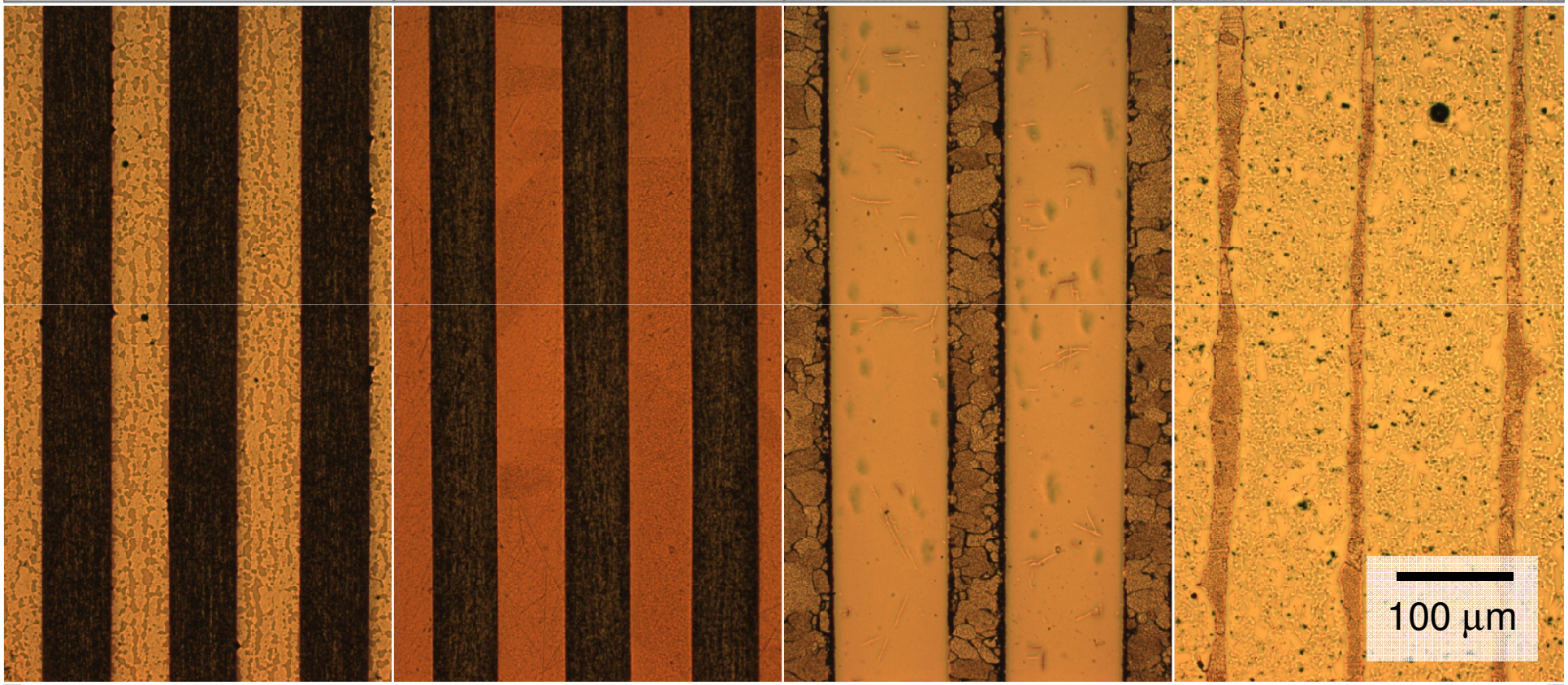
Project with Marcin Rosinski

Project with Fraunhofer, ICT

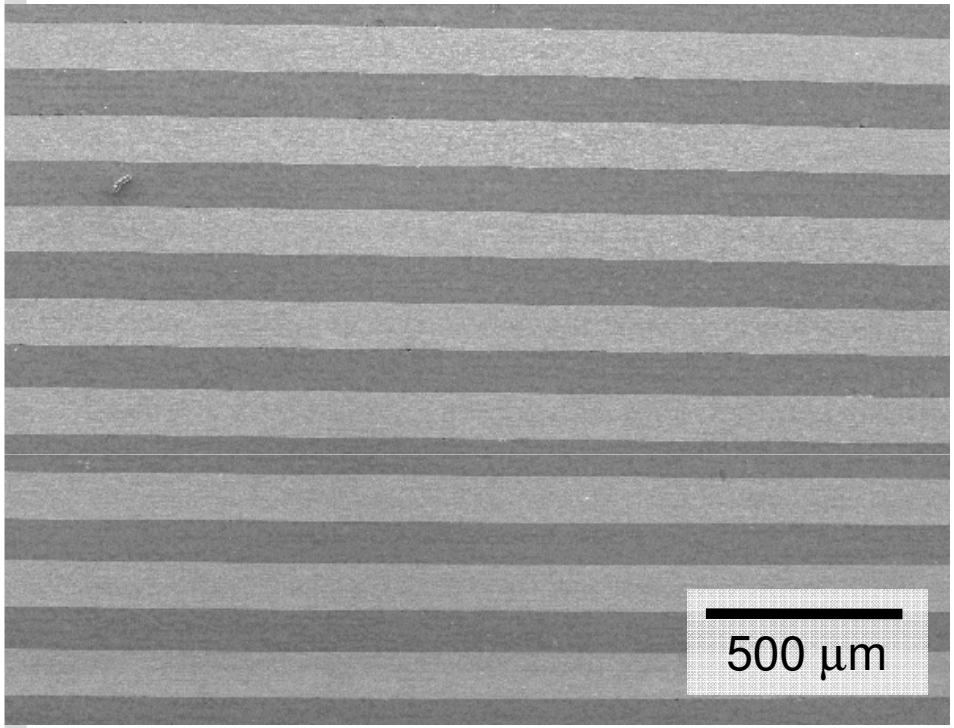
Project with ITU

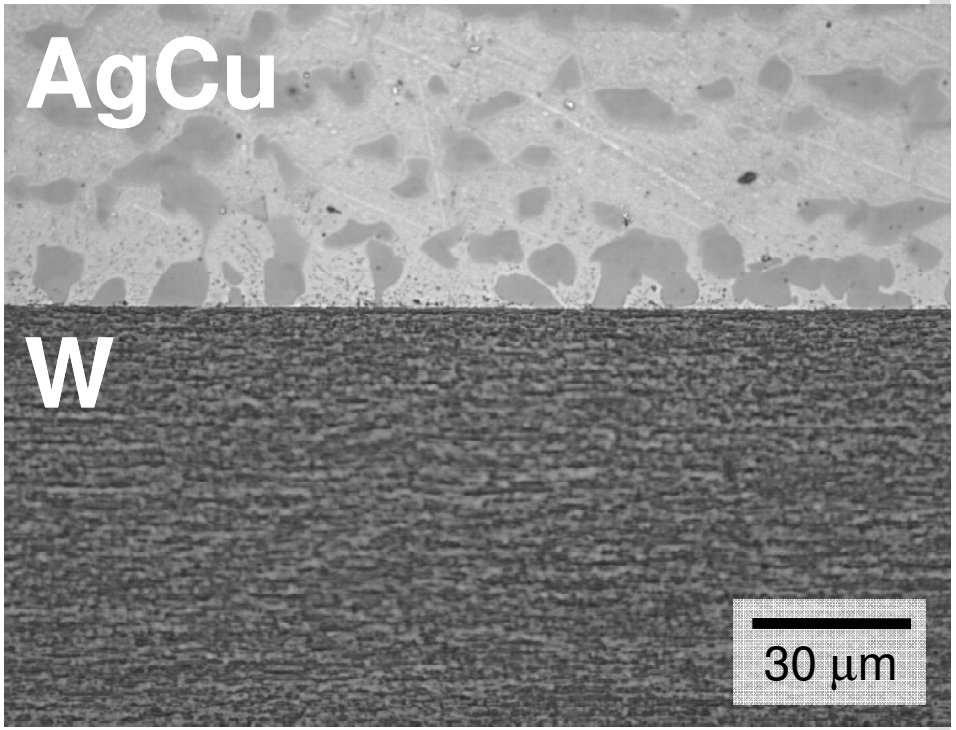
interlayer	melting temp. reaction with W
Ag72Cu28	780 °C, no reaction
Ag	960 °C, no reaction
Cu	1085 °C, no reaction
Pd	1555 °C, solid sol.
Fe	1540 °C, interm.
Ti	1670 °C, solid sol.
Zr	1860 °C, interm.
no interlayer	

