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

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## ABSTRACT


- D permeability of CVD-W at temperatures in the range of 973-1173 K was larger than that of the commercial pure W.
- The D plasma exposed CVD-W exhibited a mitigated blistering behavior and lower D total retention.
- Surface degradation induced by the heat flux loading has a strong grain orientation dependence.
- The exposed CVD-W exhibited a much more uniform plastic deformation, and no cracks along grain boundaries were observed.
- The industrial-scale production of CVD-W-based PFMs and mockups has also been demonstrated.


## BACKGROUND

- Strategies that could increase the crystallization temperature of W are attracting more and more attention for the R&D of PFMs.
- CVD-W coating with thickness at millimeter level has advantages such as high purity, excellent thermal conductivity, and thermal shock performance, manifesting its great potential in fusion application.
- However, there are still some concerns in the fusion application of the CVD-W coatings. Therefore, experimental results of D gas-driven permeation (GDP), D plasma irradiation, and high heat flux testing of the CVD-W samples are presented.

## METHODS

**Sample preparation and characterization**

Thick CVD-W coatings with thicknesses of about 2.5 mm on copper (Cu) substrates were supplied by the Xiamen Tungsten Co., Ltd. (China). After deposition, the Cu substrate was chemically etched to get the pure CVD-W coating. CVD-W pieces for D GDP, D plasma irradiation, and heat flux testing were cut from the as-received coating by wire electrical discharge machining (EDM).

**Gas-driven permeation**

D permeability of the CVD-W sample was investigated by a GDP system. The sample with a thickness of 0.5 mm was used. The sample was first heated to the designed temperature in the range of 973 K to 1073 K by a furnace. Then D gas was filled up in the upstream chamber to a pressure of 100 kPa.

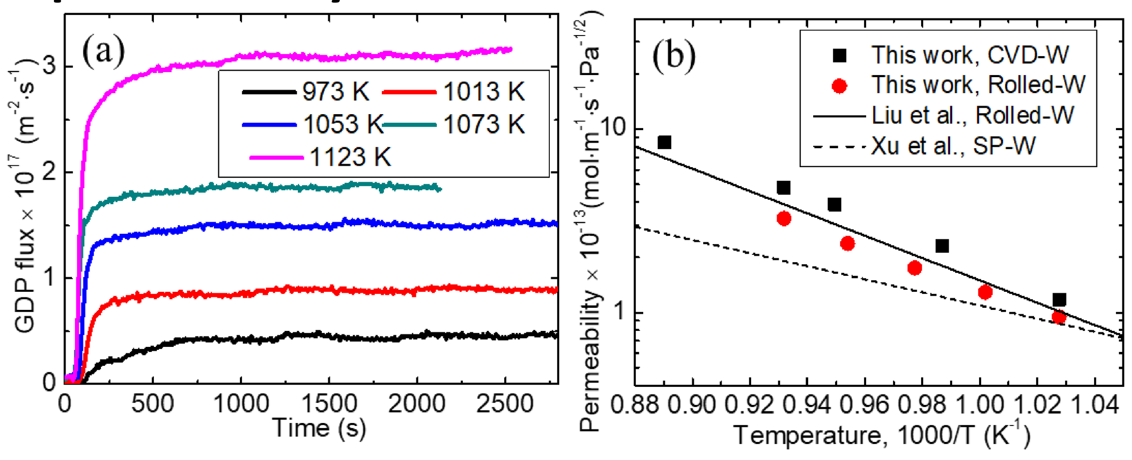
**D plasma irradiation**

CVD-W samples were exposed to low energy, high flux D plasma at Magnum-PSI. Three CVD-W samples annealed at temperatures of 1273 K (C-1-1), 1773 K (C-1-2), 2373 K (C-1-3) for 1 h were exposed. A commercial pure W sample annealed at 1773 K for 1 h (R-1-1) was also exposed for comparison. D retention and desorption behavior of the exposed samples were investigated by thermal desorption spectroscopy (TDS).

CVD-W coatings annealed at temperatures of 1673 K (C-2-1) and 1873 K (C-2-2 and C-2-3) for 1 h were exposed to steady-state and transient heat flux simultaneously. For comparison, commercial pure W samples with the same annealing conditions were also exposed to the same plasma conditions. The steady-state heat flux was simulated by H plasma generated by the cascade arc source of Magnum-PSI, while the transient heat flux (1 ms, 10000 times) was supplied by a 1064 nm Nd:YAG laser (LASAG FLS 352-302).

