Development of Chromium – Tungsten Alloys

Ömer Doğan, David Alman, Jeffrey Hawk

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Program Goals

- Develop high strength casting alloys for increased service life and power plant operational efficiency

- Develop melting and casting methods to produce the new alloys

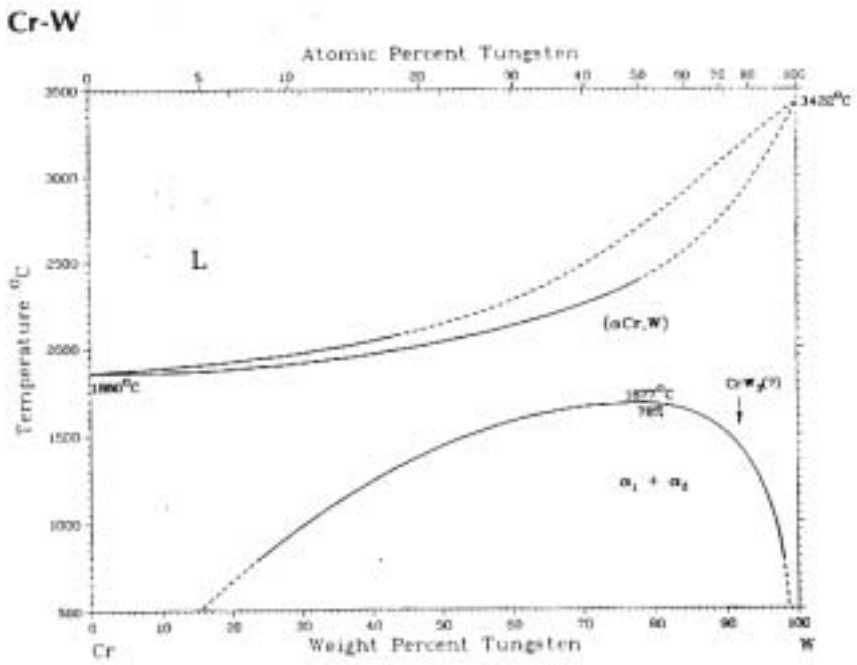
Chromium Alloys

- Advantages
  - High melting point
  - High strength at elevated temperatures
  - High temperature corrosion resistance
  - Relatively low cost
- Challenges
  - High melting point
  - Room temperature brittleness
  - High vapor pressure

Outline

- Chemistry and microstructure
- Room temperature and high temperature strength
- High temperature oxidation resistance

Cr-W Phase Diagram



From ASM Handbook Vol. 3

Chemical Compositions, wt%

7 Compositions were melted
using electrolytic Cr (Series I)

100% Cr
95Cr-5W
90Cr-10W
85Cr-15W
80Cr-20W
75Cr-25W
70Cr-30W

4 compositions were made
using low oxygen Cr (Series II)

100%Cr
90Cr-10W
80Cr-20W
70Cr-30W

Starting Materials

Series I

Electrolytic Cr (0.4 wt% O)
High Purity W

Series II

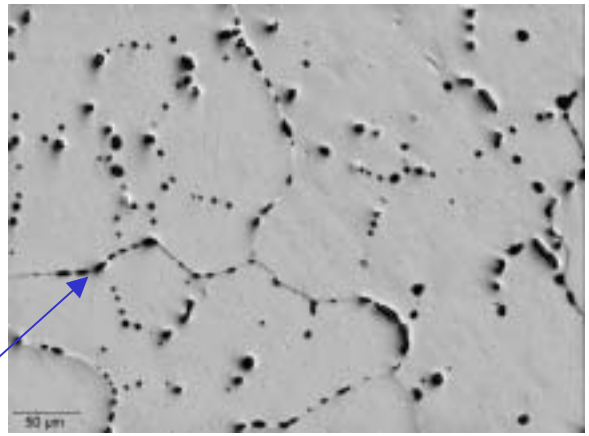
High Purity Cr (0.002 wt% O)
High Purity W

