W thick coatings on CuCrZr and steel for plasma facing components

F. Casadei [a], R.Donnini [b], S. Lionetti [a], G. Maddaluno[c], R. Montanari [b], N. Ucciardello [b]

[a] Centro Sviluppo Materiali (CSM), Via di Castel Romano 100, 00128 Rome, Italy
[b] Department of Mechanical Engineering, University of Rome - Tor Vergata, Via del Politecnico 1, 00133 Rome, Italy
[c] Association EURATOM-ENEA on Fusion, P.O. Box 65, I-00044, Frascati (Rome), Italy

INTRODUCTION

Thick tungsten coatings represents a viable solution for the manufacture of the plasma facing first wall material in future devices. The heat loads, much smaller than for divertor components, they are foreseen to withstand and their capability in limiting erosion by sputtering guarantee a long time life to this first wall solution.

Among the techniques able to deposit thick W coatings, plasma spray is probably the simplest and the most attractive from the economical point of view.

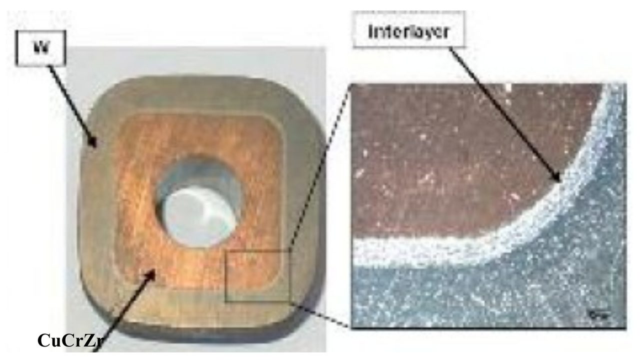
For the successfull outcome of the coating, an appropriate interlayer must be ideposited on the substrate to limit the mismatch between substrate and W.

In this work some investigations on the effectiveness of the following coating/interlayer/substrate combinations are reported and discussed:

Plasma facing coating	Interlayer	Substrate
W	NiAl, SiAl and W	CuCrZr
W	NiAl, SiAl and W	AISI 316
W	SiAl and W	AISI 316

MATERIAL

W on CuCrZr ; Interlayer: W + Ni-20%Al + Al-12%Si

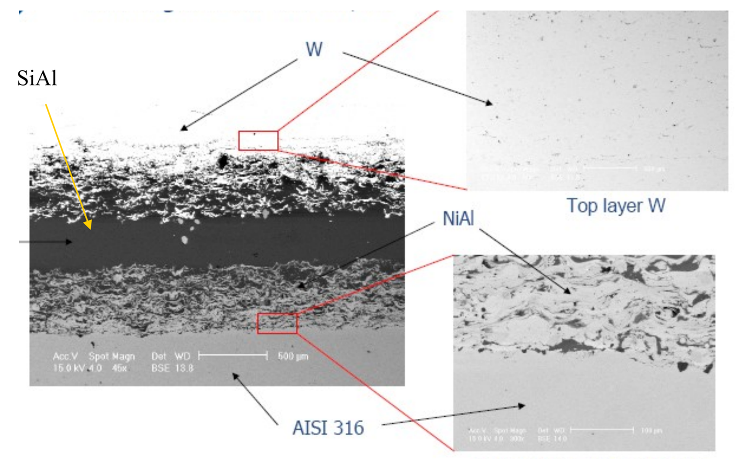


This coating/interlayer/ substrate combination has been successfully tested under thermal fatigue tests performed at the electron beam facility FE200 (Le Creusot-France). The mock up with 5 mm thick W coating realised with the **low pressure plasma spray** technique withstood heat fluxes up to 5 MWm^{-2} in cooling conditions relevant for ITER.

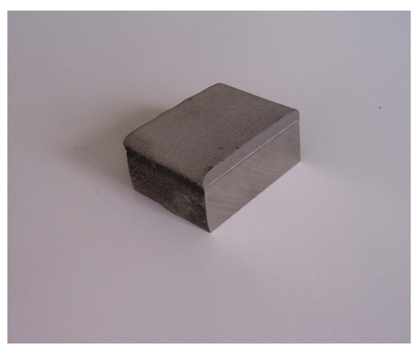
B.Riccardi et al., 17th IEEE/NPSS Symposium on Fusion Engineering, (1997) vol 2 pag. 910

