# Mechanical Properties and Drilling Performance of Ultra-fine Grained Cemented Carbide Produced Using Direct Carburized WC Powder

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**Abstract**

*In recent years, PCB drills with smaller diameters less than 0.1 mm are used and thus there are growing needs for ultra-fine grained cemented carbides. However, ultra-fine WC powder usually causes extraordinary grain growth during sintering which weakens mechanical strength of ultra-fine grained cemented carbides. So we examined several kinds of WC powders to make new ultra-fine grained cemented carbides having superior performance. We found that direct carburized WC powder is very good as a WC raw material. The PCB drills made of the developed ultra-fine grained cemented carbides have higher hardness, toughness and stiffness than conventional ones.*

**Keywords : cemented carbide, WC, PCB drill, grain growth inhibitor**

## 1. Introduction

In recent years, there are growing needs for drilling printed-circuit boards with high speed and high density. Moreover, circuit boards are becoming hard for higher heat resistance and corrosion resistance. This trend requires harder and tougher cemented carbide material. Cemented carbides are hard materials mainly composed of WC as a hard phase and Co as a binder phase, and its mechanical properties depend greatly on particle sizes of WC grains[1]. As WC grains are fining down, cemented carbides become hard and tough. Now for use of microdrill, WC grain size of cemented carbides for PCB drills goes down to 0.3 μm and is desired to be still finer. In order to produce such ultra-fine grained cemented carbides, it is necessary to use finer WC powder as a raw material and to prevent grain growth during sintering. Techniques to reduce the particle size of WC powder are hard milling or the use of finer raw material. However, hard milled WC powders have wide distribution in grain sizes. As a result, extraordinary grain growth happenes because of Ostwald grain growth, which weakens mechanical strength of ultra-fine grained cemented carbides. In such reason, it is difficult to make ultra-fine grained cemented carbides with grain size less than 0.3 μm. In this study we found that direct carburized WC powder is very good as a WC raw material. Here, we show the results of the two kinds of WC powders produced by a conventional manufacturing process and a direct carburization process. The PCB drills made of the developed ultra-fine grained cemented carbides have higher hardness, toughness and stiffness than conventional ones.

## 2. Experimental and Results

In the conventional manufacturing process of WC powder, tungsten oxide ($WO_3$) is reduced to metallic tungsten (W). Then W is carburized to WC. But in this study, we used WC powder which is directly carburized from $WO_3$[2]. In the conventional reduction carburization process, high carburization temperature (1900-2300 K) is usually needed and causes grain growth. On the other hand, the directcarburization process does not need high temperature (1600-1800 K) and can be produced finer WC powder than conventional ones[2, 3]. Fig. 1 shows SEM images of WC powder produced by conventional process and direct carburized process before and after milling with ball mill. Direct carburized WC powder is finer and has narrower grain distribution than conventional WC powder. Such properties of direct carburized WC powder would be good for making ultra-fine grained cemented carbides.

The direct carburized WC powders with grain sizes of 0.15 μm and the WC powder produced by conventional reduction carburization process with the grain size of 0.3 μm (A. L. M. T.) were used. The two grades of ultra-fine grained cemented carbides with the composition of WC-8%Co-0.8%$Cr_3C_2$-0.25%VC (sample A and B made from the WC powders of 0.15 μm and 0.3 μm grade, respectively) were prepared by milling with ball mill for 24 hours, pressed at 1 ton/cm$^2$ and sintered at 1673 K for 1 hour in vacuum. The SEM images of the sample A and B are shown in Fig. 2. They show that the sample A has good uniform microstructure and that finer WC grains than the sample B.

