DOE/NETL-IR-2007-080

National Energy Technology Laboratory

Microstructure and high temperature oxidation behavior of Cr-W alloys

Ömer Doğan
NETL-Albany, Oregon

National Energy Technology Laboratory

Office of Fossil Energy

High Temperature Materials in Power Generation

- **In energy systems, there is an increasing demand for new materials with**
  - higher strength,
  - creep resistance,
  - corrosion resistance,
  - thermal fatigue resistance, and
  - wear resistance
- **to increase generation efficiency,**
- **to reduce environmental pollution,**
- **to make new energy generating technologies economically feasible.**

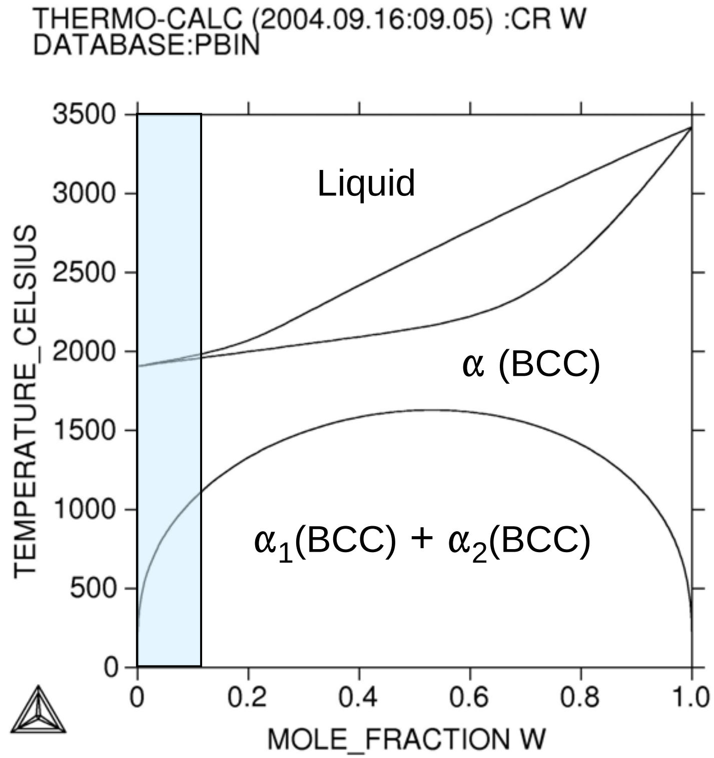
NETL

High Temperature Materials in Power Generation

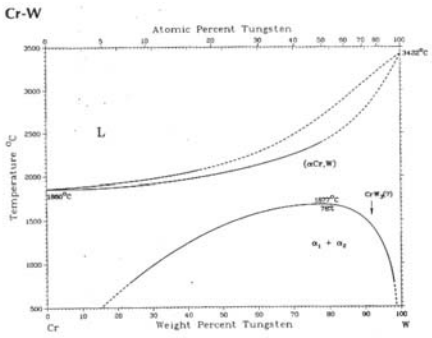
- New technologies such as ultra super critical steam plants, integrated gasification combined cycle, pressurized fluidized bed combustion, and solid oxide fuel cells are being developed to meet this demand.
- One common barrier in the development of these different technologies is insufficiency of existing materials.
- Even the highly alloyed and high cost Ni based superalloys do not have desired properties at the temperatures that some parts of the future energy generating systems will be exposed.
- Therefore, there is an urgent need to develop structural alloys with desirable properties using elements with high melting point.

