(Hot) Explosive cladding of tungsten on copper and stainless steel substrates

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TNO | Defence, Security and Safety

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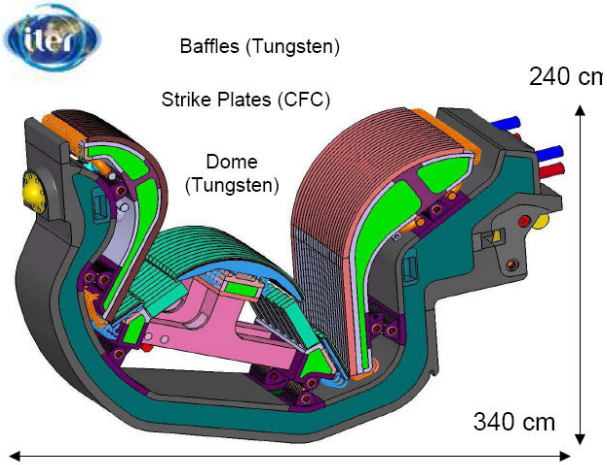
Content

- Background
- Foil cladding
- Hot cladding
- Conclusions

W coating for ITER reactor wall parts



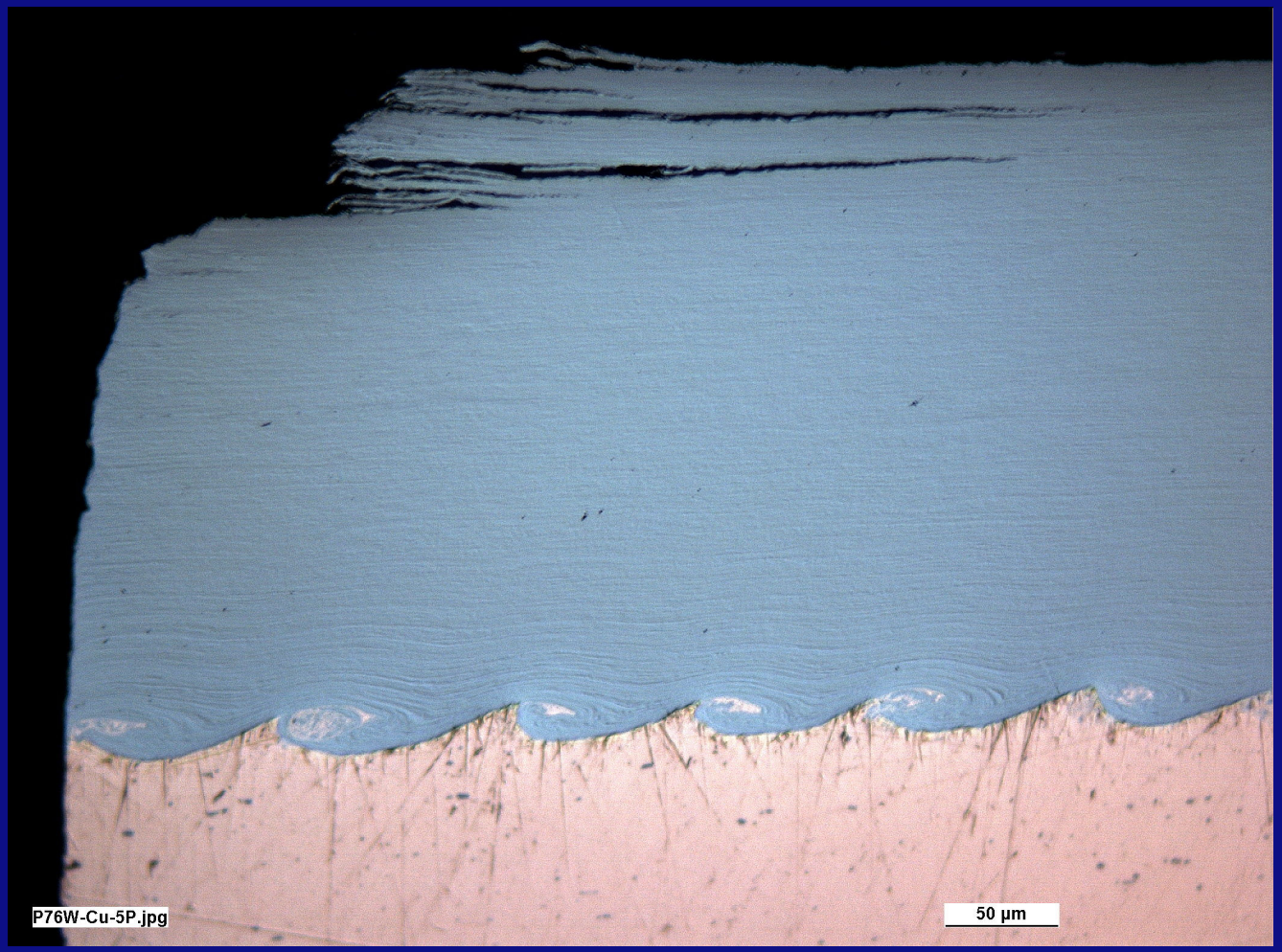
- Rationale for W as armor on wall parts (heat exhangers)
  - high melting point, high heat conductivity, high Z, nuclear properties aceptable

- EFDA[1] feasibility study with NRG –
  - W by explosion bonding 1-2 mm on Cu and ss for heat exchangers? - brittleness, no intermetallics[2] →