Alloy preparation in a water-cooled, copper-hearth arc furnace

Microstructure

With Electrolytic Cr Charge

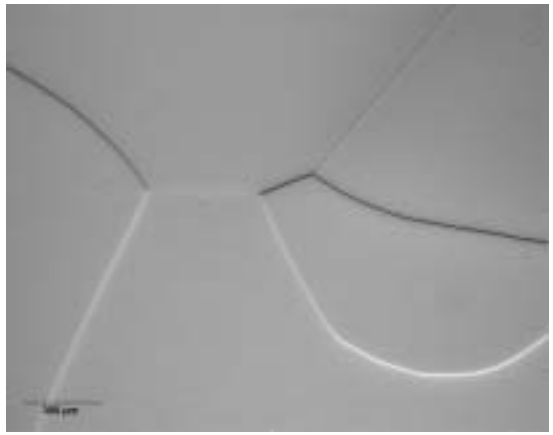
With High Purity Cr Charge



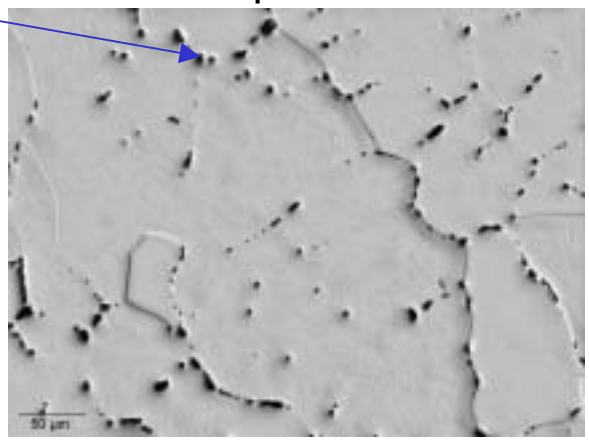