Syntheses of a W laminate

W0.1 AgCu0.1	W0.1 Cu0.1	W0.1 Ti0.15	W0.1 Zr0.1
			
$T^{AgCu}_{melting}$ = 780 °C	$T^{Cu}_{melting}$ = 1085 °C	$T^{Ti}_{melting}$ = 1670 °C	$T^{Zr}_{melting}$ = 1860 °C

Syntheses of a W laminate

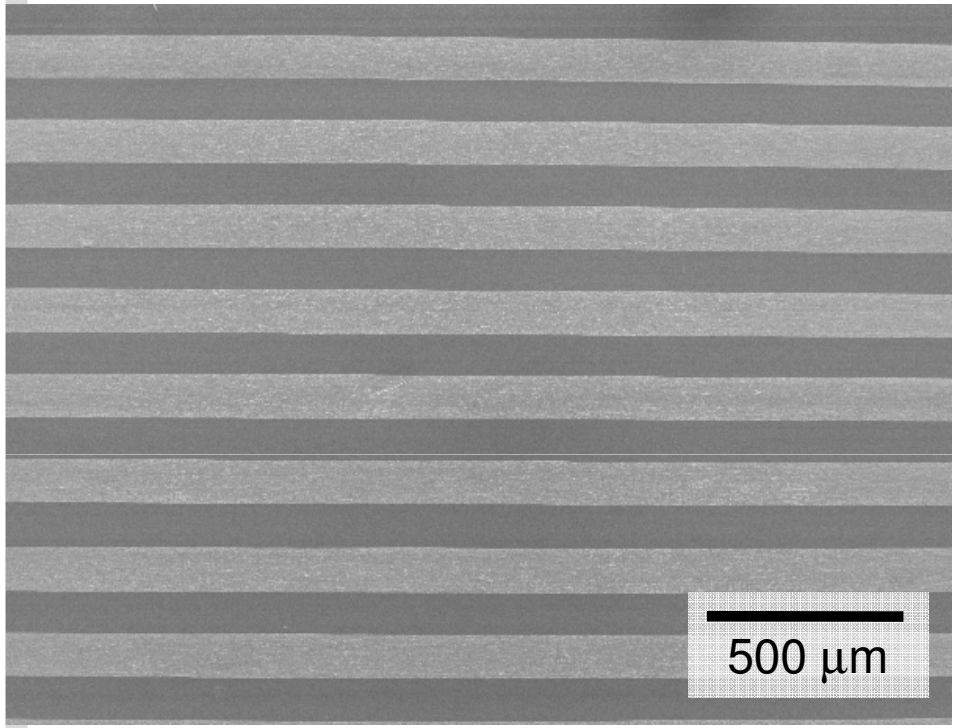


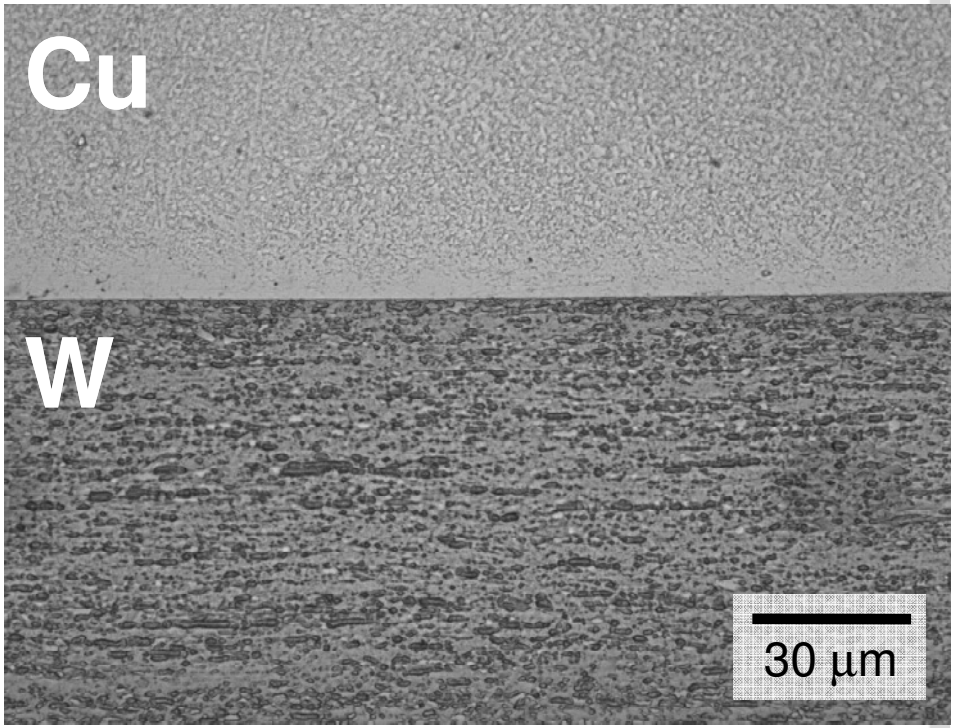


excellent wettability

no diffusion into W

Syntheses of a W laminate