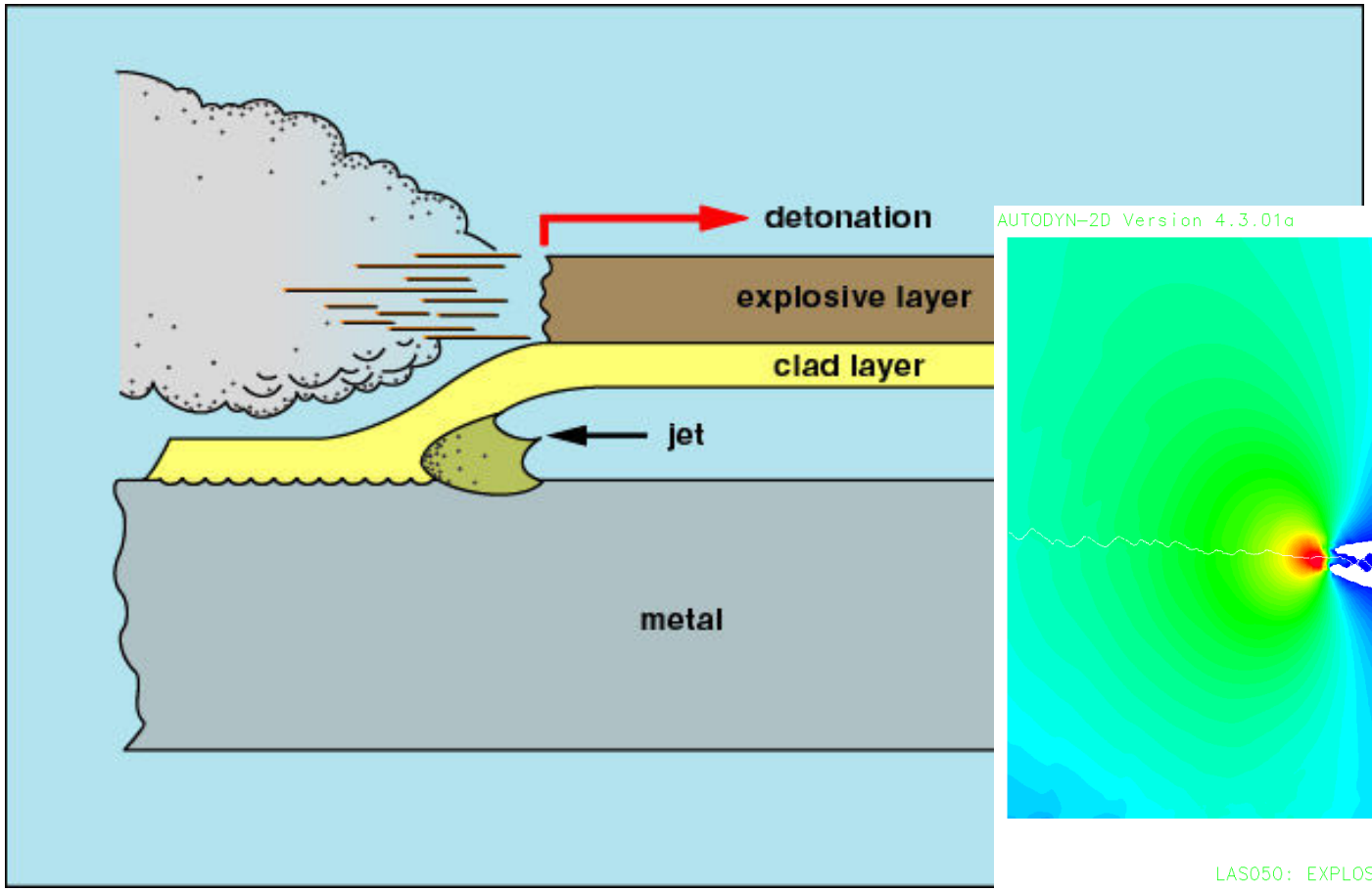
2) A. Oberg et al. Metallurgical Trans. A, Vol. 16 A, p. 841, (1985)

1) This work was partly supported by the Dutch Government in the framework of the 2006 ITER-UPL project and by the EC under the Contract of Association A 4323 between EURATOM-FOM.

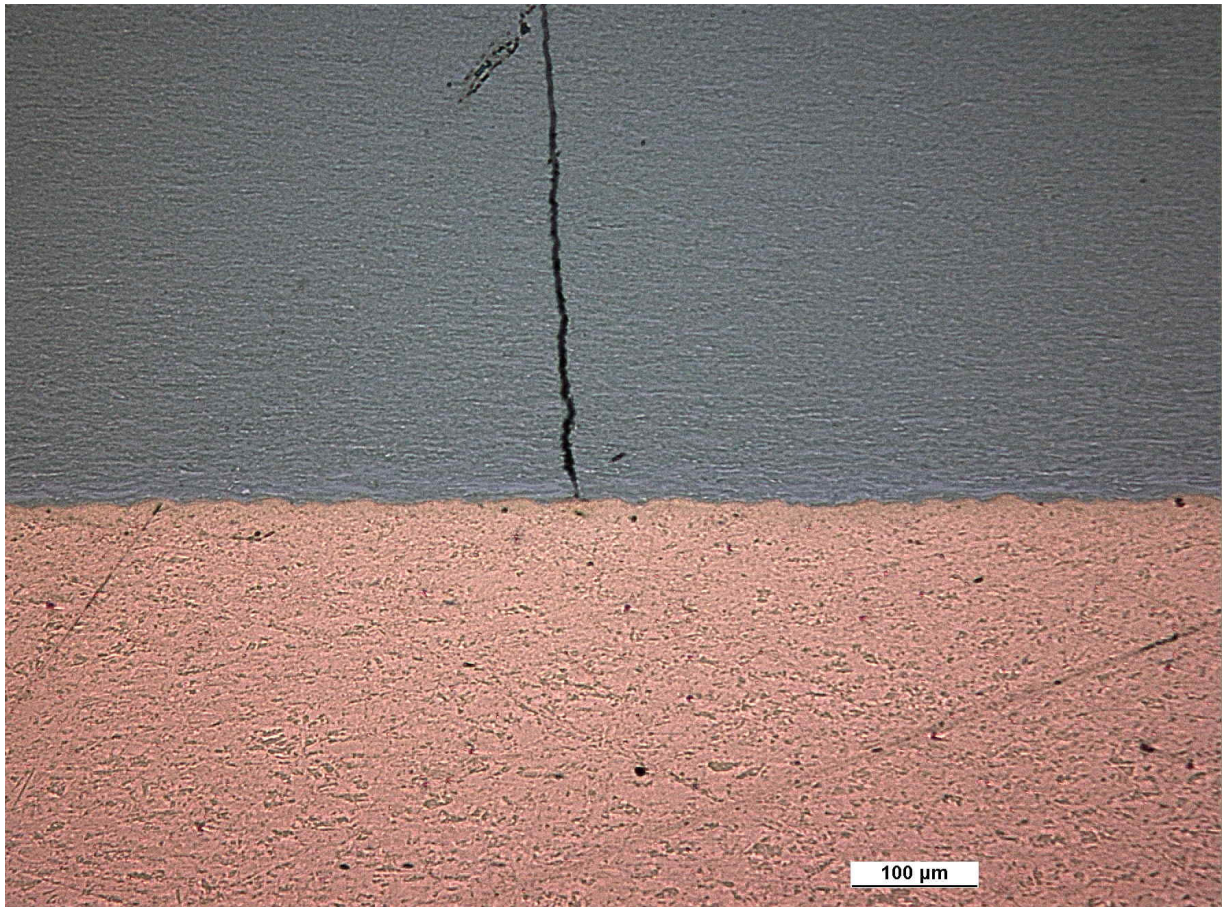
W (0.3 mm) brittleness and ductility under high impact
No intermetallic phase between W and Cu (Miedema model)