Cr_2O_3

100 µm

Cr



600 µm

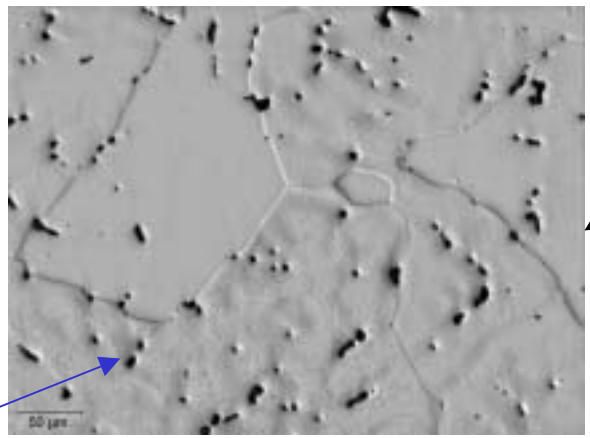


90Cr-10W

Microstructure

With Electrolytic Cr Charge

With High Purity Cr Charge

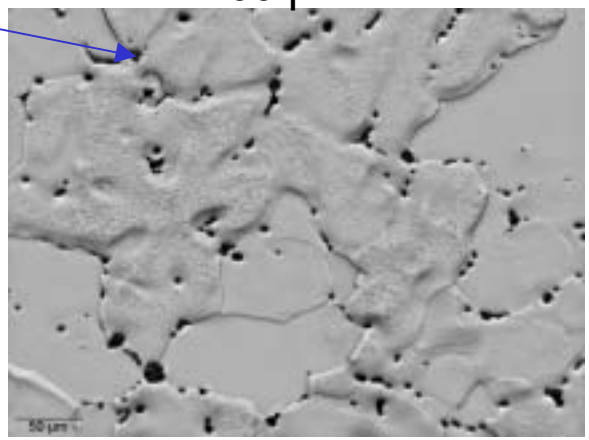


80Cr-20W

