Study of nitriding of WC-Co in the electron beam excited plasma

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We have achieved to form a hardened layer of more than several tens µm in WC-Co by nitriding using electron beam excited plasma (EBEP), which can produce stable high-density plasma under 0.5 Pa process pressure. The diffusion depth of atomic nitrogens from the surface is estimated to be about 100 µm or more by EPMA on the cross section of WC-Co. The surface hardness of the nitrided WC-Co samples increased by more than 1.3 times that of the untreated ones.

Keywords: *Cemented carbide, nitriding, electron beam excited plasma, WC-Co*

1. Introduction

In recent years, cutting tools such as end mills, punches, and dies made of WC-Co had been widely used. In order to extend a service life of these tools, the hard film had been coated on the WC-Co tool. However, there are problems such as peeling of the hard film during use. Plasma Immersion Ion Implantation (PIII) method has been conducted as research to extend the service life of WC-Co tools other than film coating. In the PIII methods [1)], the study was made to increase the surface hardness by bombarding nitrogen atom ions generated in the plasma with acceleration above 20 kV. However, the observed distribution of implanted nitrogen ions were stopped at the region around 100 nm depth from the WC-Co surface. At present, the film thickness formed by hard film coating, which is the mainstream, is around 3 µm, and the PIII method cannot penetrate nitrogen to a sufficient depth.

In the present study, we have achieved to form a hardened layer of more than several tens µm in WC-Co by nitriding using electron beam excited plasma (EBEP), which can generate stable high-density plasma under 0.5Pa process pressure.

2. Experiment

Figure 1 shows the nitriding equipment used in the present study. The WC-Co sample was placed 30 cm away from the accelerating electrode in the plasma process area. The used samples were WC-Co (G5) in the form of flat plates of 2 cm square. The sample was heated by an external heater and the sample temperature was controlled at 700°C. Nitriding was performed at a process chamber pressure of 0.3 Pa. The nitriding treatment time was changed from 12 to 48 hours. The surface hardness and depth profile of hardness were measured with a Vickers hardness tester. After the treated samples were cut, these cross sections were flattened by ion milling, to perform quantitative analysis by EPMA. Hardness changes due to nitriding and the state of nitrogen diffusion into the WC-Co were observed.

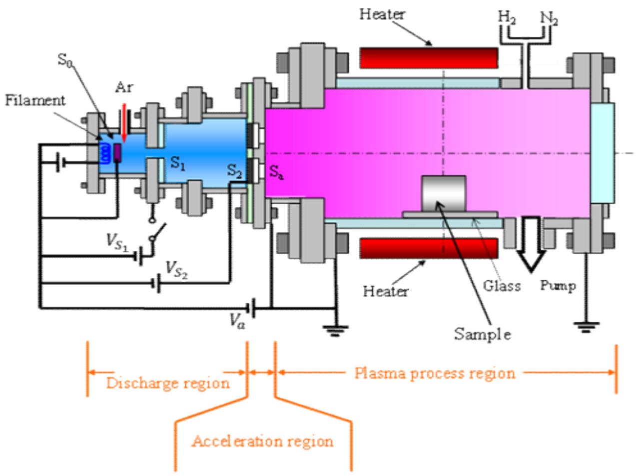

Fig.1 Schematic of the nitriding equipment

3. Results

Figure 2 shows the result of EPMA observation of the cross section of WC-Co nitrided during 24 hours under low plasma source power. From Fig. 2, it can be observed that the Co rich area in the cemented carbide coincides with the area containing nitrogen atoms. This indicates that nitrogen atoms easily diffuse in the Co layer and reach a depth of 30 µm from the surface of WC-Co. The lower right graph shows the concentration distribution along the line in the figure of nitrogen. The diffusion depth of dense nitrogen was estimated to be around 2 µm from the surface. It was thought that the initial nitriding had been started. From these results, it is considered that nitriding of WC-Co begins with the introduction of nitrogen along the Co.

Figure 3 shows the depth profile of atomic nitrogen observed by EPMA on the cross section of WC-Co nitrided during 24 hours under the enhanced power of the plasma source. The nitrogen concentration was the highest near the surface and tended to decrease toward the inside. The diffusion depth of atomic nitrogen is estimated to be about 100 µm or more.

The depth profile of hardness of the nitrided sample is shown in Fig. 4. The surface hardness of the nitrided samples increased by more than 1.3 times that of the untreated WC-Co. From the observed depth profiles, it is clear that the hardness has increased to a depth of 100 μm or more when the treatment time is 48 hours. When the treatment time is 12 hours, the hardness has increased to a depth of 50 μm.