Explosive cladding with pressure modelling (look at jet!)



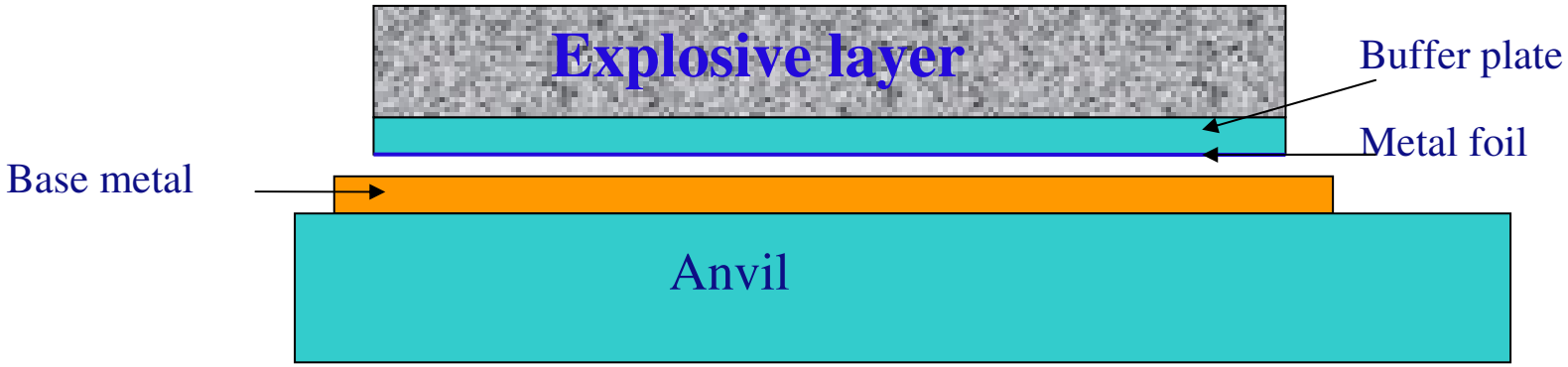
Cu flyer (3 mm) onto W base (1 mm) – containment - self-castellation (I17)



Multiple foil cladding (2 x 0.5 mm/ 3 x 0.3 mm)

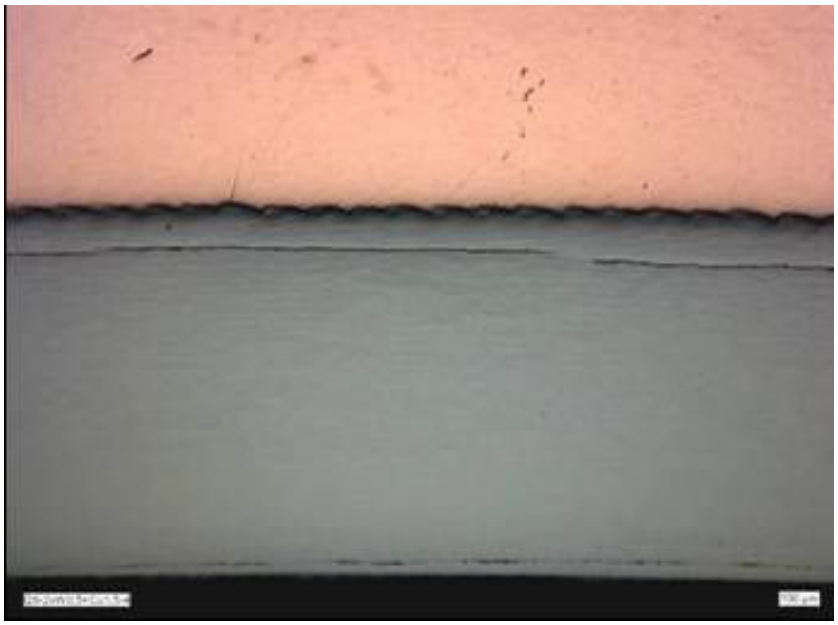
Foil cladding

- Foil attached to buffer plate
- Same process as cladding thicker plates
- Buffer does not bond (no inclined impact)