## OUTCOME

### D permeability



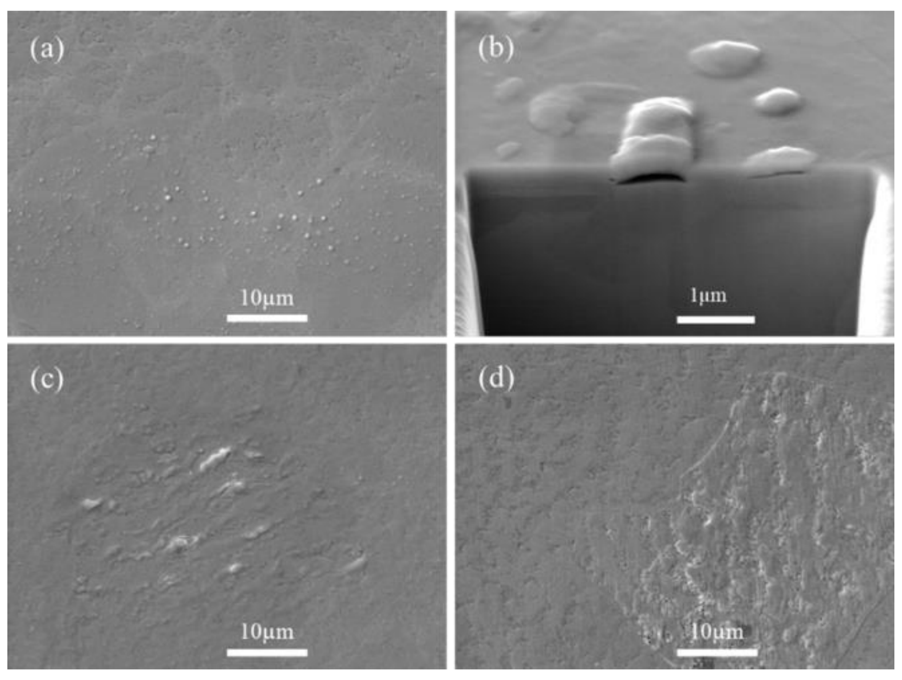

*(a) D GDP curves of the CVD-W as functions of time, (b) D permeability of the CVD-W and commercial pure W.*

$$\Phi_{CVD-W} = 1.44\times10^{-7}\exp\left(-\frac{1.17eV}{kT}\right), \mathrm{mol\cdot m^{-1}\cdot s^{-1}\cdot Pa^{-1/2}}$$

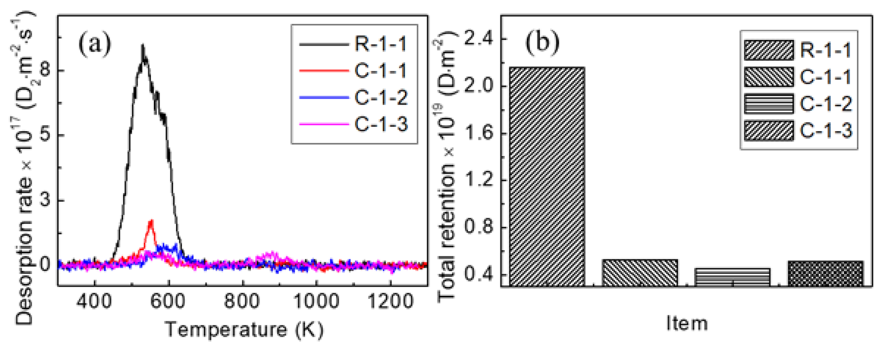
$$\Phi_{rolled-W} = 7.14\times10^{-8}\exp\left(-\frac{1.14eV}{kT}\right), \mathrm{mol\cdot m^{-1}\cdot s^{-1}\cdot Pa^{-1/2}}$$

- D permeability of CVD-W at temperatures in the range of 973-1173 K was larger than that of the commercial pure W.

### D plasma exposure and TDS

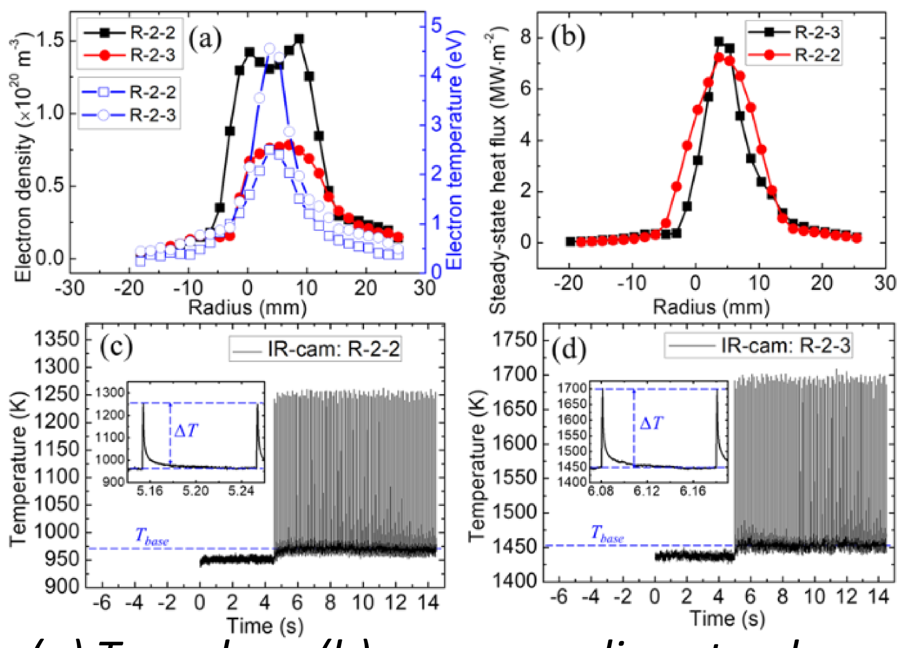


*(a)/(b) The commercial pure W after D plasma exposure. (c)/(d) The exposed CVD-W annealed at 1273K/2373K.*

