Research on Microstructure and Properties of TiN, (Ti, Al)N and TiN/(Ti, Al)N Multilayer Coatings

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Abstract

Magnetron sputtered TiN, (Ti, Al)N and TiN/(Ti, Al)N multilayer coatings grown on cemented carbide substrates have been characterized by using electron probe microanalysis (EPMA), X-ray diffraction (XRD), scanning electron spectroscopy (SEM), nanoindentation, scratcher and cutting tests. Results show that TiN coating is bell mouth columnar structures, (Ti, Al)N coating is straight columnar structures and the modulation structure has been formed in the TiN/(Ti, Al)N multilayer coating. TiN/(Ti, Al)N multilayer coating exhibited higher hardness, better adhesion with substrate and excellent cutting performance compared with TiN and (Ti, Al)N coating.

Keywords : coating, cemented carbide, hardness, cutting properties

1. Introduction

(Ti,Al)N coating, incorporated with aluminum in TiN coating, has a higher hardness (~35GPa) and superior oxidationresistance (~900℃)[1-3]. In recent years, considerable efforts have been devoted to the development of multilayered structures to further improve their properties.The multilayer coating compounding different materials can offset limitation of monolayer coating[4, 5]. The properties of multilayer coating are superior to the single material coating. In the present paper, the microstructures and the mechanical properties of TiN, (Ti, Al)N monolayer and TiN/(Ti, Al)N multilayer coatings have been evaluated.

2. Experimental and Results

Magnetron sputtered TiN, (Ti, Al)N and TiN/(Ti, Al)N multilayer coatings grown on TNMG120408 style cemented carbide (WC–6%Co) inserts have been characterized by using electron probe microanalysis (EPMA), X-ray diffraction (XRD), scanning electron spectroscopy (SEM), nanoindentation, scratcher and cutting tests. The atomic ratios of Al against Ti of titanium aluminium alloy target was 5:5. The cutting conditions were a cutting speed (vc) of 220m/min, a depthe of cut (ap) of 0.2mm and a feed rate (f) of 0.2mm/r. Flank wear lands were measured using a microscope at intervals of 3 minutes and the inserts were deemed to have failed when the wear lands exceeded 0.5mm.

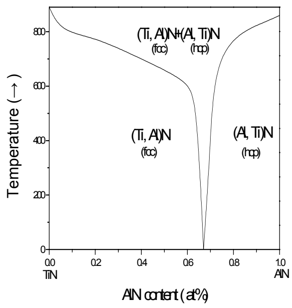


Fig. 1. TiN-AlN phase diagram.

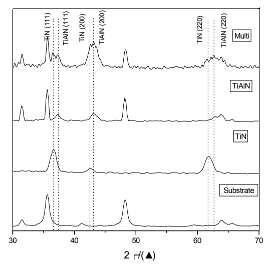
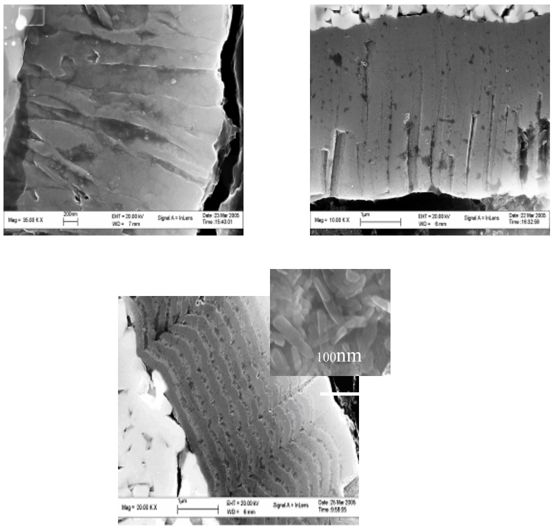


Fig. 2. XRD pattern of (Ti, Al)N monolayer coating.