NETL

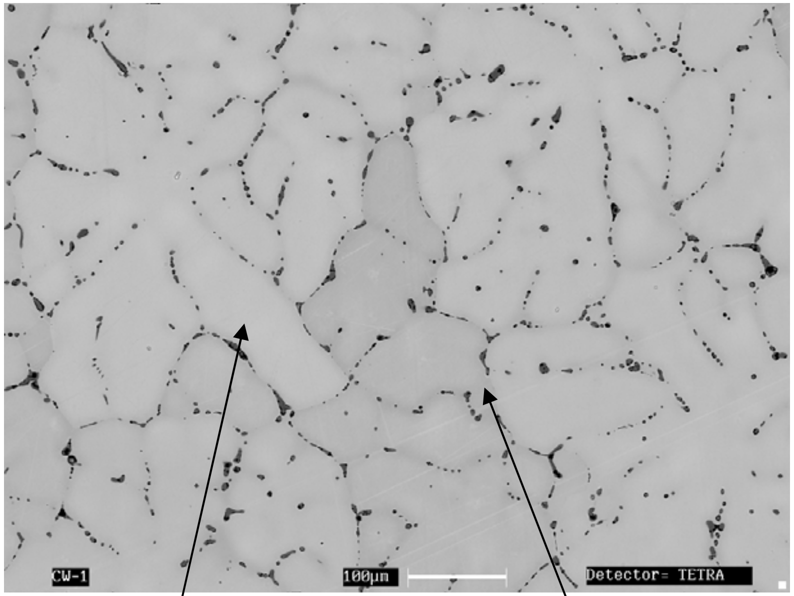
Cr-W Equilibrium Phase Diagram

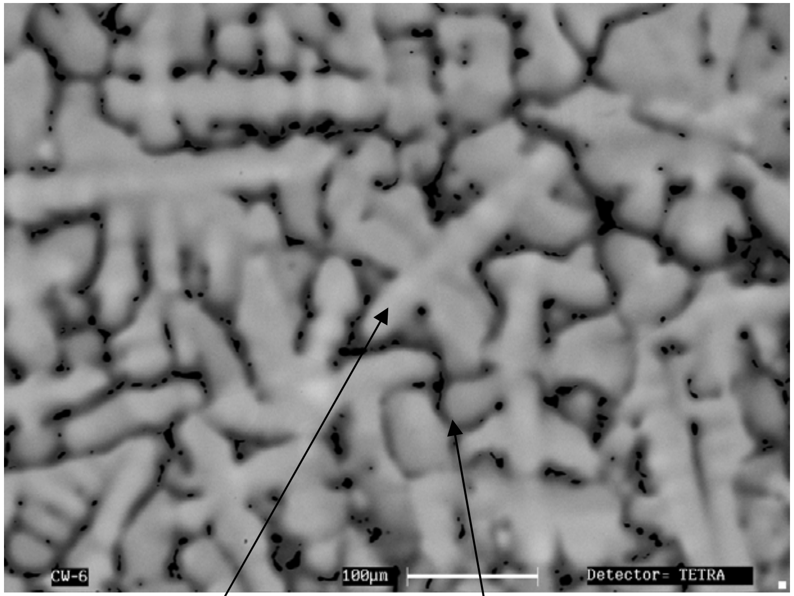


Microstructure



Cr-5W	Cr-30W





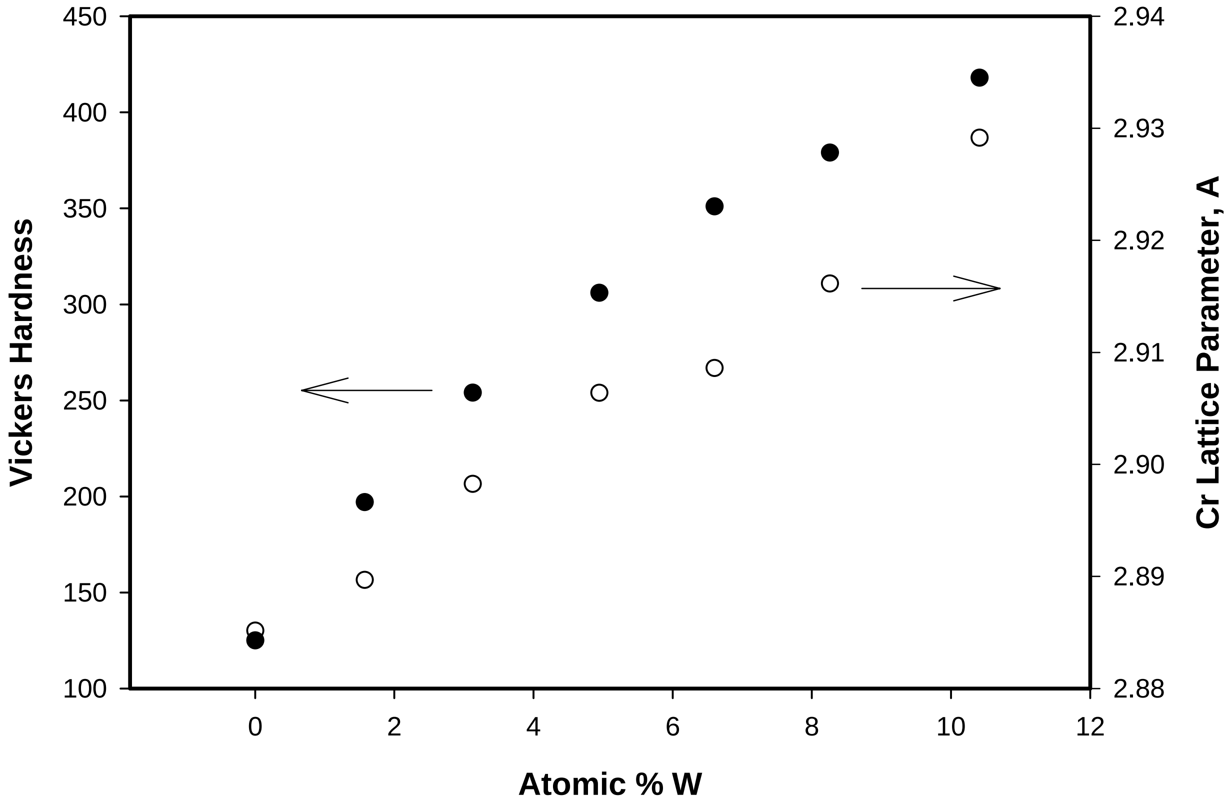
6%W
94%Cr

5%W
95%Cr

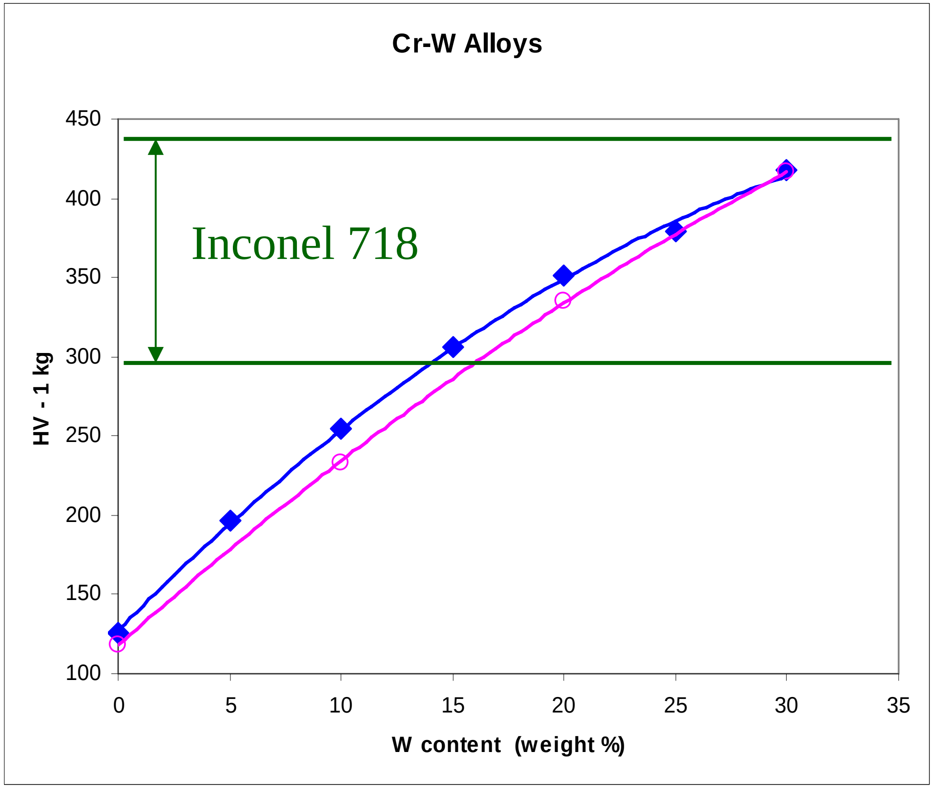
36%W
64%Cr

20%W
80%Cr