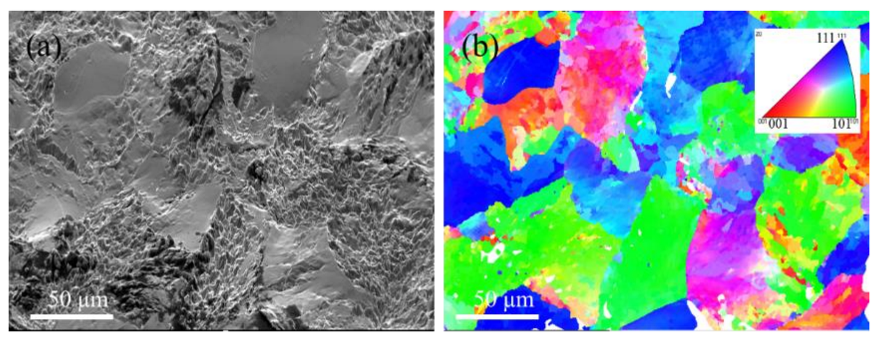



*(a) TDS spectra (D2 signal) and (b) Total D retention of commercial pure W counterpart and CVD-W samples annealed at different temperatures.*

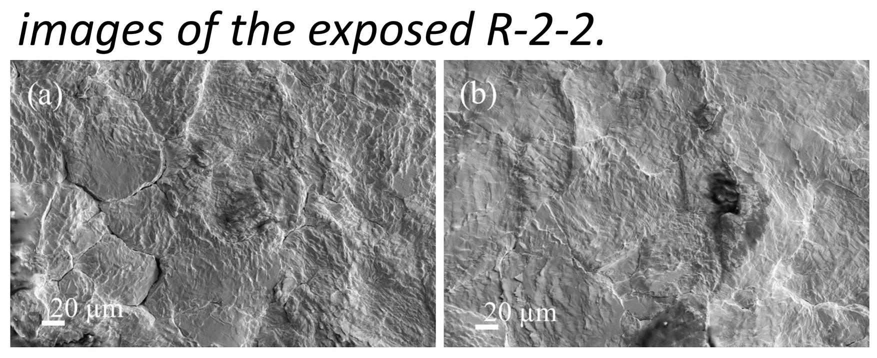
- The D plasma exposed CVD-W exhibited a mitigated blistering behavior and D retention.




*(a) Te and ne, (b) corresponding steady-state heat fluxes. (c) and (d) show the surface temperatures.*

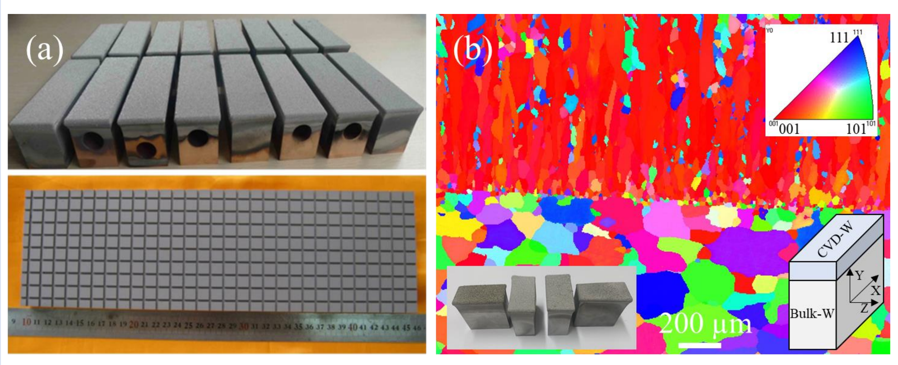


*(a) SEM and (b) corresponding EBSD images of the exposed R-2-2.*



*(a)/(b) images of the exposed R-2-3/C-2-3*

- Surface degradation induced by the heat flux loading has a strong grain orientation dependence, where preferentially occurred on the surfaces of grains with normal directions close to [101].
- The exposed CVD-W exhibited a much more uniform plastic deformation, and no cracks along grain boundaries were observed.



- The industrial-scale production of CVD-W-based PFMs and mockups has also been demonstrated.
- CVD-W exhibited a excellent thermal stability.

*(a) large-scale CVD-W/CuCrZr mockups, (b) CVD-W deposited on Bulk-W substrate after heat treatment.*

## CONCLUSION

- The CVD-W showed a higher D permeability compared to the commercial pure W counterpart.
- A mitigated blistering and low D retention characteristics were confirmed.
- The surface degradation induced by steady-state and transient heat flux exhibited a strong grain orientation dependence.

## ACKNOWLEDGEMENTS

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