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Analysis of carbon content effect on the shape evolution of WC grains in the WC-Co alloys by X-ray diffraction method

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Cemented tungsten carbide of WC-Co has a dual phase structure consisting of facet WC grains embedded in a cobalt-rich matrix. The properties of this composite material are known to depend sensitively on the size and size distribution of WC grains, its carbon content determining phase fields, and its cobalt content. Until now, even though the WC grains have faceted shape, an effect of WC grain shape on the mechanical properties of WC-Co alloys has not been determined systematically, because the shape of WC grains is regarded to be invariant with respect to chemical composition of WC-Co alloy. However, recently Sona Kim et al reported that the WC grains change their shape with carbon content in the WC-Co alloys. Therefore, the mechanical properties of WC-Co alloys can not be free from the shape of WC grains.

Sona Kim et al clearly showed microstructural evidence for shape change of WC grains with carbon content, but the data required to analyze quantitatively the shape change of WC grains were not given yet. If the WC grains change their shape with carbon content, large number of WC grains, at least growing WC grains, should have a similar shape in the same alloy. It means that there may exist macroscopic data showing the shape change with carbon content. It was from the x-ray diffraction study of the sintered WC-Co alloys with different carbon content that we found a possibility to explain this shape change with carbon content quantitatively.

From the x-ray diffraction patterns of WC-Co alloys with different carbon content, relative intensity of basal and prismatic planes of WC crystal, (0001) and $(10\bar{1}0)$, changes abruptly with change of carbon content from two-phase region of WC and β-Co to three-phase region of WC, β-Co, and free carbon. The peak intensity of basal plane (0001) is stronger than that of prismatic plane $(10\bar{1}0)$ in the three-phase region, while relative intensity of these two peaks is reversed in the two-phase region. This result shows direct evidence of preferential growth of basal plane in the three-phase region with excess carbon. This agrees well with Sona Kim et al's microsrtuctural evidence.

Figure 1 shows the x-ray diffraction patterns of WC-30wt%Co alloys with different carbon content, sintered at 1450°C for 2 h.(All the fractions are in the weight percentage.) Each x-ray diffraction pattern was obtained from the surface of the sintered WC-Co alloys after grinding the sintered surface by about 1 mm in thickness. Roughly speaking from the observation of sintered microstructures, the alloy with 0.1~0.3% carbon belongs three-phase region of WC, β-Co, and η-phase (Co_3W_3C), the alloy with 0.3~0.7% carbon does two-phase region of WC and β-Co, and the alloy with carbon more than 0.7% does three-phase region of WC, β-Co, and free carbon. A graphite peak appearing at 26.83° was observed above 0.7% carbon.

In addition, Figure 2 shows the x-ray patterns of WC-30%Co-0.5%TiC alloys with different carbon content. The WC-30%Co-0.5%TiC alloys exhibit similar x-ray diffraction patterns with WC-30%Co alloys shown in Figure 1. The relative peak intensity of $(0001)/(10\bar{1}0)$ with carbon content measured from the WC-30%Co and

WC-30%Co-0.5%TiC alloys was presented in Figure 3 with variation of carbon content. The WC-30%Co-0.5%TiC alloys have a high relative intensity over whole range of carbon content, regardless of phase fields. The added Ti element is regarded to contribute to preferential growth of basal planes and finally results in a shape change of WC grains. The Effect of Ti addition in the present study is well agreed with Shatov et al's result obtained in WC-Ni alloys.

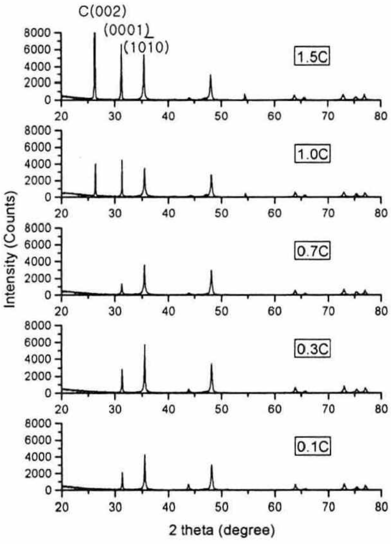

Figure 1. X-ray diffraction patterns of WC-30%Co alloys with different carbon content, sintered at 1450°C for 2 h.

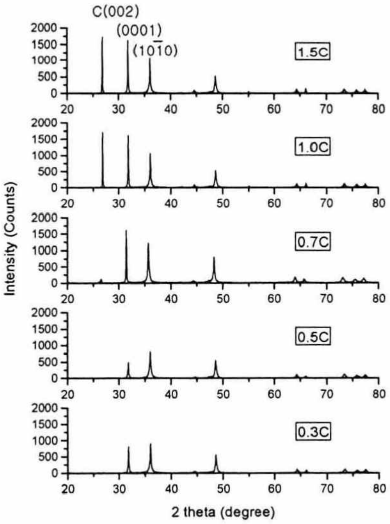

Figure 2. X-ray diffraction patterns of WC-30%Co-0.5%TiC alloys with different carbon content, sintered at 1450°C for 2 h.

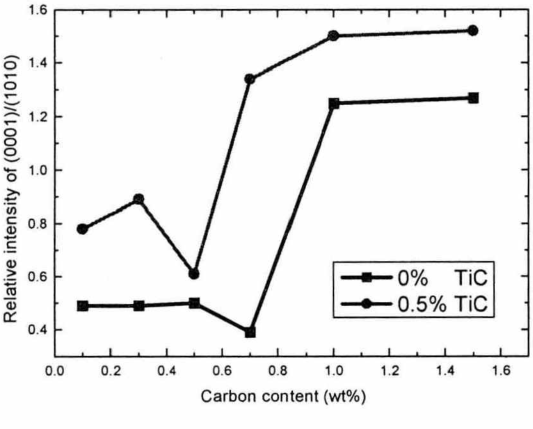

Figure 3. Variation of Relative intensity of (0001) / (10$\bar{1}$0) peak in the WC-30%Co and WC-30%Co-0.5%TiC alloys with carbon content.