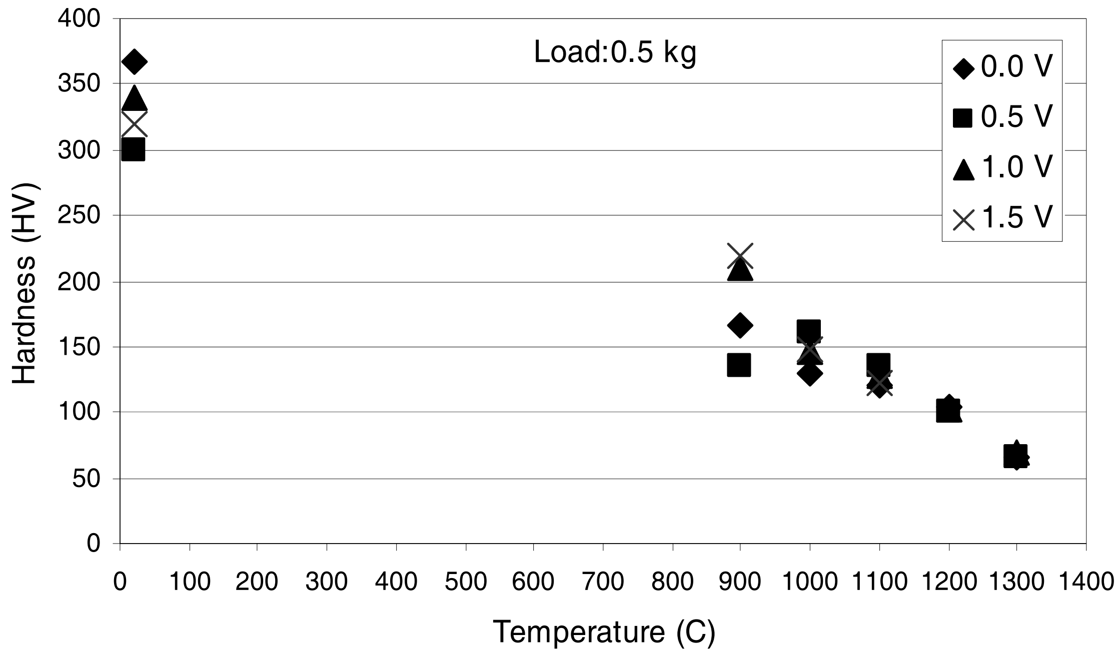
Solid solution strengthening



Room Temperature Strength

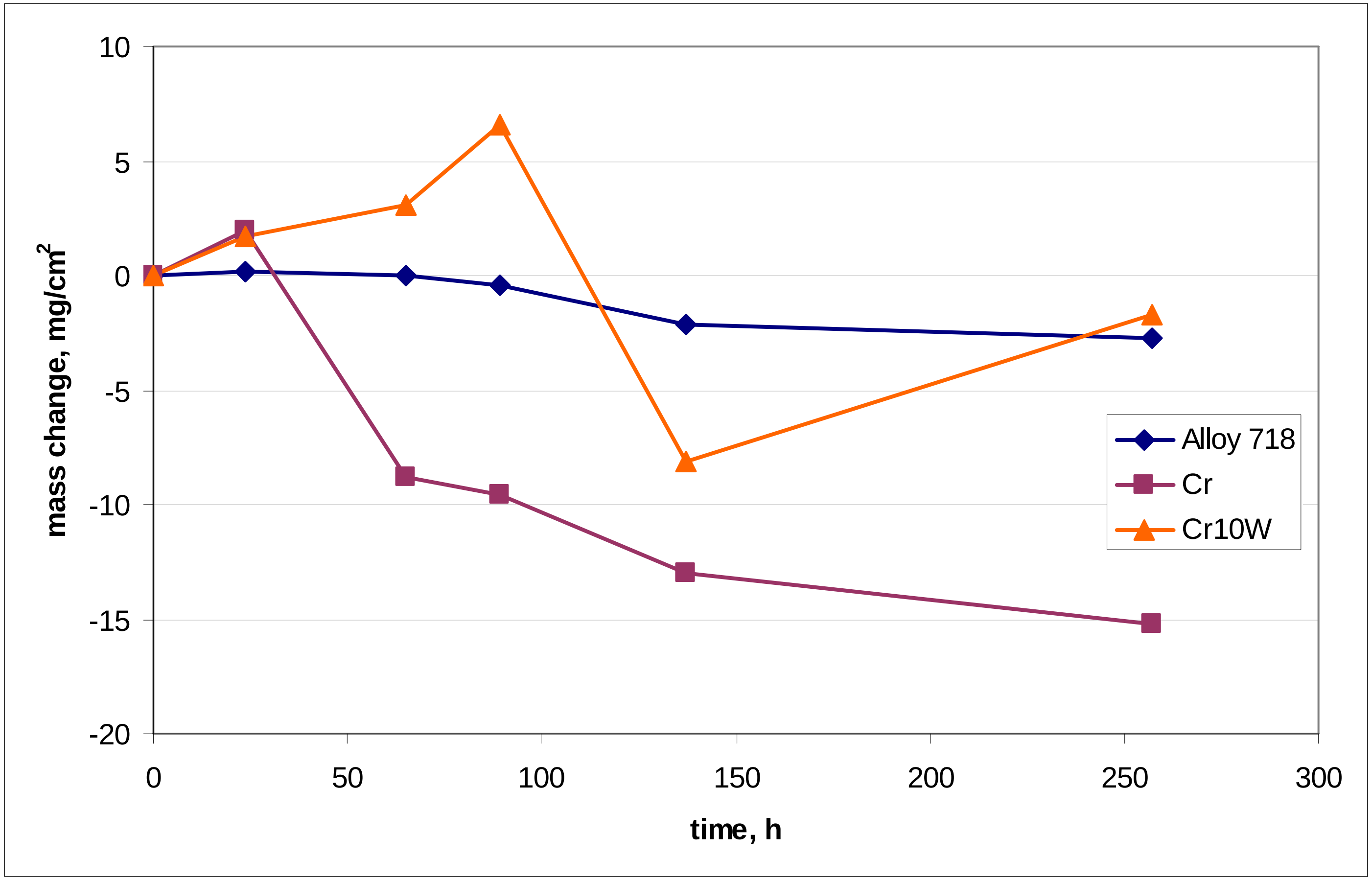


Hardness at Elevated Temperatures



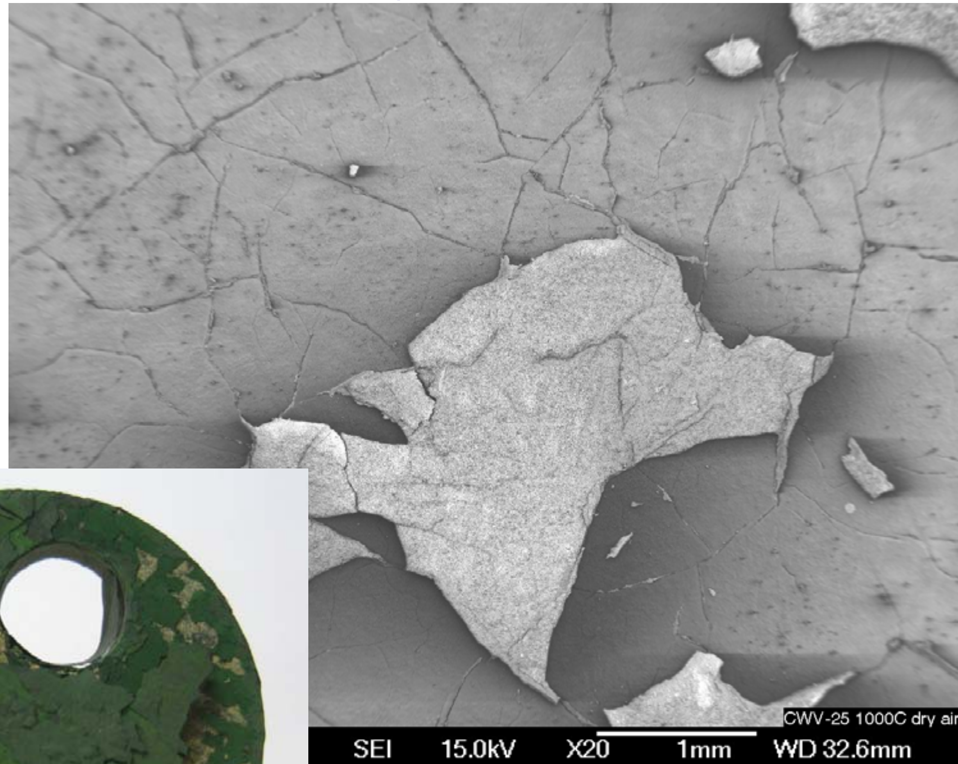
Results of hot hardness tests done using 0.5 kg load on Vicker’s indenter.

