Enhancement of Life Time for PCB (Printed Circuit Board) Drill Bit by Nitrogen Ion Implantation

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Implantation of metals and ceramics with ions of nitrogen and other species has improved surface properties such as friction, wear and corrosion in numerous industrial applications. In recent years, PCB drills tend to be more minimized increasingly as the electronics components have been more highly accumulated and minimized. Therefore nitrogen ion implantation was performed onto PCB drill (0.15 & 0.3 mm in diameter), in order to investigate mechanical properties of WC-Co cermets surface through Nano-indentation tests. PCB drill was implanted at energy of 70 keV, 90 keV, 120 keV and with the dose range of 1×10^{17} and 5×10^{17} ions/cm^2. After ion implantation, WC-Co PCB drill bits was tested in actual operating situation to apply cutting tools industry and is concluded that the life time of nitrogen ion implanted PCB drills is one and a half times longer than the unimplanted.

Keywords : Ion implantation, WC-Co cermets, PCB drill

1. INTRODUCTION

Cobalt cemented tungsten carbide(WC-Co) are used in a variety of important industrial components and parts, such as cutting tools, milling tools, mechanical face seals, drills, punches, submersible pumps, and so on[1]. Coatings and ion implantation techniques are included in the major surface modification techniques to enhance the wear resistance of metal parts to abrasion. Coating processing such CVD and PVD for cutting tools is caused alteration of tool shape and dimensions as well as abruption of intermixing between the bulk and the treated layer. Therefore such coating processing is inadequate method which is applied to the surface treatment of the precision mechanical parts with submicrometer tolerances. On the other hand, nitrogen implantation in metals and metallic alloys generally improves surface properties, with the objectives of ensuring a low friction coefficient or surface hardening and producing protective or anticorrosion coatings as well as no influence on surface finish, tool shape and dimension although shallow implanted depth[2].

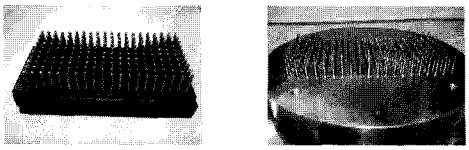
For several decades, many previous works on ion implantation of WC-Co have shown that Nitrogen implantation can improve wear resistance and domestic precision surface treatment technology, PVD or CVD, is used to improve the life time of PCB drills but there are some problems for the practical use because of margin and adherence. Korea Atomic Energy Research Institute developed implanters for industrial uses[3] and equipment and technology was transferred to domestic company in 2003.

And now, we can apply ion implantation technology on the basis of upper experience for the improvement of life time of micro (0.15 mm & 0.3 mm in diameter) PCB drills.

2. EXPERIMENTAL

The simplest and most economical process for the strengthening of metallic surfaces is by the ion implantation of nitrogen which, being an elemental gas does not require mass analysis due to beam current and equipment price. But for this application, the inevitable mixture of molecular, atomic and some fast neutral species in the extracted beam is acceptable, and enables the full output of the ion source to utilized[4]. Therefore, it consists of a DuoPIGatron ion source[5], vacuum system, diagnostic system, power supply, an accelerator tube, target chamber and target cooling system. The nitrogen beam current is up to 10 mA, 40 keV and

accelerated up to 120 keV. The typical beam profile is measured by a linear scanning system based on a Faraday cup with 5 mm diameter. Figure 1 shows cobalt cemented tungsten carbide drills (WC-Co, Co : 6 wt%), 0.15 and 0.3 mm in diameter which were used as samples.



(a) (b)

Fig. 1. The sample of PCB drills.
(a) The collection of drills
(b) Jig fabrication for semi-mass production (200ea drill cassette))