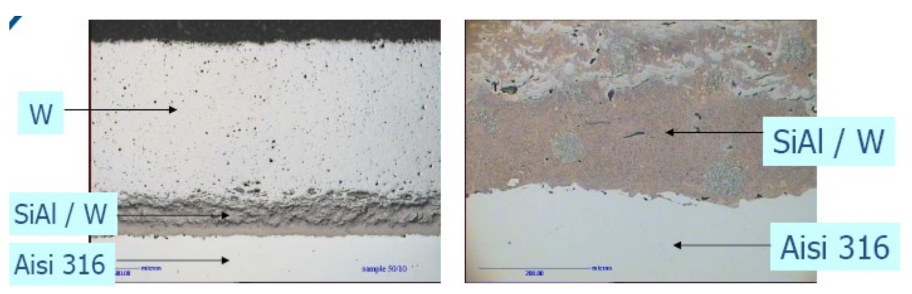
W on AISI 316 ; Interlayer:W + Ni-20%Al + Al-12%Si

High Pressure Plasma Spray



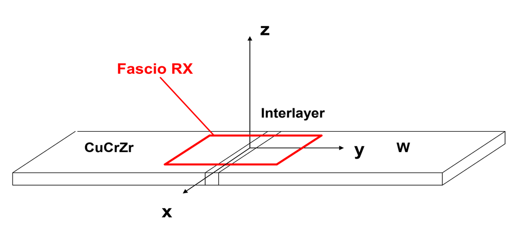
W on AISI 316 ; Interlayer: W + Al/12%Si





ANALYTICAL TECHNIQUES

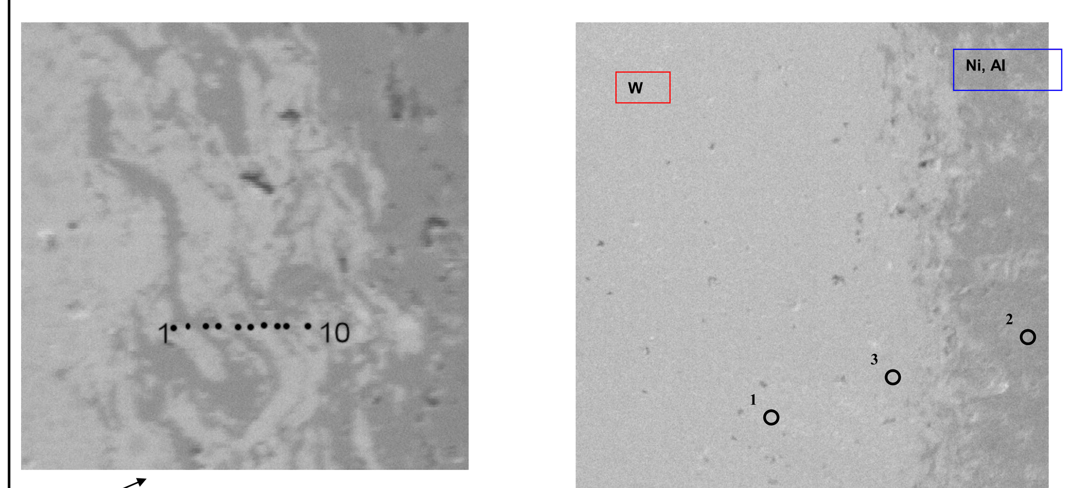
- Density measurements
- Optical and electron microscopy
- X-ray difrattometry (up to 400 °C in argon atmosphere)
- EDS mapping, XPS, AES
- Inductively coupled plasma emission spectroscopy (ICP-ES)
- Flat top cylindrical indentation (FIMEC)