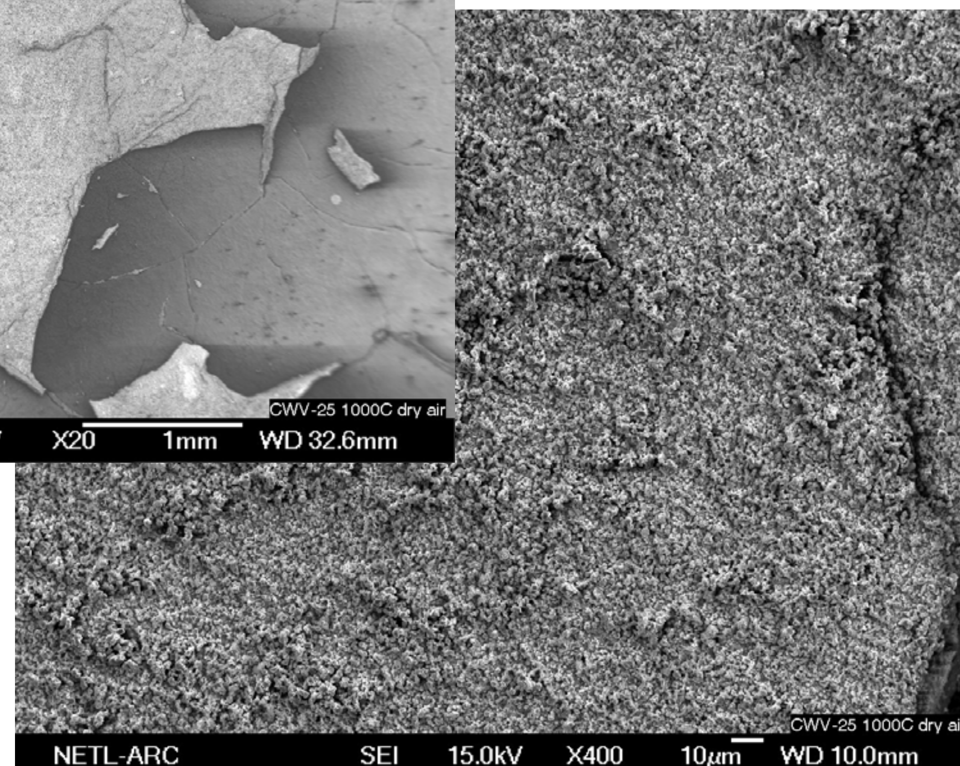
High Temperature Oxidation



@1000°C in dry air

Oxidation of Cr-10W in dry air at 1000ºC





NETL

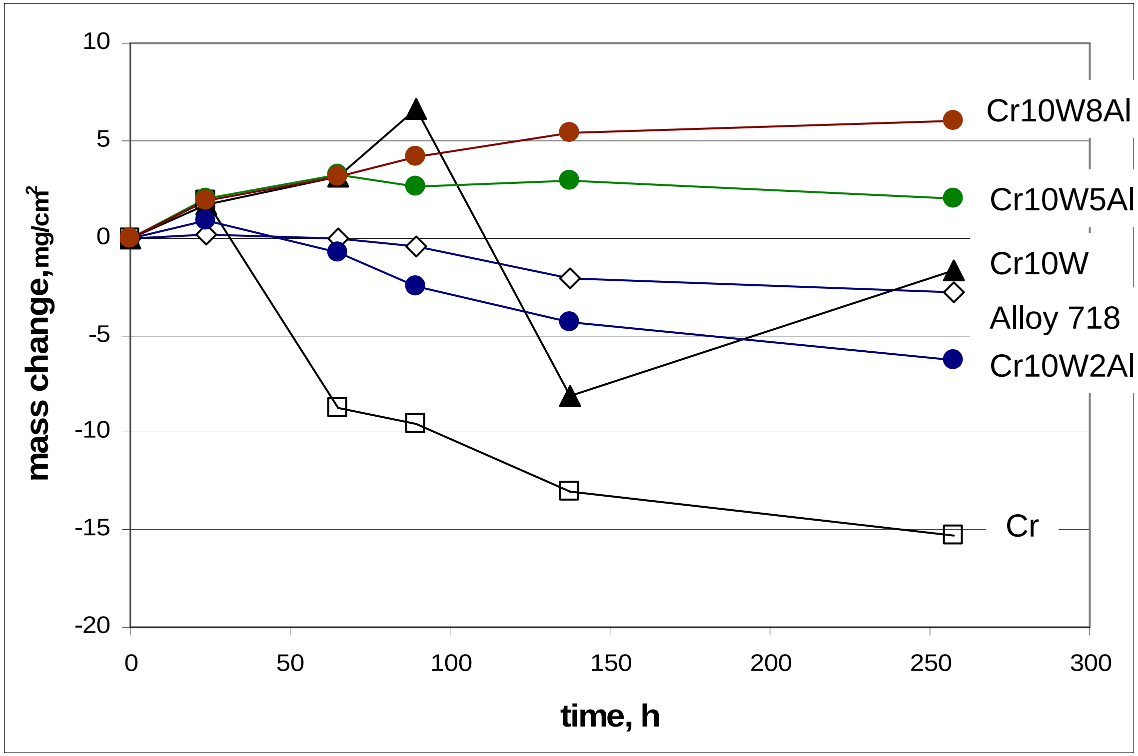
To improve high temperature oxidation resistance of Cr-W alloys

- Prevent Cr_2O_3 scale from spalling
- Obtain stable scales at temperatures above 900°C

Alloying with Aluminum

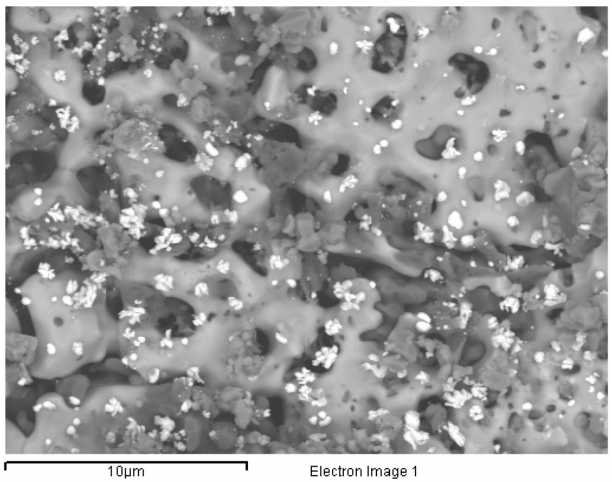
- **Aluminum is added to Cr-10W alloy**
  - 2 wt%
  - 5 wt%
  - 8 wt%

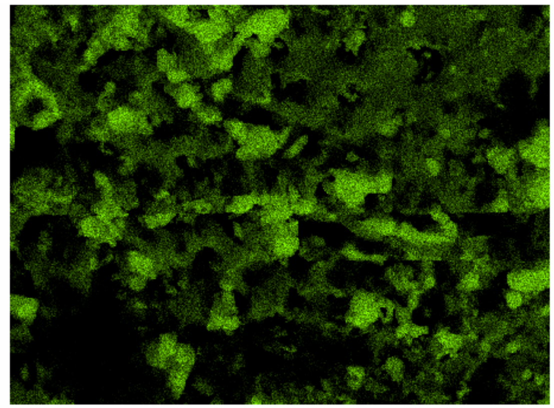
Oxidation of Cr-10W-Al Alloys



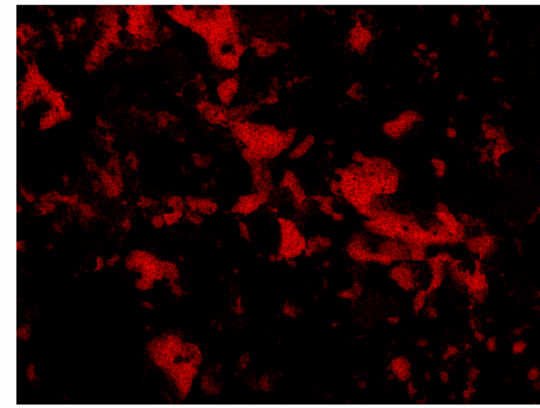
@1000°C in dry air

Elemental X-ray maps of oxidation scale on Cr-10W-8Al after exposure to dry air at 1000ºC

