Thick Tungsten and Rhenium coating by Chemical Vapor Deposition

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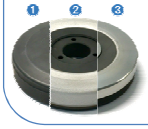
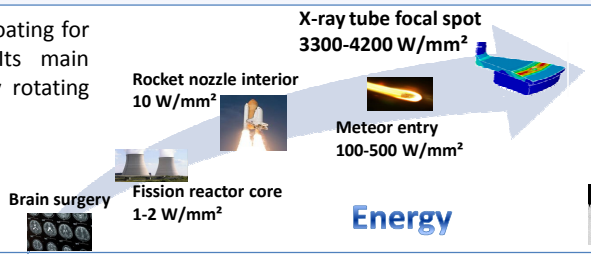
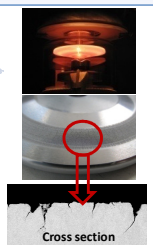
ACERDE has developed a W-CVD coating for X-ray and fusion applications. Its main activity is the production of X-ray rotating anodes:



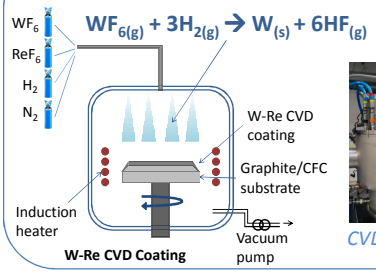
Anode elaboration:
1. *Substrate design*
2. *Coating*
3. *Machining*





Innovation:
ACERDE proposes solutions to improve the resistance to carburization and cracking:
- Limitation of carbon diffusion in Tungsten and improvement of coating adhesion on the substrate
- Increase of coating cracking resistance

W-Re CVD coatings



CVD reactor

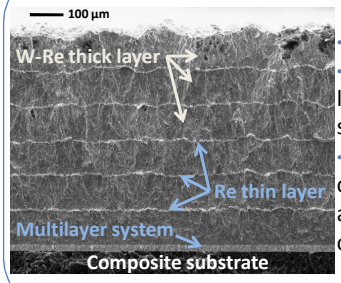
CVD: 1 operation

1. Interface
   - Re barrier
   - Alternation of thin W and Re layers
2. W Coating
   - Stack of thin Re interlayers and thick W layers

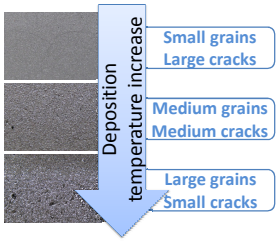
Experiments

CVD → Short annealing → TESTS 1200/1400 °C

Results: Cracking resistance 2



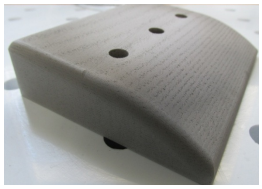
- In-situ deposition
- Cooling before each Re layer to reduce thermal stress
- Re layer interferes to the cracks propagation and avoid the complete cracking of the coating



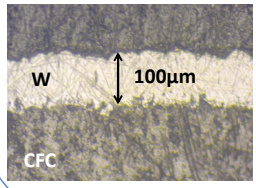
→ *Patents **FR2962591** and **FR1451695***

Applications

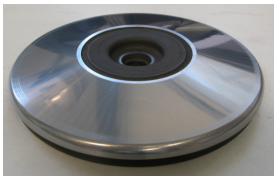
Plasma facing components



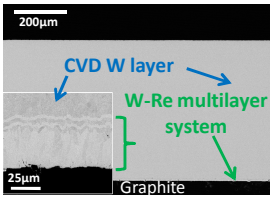
CFC brick with W-coating for first wall – Currently tested by IRFM-CEA



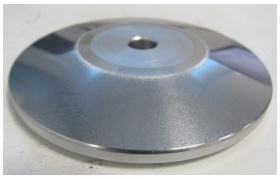
Lightweight anodes



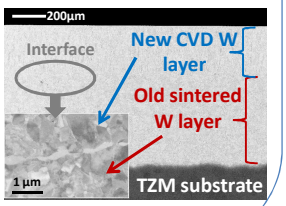
W-Re layer deposited on graphite or CFC substrate



Refurbished anodes

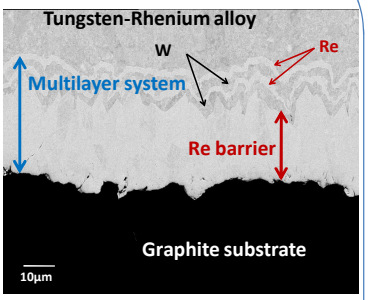


W-Re CVD layer deposited on an old sintered W layer

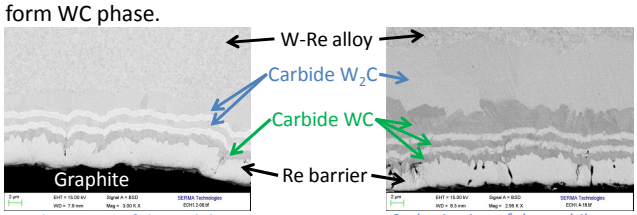


Results: Carburization resistance 1

Interface system:
It is well-known [1,2,3] that a W-Re multilayer system can act as a diffusion barrier to prevent carbon migration.
This multilayer system is deposited in-situ before the W layer deposition, and is composed as shown against.



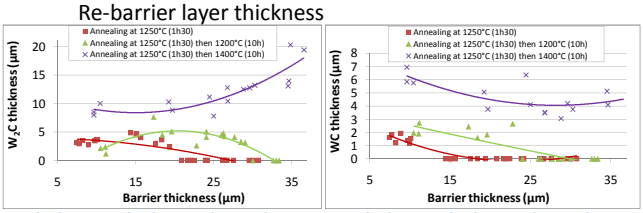
Carburization:
During high temperature exposure, carbon diffusion from the substrate to the W-layer leads to W_2C formation [4,5]. Then, carbon atoms from the substrate react with W_2C phase to form WC phase.



Carburization of the multilayer system after annealing at 1250°C – 1h30

Carburization of the multilayer system after annealing at 1250°C – 1h30 + 1400°C – 10h

→Acerde studied carburization progression depending on the Re-barrier layer thickness



Carbide W_2C thickness depending on barrier thickness

Carbide WC thickness depending on barrier thickness

- Barrier thickness <20µm: after a short annealing at least at 1250°C, a controlled carbide layer is formed. This will reduce unwanted carburization during use at low temperature (1200°C) and high temperature (1400°C).
- Barrier thickness >25µm: only W_2C at 1200°C is formed but there is uncontrolled carburization at 1400°C

Conclusion

Carburization:
- The best barrier thickness is between 20 and 25 µm ; this allow first controlled carbide layer formation which will prevent uncontrolled carbide formation during use at low temperature

Cracking resistance:
- Depositing several successive layers with intercooling allows to reduce thermal stresses and control cracking
- High temperature deposition leads to less critical crack appearance

- **Using HTCVD process developed by ACERDE, W-layers and Re-interlayers can be deposited in-situ in only one run**
- **The process can be applied to graphite, CFC composite or sintered metallic substrates up to 250mm diameter**

(1) Liu et al. – J. of Nuclear Materials 329-333 (2004) 687-691 ; (2) Hirai et al. – J. of Nuclear Materials 392 (2009) 40-44 ; (3) Tamura et al. – J. of Nuclear Materials 329-333 (2004) 711-716 ; (4) Schmid et al. – J. of Nuclear Materials 302 (2002) 96-103 ; (5) Luthin and Linsmeier – Surface sciences 454-456 (2000) 78-82

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