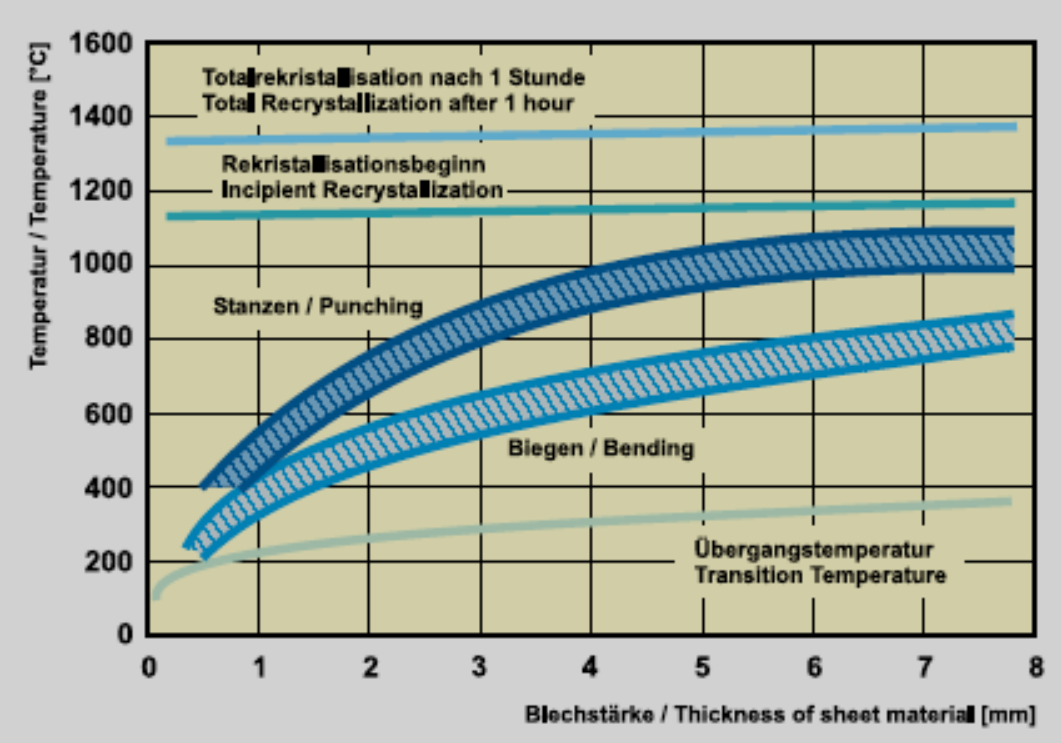
Multiple clad (3 x 0.3 mm W) – spall (I23)

