An overview of thick tungsten coating prepared by chemical vapor deposition and manufacture of relevant mockup

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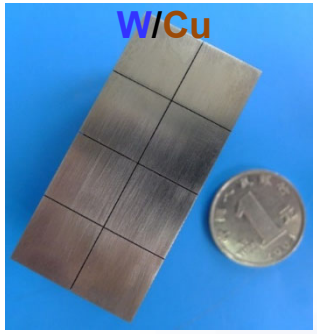
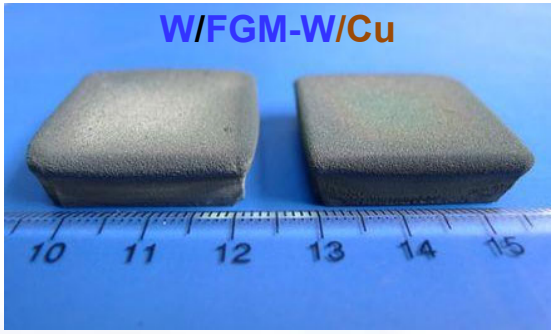
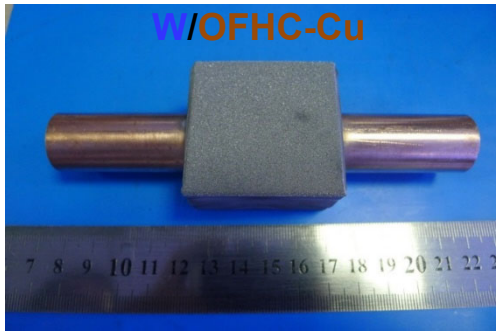
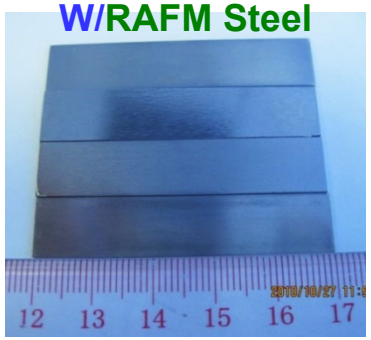
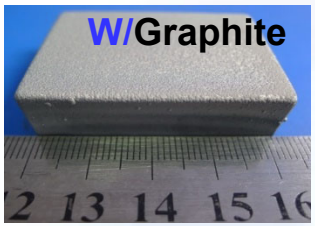
CVD-W: preparation, purity, TC, and CTE

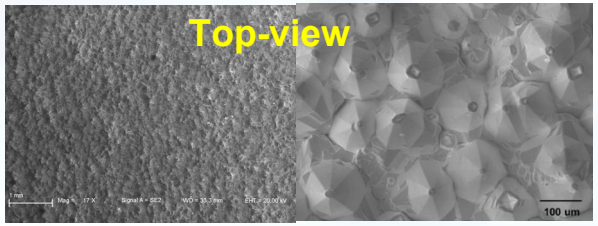


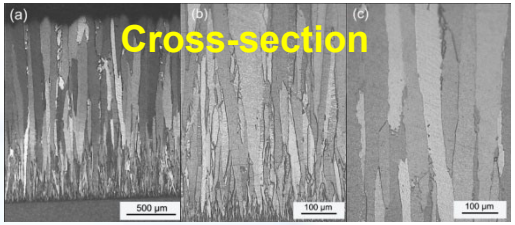




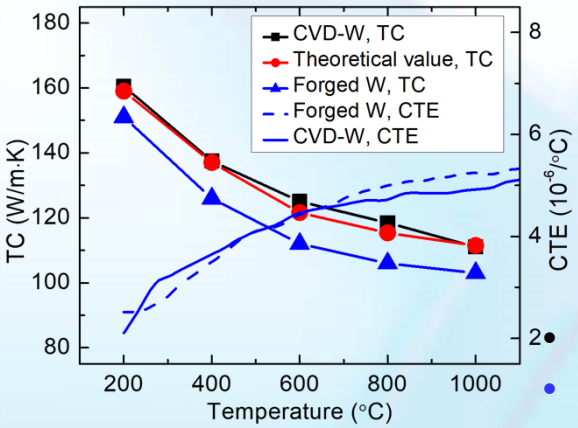








- Controllable preparation of CVD-W coatings on different substrates has been achieved.