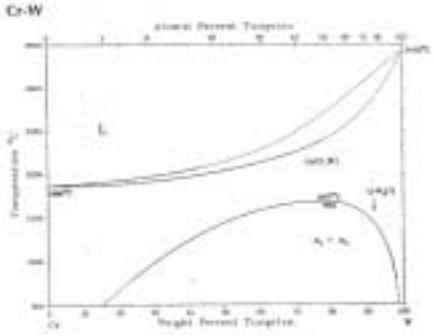
Cr_2O_3

100 µm

600 µm

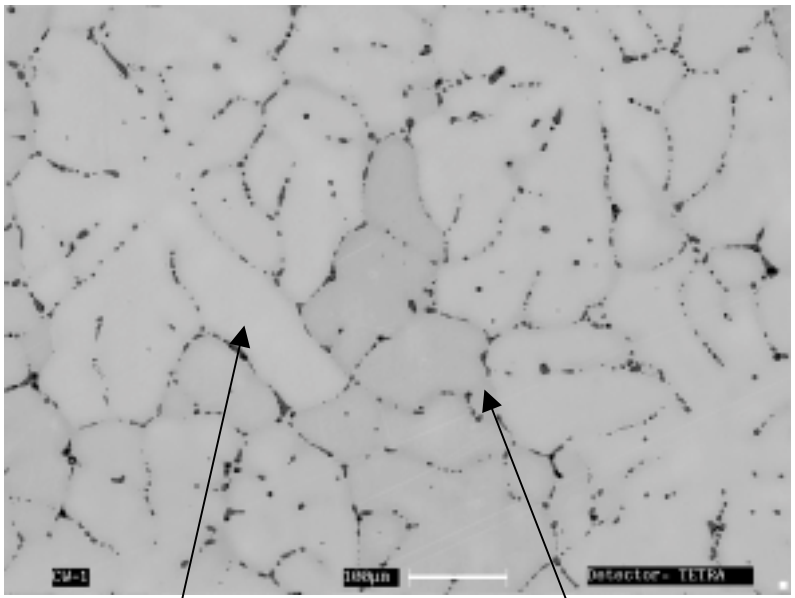


70Cr-30W



Microstructure

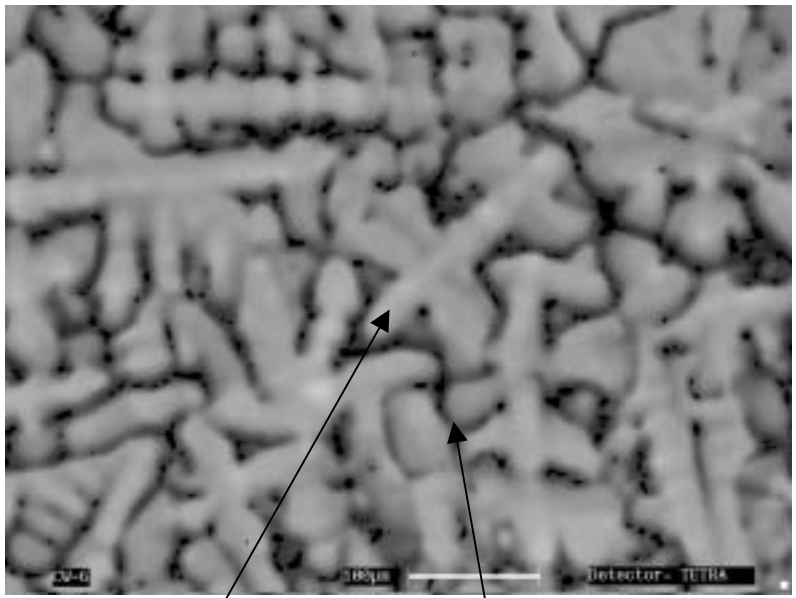
Cr-5W



6%W
94%Cr

5%W
95%Cr

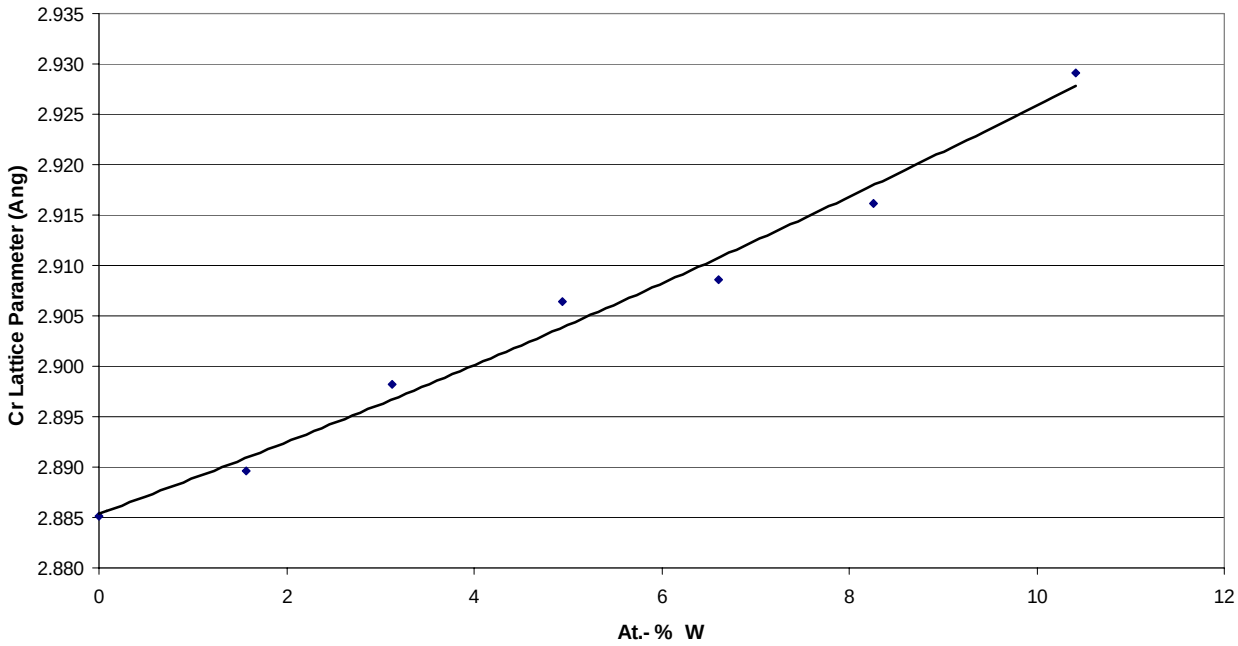