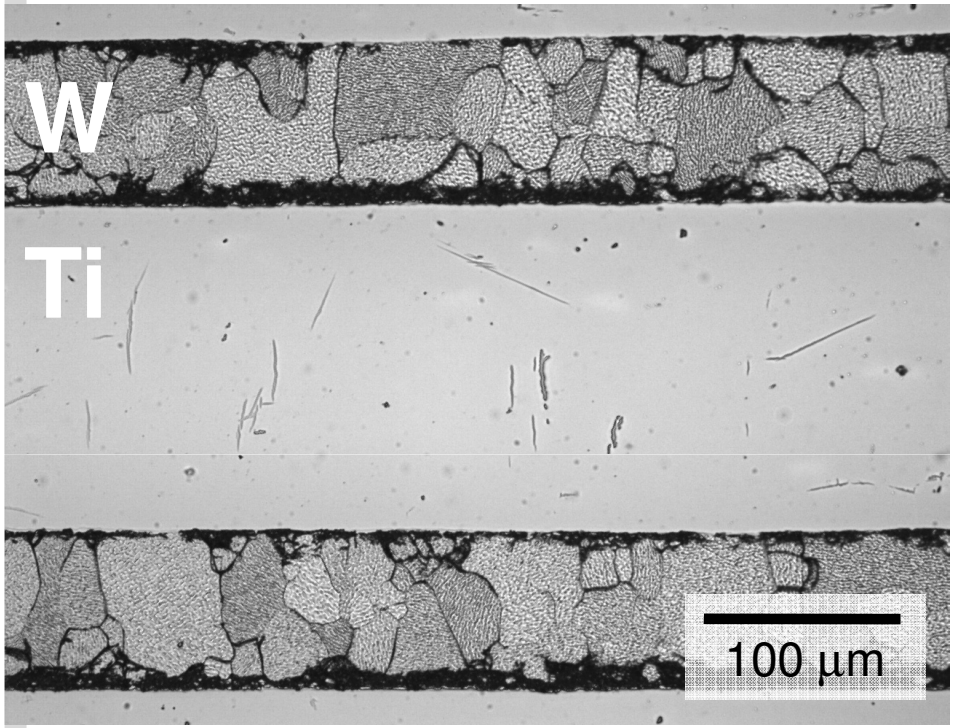


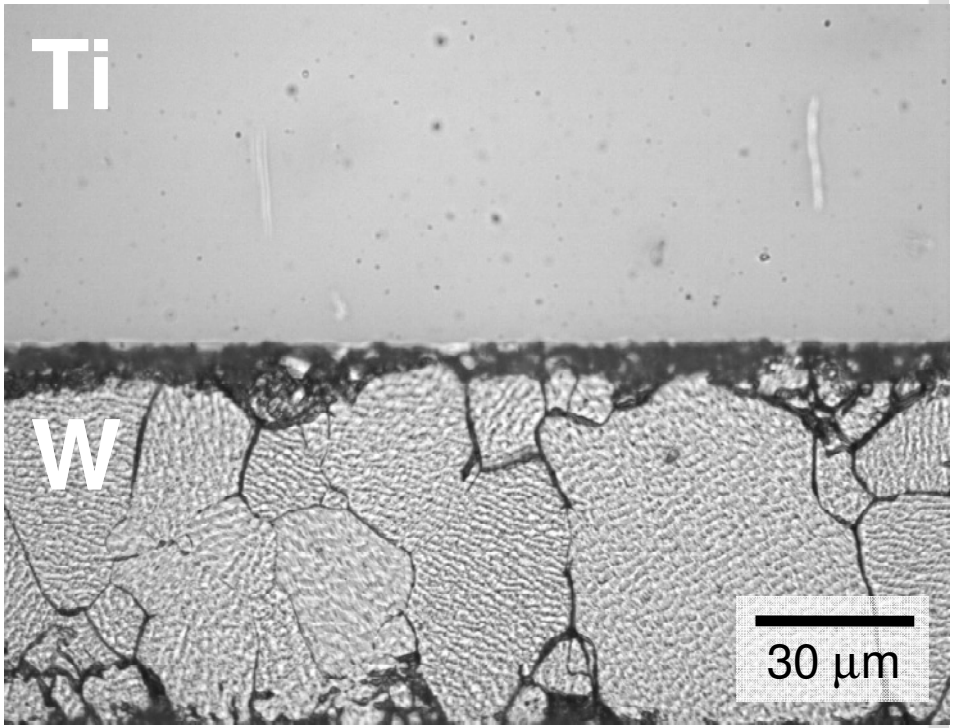


excellent wettability

no diffusion into W

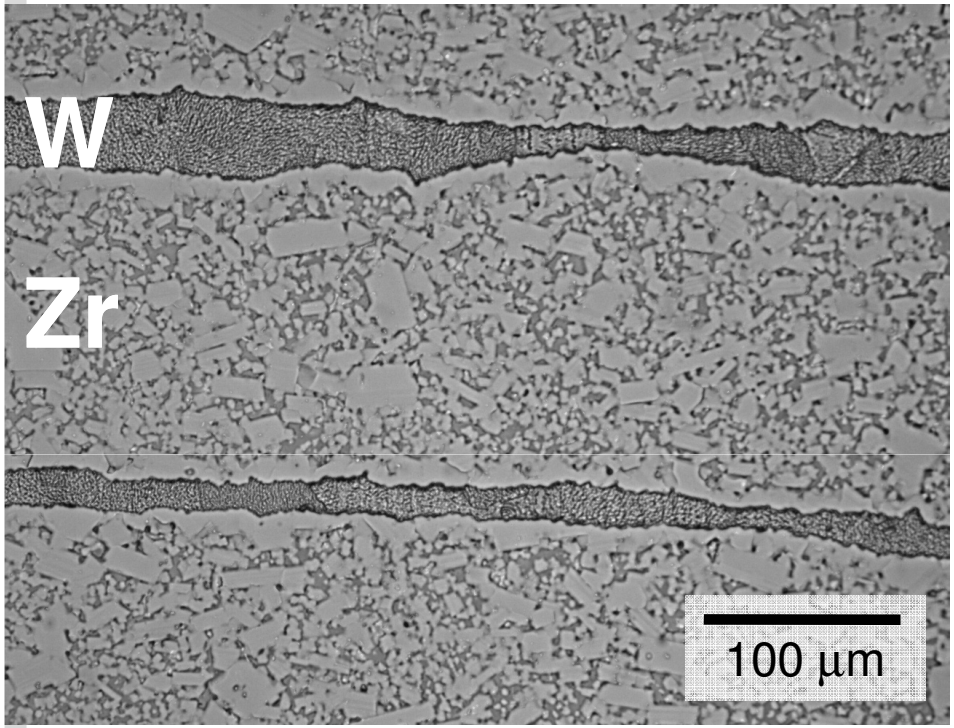
Syntheses of a W laminate

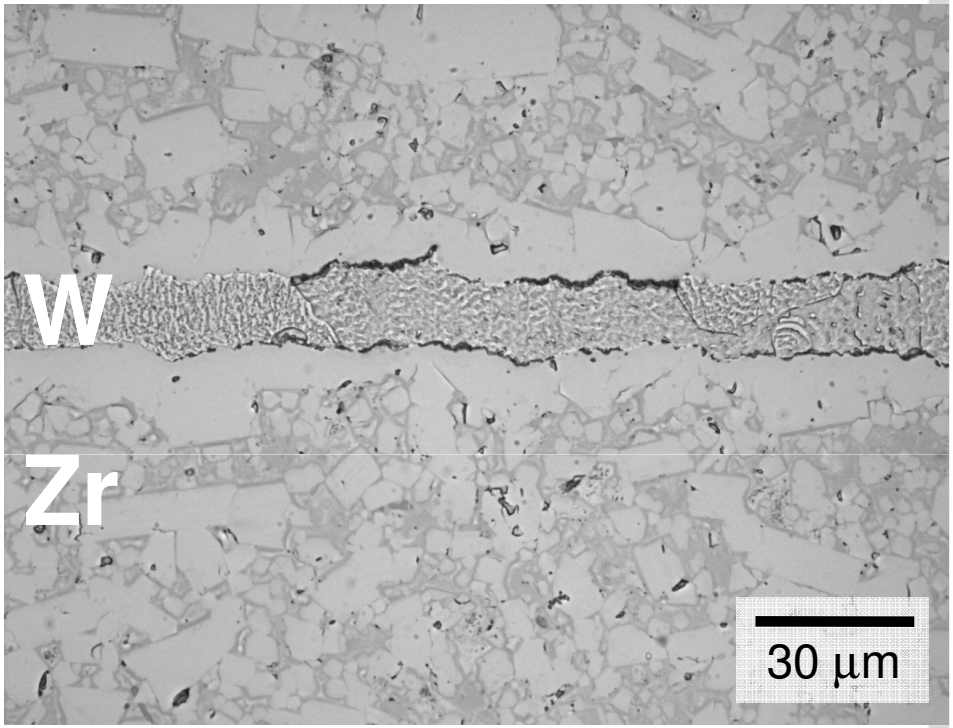




foil recrystallized
W solid solution

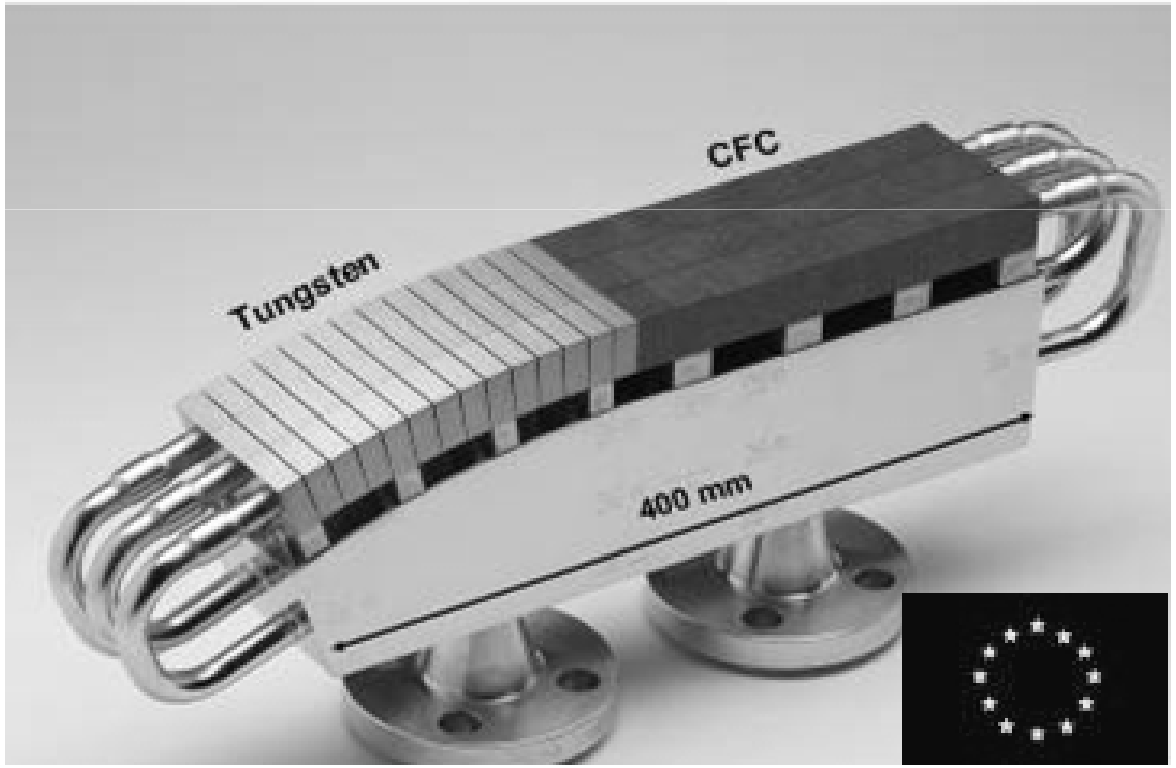
Syntheses of a W laminate





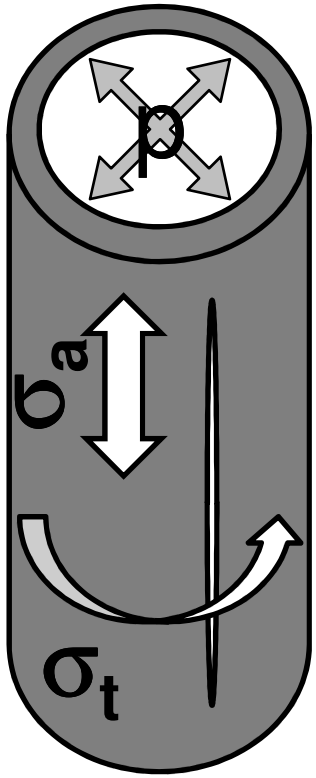