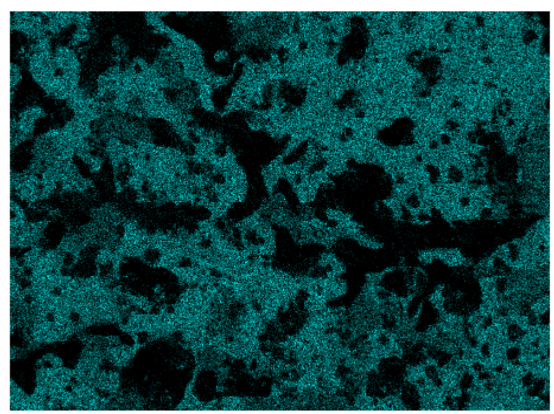




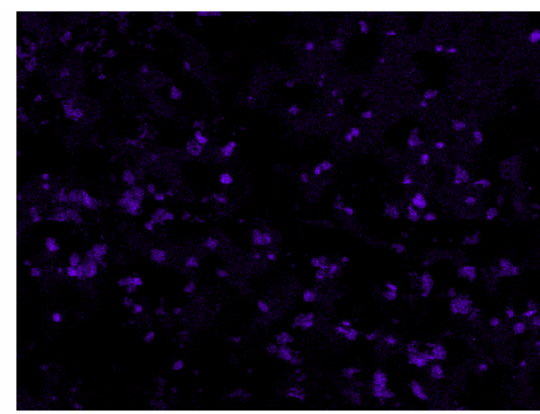
O $K_{\alpha 1}$



Al $K_{\alpha 1}$



Cr $K_{\alpha 1}$

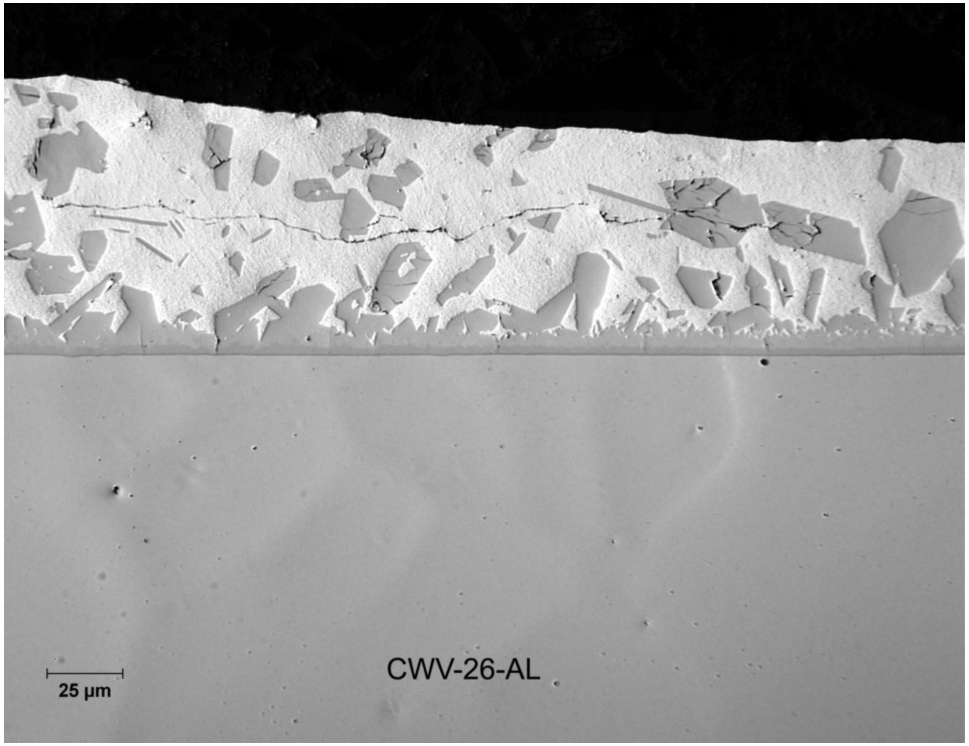


W $M_{\alpha 1}$

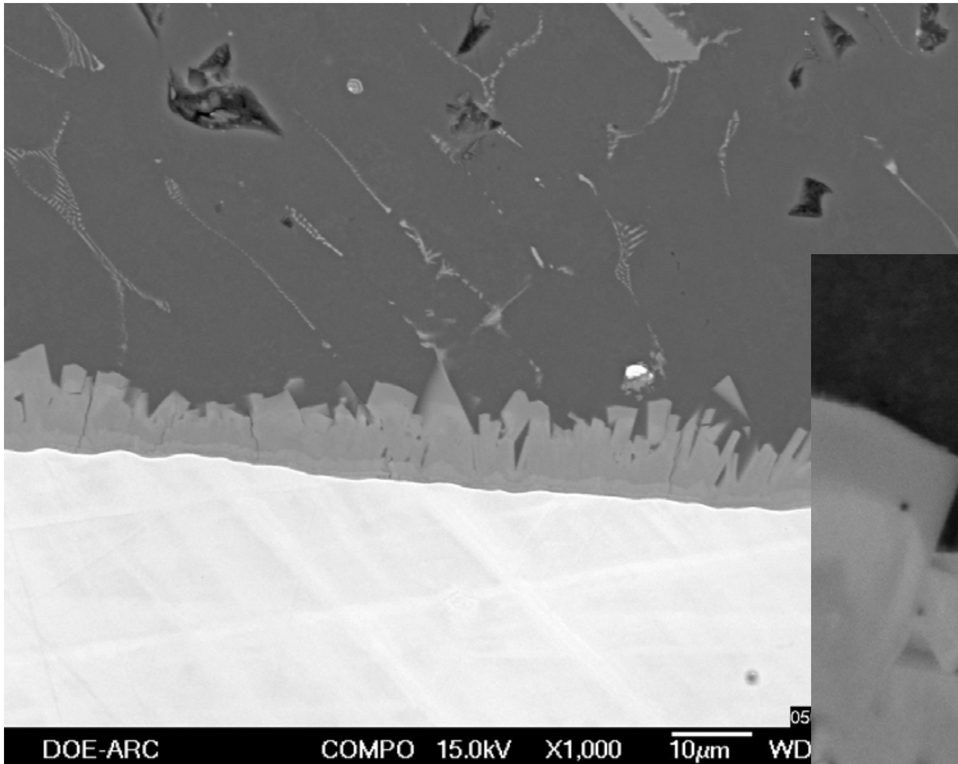
Alloying with Aluminum

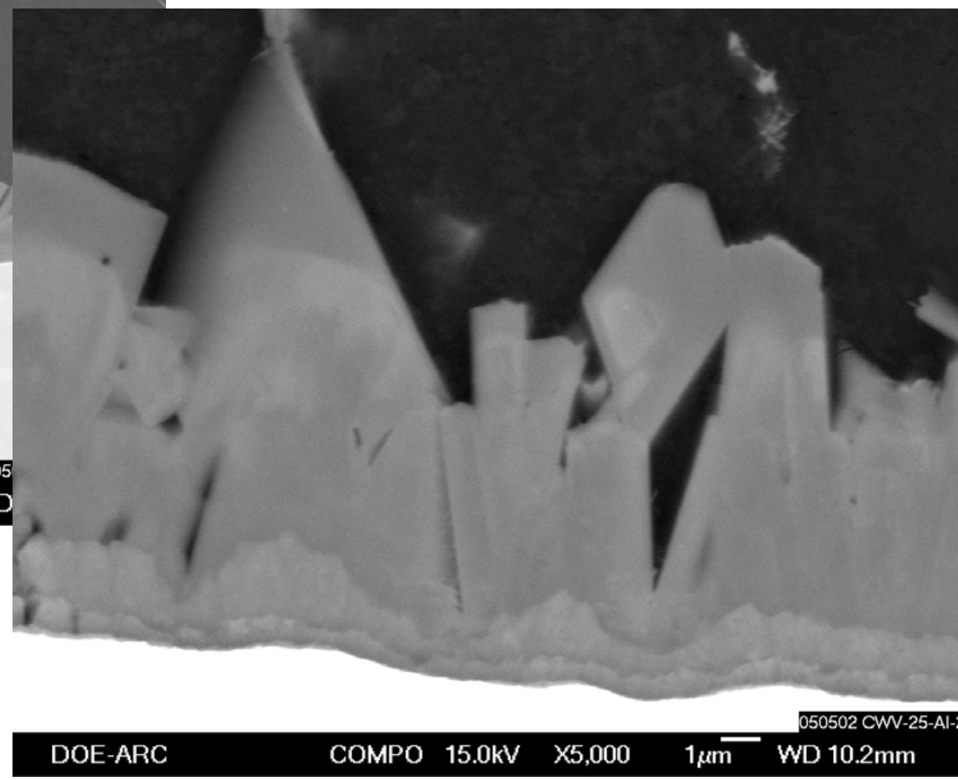
- **Improved oxidation resistance**
  - by reducing spallation drastically
  - by forming stable Al_2O_3
- **Increased brittleness**