Cr-30W



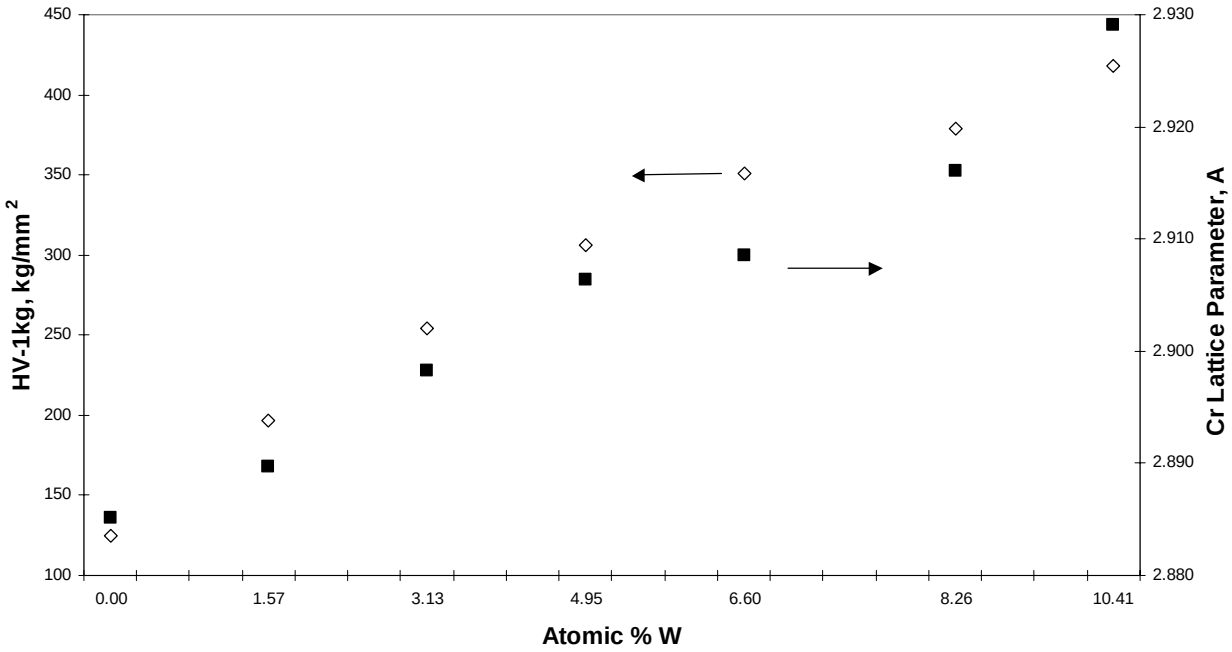
36%W
64%Cr

20%W
80%Cr

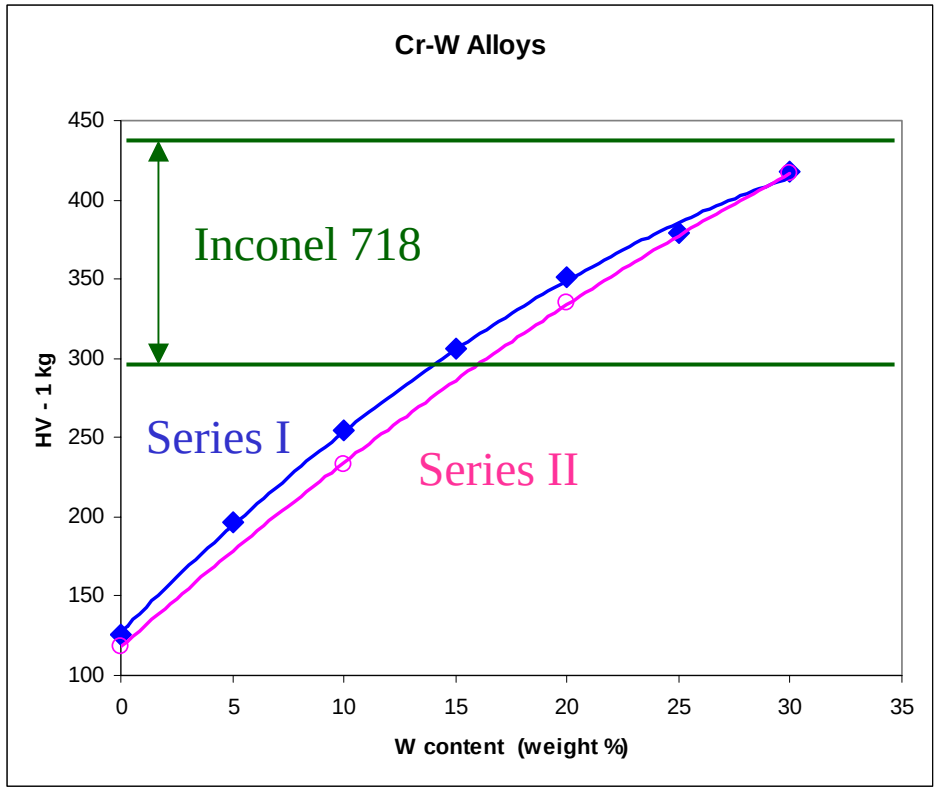
X-ray Diffraction



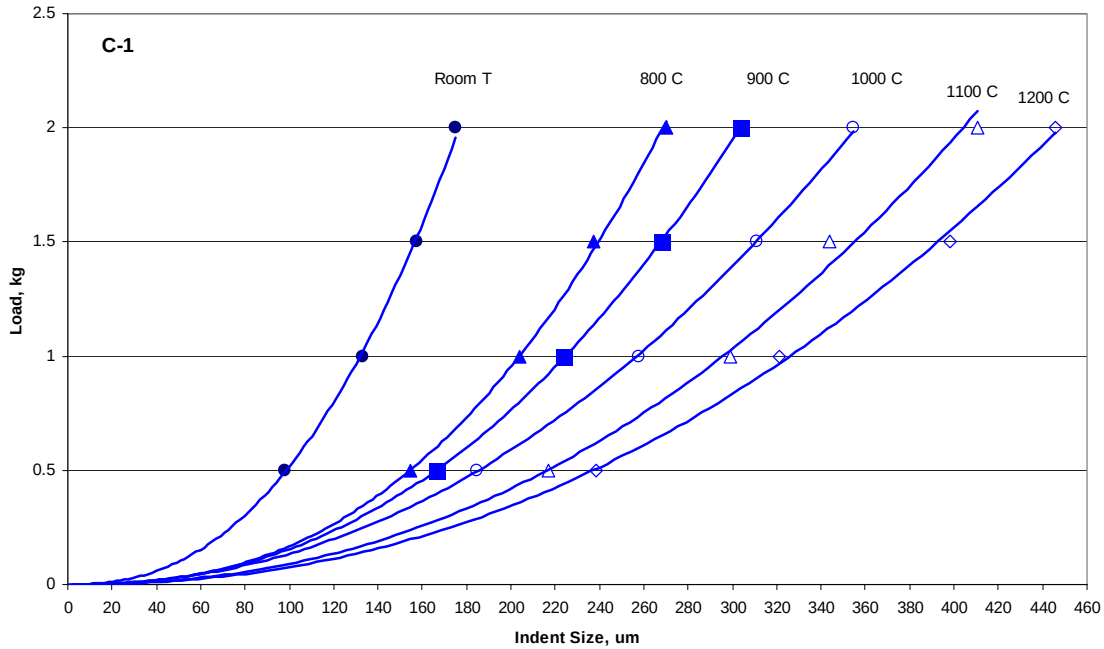
Solid Solution Strengthening



