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Stress Development on Carburisation and Decarburisation of Transition Metal Monocarbides (TMMCs) Above 1500°C

A. G. Metcalfe and N. B. Elsner
Hi-Z Technology, Inc.
7606 Miramar Road, San Diego, CA 92126
E. Wuchina and M Opeka
Naval Surface Warfare Center
West Bethesda, MD 20817

ABSTRACT

Small changes in composition of the surface of TMMCs can cause extremely high tensile or compressive stresses to be formed in a thin surface layer. Above 1500°C, loss of carbon from the surface becomes likely in a test atmosphere because of the increasingly low free energy of formation of carbon monoxide as the temperature is raised. Gain of carbon by carburisation can generate such high stresses that spontaneous cracks have occurred in a niobium carbide on cooling from 2200°C.

Analysis has shown that the stresses are of two origins. Isothermal addition or subtraction of carbon from the face centered cubic cell generates strains measured by ± • a/a where a is the unit cell dimension. This has been called the formation strain. On cooling a test specimen with such a modified surface, the difference in coefficient of expansion will cause additional strains between core and surface. These are called cooling strains. Both types of strain may be small, but the very high elastic moduli of these materials makes these strains the cause of high stresses.

If the isothermal addition or subtraction of carbon from the surface takes place in the plastic region, the formation strains may be wholly relaxed. In this case only the cooling strains may need to be considered. Measurements at 2200-2400°C for tantalum carbide satisfy this condition.

Both the formation and cooling strains may be tensile or compressive. The highest melting point material know, tantalum carbide (M.Pt 3985°C) can exhibit both types of strain. This material is analyzed in greater detail because of its importance for the very highest temperatures of application. Typical results are shown in the Table.

Measurement of the mechanical and physical properties of TMMCs requires control of the surface composition. Reduction in carbon content of a thin surface layer is predicted to be from 6.22% (TaC) to 6.15% to reduce the strength by the amount observed in recent bend tests. Measurement of this small amount of decarburisation is a difficult task and is under study.

Internal reaction with dissolved oxygen, evaporation of carbon and reaction with oxygen in the test atmosphere have been cited as potential causes of loss of carbon at the surface. Each of these is discussed to assess its importance.

Table
Calculated Strain and Stress Development in Tantalum Carbide (TaC_X)for • x = ± 0.01

Line	Stress or Strain Origin	$TaC_{0.99}$		$TaC_{0.75}$	
		• x = -0.01	• x = +0.01	• x = -0.01	• x = +0.01
1	Strain formation at 1650°C (Units of 10^{-6})	360 Tens.	360 Comp.	360 Tens.	360 Comp.
2	Stress at 1650C (psi) (Assume E = 30 million psi)	10,800 Tens.	10,800 Comp.	10,800 Tens.	10,800 Comp.
3	Cooling strain at ambient (Units of 10^{-6})	67 Comp.	67 Tens.	140 Tens.	140 Comp.
4	Total strain at ambient (Units of 10^{-6})	293 Tens.	293 Comp.	500 Tens	500 Comp.
5	Stress at ambient (psi) (E = 70 million psi)	20,500 Tens.	20,500 Comp.	35,000 Tens.	35,000 Comp.

Note: Tens. indicates tensile; Comp. Indicates compressive.