Aluminized Cr-10W surface

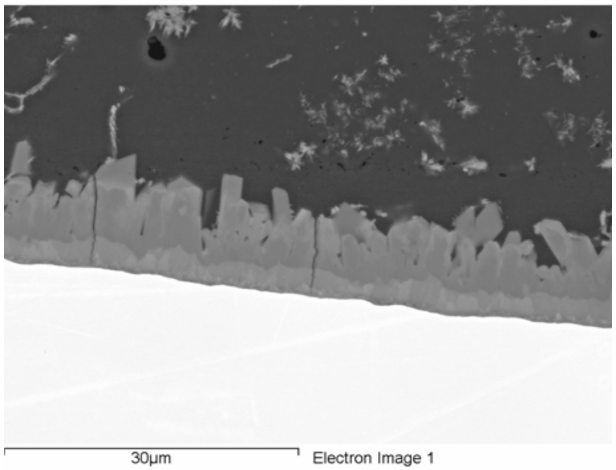


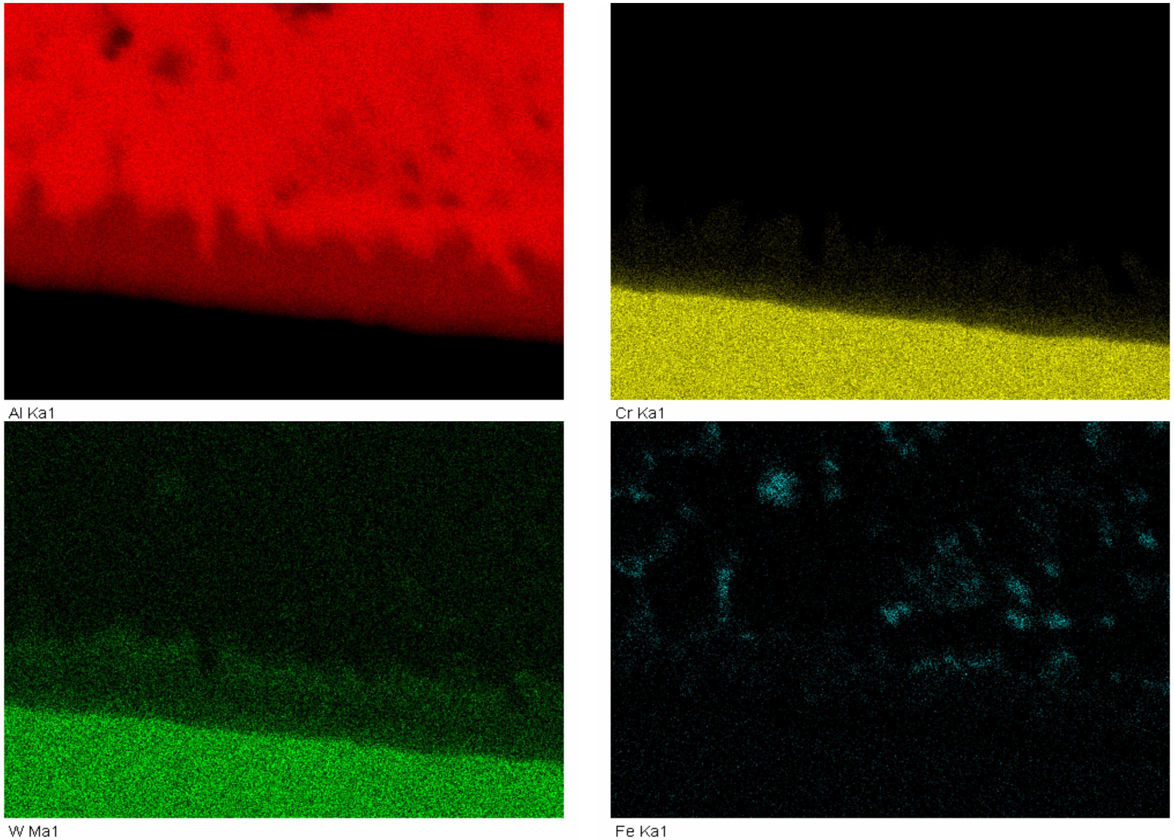
Aluminized Cr-10W surface



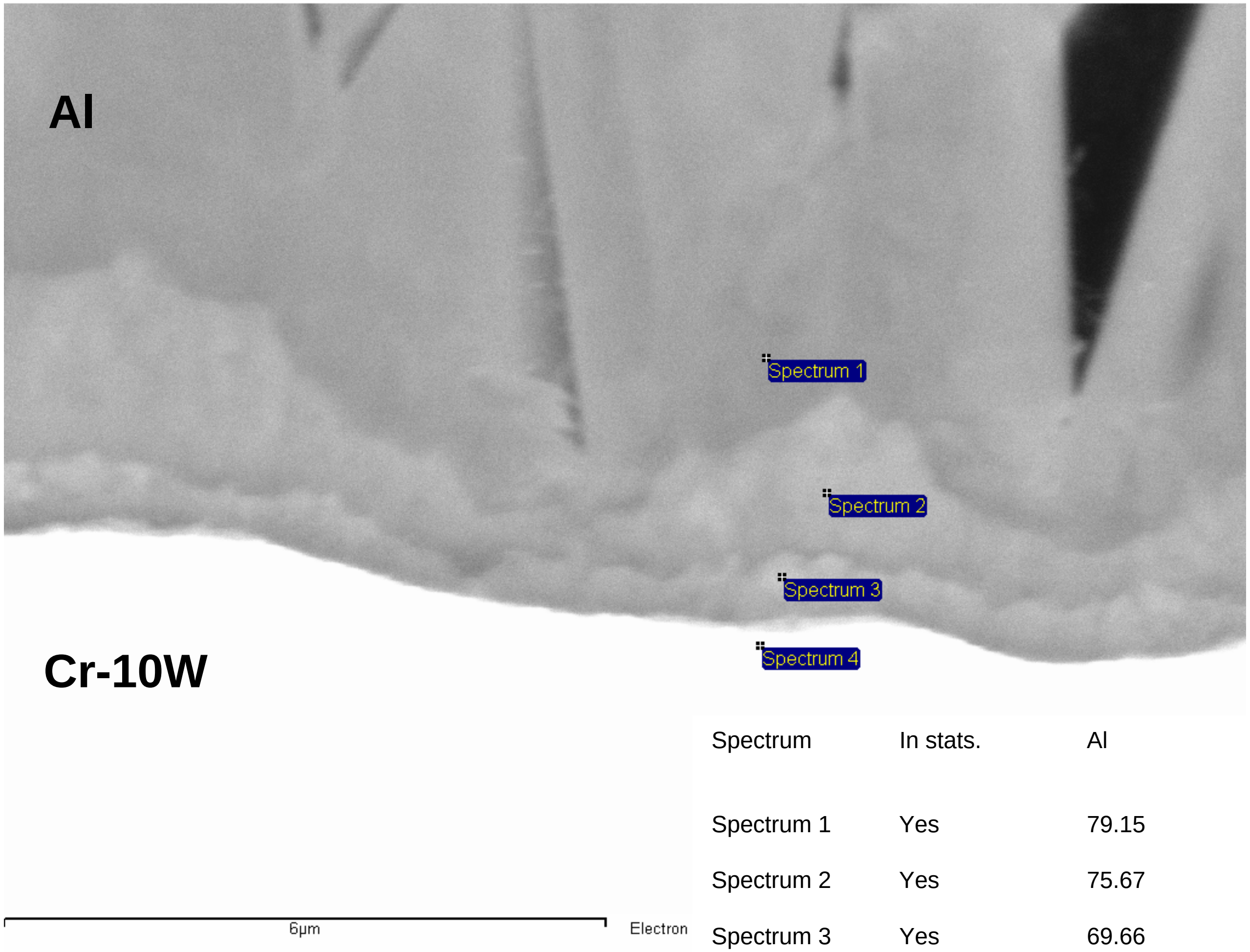


Aluminized Cr-10W surface





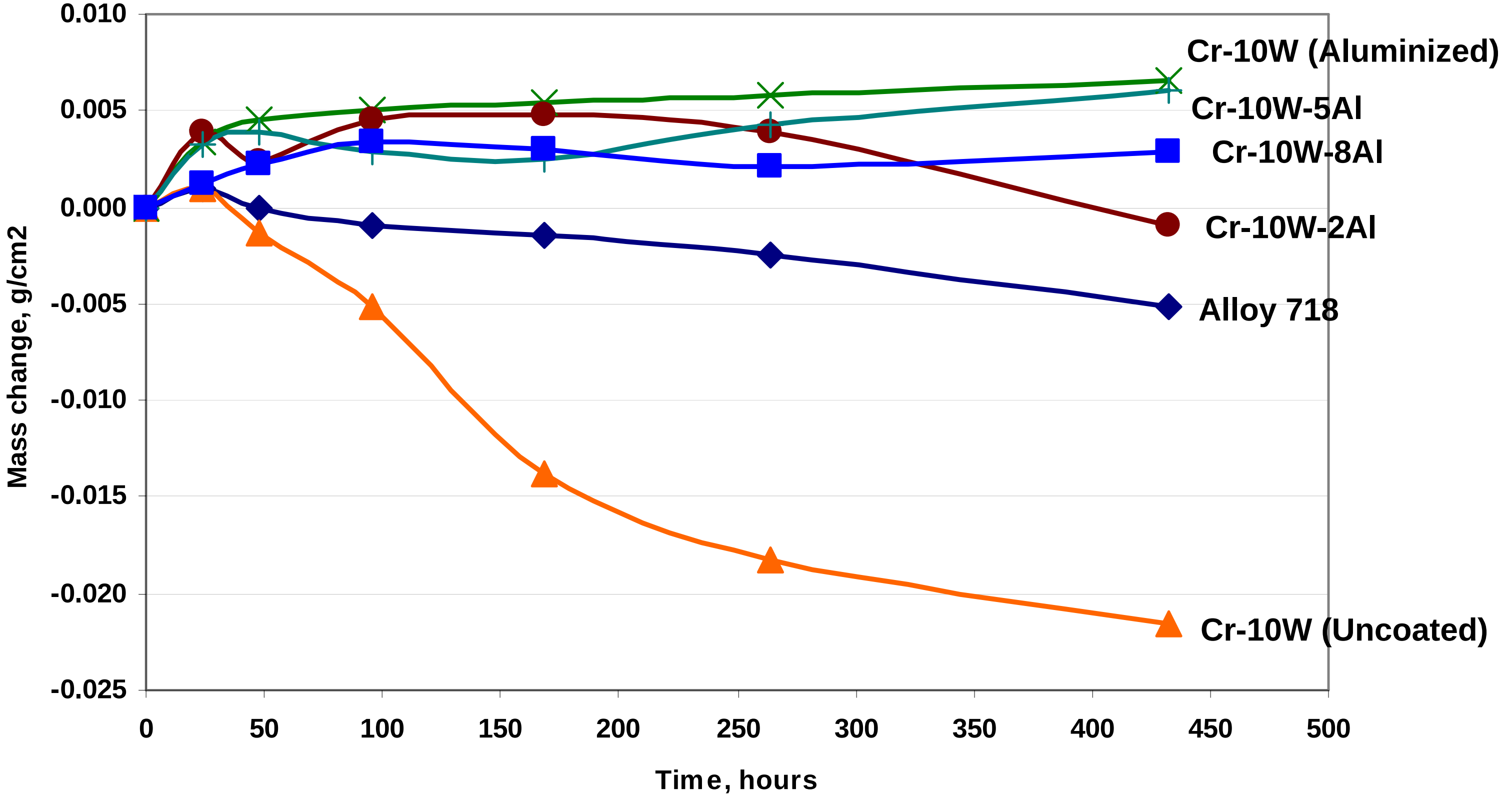