Cu (flyer) onto 2 x W foils (0,5 mm) – *I28*

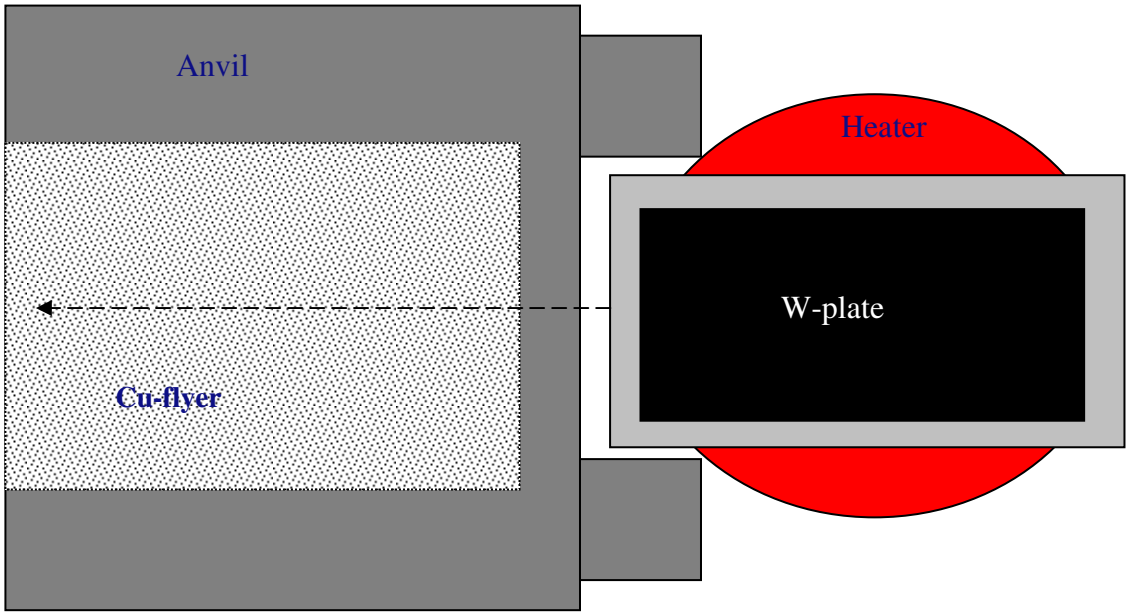


Cladding at elevated W temperature

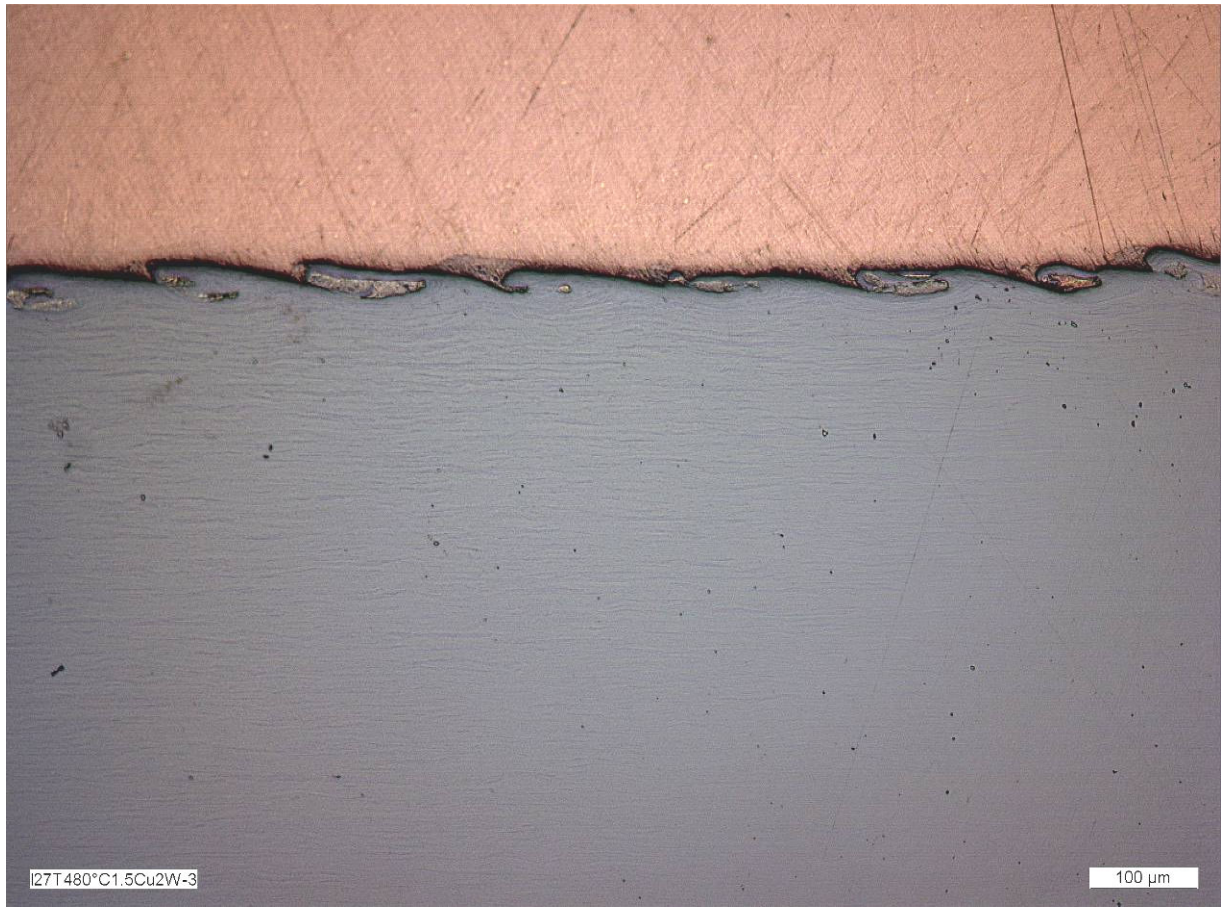