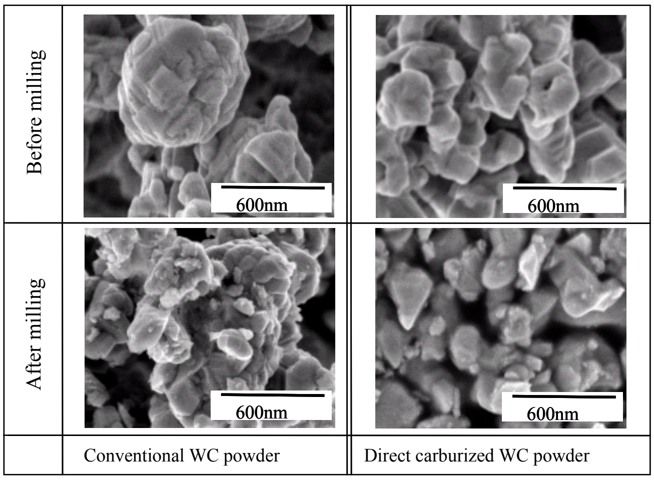


**Fig. 1. Scanning electron microscope images of WC powder manufactured by conventional process and direct carburized one**

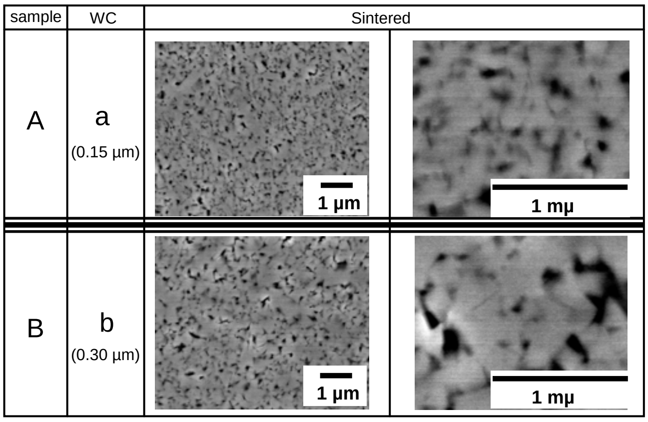


**Fig. 2. Scanning electron microscope images of cemented carbides made from the WC powders of 0.15 µm and 0.3 µm grade.**

The sample A and the sample B were examined in transverse-rupture strength (TRS), Vickers hardness (Hv) and elastic modulus. The values of Hv, TRS and elastic modulus of the sample A and B are shown in Table 1. In Hv, the sample A is superior to sample B by 7% and in TRS by 7%. The cemented carbides of A and B were fabricated to PCB drills with the size of 0.075mm in diameter and 0.9 mm in length. The drilling performances of sample A and B are estimated. Hit numbers until they

**Table 1. Mechanical properties of sample A and B Fig.**

| | Hv (GPa) | TRS (GPa) |
|---|---|---|
| Sample A (0.15 µm) | 19.6 | 5.22 |
| Sample B (0.3 µm) | 18.2 | 4.85 |

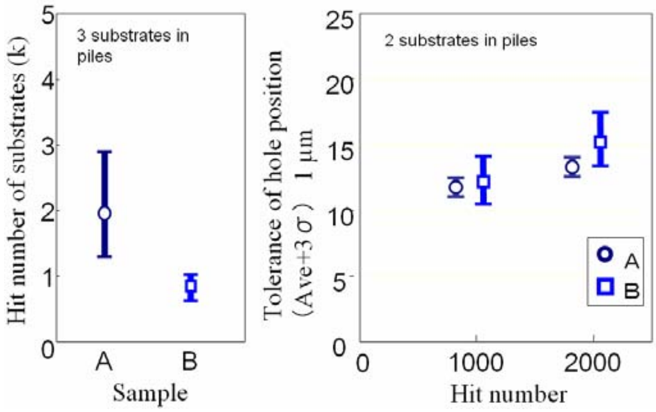


**Fig. 3. Drilling performance of sample A and B (rotational speed: 250kmin$^{-1}$, feed :5 µm /rev and substrate: CCL-HL832HS).**

break and tolerance of drilling positionwere measured. The results are shown in Fig. 3. The lifetime of the sample A is about twice as long as that of the sample B. The tolerance of drilling position of the sample A is better than that of the sample B.

## 3. Summary

Two grades of ultra-fine grained cemented carbides were produced using direct carburized WC powders and examined. In TRS and Hv, the sample of 0.15 µm grade is superior to 0.3 µm grade. The life time of the sample A is twice as long as that of the sample B. And the sample A is better intolerance of drilling position than the sample B. The ultra-fine grained cemented carbide with grain size of 0.15 µm produced using direct carburized WC powder seemed to have superior performance for PCB drill tools.

## 4. References

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