Aluminized Cr-10W surface



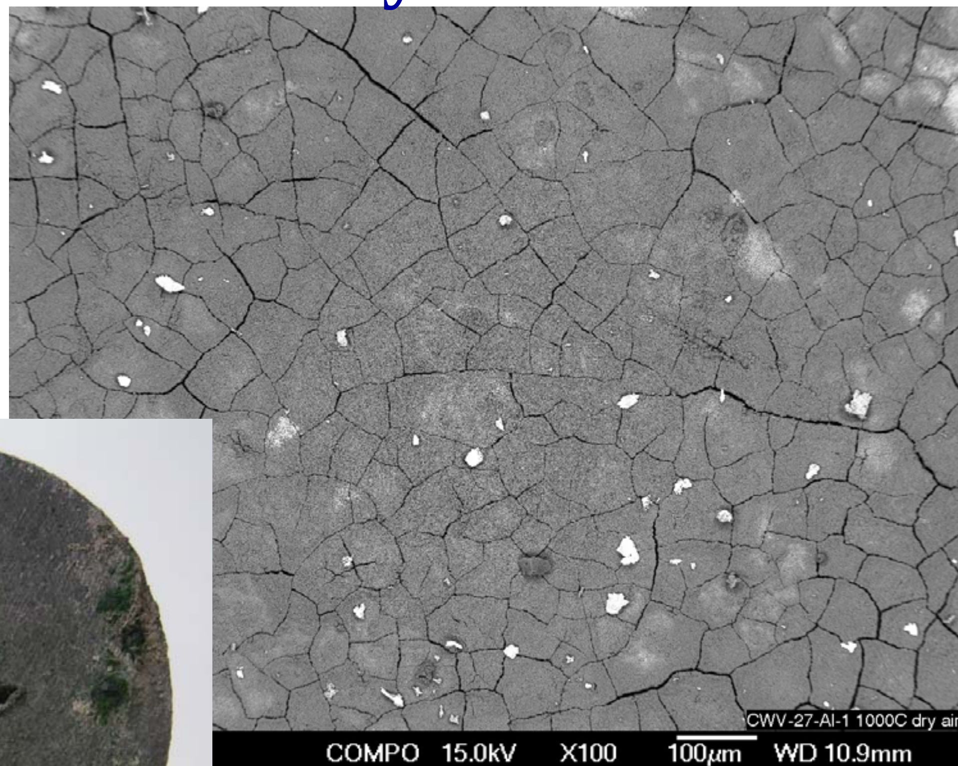
Spectrum	In stats.	Al	V	Cr	W
Spectrum 1	Yes	79.15	0.00	20.19	0.65
Spectrum 2	Yes	75.67	0.00	23.34	0.98
Spectrum 3	Yes	69.66	0.31	28.79	1.24
Spectrum 4	Yes	27.43	0.37	69.36	2.83