foil recrystallized
intermetallics

Mockup Fabrication

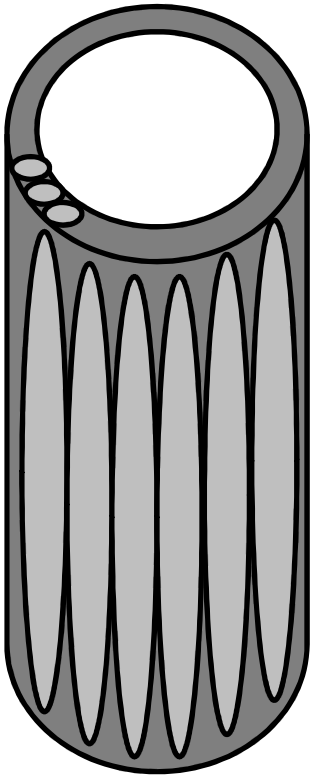


Syntheses of W pipes

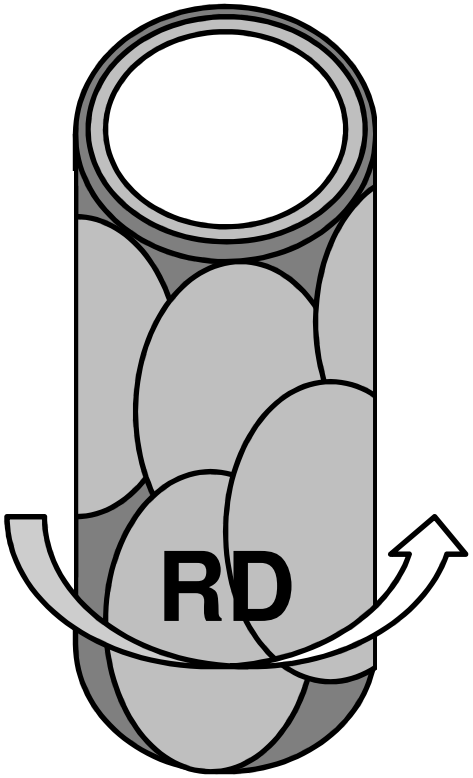
a) stresses



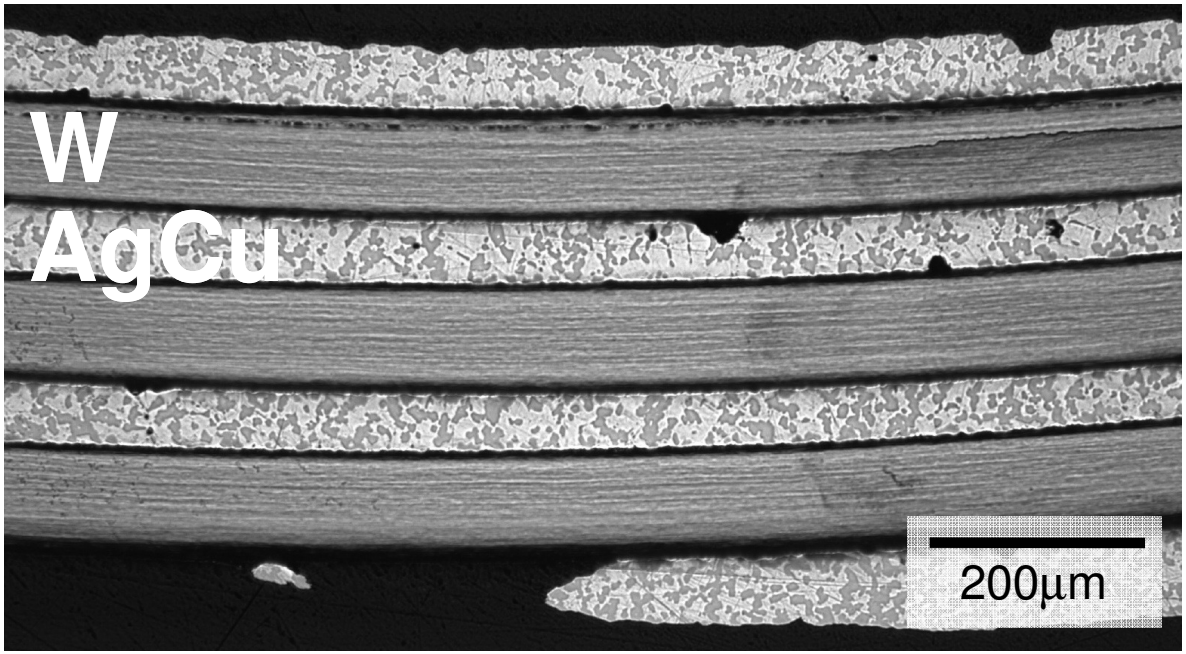
b) W pipe made from a W rod



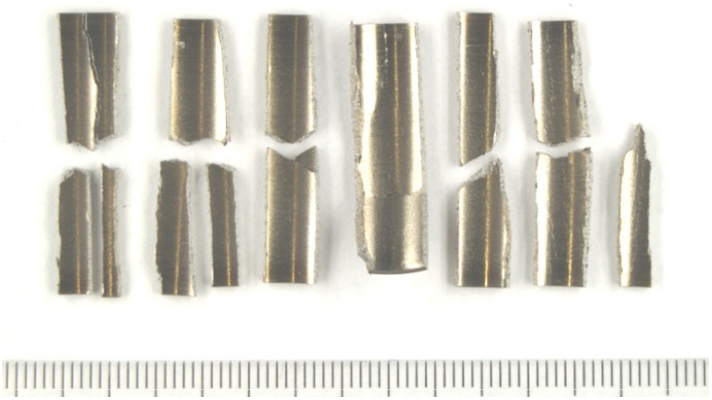
c) W pipe made of W foil

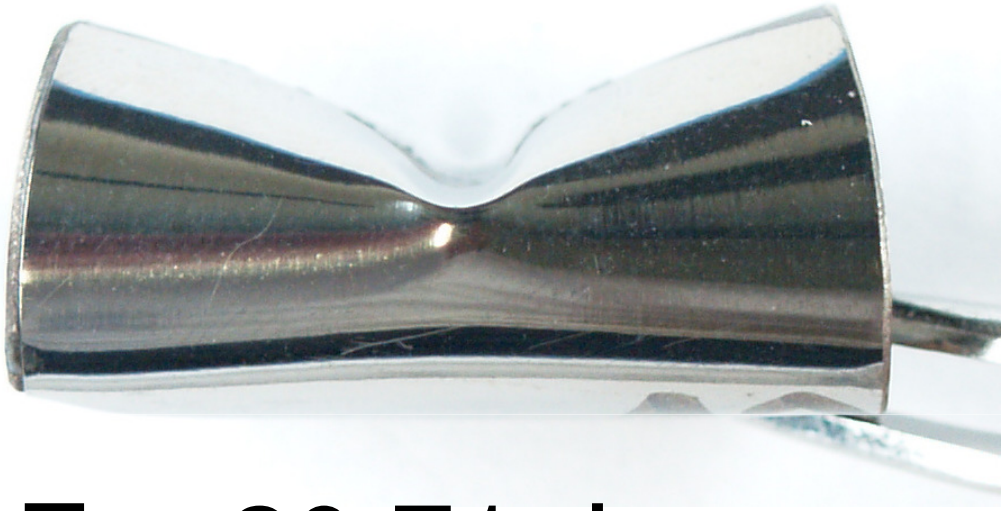


Syntheses of W pipes