Element	C	Element	C	Element	C	Element	C
C	<5	Al	0.03	Cr	0.08	Ni	0.02
O	<10	S	0.02	Fe	0.01	Zn	0.02
N	<5	Ca	0.03	Ti	0.002	Co	0.008
Ta	<1	Hg	<0.1	Re	<0.05	F	<0.01
Th	<0.0001	U	<0.0001	Others	<0.38	W	Matrix

C is the concentration of an element with a unit in wt. 10^{-4}%

- Purity ≥99.99%

- Comparable thermal conductivity (TC) to the theoretical value of W.
- ≥670℃, lower coefficient of thermal expansion (CTE) vs forged-W

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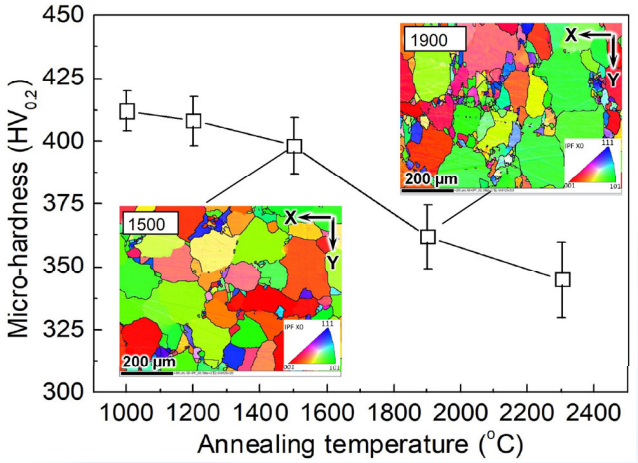
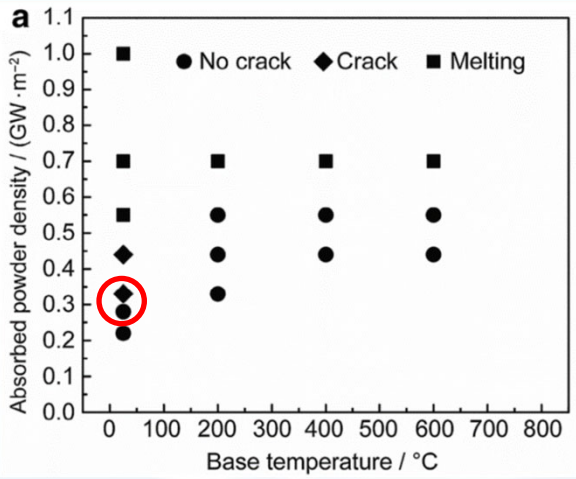
Thermal stability, transient heat flux, permeability

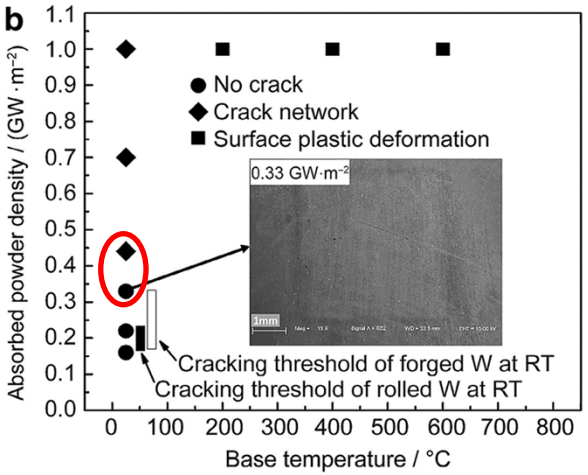


Annealing: 1200–2300 ℃, 3 h

- Excellent recrystallization resistance.

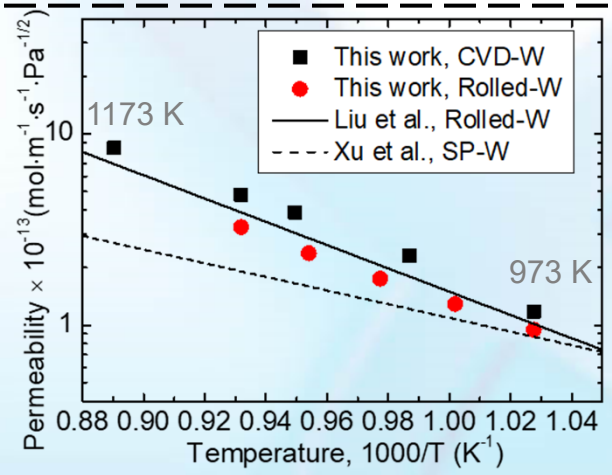


Disruption-like thermal loading



ELM-like thermal loading

- CVD-W: cracking threshold at RT, 0.28–0.33 GW·m^{-2}.
- CVD-W: cracking threshold at RT, 0.33–0.44 GW·m^{-2}.



$$\Phi_{CVD-W} = 1.44 \times 10^{-7} \exp\left(-\frac{1.17eV}{kT}\right), \mathrm{mol \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1/2}}$$

$$\Phi_{rolled-W} = 7.14 \times 10^{-8} \exp\left(-\frac{1.14eV}{kT}\right), \mathrm{mol \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1/2}}$$

- D permeability of the CVD-W was higher than commercial pure W, while their activation energy values were almost the same.