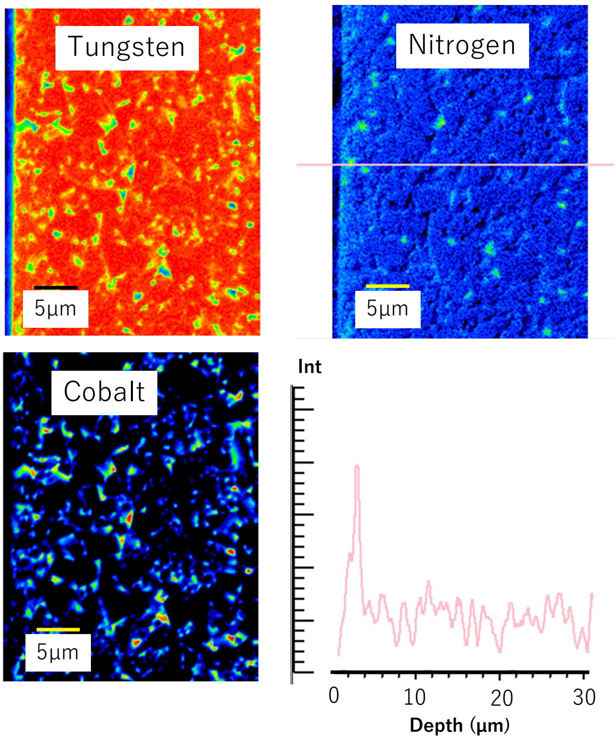

Fig.2 EPMA observation of the cross section of nitrided WC-Co at low plasma source power.

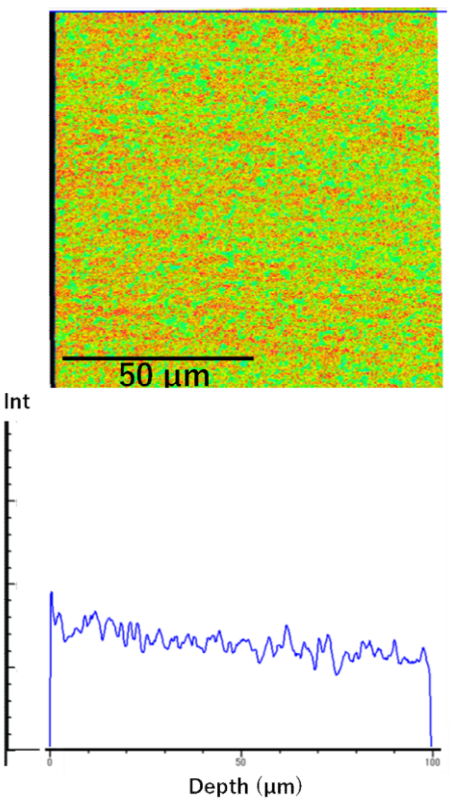

Fig. 3 Depth profile of atomic nitrogens on the cross section of nitrided WC-Co.

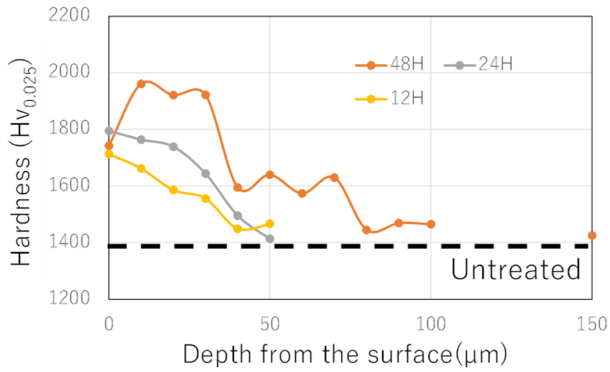

Fig. 4 Hardness depth profile of nitrided WC-Co.

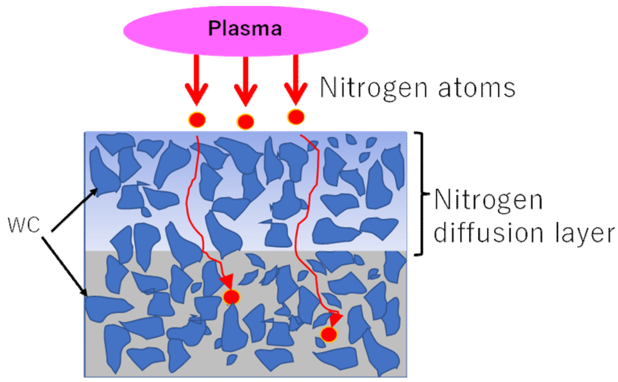

Fig. 5 Nitriding mechanism of WC-Co.

Figure 5 shows the nitriding mechanism of WC-Co. At first, atomic nitrogens generated in EBEP reach the WC-Co surface. These atomic nitrogens diffuse inward along the Co of the WC-Co during the nitriding process. Since a high concentration of atomic nitrogens continues to be supplied to the WC-Co surface, it is thought that the atomic nitrogens entered the WC particle near the surface. At the same time, the atomic nitrogens supplied into the WC-Co through Co entered the inside of the WC particle located deep. As a result, it is thought that the hardness of the WC-Co is enhanced.

4. Conclusions

The surface hardness of WC-Co has been increased by the nitriding treatment at 700℃ using electron beam excited plasma. It is concluded that the hardness enhancement of WC-Co is due to atomic nitrogens diffused inside the WC-Co.

Reference

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