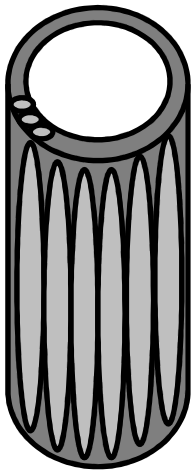


Characterization of W pipes: Charpy 300 °C

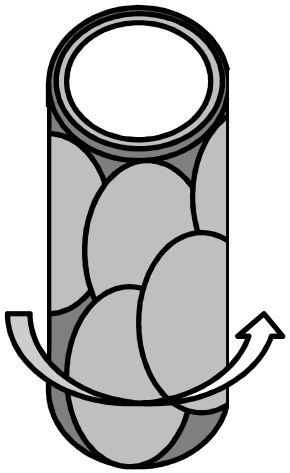




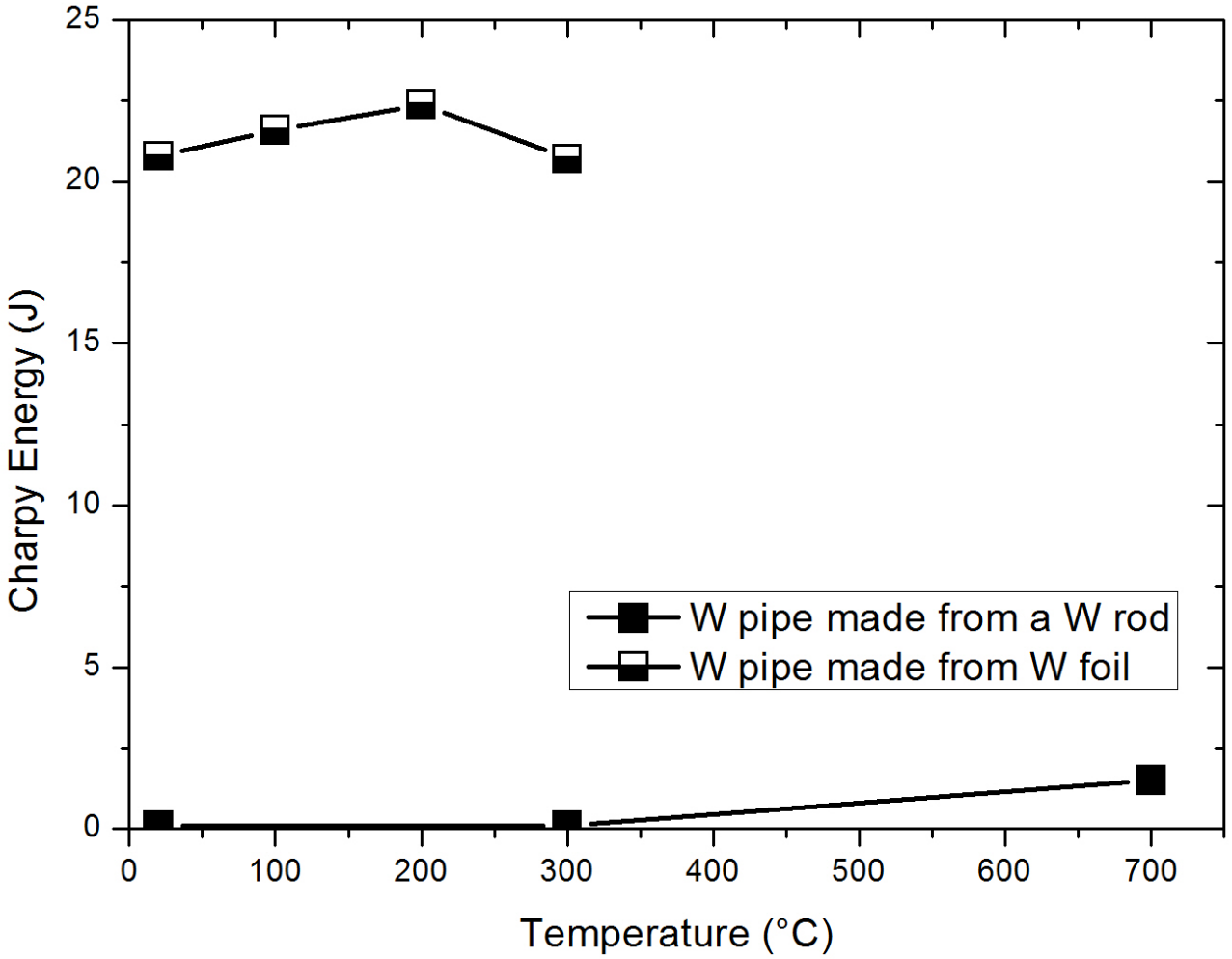
E = 0 J



E = 20.71 J

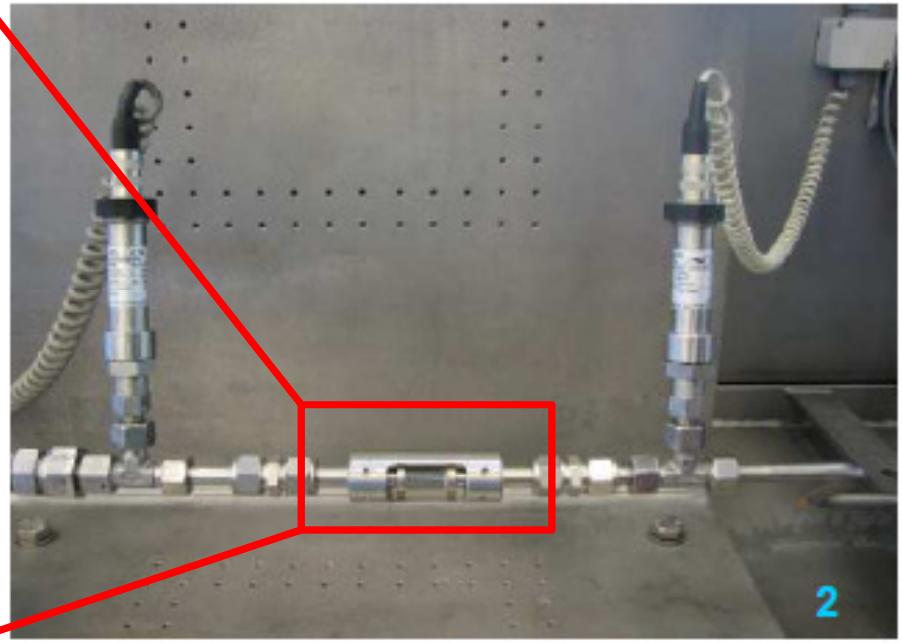


Characterization of W pipes: Charpy



Characterization of W pipes

- inner pressure test: Plansee SE, Reutte: W0.1 AgCu0.1



→ **1000 bar**, pipe o.k.

