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EFFECT OF COATING ARCHITECTURES ON MECHANICAL PROPERTIES OF AL–N/CR–N MULTILAYER COATINGS

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Abstract-*Two coating architectures with different deposition times (Dts) for each layer and N_2 gas flow rate ratio η (N_2/(N_2 + Ar)) of Al– N/Cr– N multilayer coatings were developed utilizing unequal magnetron responsive sputtering. Utilizing a same coating process, two coating architectures were deposited on the high speed tool steel and Si wafer, one starting with an Al– N layer composed as the Al– N/Cr– N/…/Cr– N/Al– N (design A) and the other starting with a Cr– N layer composed as the Cr– N/Al– N/…/Al– N/Cr– N (design C). The N_2 gas stream rate proportion η was set at 15%, 20% and 25% to control the Cr– N and Al– N layer stages. The present investigation is based on effect of coating architectures on hardness, young's modulus of coating.*

Keywords: *Reactive sputtering, Al–N/Cr–N coatings, Multilayer coating, Hardness.*

Introduction

Physical vapour deposition (PVD) techniques have been utilized as a part of the preparation of hard coatings [1– 3]. PVD nitride coatings shows great wear resistance and chemical stability and have been effectively utilized for modern protective use [4– 11]. The original hard PVD coatings comprised of monolayer metal nitrides, for example, TiN, CrN and ZrN. These PVD coatings are as yet utilized broadly. CrCN and TiCN shows lower wear rates than CrN and TiN [1, 3]. Mixing of Al alloy into the TiN and CrN structure serves to build oxidation resistance and in addition better tribological properties [8, 12–15]. Superior tribological performance has been accomplished utilizing multilayer structures, for example, TiN/TiCN, TiN/CrN, TiN/AlN, and CrN/CrCN [16– 21]. In addition to wear resistance, a higher water contact angle (WCA) is additionally an essential property for plastic injection moulds [22]. The coating's anti-sticking property is related to the polar components of surface energy, with lower polar components corresponding with increased water-repellency as well as a higher water contact angle (WCA) [23, 24]. WCA estimation is a convenient strategy to examine the water-repellency conduct of coatings. A higher WCA relates with enhanced discharge execution for plastic injection molds. Past research has concentrated on nano-organized CrN/AlN multilayer coatings [25, 26]; however the impact of design and layer thickness proportion on wear and hydrophobic properties has been disregarded. The Al– N/Cr– N multilayer coatings were kept in Ar/N_2 plasma with different N_2 gas stream rate proportions by receptive magnetron sputtering. The impacts of engineering, N_2 stream rate proportion and layer thickness proportion on wear protection and WCA were researched. Specifically, the diverse practices comparing to different designs of Al–N/Cr–N/Cr– N/Al– N and Cr– N/Al– N/Al– N/Cr– N are investigated.

Experimental Procedure

The multilayer coatings were prepared to utilize a close field unequal magnetron sputtering system with four vertical cathodes at interval of 90°. The deposition chamber was 550 mm in diameter across and 500 mm tall, while the measurements of the objective are 300 mm × 109 mm × 10 mm. Two Al (virtue 99.999%) targets were fueled by a medium-frequency (MF, 40 kHz) control power for the deposition of the AlN layers. A Cr target was controlled by a DC control power for the deposition of the Cr– N covering. The gas purity of both the Ar and N2 is 99.999%. For the wear test, JIS SKH51 high steel examples estimating 40mm×40mm× 4mm were warmth treated to a hardness of 62.5±1 HRc. Morphological anisotropy influences the water contact point [27] and in this examination, this effect was limited utilizing cleaned Si (100) substrates. Test examples were cleaned in a ultrasonic cleaner with surfactant for 15 min took after by de-ionized water for 10 min and after that dried at 100 °C for 15 min before the covering statement. Prior to deposition, the coating chamber was pumped down to 2.6 × 10−3 Pa. Substrates were bombarded with argon ions (Ar+) at a pressure of 0.57 Pa and a bias of −450 V for 20 min before deposition. The formulation Z-Dt-η represents the architecture (Z), deposition time (Dt) of individual Al–N or Cr–N layer and N2 flow rate ratio (η). Table 1 provides a detailed description of the formulation. Two architectures were designed: Al–N/Cr–N/…/Cr–N/Al–N (architecture A) and Cr–N/Al–N/…/Al–N/Cr–N (architecture C). The Dt was respectively set at 1, 2 and 3 min, to obtain the various layer thicknesses. Table 2 shows all of the deposition parameters for the Al–N/Cr–N multilayer coatings.

Table 1 Detailed description of formulation

Formulation	Architecture	Deposition rate	Flow rate
Z-Dt-η	A: Al–N/Cr–N…Cr–N/Al–N	1:1 min.	15:15 %
	C:Cr–N/Al–N	2:2 min.	20:20%

Table 2 Deposition parameters for Al–N/Cr–N multilayer coatings

Coatings	Al–N layer	Cr–N layer
Interlayer		
Substrate bias frequency (kHz)	50	50
Total flow rate (Ar) (sccm)	30	30
Thickness of interlayer (nm) Multilayer:	60	60
Target sputtering current (A)	3	3
Target materials	Cr	Cr
Bias of substrate (−V)	70	70
Target materials	Al	Cr
Total flow rate (Ar + N_2) (sccm)	50	50
Duty cycle (%)	15	15
Flow rate ratio N_2/(Ar + N_2) (%)	15, 20, 25	15, 20, 25
Working pressure (Pa)	0.40	0.40
Distance, target to specimen (cm)	7	7
Substrate bias frequency (kHz)	100	100
Bias of substrate (−V)	75	75
Target sputtering current (A)	3	3

Results

In this study, two architectures of Al–N/Cr–N multilayer hard coatings were prepared with various layer deposition times (Dts) and N_2 gas flow rate ratios (η) using a closed field unbalanced magnetron reactive sputtering system. The effects of architecture, Dt and η on wear rate and WCA of the coatings were studied. Better wear resistance can improve the lifespan of tools and molds. Higher degrees of WCA corresponded with increased water-repellency. The coatings with η of 20% and 25% for both architectures A and C exhibit better wear resistance than that with η of 15%. Table 3 shows the hardness (H), Young's modulus (E) and H/E for the selected coatings with η of 20% and 25%. The coatings of architecture A generally show greater H/E values than architecture C.

Table 3 Hardness (H), Young's modulus (E) and H/E for selected coatings.

N2 Flow rate ratio	20%			25%		
	H(GPa)	E(GPa)	H/E	H(GPa)	E(GPa)	H/E
A-1	15.1 ± 0.5	157.5 ± 11.2	0.102 ± 0.009	17.3 ± 0.5	156.1 ± 9.8	0.115 ± 0.007
C-1	15.9 ± 0.4	166.7 ± 15.2	0.101 ± 0.011	17.9 ± 0.6	180.2 ± 13.7	0.103 ± 0.009
A-2	17.2 ± 0.3	134.9 ± 9.3	0.135 ± 0.008	19.3 ± 0.4	164.7 ± 11.9	0.122 ± 0.004
C-2	17.6 ± 0.6	162.9 ± 8.9	0.118 ± 0.007	20.3 ± 0.6	204.0 ± 14.2	0.103 ± 0.005
A-3	17.7 ± 0.7	165.4 ± 10.3	0.116 ± 0.007	20.2 ± 0.6	176.7 ± 15.4	0.117 ± 0.006
C-3	17.9 ± 0.6	196.3 ± 12.3	0.101 ± 0.006	20.4 ± 1.0	211.3 ± 17.3	0.101 ± 0.007

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