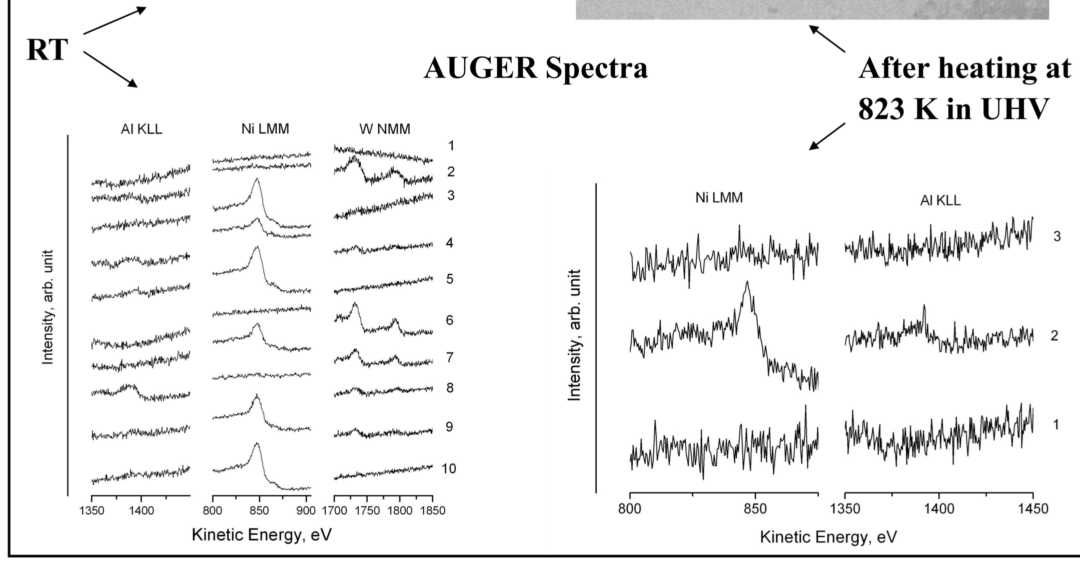
RESULTS

W on CuCrZr

SEM images of W/interlayer boundary

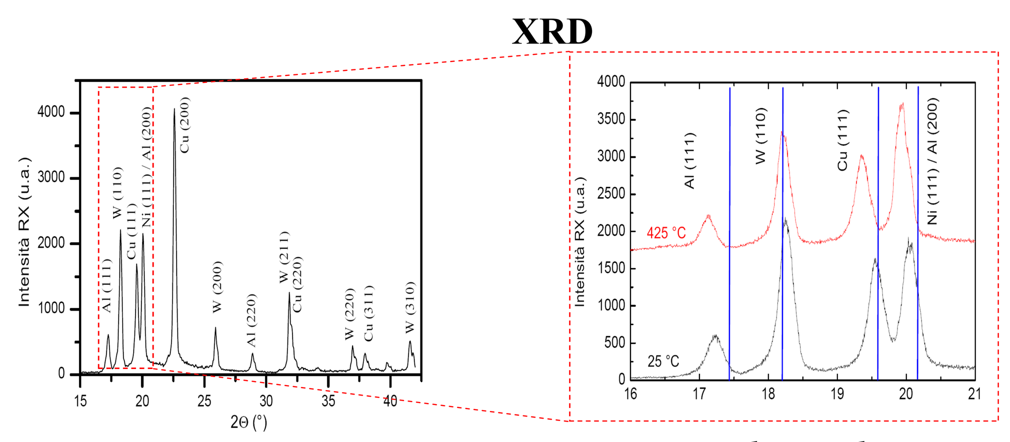


The presence of Ni in the external layer of W coating is of concern because of its high activation under the neutron flux in future fusion device beyond ITER



No long-range elemental interdiffusion takes place (substrate temperature kept below about 180 °C during deposition) even after heating at 823 K in UHV.

XRD



$$\varepsilon = \frac{d_{EXP} - d_{CALC}}{d_{CALC}}$$

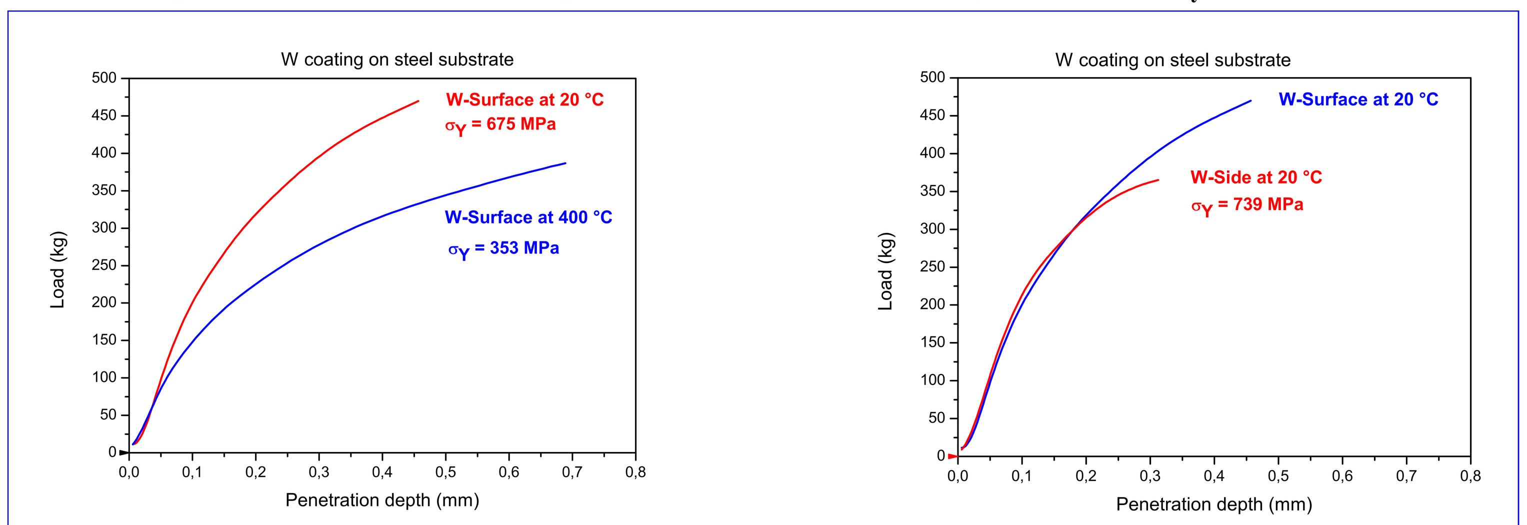
	Al				W			
	25 °C		425 °C		25 °C		425 °C	
	Exper	Calc	Exper	Calc	Exper	Calc	Exper	Calc
d (nm)	0.2369	0.2338	0.2383	0.2359	0.2239	0.2238	0.2243	0.2242
ε	1.3 x 10^{-2}		1.0 x 10^{-2}		4.4 x 10^{-4}		4.4 x 10^{-4}	