Ductile to brittle temperature (T_{DTBT})– versus W metal thickness (Plansee SE)



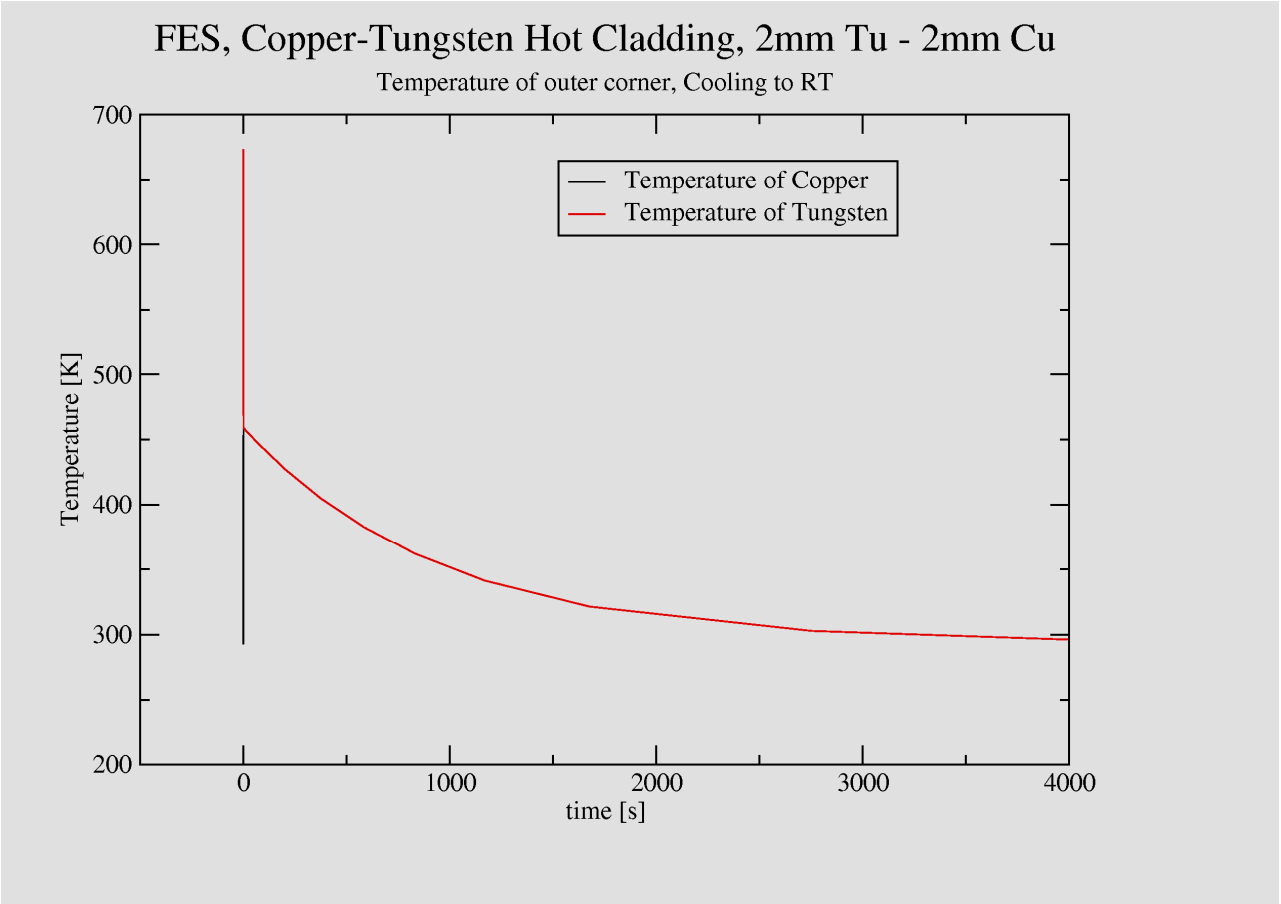
Set-up for hot cladding of Cu onto W – type I (pull and draw)