T. Huber, A. Zabernig
Plansee SE

Characterization of W pipes

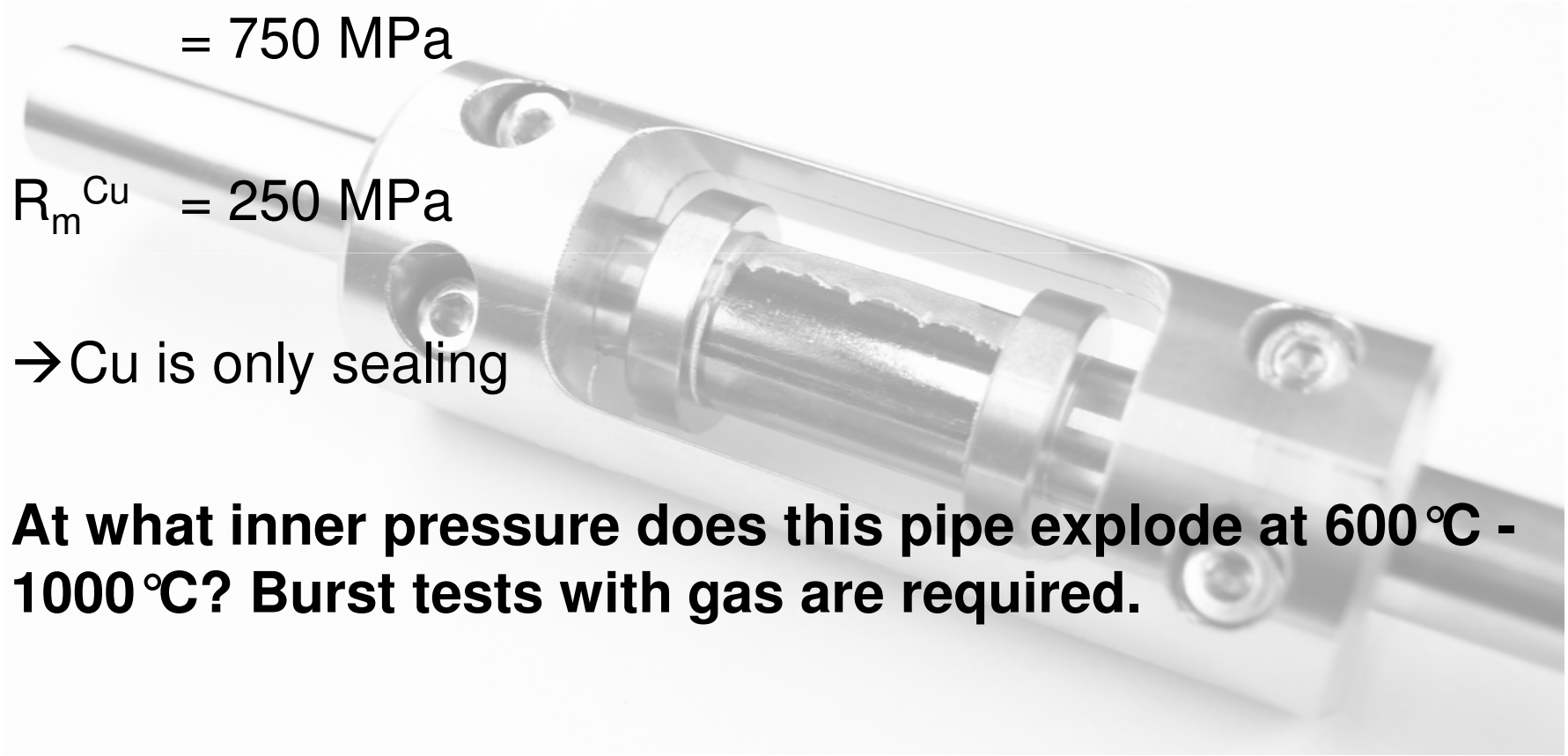
σ_t = p * r / t

= (100 MPa * 7.5 mm) / 1 mm

= 750 MPa

R_m^{Cu} = 250 MPa

→Cu is only sealing



At what inner pressure does this pipe explode at 600°C - 1000°C? Burst tests with gas are required.

What is a W laminate good for?