Room Temperature Strength



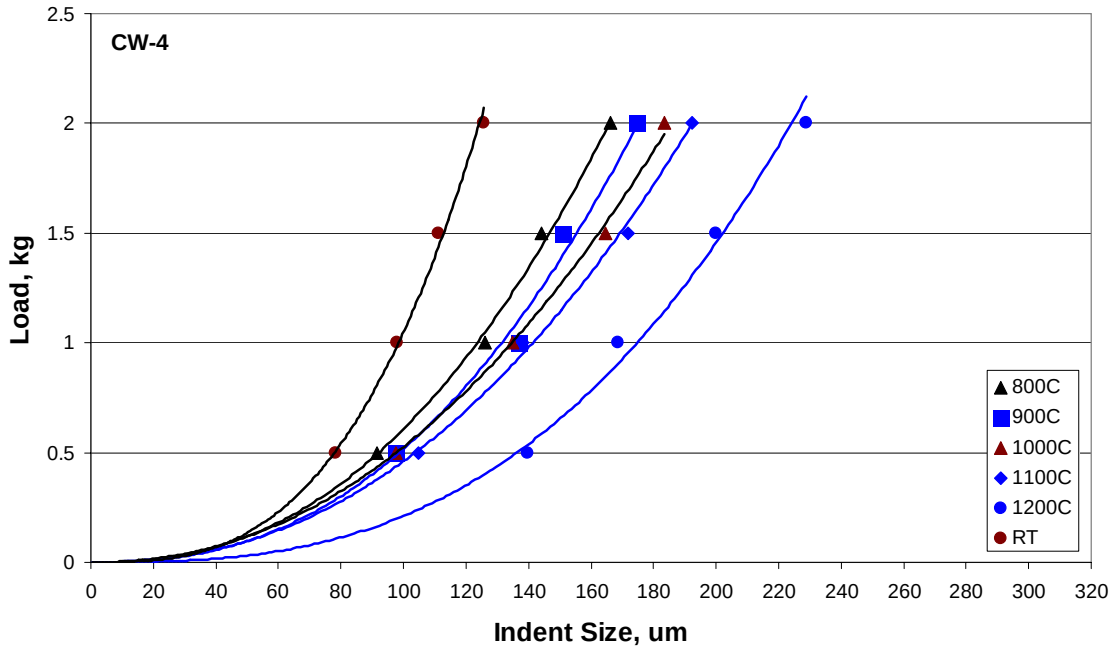
High Temperature Strength



Cr

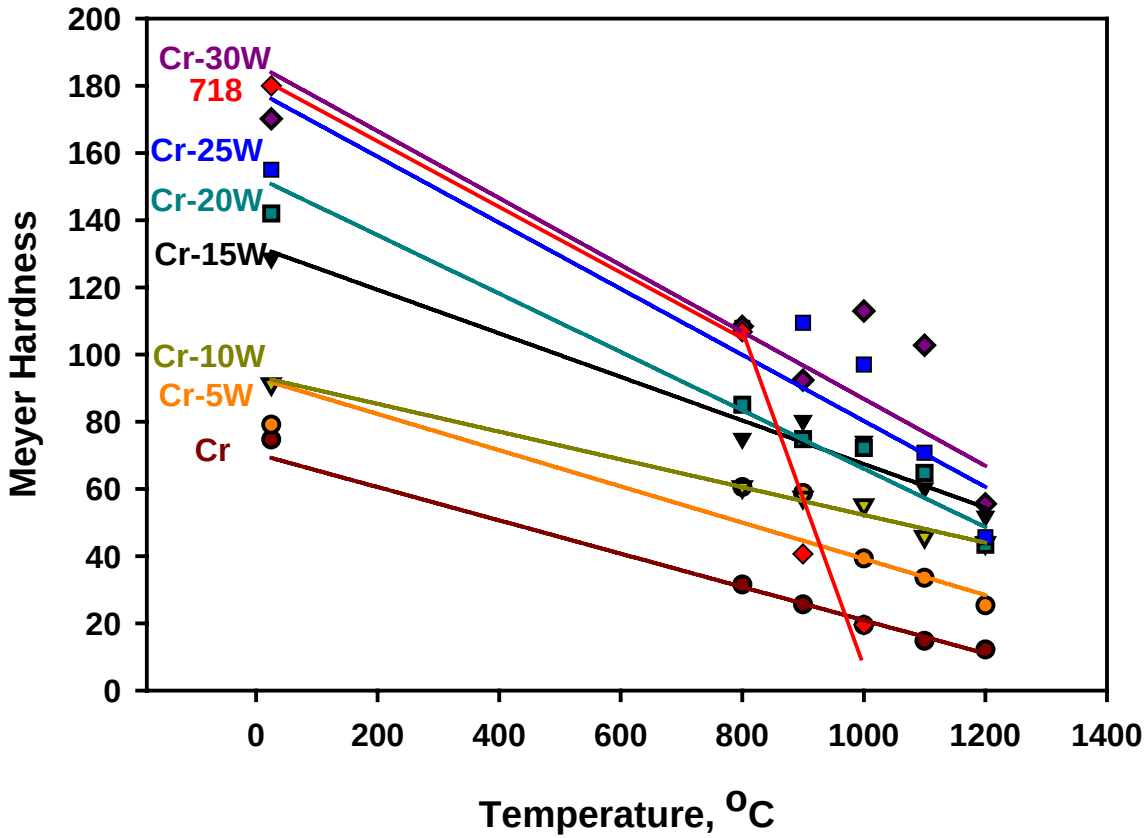
High Temperature Strength

Load = A (Diameter)^n

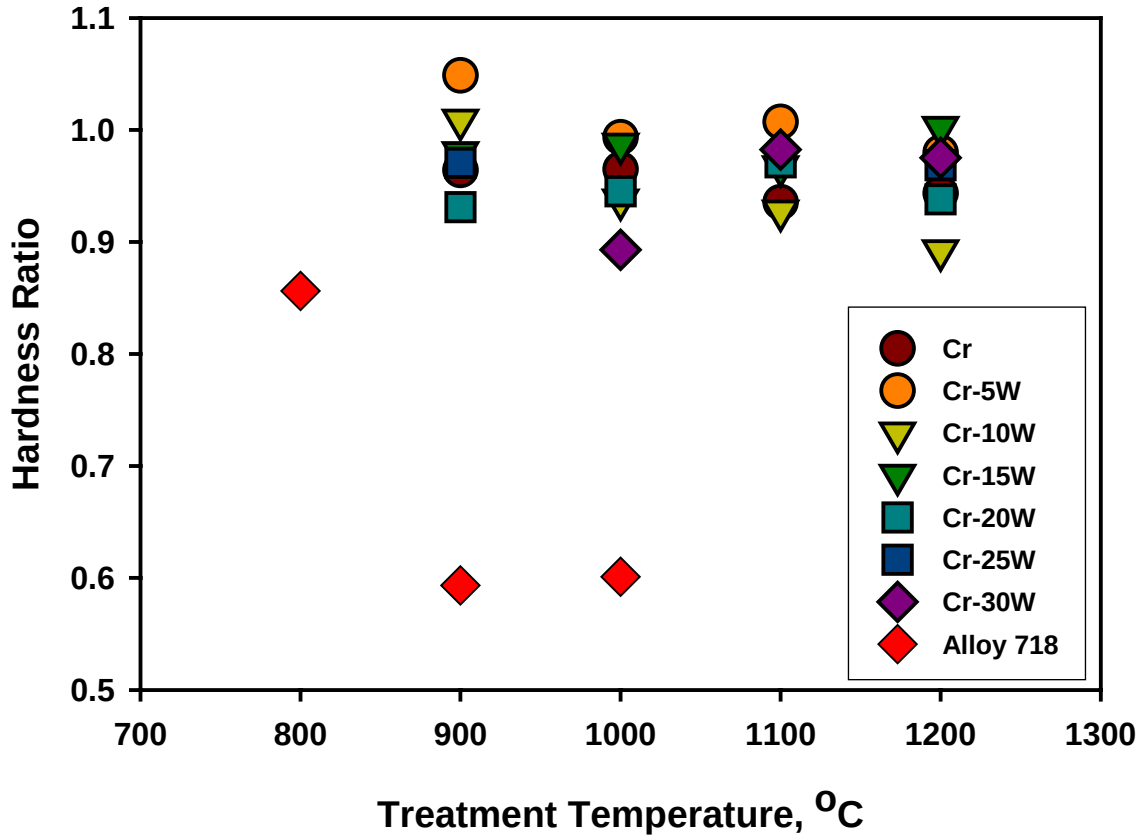


