Chemical vapor deposition of tungsten coatings on X-ray rotating light anodes made of carbon-based materials

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Overview

Deposition of **CVD** materials : W, **W-Re**, Re, SiC
On high thermal conductivity **graphite and C/C composite** targets
"Plug & Play" **X-ray Rotating Anodes** (60 to 250 mm diameters)
Medical application : CT scanners, Mammography, Angiography, Cardiography…

CVD Process for W-Re coating

Gaseous precursors (WF_6 and/or ReF_6) are reduced by H_2, and metallic (polycrystalline) tungsten, rhenium, W-Re alloys layers are deposited.

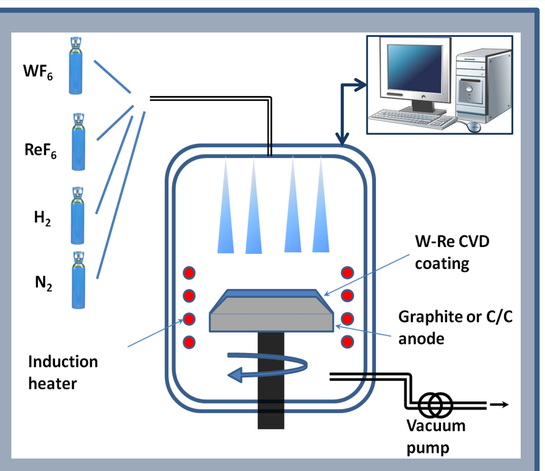
WF_6 (g) + $3H_2$ (g) ➔ W (s) + 6HF (g)
Thermally activated phenomenon
(surface diffusion, adsorption, desorption)

Graphite or C/C target heated by electric induction
High purity gaseous precursors (WF_6, ReF_6)
Deposition rate and deposition yield depend of base pressure, precursors fluxes and substrate temperature

Main characteristics of **CVD WRe layers** :

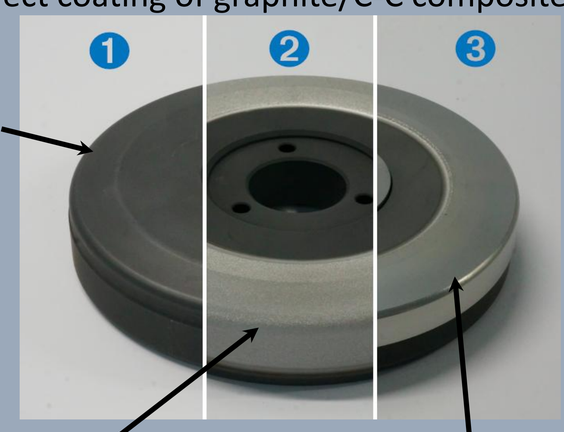
✓ Highly **dense** (volumic density similar to bulk material),
✓Fine **control of deposited thicknesses** (from few µm to several mm),
✓High purity, fine grain structure, high thermal conductivity
✓Re content simply adjusted from precursors flux ratio

$$\%Re = \Phi_{ReF6}/(\Phi_{ReF6} + \Phi_{WF6})$$



X-ray anodes manufacturing

From raw material to "plug & play" anodes
100 % graphite design
(direct coating of graphite/C-C composite)

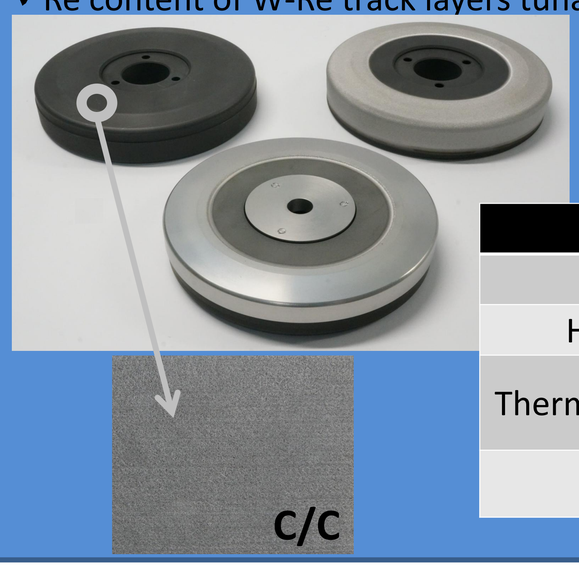


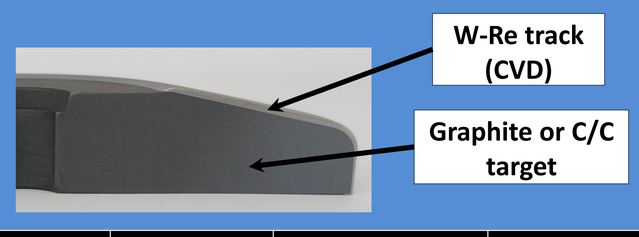
Anode design (graphite and C-C targets)