There are various hardening mechanisms of metal parts. However, The XPS(X-ray photoelectron spectroscopy) or XRD(X-ray diffraction) analysis results indicate, the formed nitrides on surface play an important role in the enhanced surface harness. Also, it turned out that much more nitrogen ions were implanted into the specimens in this work as compared with our previous experiment[6]. The cleaned the WC-Co samples with ultrasonic cleaner was implanted with nitrogen ion at an energy of 70 keV, 90 keV, 120 keV, beam intensity of 10 $\mu A/cm^2$, and with doses of 1×10^{17} and 5×10^{17} ions/cm^2. Micro hardness tests were carried out on a nano-indenter XP (MTS). Polished WC-Co plate, diameter 6 mm by thickness 3 mm, was used for the micro hardness and modulus tests. Ion implanted WC-Co PCB drill bits have been tested in actual operating situation. On the drilling, two circuit boards (0.4t for 0.15 mm drill bit) and six circuit boards (0.4t for 0.3 mm drill bit) are stacked one above the other for field test of PCB respectively. Drills are refurbished when the accuracy of punching is over 20 μm for the highest board and 40 μm for the lowest board. One bit drilled 6000 holes and we took a picture after 2000(0.15 mm in diameter), 3000 (0.3 mm in diameter) holes every 500 holes. The rate of rotation is 300 krpm for 0.15 mm PCB drills and 200 krpm for 0.3 mm PCB drills. 10 piece of implanted and unimplanted drills were tested.

3. RESULT

In unimplantation, Fig. 2 shows about 2000 holes can be drilled per a bit but the drills punching over 2000 holes are impractical because of the reduction in shank diameter beyond acceptable limits. In Fig. 3, the result as a function of dose and energy shows that the most of the micro-harnesses are improved than that of unimplanted. The hardness improvement is due to the high concentration of nitrogen in the implanted region at depths between 25 and 50 nm below the surface. And an effective hardness was increased of nearly 40 % in the implanted region. From above results, it was expected that the life time of PCB drill would be longer than other experimental conditions because optimum hardening occurs at 90 keV, 5×10^{17} ions/cm^2.

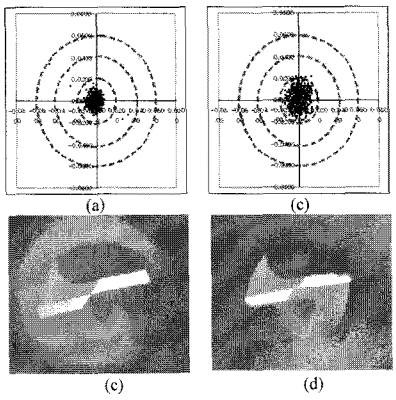


Fig. 2. The Accuracy of of punching and the blade shape change of unimplanted PCB drills.
(a) the accuracy of punching in the early stage
(b) the blade shape in the early
(c) the accuracy of punching after 2000 holes
(d) the blade shape after 2000 holes punching

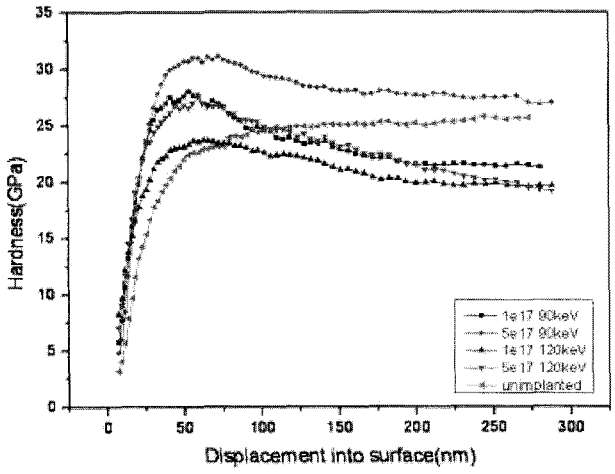


Fig. 3. The hardness for unimplanted and nitrogen ion implanted WC-Co with does and energy versus nano-indentation depth.

But a condition of 120 keV energy is more effective to improve the punching life than 90 keV energy in the actual field test with Table 1. It is figured out that the surface of PCB drill is easy to brittle due to improving surface under conditions (90 keV, 5×10^{17} ions/cm^2). As a result with Table 1, the optimum experimental condition is obtained when the specimen was implanted with 120 kV energy and is a 1.5 times larger durability than those the non-implanted. The Fig. 4 shows the blade shape change and accuracy of punching of unimplanted and implanted drill at energy 120 keV. As shown in this figure, implanted drill was enhanced the life time up to 4500 punching comparing with unimplanted drill.

Table. 1. The results of field test.