Cr-20W

High Temperature Hardness

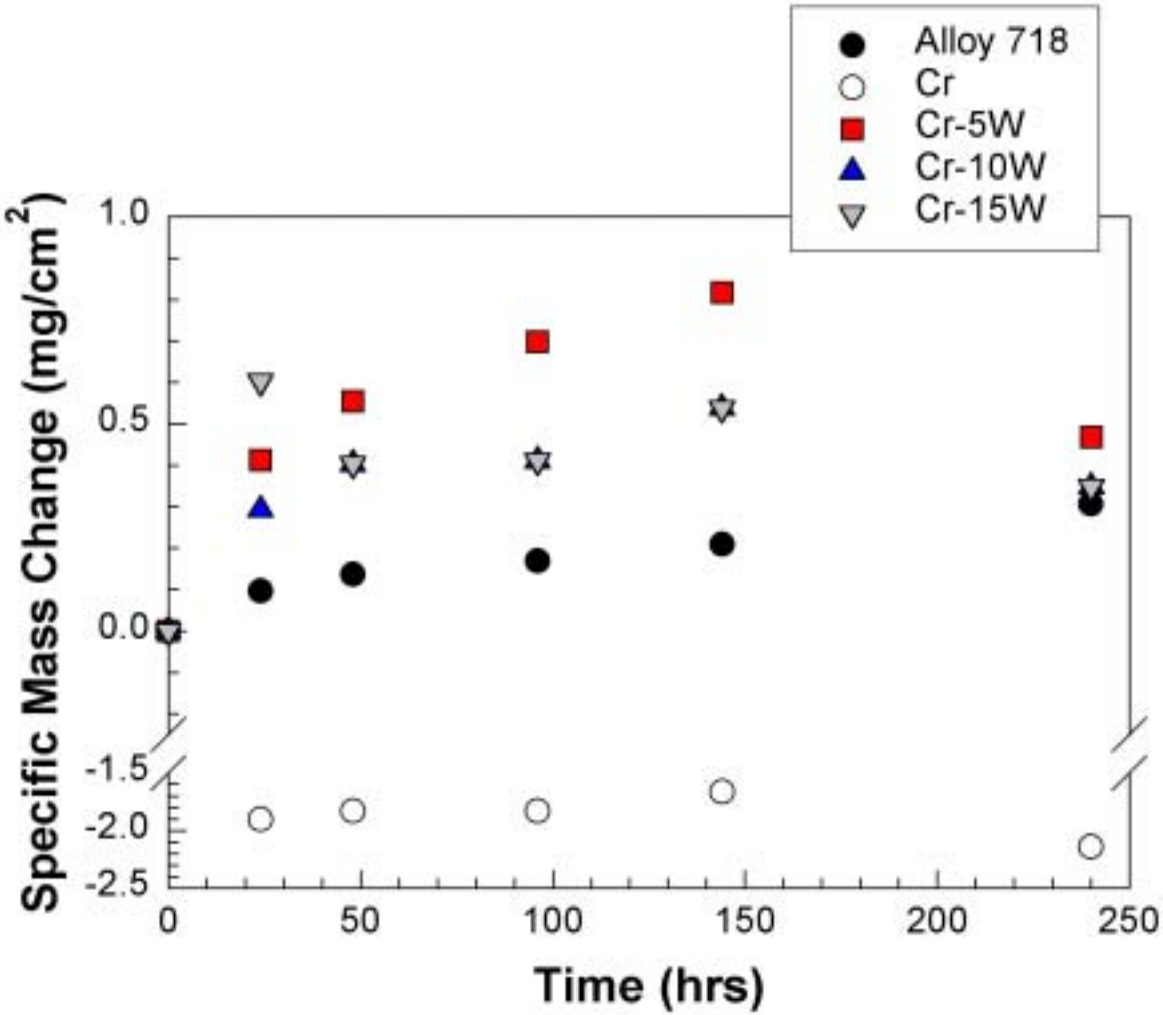


Room T Hardness After Heat Treatment



$$Hardness\ Ratio = \frac{RT\ Hardness\ after\ Heat\ Treatment}{RT\ Hardness\ before\ Heat\ Treatment}$$