Cu clad onto 2 mm W at 480 deg C – no cracks *I27*



Hot cladding vs. Thermal stresses

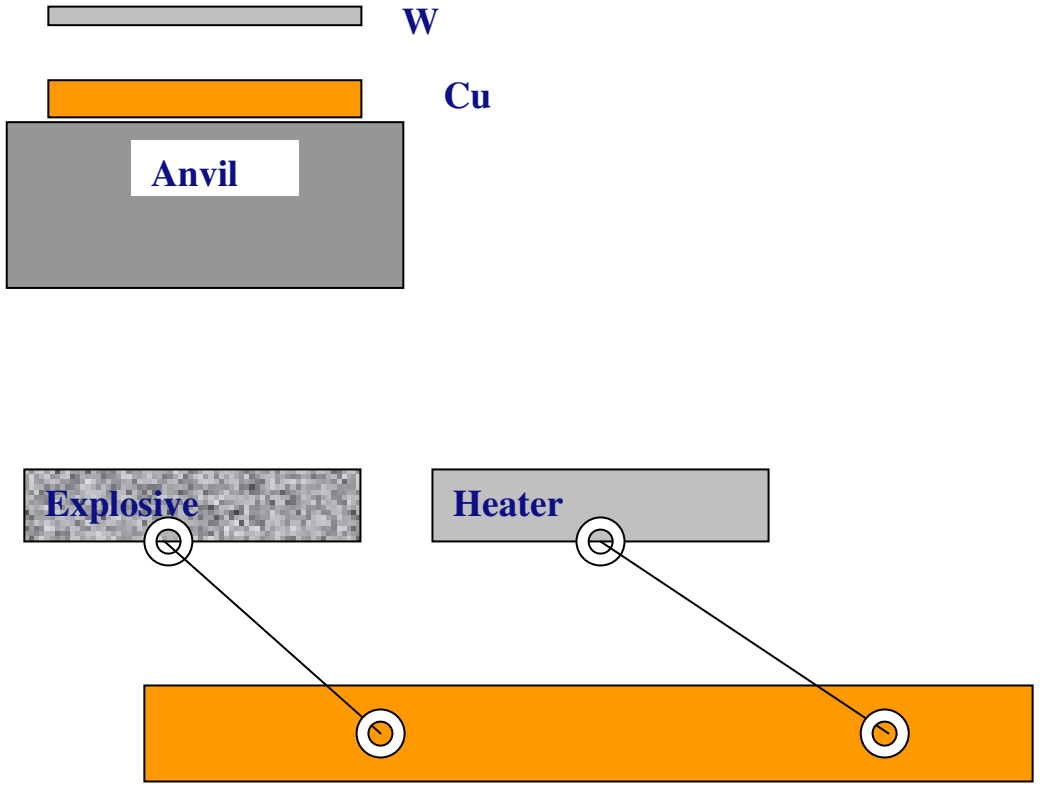


Hot cladding - W heated above T_{DBTT}

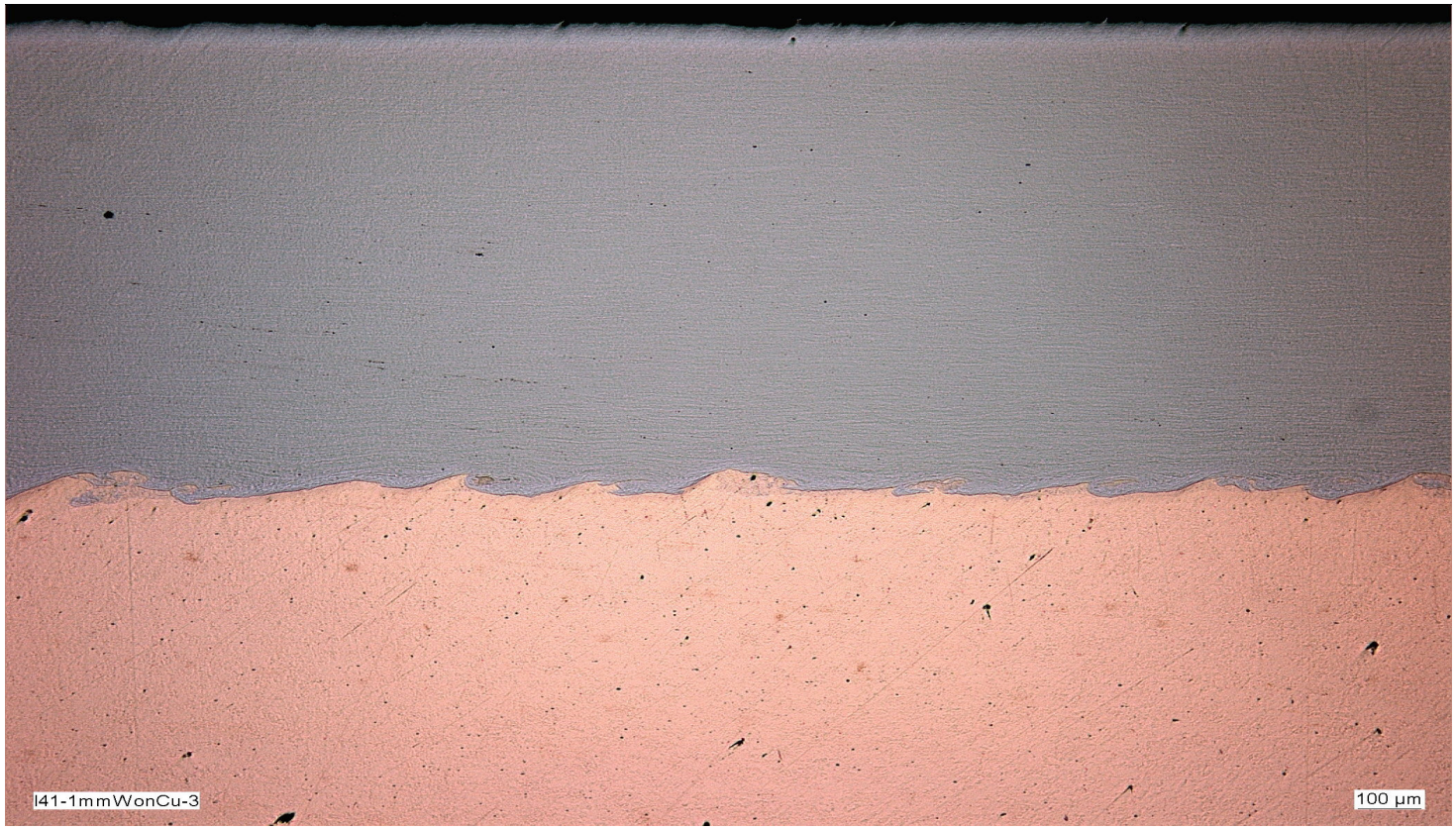
- W clad onto Cu, CuCrZr and stainless steel (316) - selection

No	flyer	flyer	flyer	base	base	base	Quality	Interface		
			T			T		s	T (eq)	d_{Cu}/d_W
	metal	(mm)	(deg C)	metal	(mm)	(deg C)		(MPa)	(deg C)	
I27	Cu	1.5		W	2	480	+	1016	246	0.75
I34	SS 316	2.5		W	2	500	+	465	192	1.25
I36B	CuCrZr	1.9		W	2	500	+	935	228	0.95
I44	Cu	1.5		W	2	500	+	1061	256	0.75
I45	Cu	3		W	2	550	+	777	193	1.5
I41	W	1	500	Cu	5	65	+	450	120	5
I31	Cu	1.5		W	5	500	x	1623	381	5