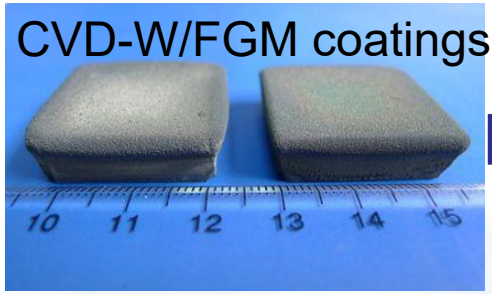
Appl. Surf. Sci. 390 (2016) 167–174; J. Nucl. Mater. 455 (2014) 371-375

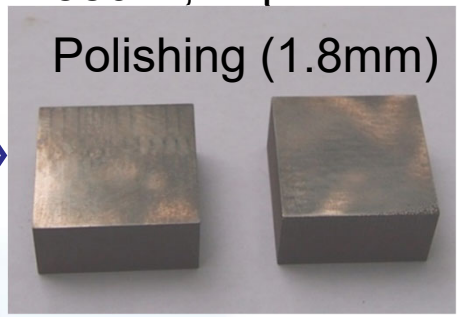
Thermal fatigue

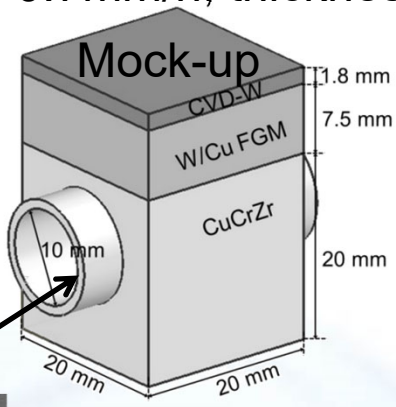
CVD-W/FGM/CuCrZr component

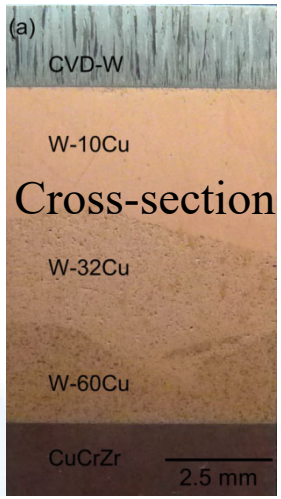
Fusion Eng. Des. 88 (2013) 1694-1698

Deposition temperature: 580℃, deposition rate: 0.7mm/h, thickness: 2mm

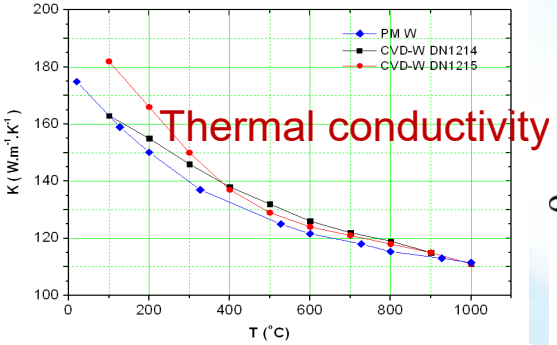


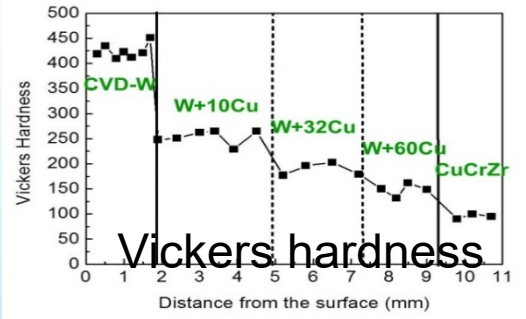


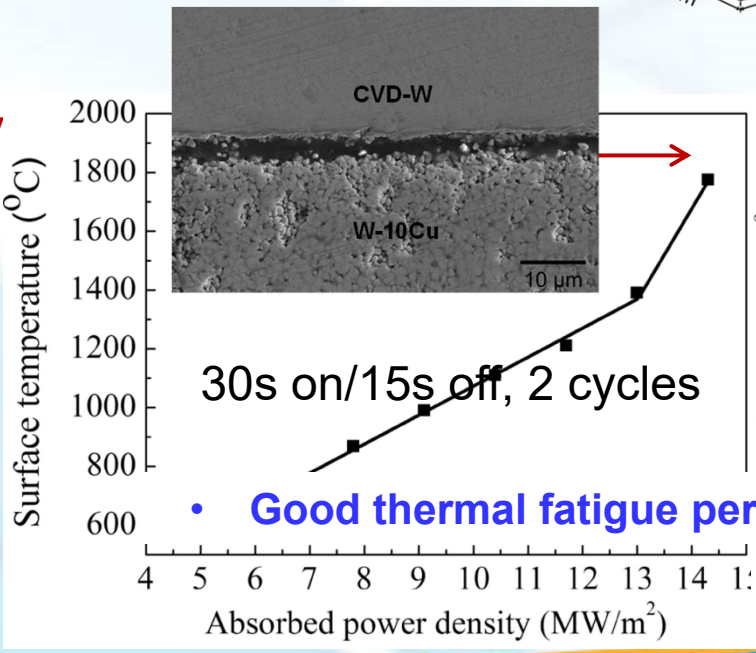


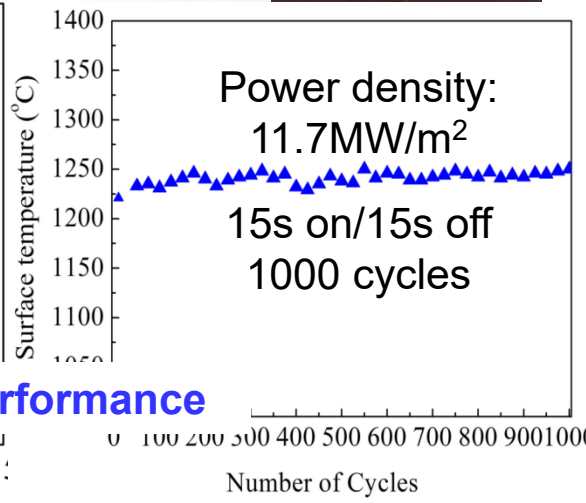


Brazing with CuCrZr with FGM, 950℃，20min





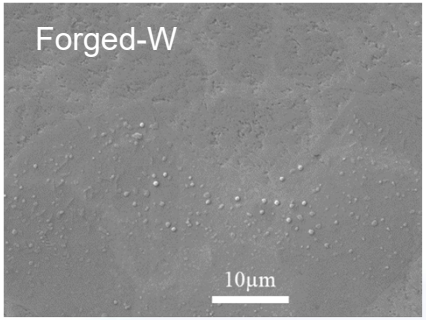


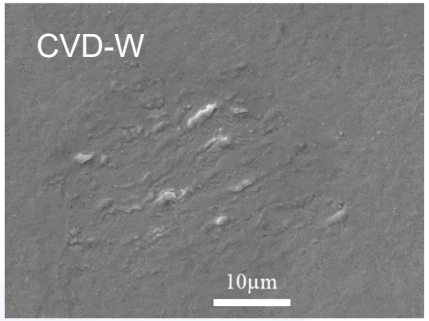


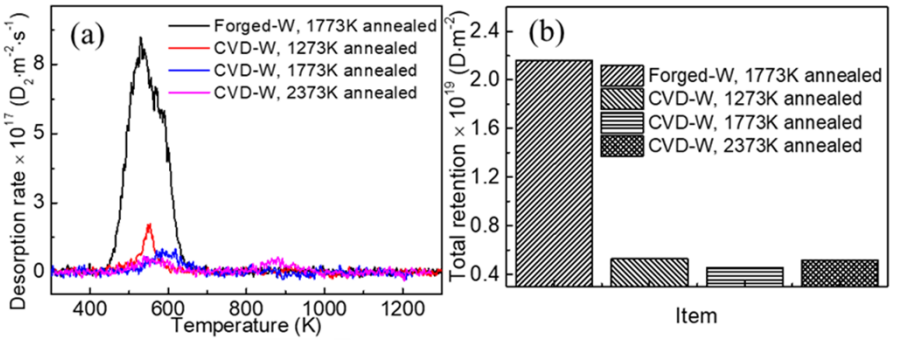
- **Good thermal fatigue performance**