High Temperature Oxidation

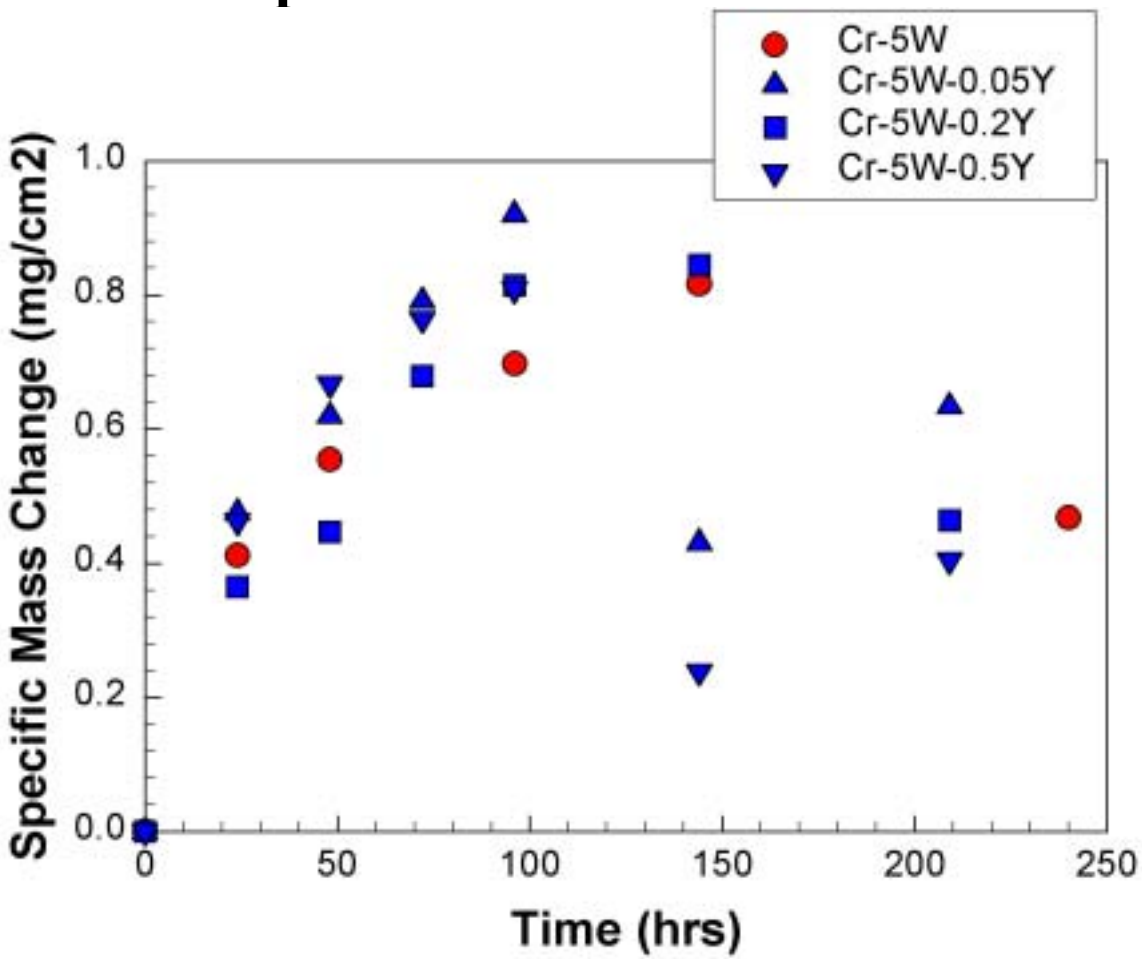


Cyclic oxidation at 800°C in dry air

Challenges to improve high temperature oxidation resistance of Cr-W alloys

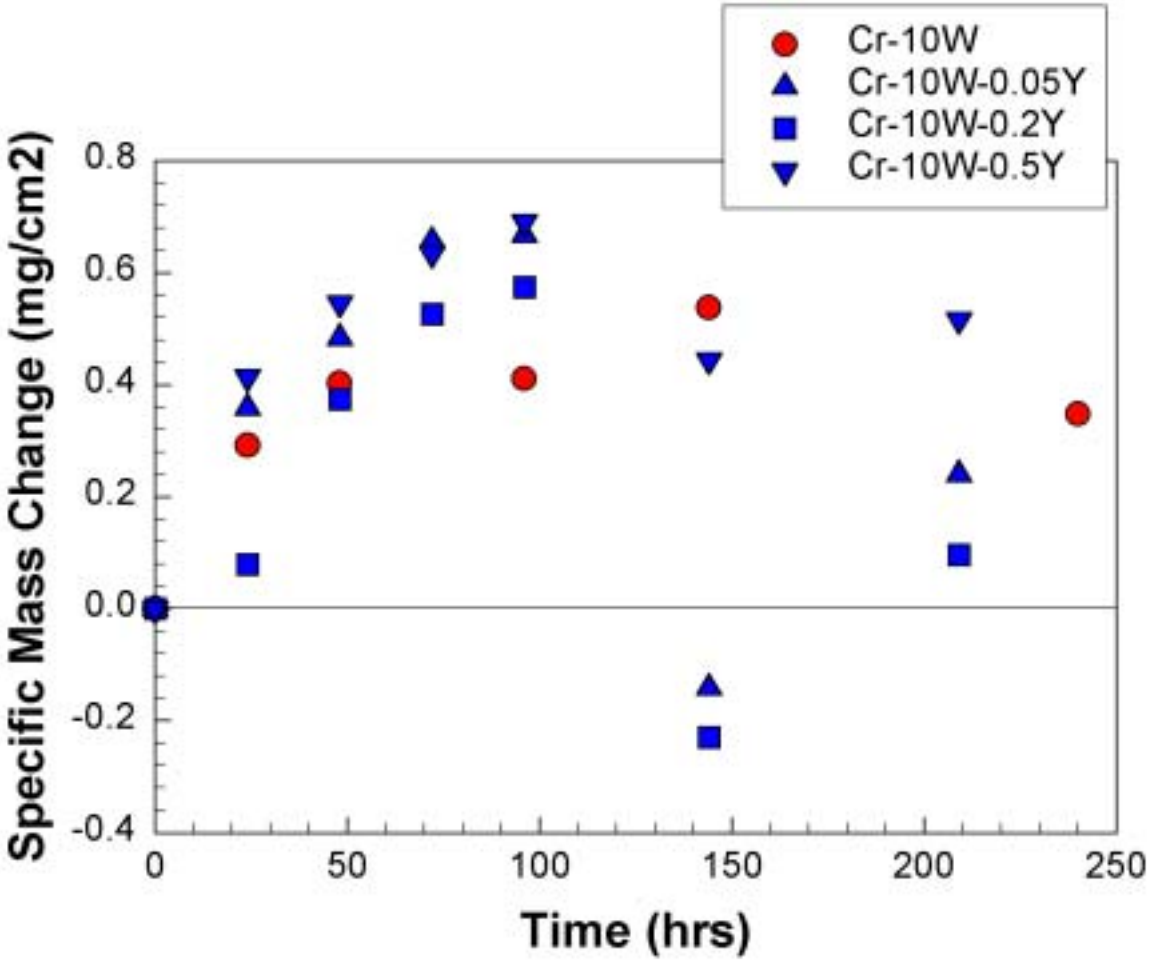
- How to prevent Cr_2O_3 scale from spalling below 900°C
- How to obtain stable scales at temperatures above 900°C

Effect of Yttrium on High Temperature Oxidation



Cyclic oxidation at 800°C in dry air

Effect of Yttrium on High Temperature Oxidation



Cyclic oxidation at 800°C in dry air

Summary

- W is an effective solid solution strengthener for Cr.
- Cr-W alloys have a linear decrease in hardness from room temperature up to 1200^{o}C where they still have sufficient strength for structural applications.
- These alloys form a protective Cr_2O_3 scale in dry air at 800^{o}C. But the scale spalls in cyclic oxidation.