	Cu				Ni			
	25 °C		425 °C		25 °C		425 °C	
	Exper	Calc	Exper	Calc	Exper	Calc	Exper	Calc
d (nm)	0.2090	0.2088	0.2111	0.2102	0.2037	0.2034	0.2049	0.2045
ε	9.6 x 10^{-4}		4.3 x 10^{-4}		1.5 x 10^{-3}		1.9 x 10^{-3}	

W on AISI 316

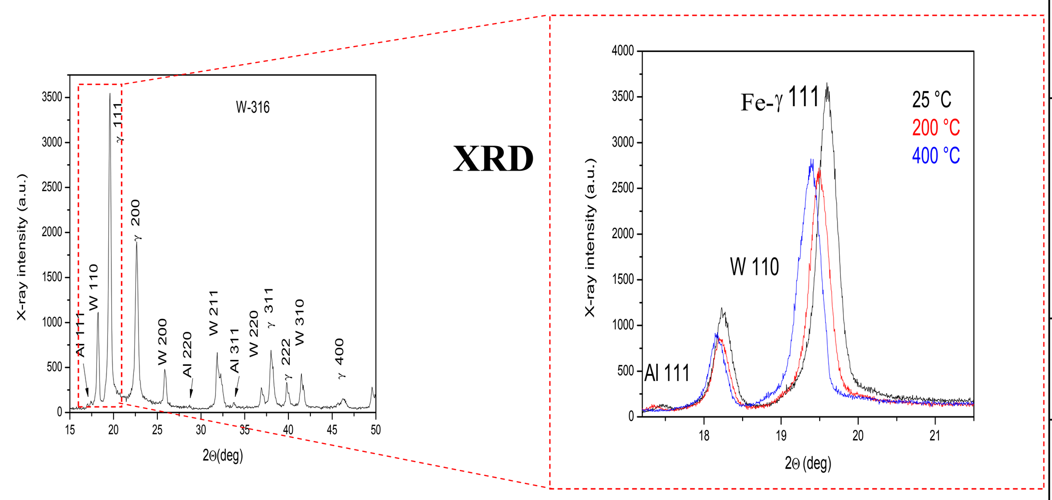
FIMEC

From load–penetration curves it is possible to determine the yield stress σ_{cy}.



Load – penetration curves for (a) indentation perpendicular to the external surface at T =20 °C and 400°C; (b) indentation perpendicular and parallel to the external surface at T = 20 °C

XRD



Metal		Al	Fe-γ	W
Calculated values JCPDS-ICDD	a (nm)	0.40494	0.35966	0.31648
	d (nm)	0.23379	0.20765	0.22379
Experimental values	d (nm)	0.23389	0.20867	0.22397
Residual strain	ε	4.28 x 10^{-4}	4.91 x 10^{-3}	8.04 x 10^{-4}

CONCLUSIONS and FUTURE WORK

Thick tungsten coating can be manufactured by plasma spray without macroscopic defects and with a density of W coating higher than 90% of the bulk material.

The coatings exhibited a good microstructure and satisfactory thermal properties (tested only for ELBRODUR substrate): the mechanical properties, especially for steel substrate, appear worse than the bulk material ones.

For W coated ELBRODUR samples the major residual stress is concentrated in the interlayer, while for AISI 316 samples the interlayer is subjected to the lowest strain, probably due to not well optimised substrate temperature during deposition.

A limited cohesion of the sprayed layers through the thickness can be deduced from the indentation behaviour of W coating which changes significantly if the penetration is operated in direction perpendicular to the coating external surface or parallel to this surface when the test is carried out on a sample cross section.

Thick W coatings are foreseen to be deposited on martensitic stainless steel samples suited to be actively cooled during deposition and heat load tests.