Wide range of applications

Anode diameters from 60 mm, up to 150 mm
(200-250 mm in progress)

✓ Specific **CVD Anode design (graphite-based) with superior heat capacity** compared to TZM-based anodes
✓ **Weight saving up to 80 %** , due to low volumic density of graphite, "on demand" design
✓ W-Re track thickness from 0.5 mm to 2 mm
✓Re content of W-Re track layers tunable from 0 to 25 %





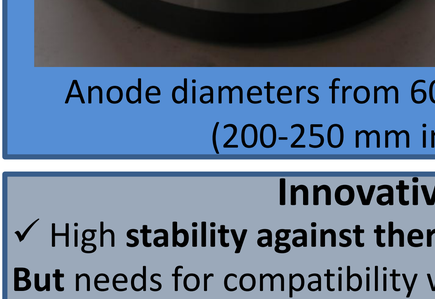
Material properties	Graphite	TZM	C/C composite
Density @ 25 °C [$g.cm^{-3}$]	1.7-1.9	10.1	1.6-1.8
Heat capacity @ 25 °C [$J.g^{-1}.K^{-1}$]	0.75	0.2	0.75
Thermal conductivity @ 25 °C [$W.m^{-1}.K^{-1}$]	80-130	123	10-250 *
CTE 20-1000 °C [µm. $m^{-1}.K^{-1}$]	4.5-5.9	6	1-7 *

* depending in carbon fiber weaving

Innovative material : CVD anode on C/C target

✓ High **stability against thermal and mechanical loads**
But needs for compatibility with CVD process :
1.isotropic surface properties
2. CTE matching with W-Re coatings (α = 4.6 µm. $m^{-1}.K^{-1}$)

Material properties	Graphite	2D weaving C/C	Isotropic C/C
Density [$g.cm^{-3}$]	1.7-1.9	1.6	1.8
Heat capacity [$J.g^{-1}.K^{-1}$]	0.75	0.75	0.75
Thermal conductivity [$W.m^{-1}.K^{-1}$]	100	⊥10	⊥200
		// 40	// 250
CTE [µm. $m^{-1}.K^{-1}$]	4.5-5.9	⊥ > 7	⊥ 3
		// < 1	// > 2
Young's modulus [GPa]	13	80	15
Ultimate tensile stress [MPa]	40	170	30

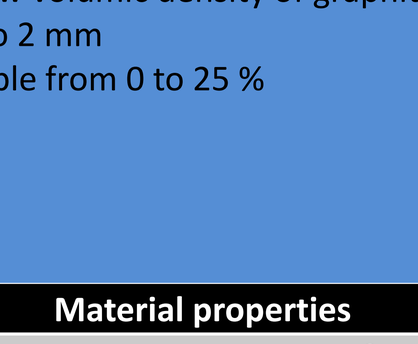


Deposition on 2D weaving C/C leads to cracks pattern after cooling down

Deposition on isotropic C/C
✓**No** cracks formation after cooling down

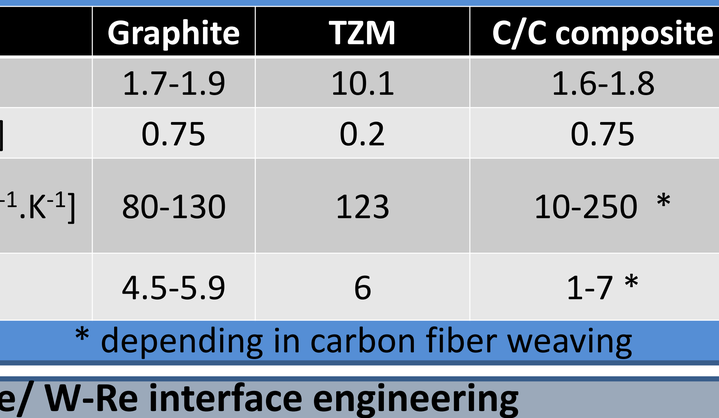
Graphite/ W-Re interface engineering

During high temperature exposure, formation of brittle carbide compounds, due to carbon diffusion from the target



✓ **Carbon diffusion barrier layers**

Multi-layer interface to prevent C diffusion



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