D plasma exposure, steady-state and transient, mockups

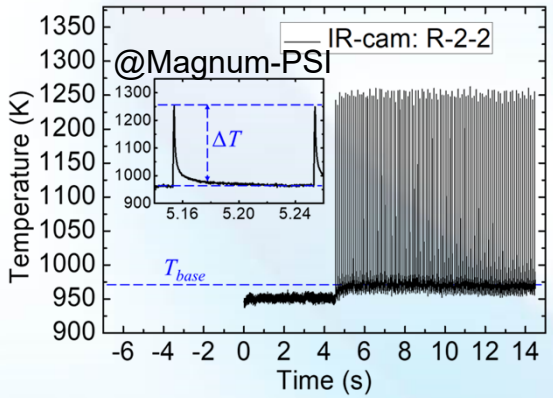
@Magnum-PSI, 50 eV, 823 K, Te=1.65 eV, ne = $4.73\times10^{19}m^{-3}$, Fluence=1.02×10^{26} m^{-2}





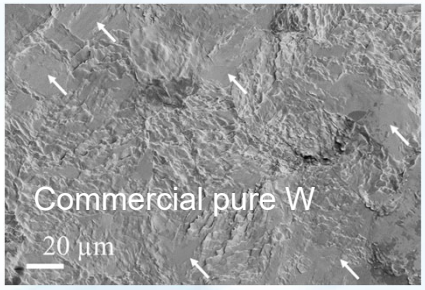


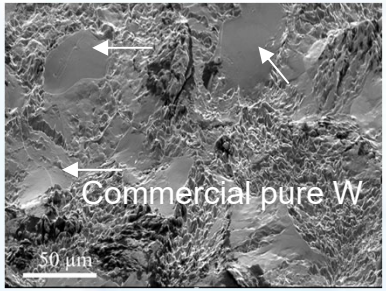
- **CVD-W: a mitigated blistering behavior, lower D retention VS the forged-W.**

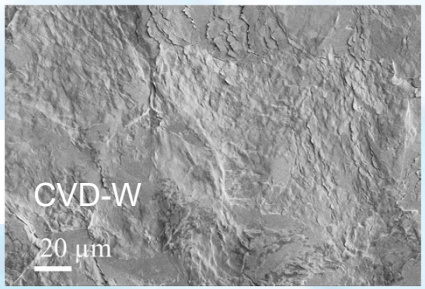


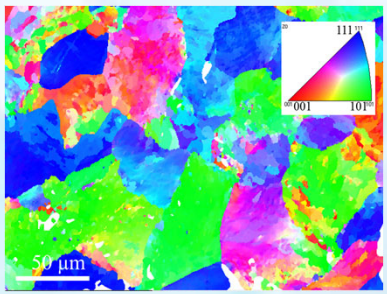
Steady-state: H plasma, 8.6MW·m^{-2}

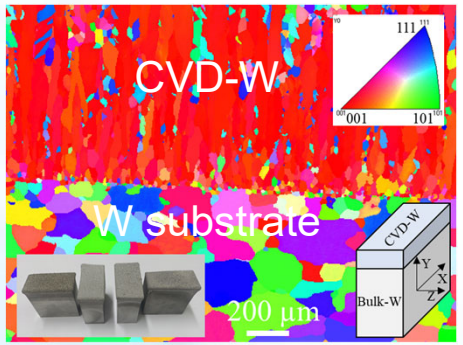
Transient: laser beam, 4MW·m^{-2}·s$^{0.5}$

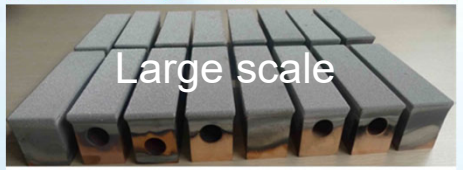












CVD-W: smoother surface

- **Strong grain orientation dependence of surface degradation**
- **Degradation preferentially occurred on the planes close to (101)**

Summary (2)

1. CVD (chemical vapor deposition)-W on different substrates including Cu, RAFM steel, and graphite are successfully prepared.
2. The CVD-W showed an excellent recrystallization resistance and a good thermal fatigue performance. In addition, a mitigated blistering and low D retention characteristics were confirmed. The CVD-W showed a higher D permeability compared to the commercial pure W counterpart.
3. The surface degradation induced by steady-state and transient heat flux exhibited a strong grain orientation dependence.
4. The large-scale CVD-W/CuCrZr mockups have also been developed. The preparation and heat loading tests of the CVD-W based water-cooled mono-block are undergoing.