Field test (quantity x 1000)													
Energy	0	70 keV				90 keV				120 keV			
Dose	0	1×10^{17}		5×10^{17}		1×10^{17}		5×10^{17}		1×10^{17}		5×10^{17}	
Angle	0	0°	25°	0°	25°	0°	25°	0°	25°	0°	25°	0°	25°
0.15 mm 300 krpm	3.5	-	4.0	-	4.0	4.5	4.5	3.5	2.0	3.0	4.5	3.5	4.0
0.30 mm 200 krpm	3.5	-	4.5	-	4.5	3.0	3.0	3.0	4.5	5.0	5.0	-	3.0
0.30 mm 160 krpm	3.0	-	3.0	-	3.0	3.0	3.0	3.0	3.0	4.5	3.5	3.5	3.0

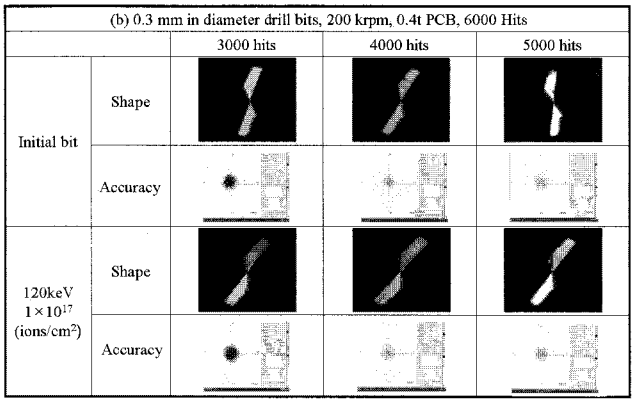


Fig. 4. The blade shape change and the accuracy of punching of unimplanted and implanted PCB drills at energy 120 keV, 1 x 10^{17} ions/cm^2, 0.4 t PCB, 6000 hits.
(a) drill bits of 0.15 mm in diameter, 300 krpm
(b) drill bits of 0.3 mm in diameter, 200 krpm

The adherence strength is also very important because of the reduction in shank diameter by high-speed rotation. And the surface treatment thickness by ion beam implantation doesn't matter for ultra-precision industrial tool because ion implanted region in 120 keV energy is depth several hundred nm below the surface. So, ion implantation, which makes no change in manufacturing margin and is a good method for adherence, is efficient way to improve life time of a PCB drill. There is a little difference in between the result of nano-indentation data and field test data of PCB drills. But the most of implanted PCB drills' life time increased. And ion implantation can be used as the last process. A precision instrument design technique and ion source optical design technique are needed to manufacture ion source.

4. CONCLUSION

WC-Co tools were implanted with nitrogen and tested in practical applications. Nitrogen ion implantation can increase the surface hardness of PCB drills. The implanted PCB drills appear to last more than 1.5 times longer than unimplanted. 200 PCB drills were ion implanted successfully at the same time for semi-mass production process.

ACKNOWLEDGMENTS

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REFERENCES

[1] J. W. Park and J. H. Cho, "Properties of polymeric, metallic, and ceramic materials surface-modified with low energy accelerating beam bombardment", J. Korean Phys. Soc., Vol. 48, No. 4, p. 815, 2006.
[2] C. A. Straede, "Application of ion implantation in tooling industry", Nucl. Inst. Meth. B, Vol. 113, Issue1-4, p. 161, 1993.
[3] J. H. Lee, C. H. Lee, and J. K. Kil, "Optical transmittance property of polycarbonate film at UV range by ion implantation", J. of KIEEME(in Korean), Vol. 16, No. 12, p. 1091, 2003.
[4] Dearnaley and G. Nul, "Ion implantation part II: Ion implantation in nonelectronic materials", Nucl. Inst. Meth. B., Vol. 24, p. 506, 1987.
[5] C. B. Choi and H. D. Kang, "High current deuterium ion extraction with low emittance", New Korean. Phy. Soc., Vol. 26, No. 6, p. 563, 1986.
[6] J. H. Lee, J. W. Park, J. S. Lee, C. W. Sohn, and J. K. Kil, "Studies of N-ion-implanted stainless steels oriented for industrial applications", Surface & Coatings Tech., Vol. 196, p. 353, 2005.