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Toughness modulation of CrN/CrCN multilayered coatings for application in wood processing

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Keywords: CrN/CrCN multilayered coatings; toughness enhancement; H/E ratio; mechanical properties; wood cutting

Abstract: Wood machining and cutting tools require special mechanical properties because of differences in the physical and chemical structures and bulk properties of wood and metal[1, 2]. Coatings on woodworking tools should possess outstanding fracture toughness and large of H/E. Addition of carbon to CrN coatings reduces the residual stress[3, 4] and Cr-C-N films thus have higher hardness, wear resistance than CrN films[5, 6]. The amount of carbon should be optimized to yield the best properties. However, CrCN coatings have been studied extensively in terms of the structure and self-lubricating effects, there have been few investigations on improving the toughness by introducing multiple layers and carbon doping.

In this work, CrN/CrCN multilayered coatings are deposited at different C_2H_2 flow rates. The phase composition, microstructure, mechanical properties, and tribological characteristics are investigated systematically including industrial tests conducted on coatings fabricated on HSS and cemented carbide tools.

A CrN/CrCN multilayered coating (7 bilayers) modulated by carbon doping is deposited on M2 high-speed steel (HSS) and Si (100) by cathodic arc evaporation with different C_2H_2 flow rates and characterized systematically.

Addition of carbon to the CrN coatings enhances the toughness of coatings and the H/E ratio is improved by introducing a proper amount of carbon at a C_2H_2 to N_2 flow rate of less than 5%. The H/E and H^3/E^2 ratios reach 0.085 and 0.176, respectively, indicating high fracture toughness and resistance to plastic deformation (Fig. 1). The maximum nanohardness of is 24GPa (Fig. 1) and the smallest friction coefficient is 0.48 (Fig. 2) together with the optimal adhesion force between the film and substrate (HF1) (Fig. 3). A larger C_2H_2 flow rate produces a porous and loose microstructure with poor mechanical properties (Fig. 4).The lifetime of HSS and cemented carbide tools deposited with the CrN/CrCN multilayered coatings increases to 270% and 210%, respectively(table 1).

CrN-based multilayered coatings are deposited by the cathodic arc technique and a proper amount of carbon enhances the toughness and wear resistance. The coating deposited at a C_2H_2 flow rate of 10sccm and nitrogen flow rate of 400sccm has excellent toughness, large H^3/E^2 ratio (0.176), large hardness (24.3GPa), small friction coefficient (0.48). Incorporation of the optimal amount of carbon decreases the grain size but excessively large carbon concentrations or C_2H_2 flow rates give rise to a porous and loose microstructure with low surface hardness and poor wear resistance. The industrial wood processing tests reveal that the blades with the CrN-based coatings with the optimal carbon concentration deposited on HSS and cemented carbide tools show a durability increase of 170% and 110%, respectively.

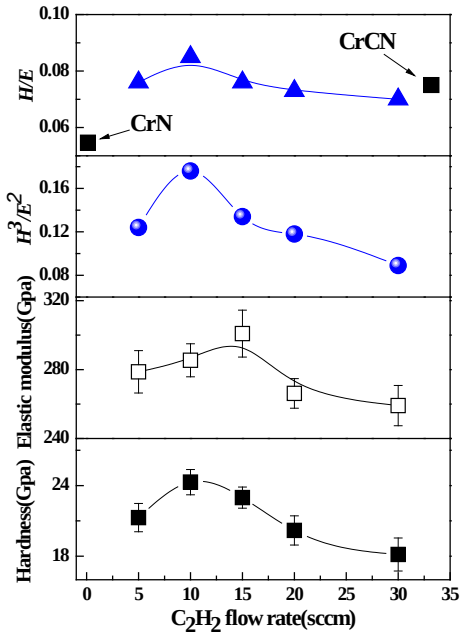

Fig.1 Relationship between the hardness, elastic modulus, and H^3/E^2 ratio with the C_2H_2 flow rate

Table 1 Cutting number of the different knives

Samples	Number of tree boles cut		
	Un-coated	CrN-coated	CrN/CrCN-coated
HSS-substrate	15	30	40
Cementedcarbide-substrate	188	372	397

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