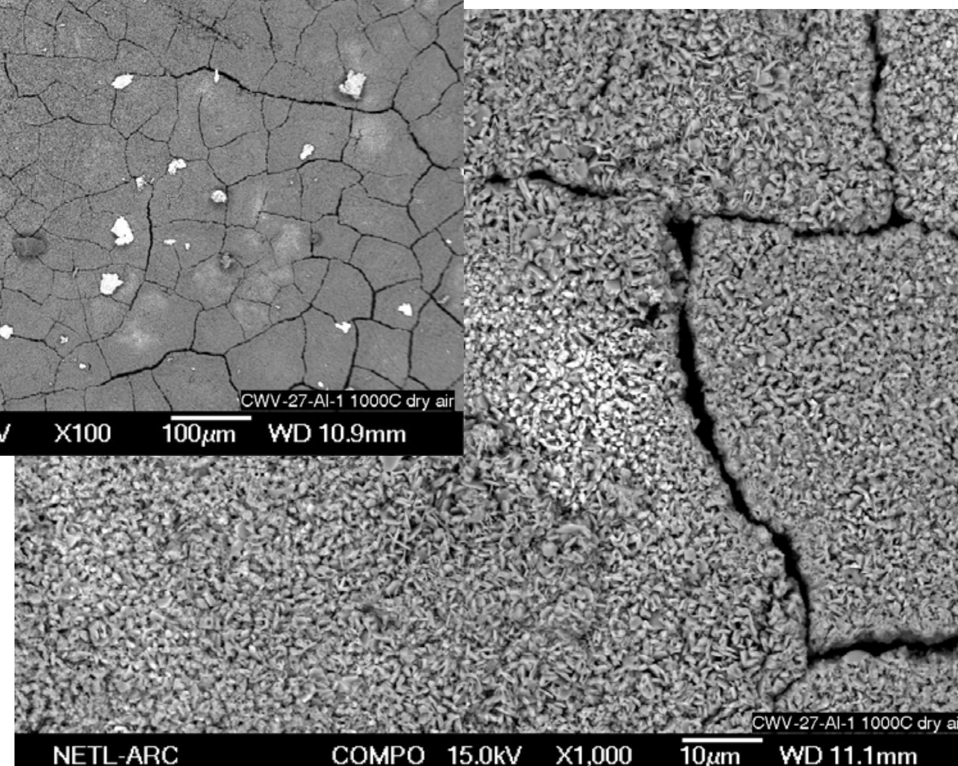
All results in atomic%

Oxidation of Cr-W in dry air at 1000ºC

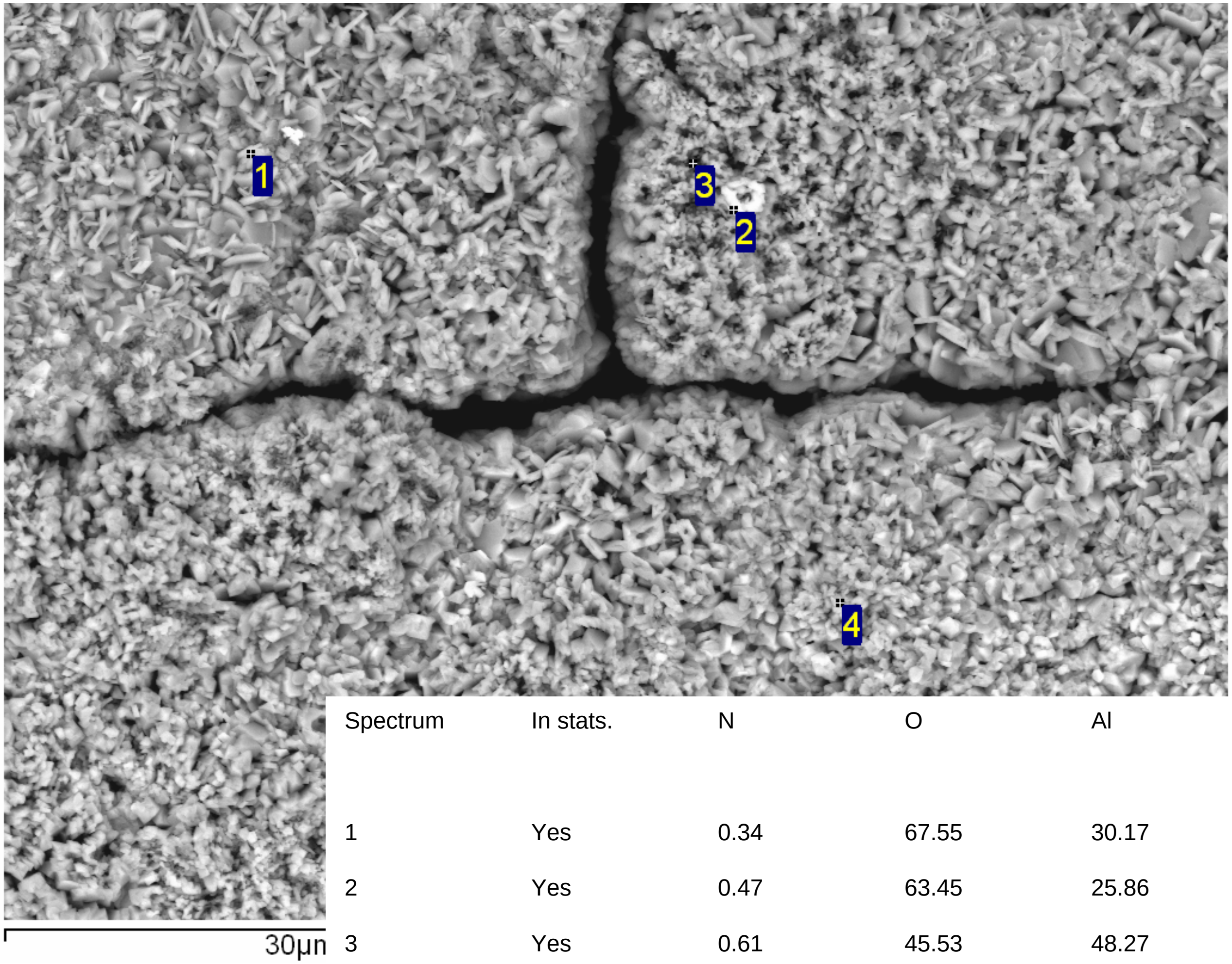


Oxidation of Aluminized Cr-10W in dry air at 1000ºC





Oxidation of Aluminized Cr-10W in dry air at 1000ºC



Spectrum	In stats.	N	O	Al	V	Cr	W
1	Yes	0.34	67.55	30.17	0.00	1.83	0.11
2	Yes	0.47	63.45	25.86	0.00	10.23	0.00
3	Yes	0.61	45.53	48.27	0.00	5.25	0.35
4	Yes	0.00	64.39	31.86	0.00	3.64	0.10

All results in atomic%

Summary

- Cr-W alloys have high strength between 1000ºC and 1300ºC.
- Cr-W alloys have poor oxidation resistance at 1000ºC in air.
- Oxidation resistance can be improved by alloying with aluminum.
- However, alloying with Al increases brittleness.
- Therefore, a better approach is aluminizing surface of Cr-W alloys.
- Aluminizing improved the oxidation resistance in dry air at 1000ºC dramatically.