PM2006
2006 POWDER METALLURGY
World Congress

PC07-T-19

Microstructure Features of Large Grains in WC-Co Alloys

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Abstract

This paper presents a study of large grains by transmission electron microscopy in two WC-Co alloys, one W rich and one C rich. In the W rich alloy, some large grains are found in contact with the η phase. The C content influences the morphology of large grains: they are flatter in the C rich alloy with smoother interfaces. Whatever the C content, they contain few dislocations compared to matrix grains except often in a small area. Small WC grains are often found inside the large grains. They have likely been engulfed during the growth of the large grains owing to the low boundary energy.

Keywords : WC-Co, abnormal grains, grain shape

1. Introduction

Submicron and ultrafine–grained WC-Co alloys are now developed for applications such as microdrills for printed circuits boards and metal cutting inserts. As the driving force for densification is the overall interface energy decrease, the sintering process is intensified. The typical features induced by the use of submicronic particles is a large contribution of the solid-state densification and the occurrence of the abnormal growth [1]. The control of grain growth and the avoidance of large grains is a key factor in the processing of submicron alloys. Up to now, little information is available concerning the microstructure of large grains. From literature, it is clear that variations of carbon potential greatly influence the occurrence of large grains although the enhanced coarsening mechanism is not yet assessed. In this work, the effect of carbon potential on WC large grain features is studied using transmission electron microscopy (TEM). Their location as well as their morphology and content of defects are examined. The growth mechanism is discussed regarding these characteristics.

2. Experimental and Results

Alloys with 13 at.% Co were prepared from powders of WC (0.91µm) and Co (1.25µm) supplied by Wolfram and Eurotungstene Poudres respectively. In the present study, two compositions with 13at%Co were selected: the alloy WC-Co,C has a C excess and contains graphite while the alloy WC-Co,W has a W excess and contains M_6C carbides (with M=W,Co) referred to as η. The alloys were sintered at 1450°C for 2h. More detailed information concerning the preparation is given in [2]. For the sake of conciseness, WC-Co,C is called C2h and WC-Co,W W2h in what follows.

Microstructure observations were carried out by TEM using a JEM-3010. The foils for TEM were ground on diamond grinder to about 10µm then prepared by standard ion thinning beam method. The crystal structure of WC is simple hexagonal with lattice parameters equal to a=0.2906nm and c=0.2837nm. The shape of WC grains in WC-Co alloys is a triangular prism with truncated corners. In this study, the truncation is neglected and a triangular prism is considered. Shape measurements are performed in order to quantify the shape change as a function of the C potential. The shape factor k=t/h is used where t is the thickness of the WC crystal along the [0001] direction and h is the height of the triangular basis (Fig. 1). k characterizes the elongation of the crystals.

General features of the microstructure

The microstructure is finer but more heterogeneous in W2h compared to that of C2h. The intercept distribution shows a long tail corresponding to large grains in both alloys [2]. In C2h alloy, no special location is noticed for the large grains as far as graphite particles were hardly detected by scanning electron microscopy (SEM) and never by TEM. They are usually found isolated far from other large grains. In W2h, most large grains are found isolated but some of them are connected to the η phase. Usually, several grains grow from the same η region, so large grains form groups of two or three grains.

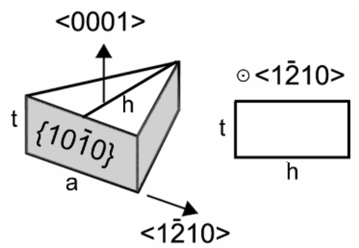

Fig. 1. Schematic WC grain shape in WC-Co alloys and projection of the grain along <1-210> direction. The grain is delimited by basal and prismatic facets.

Large grain shape

TEM observations along <1-210> indicate two different morphologies for large grains according to the composition of the alloys: they are flatter in C2h than in W2h (Fig. 2). Values of *k* factors were determined on TEM micrographs for about 10 large WC grains in each alloy in the size range determined from SEM observations [2]. A mean value of 0.40±0.08 is measured for the C side and 0.58±0.14 for the W side. Furthermore, the boundaries with smaller grains and the interfaces with cobalt are smooth in C2h and partly rounded in W2h. No step is found at the interface with cobalt while they are observed for matrix grains in the W rich alloy [2]. It indicates a different limiting step for grain growth in case of large grains.

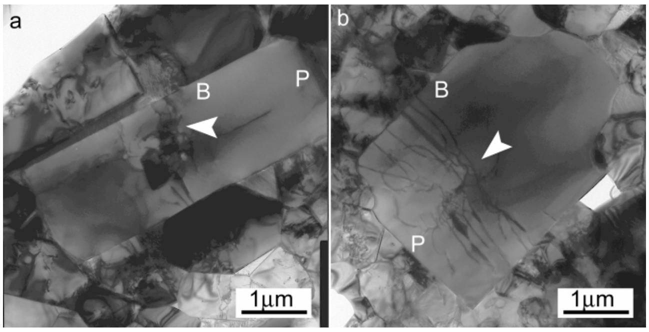

Fig. 2. Large WC grains in (a) C2h (*k*=0.35) and in (b) W2h (*k*=0.69). P and B refer to prismatic and basal facets. The arrows indicate dislocation tangles.

Large grains defects

Whatever the composition, large grains usually exhibit a very large area free from defects. A small area of the grain usually contains a dislocation tangle (Fig. 2) and also sometimes cobalt inclusions up to 200nm in size. One or even several small WC grains are often included in the large grain (Fig. 3). They are related to the abnormal grain by a small misorientation or by a Σ=2 orientation relationship. This latter corresponds to a rotation of 90° about a <10-10> axis and leads to a 3 dimensional coincidence network assuming c/a=1 [3]. In case of slightly misoriented grains, the rotation angle was evaluated from the electron diffraction patterns. They range up to about 2°. In seldom cases, the small grain is not completely in the interior of the large grain what suggests that small WC grains are included in large grains during the growth of these latter (Fig. 3b).

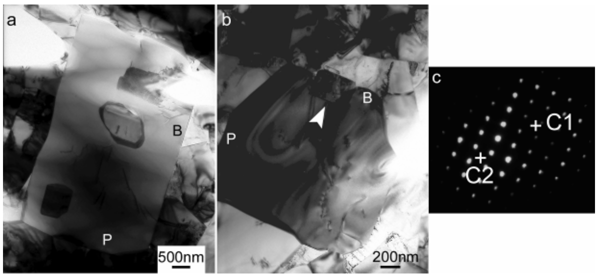

Fig. 3. Large grains in W2h. (a) Three small grains are present in the large grain. (b) Small WC grain partly engulfed in the large grain and (c) associated diffraction pattern of the large and small grains of Fig. 3b viewed along <1-210>. The centers of the axis zones are labelled C1 and C2. They reveal a small angular deviation 1.7° in projection.

3. Summary

The TEM study of large grains detects the effect of C/W ratio on the grain shape. This effect is likely related to changes in interface energy anisotropy although no equilibrium is expected after a thermal treatment of 2h at 1450°C. The microstructural features observed for large grains do not account for the assumption that they result from the calescence of slightly misorientated grains. The fact that only a part of the grain contains dislocations and Co inclusions suggests that this part is the initial grain that has undergone abnormal growth. The small grains present in the large grains have likely been engulfed during growth owing to the small interface energy associated with low angle and Σ=2 boundaries. Randomly oriented grains are likely dissolved during the large grain growth by a size effect according to the Ostwald ripening process. The enhanced grain growth depicted for grains in contact with η phase in W2h is probably connected to the growth of the η grains [4].

4. References

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