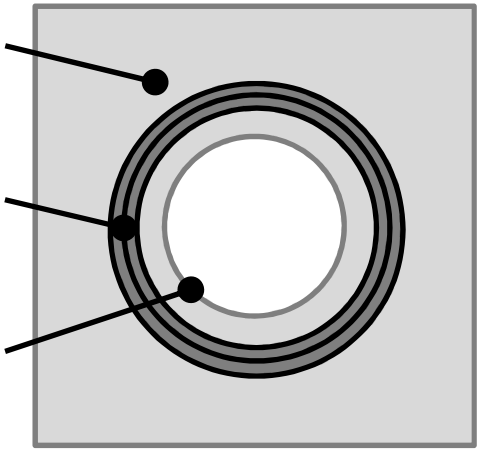
1 Transition piece between W and steel

2 Structural W material

W monoblock

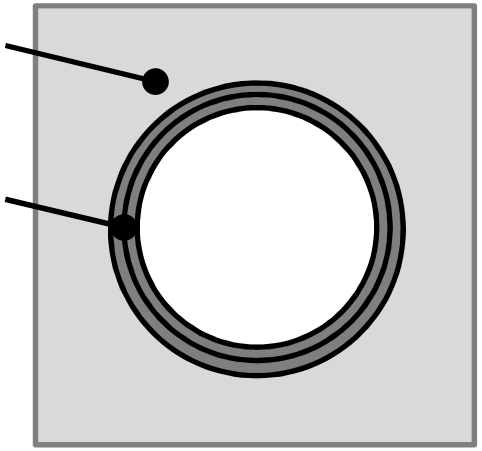
W pipe made of W foil

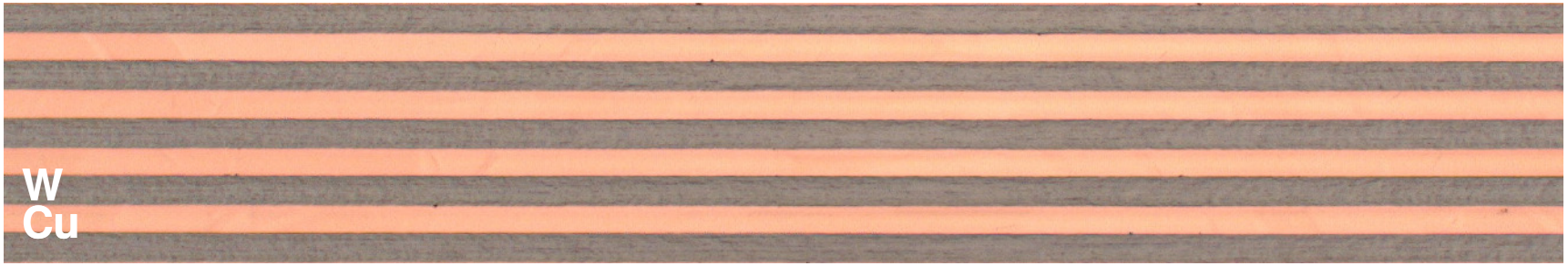
steel pipe



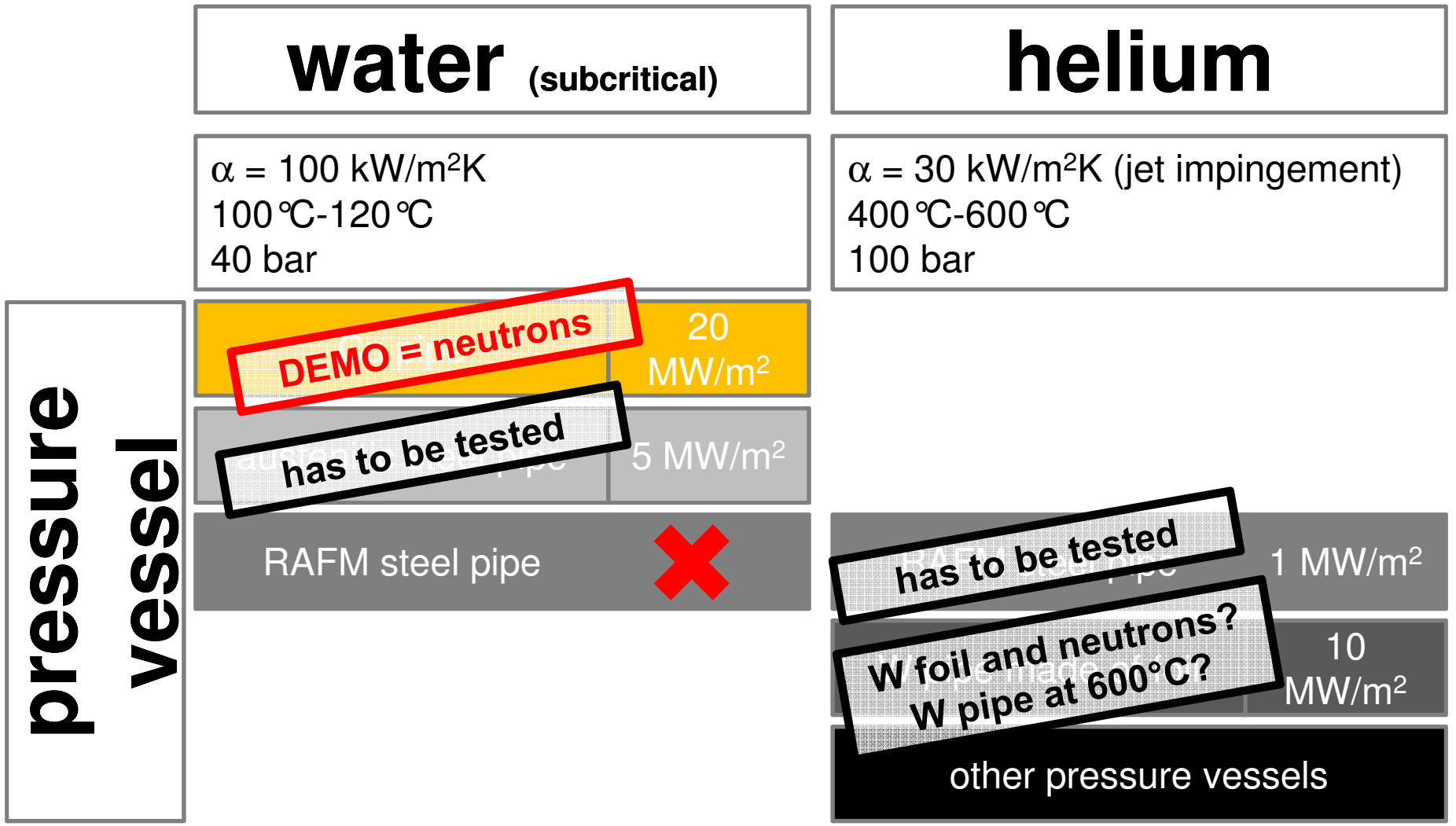
W monoblock

W pipe made of W foil

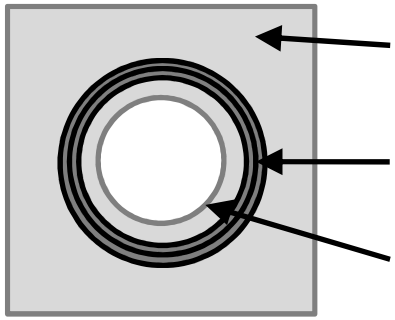




Overview


water (subcritical)
helium
α = 100 kW/m²K
100 °C-120 °C
40 bar
α = 30 kW/m²K (jet impingement)
400 °C-600 °C
100 bar
pressure vessel
DEMO = neutrons
20 MW/m²
has to be tested
5 MW/m²
RAFM steel pipe
has to be tested
1 MW/m²
W foil and neutrons?
W pipe at 600°C?
10 MW/m²
other pressure vessels