Set-up for hot cladding of W onto Cu – type hinge

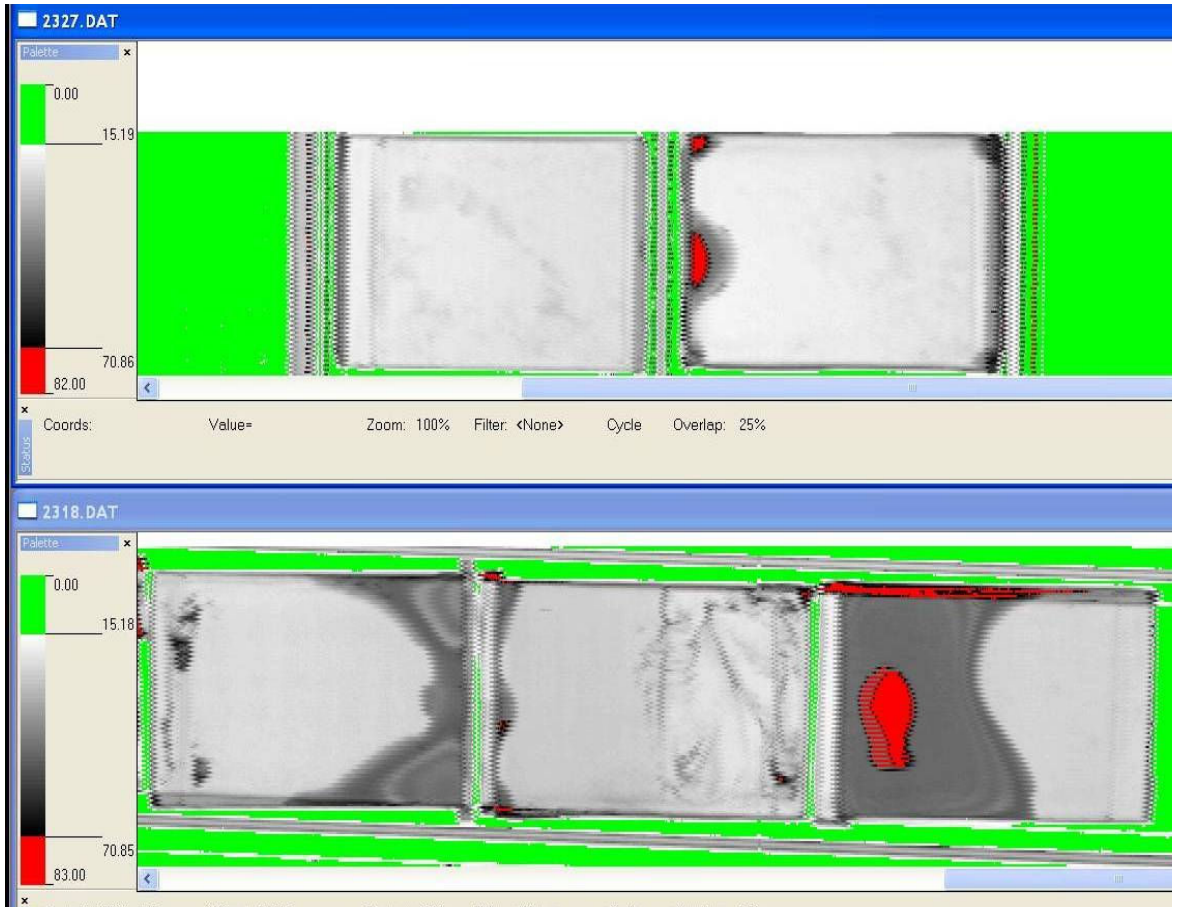


W clad (1 mm) onto Cu (5 mm) - W is the hot flyer! *(I41)*



W clad (1 mm) onto Cu (5 mm) - W used as hot flyer cont. *(I41)*

Analysis (I) – C scans - W clad (1.5-3 mm) onto Cu

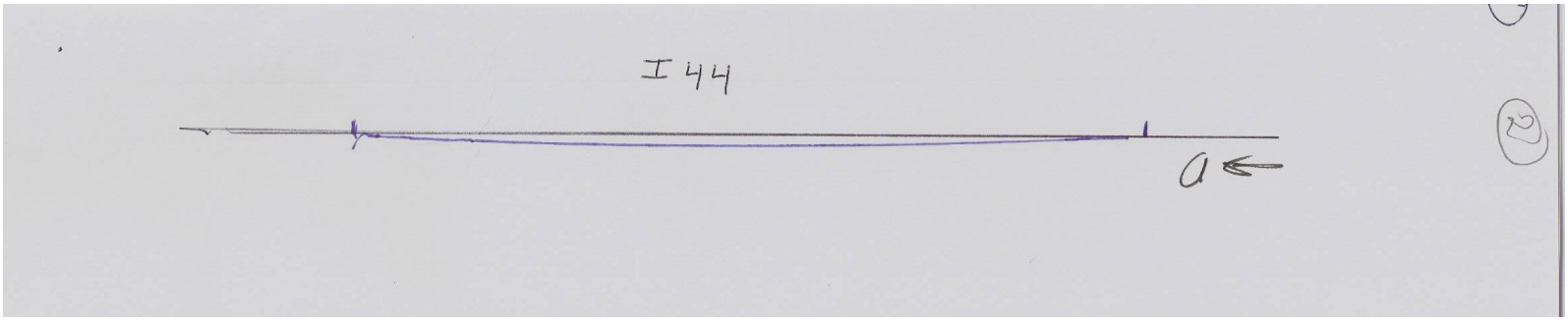


Analysis (2)

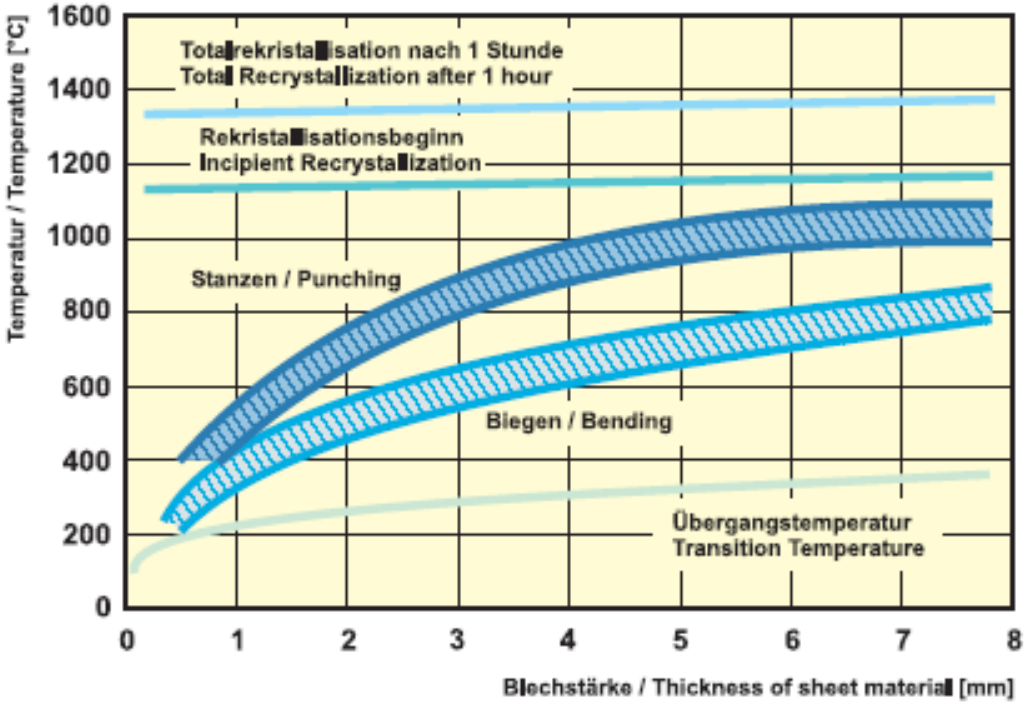
- 2 mm W onto 1,5 mm Cu (OFHC) - I44 blue is copper
- 2 mm W onto 3 mm Cu (OFHC) - I45 opposite curvature

- Flatness could be improved by hot pressing at about 500 deg C, see Plansee datasheet for “Biegen”

- W clad will be castellated for mock-up testing (heat flux)



W temperature for “Biegen” – 450-550 degC



Conclusions

- W foil (0, 3 mm) can be clad onto Cu at room temperature

(to cover larger side sections of divertor?)

- Mutiple foil cladding is not appropiate (parallel cracks)
- Hot cladding has given good results – 1-2 mm W onto Cu, CuCrZr and SS (ca. 2 mm)

Further analysis of interface by NRG (interface) and processing for mock-up testing (EFDA) to be done