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Influences of carbon content within TiC_xN_{1-x} coating to adhesivity onto tungsten carbide substrate

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ABSTRACT – TiCN is a popular hard coating for cutting tool in various applications. This paper study the influence of carbon content within the TiC_xN_{1-x} coatings to its adhesivity strength onto tungsten carbide substrate. TiC_xN_{1-x} coatings were custom made in-house through cathodic arc physical vapour deposition (CAPVD) with various CH_4/N_2 ratios. The coating composition, intensity of element, and adhesivity strength were characterised. It was found that the adhesivity strength of TiC_xN_{1-x} coatings was increased with the carbon content within a coating.

1. INTRODUCTION

Over the past few decades, TiN (titanium nitride) is a popular, gold-coloured coating that is applied on high-speed steel and carbide cutting tools [1, 2]. TiN coating improves wear resistance and prolongs the life of high-speed steel and carbide cutting tools, particularly, at high cutting speeds and feed rates [2-4].

The inclusion of carbon atoms into the TiN lattice had improved the tribological properties of coating. Compared to TiN, TiCN (titanium carbonitride) has higher chemical stability, more superior mechanical properties and excellent wear resistance [5-7].

Researchers have suggested that the properties of TiCN can be tailored by controlling its composition through the C-N ratio via several fabrication methods [5, 8, 9]. In this paper, the influence of carbon content within TiC_xN_{1-x} coatings to its adhesivity strength onto the carbide substrate were study. Coating on the cutting tool was firstly delaminated before exposed the tool material, and thus it acted as a protective film against the tool wear. Coating with higher adhesivity strength thus able to withstand longer in the machining process and prolong the tool life. Both TiC_xN_{1-x} coatings and carbide substrates were custom made in-house, and the adhesivity strength of in-house custom made TiC_xN_{1-x} coatings were then compared to commercially available TiC_xN_{1-x} coatings.

2. METHODOLOGY

There were 7 coatings tested, 5 of them were in-house custom made TiC_xN_{1-x} coatings which prepared through cathodic arc physical vapour deposition (CAPVD) and 2 were commercially available TiN and TiCN coatings. In-house custom made substrates were 14 mm × 14 mm × 3 mm tungsten carbides, WC-6Co, which were prepared through a powder metallurgy process. Coatings were deposited onto the substrates via CAPVD for 2 hours. Titanium (Ti) target with 99.9 % purity was used as a cathode and source for Ti, while methane (CH4) and nitrogen (N2) gases were source for C and N. The ratio of CH_4/N_2 and produced in-house custom made coatings are summarised in Table 1. The preparation of substrates and the deposition of coatings were followed the same process as in the previous study [10]. The adhesivity strength of the in-house custom made TiC_xN_{1-x} coatings were compared with commercial TiN-coated (C1) and TiCN-coated (C2) tungsten carbide cutting inserts. All commercial coatings were also produced by the PVD process and obtained from Sumitomo Electric.

Table 1 Deposition of custom-made TiC_xN_{1-x} coatings with different CH_4/N_2 ratios.

CH4/N2 Ratio	Coating Produced	Sample
-	TiN	T1
0.25	TiCN1	T2
1	TiCN2	T3
4	TiCN3	T4
-	TiC	T5
unknown	TiN	C1
unknown	TiCN	C2

Composition, stoichiometry and intensity of elements within a coating are functions of the CH_4-N_2 ratio. These functions were characterised by using the Bruker-D8 X-ray diffractor (XRD) and the Omicron DAR 400 X-ray photoelectron spectroscopy (XPS). The source for XRD was Cu Kα with a wavelength of 0.15406 nm, while the source for XPS was Al Kα with 1486.7 eV and a wavelength of 0.83386 nm.

The adhesion strength of the coating to substrate was measured by scratch test, and all scratch tests were performed on Micro Materials made Nano Test^{TM}. The indenter used was spherical diamond indenter with 5 μm of radius, scratching on the sample at a constant speed of 50μm/s with a progressive loading rate of 16.67 mN/s (100 N/min). The maximum load on this equipment is 500 mN, hence the progressive load will stop increased after reaching its maximum load, which was after 30 seconds and 1500 μm of scratching length. However, some of the coatings do not failed/fracture at this point, and thus scratch tests will continue at constant scratching speed of 50 μm/s and 500 mN of load, until a total 5000 μm (5 mm) of scratching length was reached.

A topography scan was run prior and after the scratch test with constant speed of 50μm/s and load at 0.2 mN. The coating adhesion failure was indicated by the sudden and drastic change in (i) topography depth, (ii) acoustic emission, and (iii) dramatic oscillation of coefficient of friction [11]. The adhesion strength in this study was described in terms of scratch distance (μm), and was determined by the average values obtained from criteria (i), (ii) and (iii).

3. RESULT

Table 2 shows effect of coating composition on the adhesion failure. In custom made coatings, TiCN coatings (T2-T4) has higher adhesivity, followed by TiC (T5) and TiN (T1) coatings. Whereas, C2 also shows higher adhesivity to carbide substrate than C1. The adhesivity of custom made TiCN coatings was increased with the increase in carbon content. This shows that carbon content within the coatings is promoting adhesivity strength. However, the better adhesivity strength of TiCN than TiC showed that it was the C-N bond within the TiCN coating that significantly improve the adhesivity strength, rather than C or N itself. Researchers have reported that TiCN is a solid solution for face-centred cubic (FCC) TiN and FCC TiC (titanium carbide) [5, 6, 12], which takes on the excellent characteristics of both TiC and TiN [6, 12]. Moreover, TiCN and TiC coatings has greater propensity to develop brittle eta-phase at the coating-substrate interface, which are beneficial to the coating adhesivity [3]. Therefore, TiCN coating can further improves the adhesivity of the coating.

Table 2 Coating composition, carbon intensity (*C*), and adhesion failure (*F*).

Sample	Coating composition	Crystal system	*C* at.%	*F* μm
C1	TiN	FCC	0	2594.31
T1	TiN	FCC	0	929.75
T2	$TiC_{0.2}N_{0.8}$	FCC	28.02	1823.73
T3	$TiC_{0.3}N_{0.7}$	FCC	47.24	1898.38
T4	$TiC_{0.7}N_{0.3}$	CCC	47.61	2782.08
T5	TiC	FCC	45.8	1447.16
C2	$TiC_{0.7}N_{0.3}$	FCC	72.35	3690.66

4. CONCLUSION

For in-house custom made TiC_xN_{1-x} coatings, TiCN coatings had higher adhesivity onto carbide substrate, followed by TiC and TiN coatings. Carbon content within the TiCN coatings promoting the adhesivity strength.

5. REFERENCES

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