On the Solubility of Chromium in Cubic Carbides in WC-Co

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Abstract

The solubility of Cr in cubic carbides in the systems WC-Co-TaC and WC-Co-ZrC has been determined using equilibrium samples. Thermodynamic calculations were used to design the alloys through extrapolations of Gibbs energy expressions. The alloys were designed to have a microstructure containing the following phases: WC, liquid, M_7C_3, graphite and cubic carbide. The alloys were investigated using scanning electron microscopy and analyzed using energy-dispersive X-ray spectrometry. The present work shows how the Cr solubility depends on which cubic carbide former that is present. The WC-Co-Cr-Zr alloy has no detectable amount of Cr whereas the WC-Co-Cr-Ta alloy has 12 % Cr in the cubic carbide.

Keywords : Cr, cubic carbides, thermodynamics, SEM, EDS

1. Introduction

Cubic carbides or carbonitrides are often added to WC-Co based compounds in order to increase the resistance to plastic deformation or as gradient formers. In the production of cemented carbides it is important to retard and control the grain growth of WC during sintering. To achieve this, grain growth inhibitors such as V, Ti, Ta, Nb and Cr are widely used. However, there is little known about the solubility of Cr in the cubic carbides.

The aim of this study is to understand how Cr will distribute between the different phases in cemented carbide systems at equilibrium. The following systems have been investigated in this study: C-Co-W-Cr-Ta and C-Co-W-Cr-Zr.

2. Experimental and Results

2.1 Thermodynamic calculations

Each sample contains five elements; C, Co, Cr, W and M (M = Ta, Zr). The model alloys were designed using the Thermo-Calc software [1] and available thermodynamic databases. Thermo-Calc is a software used for thermodynamic calculations that combines various databases for thermo-chemistry and metallurgy.

In order to be able to design alloys where Cr co-exists with cubic carbide formers the thermodynamic databases CCC1 [2] and Co-Cr-C by Markström *et al.* [3] were combined with thermodynamic data from a light-metal alloy database, called COST [4], and the stability of CrC by Lee [5]. The calculations are therefore a result of rough extrapolations and not expected to be completely accurate. The set of samples was designed to be in equilibrium with graphite.

2.2 Manufacturing of materials

The raw materials used are WC, W, Cr_3C_2, Co, C, TaC and ZrC. Appropriate mixtures of the various pure carbides, cobalt, carbon and tungsten were mixed by milling for 8 hours. After mixing, the powders were dried, pressed and sintered. The samples containing Ta were sintered for 24 h in vacuum at T=1410 °C , whereas the samples containing Zr were sintered for 4 h in vacuum. The long sintering times were chosen to coarsen the particles of the different carbide phases in order to facilitate the analysis. The initial cooling rate was 15 °/min from 1410–1200 °C, thereafter as quickly as possible. On cooling the liquid will transform into solid binder.

Table 1. The chemical composition of the equilibrium samples.

[at%]	W	Co	Cr	C	Ta	Zr
WC-Co-Ta	11.4	21.0	17.0	40.6	10.0	0
WC-Co-Zr	11.4	20.6	17.0	42.0	0	9.0

2.3 Analysis

The samples were initially examined by light-optical microscopy (LOM) to examine the overall microstructure. The samples were investigated using X-ray diffractometry (XRD) to assure that the MC and M_7C_3 carbides were present. To measure the metallic contents of the cubic carbides, the samples were studied using scanning electron microscopy (SEM) and analyzed using energy-dispersive X-ray spectrometry (EDS). The Ta sample was in addition analyzed by wave-length dispersive X-ray spectrometry (WDS) in the electron probe microanalyzer (EPMA).

The Zr sample has no detectable amount of Cr in the cubic carbide, whereas the WC-Co-Cr-Ta-alloy has 12 % Cr in the cubic carbide. Hence, the Cr-content of the matrix and the cubic carbides may be controlled by interacting alloying elements.

3. Summary and Conclusion

The system WC-Co-Cr-Ta results in a Cr-containing cubic carbide. Experimental work on the system WC-Co-Ta has been reported by Kruse *et al.*[6]. When comparing the work by Kruse *et al.* and the present work, the W-content in the cubic carbides with and without Cr is approximately constant (see Table 2). Hence, it is concluded that Cr replaces Ta in the cubic carbide.

Table 2. The chemical composition of the cubic carbide in the systems WC-Co-Cr-Ta (present work) compared to WC-Co-Ta (the work by Kruse *et al.*)

[at%]		Cr	W	Ta
The present work	cubic carbide	12	7	81
Kruse *et al* [6]	cubic carbide	without Cr	4	96

Comparing thermodynamic calculations based on extrapolations from the databases mentioned in the introduction, it is possible to calculate and design alloys. In Table 3 the comparison between the calculated and the experimental values are given.

Table 3. Experimental (SEM-EDS) and calculated values of the composition of the Ta-alloy (metallic elements).

[at%]		Cr	W	Co	Ta
Experi-mental	cubic carbide	12	7	----	81
	M_7C_3	58	3	39	----
Calculated	cubic carbide	9	12	1	77
	M_7C_3	64	7	29	----

The conclusion is that the solubility of Cr in the cubic carbide is strongly dependent on which cubic carbide former that is added to the system. The WC-Co-Cr-Zr alloy

4. References

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