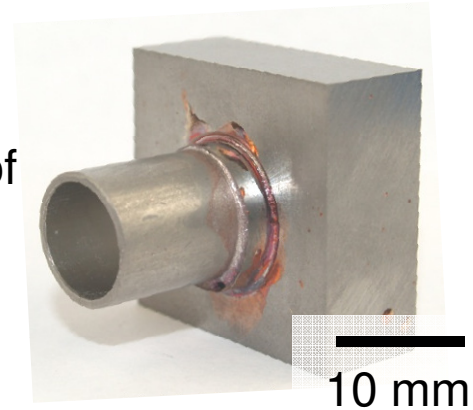
H_2O-cooled, austenitic steel

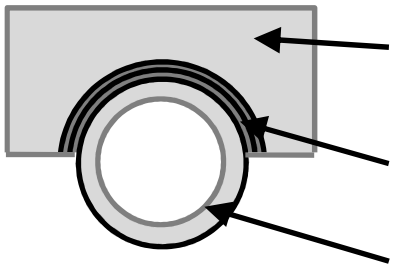


W monoblock

W pipe made of W foil

steel pipe

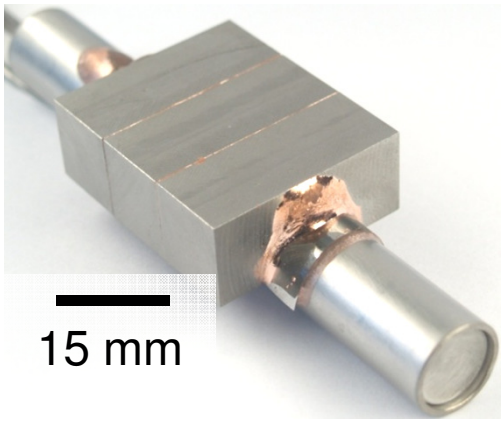


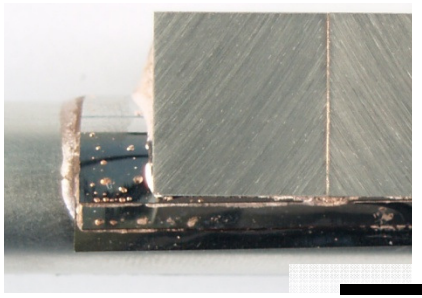


W saddle type

W laminate made of W foil

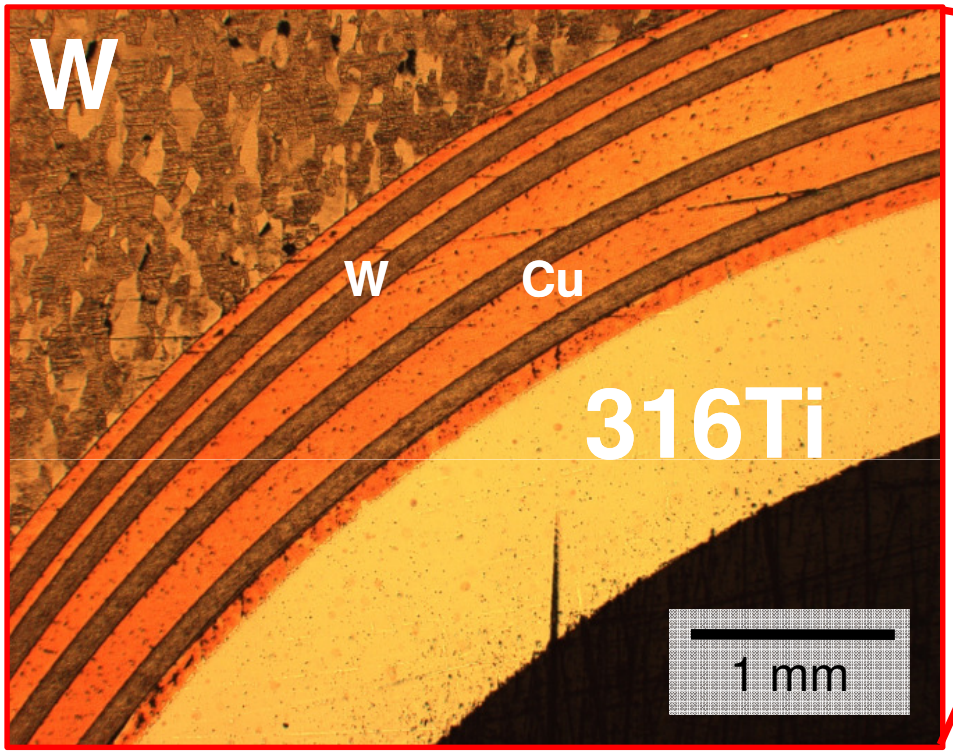
steel pipe

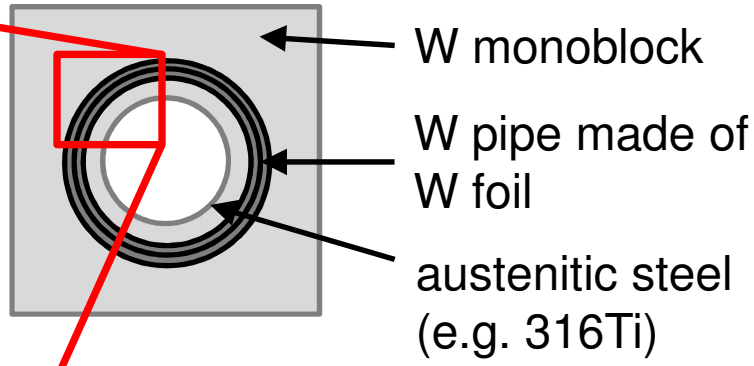




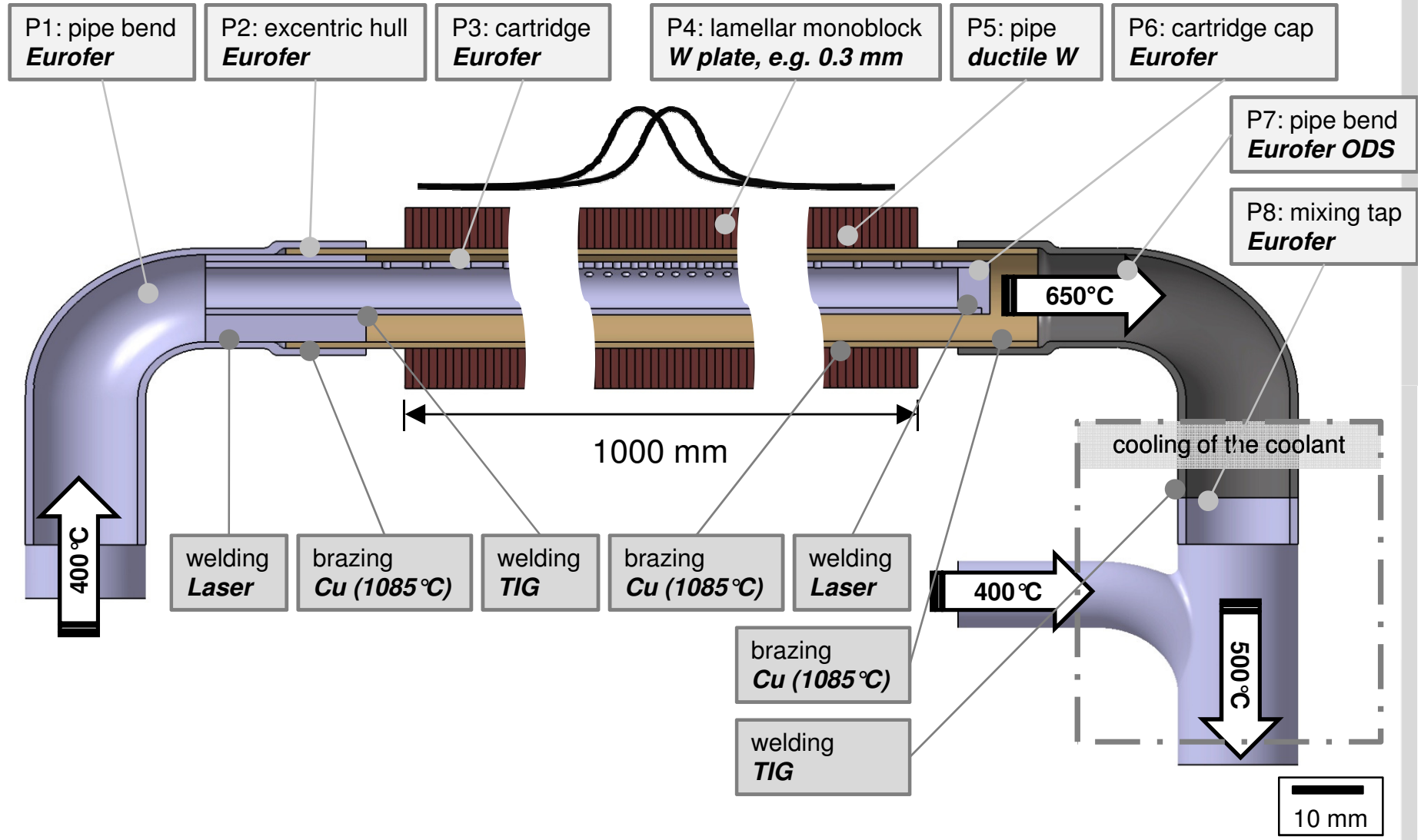
Can we remove 5 MW/m² with water and austenitic steel?

H_2O-cooled, austenitic steel

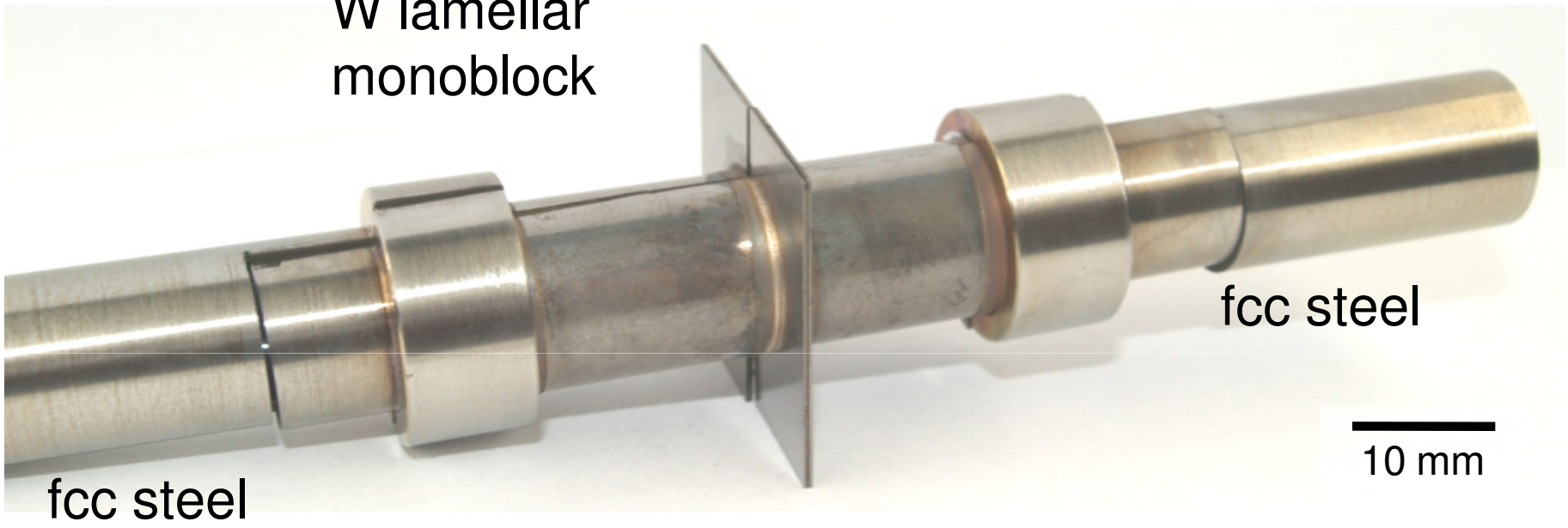




He-cooled divertor: OVT (10.1016/j.fusengdes.2012.02.010)



He-cooled divertor: OVT



Deep Drawing

Deep drawing

- Grain boundary alignment
- pure W plate material, 1 mm, PLANSEE Metall GmbH
- Temperature: 600°C
- Speed: 0.1 mm/min → has to be improved
- Force: only in one direction

→ U-profile: no 90° angles possible (elastic spring back)

- Deep drawing geometries:

Thank you for your attention

The authors are grateful to:

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