Atomic ratios of Al against Ti both in the monolayer (Ti, Al)N and in the (Ti, Al)N layer of the multilayer TiN/ (Ti, Al)N coating separately were $Ti_{0.55}Al_{0.45}N$, $Ti_{0.53}Al_{0.47}N$. It can be concluded that the (Ti, Al)N crystal structures of two coating were fcc structure from Fig.1. This was confirmed by the XRD result of the (Ti, Al)N monolayer coating. Typical XRD diffraction patterns from three coatings deposited onto cemented carbide substrate and of the bare substrate are shown in Fig.2. The TiN and (Ti, Al)N peaks from the TiN/ (Ti, Al)N multilayer coating were observed.

The hardness value measured for TiN, (Ti, Al)N and TiN/(Ti, Al)N multilayer were 22.7GPa, 32.4GPa and 33.7Gpa, separately. Compared with TiN coating, the hardness enhancement is attributed to the internal stress arising from the partial replacement of the titanium atoms in the TiN lattice by the aluminium. The hardness of TiN/ (Ti, Al)N coating was the highest. The increase in hardness can be attributed to grain size refinement based on the Hall-Petch effect and the high number of layer interfaces (dislocation blocking strain effects) contribution between TiN and (Ti, Al)N layers.



(a) TiN (b) (Ti, Al)N (c) TiN/(Ti,Al)N

Fig. 3. Cross-sectional SEM micrograph of coatings.

Fig. 3 shows the SEM micrographs of fracture cross-section of TiN, (Ti, Al)N monolayer and TiN/(Ti, Al)N multilayered coatings. The TiN coating is bell mouth columnar structures and the (Ti, Al)N coating behaves like straight dense columnar structures with most of grains extending from the interface to the surface. Fig.3 (c) shows that modulation structure is formed in the TiN/(Ti, Al)N multilayer coating, composed of alternating TiN and (Ti, Al)N layers. The (Ti, Al)N grain image at the top right corner shows that (Ti, Al)N grains are still fine columnar crystals though TiN layer periodically interrupt the growth of columnar in (Ti, Al)N.

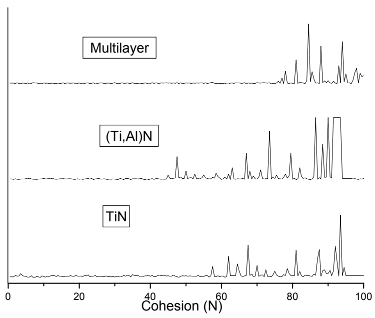


Fig. 4. The progress of flank wear of coated inserts in continuous steel turning.

Fig. 4 shows that the cohesion of TiN/ (Ti , Al) multilayer coating and substrate are the strongest, followed by TiN, and then (Ti, Al) N coating and substrate which show the worst cohesion. Fig.5 shows maximum flank wear as a function of time at a cutting speed of 220m/min in turning stainless steel. We can conclude that TiN/(Ti, Al)N multilayer coating has the best cutting properties.

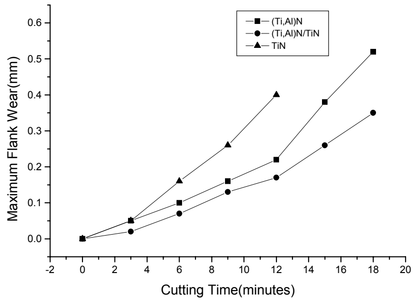


Fig. 5. Tools life of coated inserts in interrupted maching of 45# steel.

3. Summary

Based on our experiments, the following conclusions could be drawn.

1) TiN, (Ti, Al)N and TiN/(Ti, Al)N multilayer coating were deposited on cemented carbide substrates by means of magnetron sputtering process. Three coatings highlight dense structures and a good affinity between coating and substrate, with no flaking observed. The modulation structure has been formed in the TiN/(Ti, Al)N multilayer coating.

2) (Ti, Al)N coatings have higher hardness than TiN coatings because of solution strength of Al. TiN/(Ti, Al)N multilayer coatings perform the highest hardness in three coatings as a result of grain size refinement and the high number of layer interfaces contribution between TiN and (Ti, Al)N layers.

3) The TiN/(Ti, Al)N coating showed superior performance in the cutting tests.

4. References

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