Research on the performance of TiN/TiAlN nano-multilayer films

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By changing the modulation period prepared the good performance of the TiN/TiAlN nano-multilayer films. The performance tests show that nano-multilayer films obviously are much higher than the single layer films in hardness, binding force and other aspects. The cutting experiments prove that in the same thickness, TiN/TiAlN nano-multilayer films can greatly improve the service life of the cutting tool, to improving the performance of single layer films has wide significance.

(Received April 5, 2012; accepted September 20, 2012)

Keywords: Nano scale multilayered coatings, TiN/TiAlN, Cutting tools, Super-hardness coating, PVD

1. Introduction

PVD (Physical Vapor Deposition) has received a wide range of applications since it appears. For example, the application of the superhard coatings of TiN and TiAlN has multiplied the increase in cutting tool life. The development trend of hard coating layer from a single compound to the binary compound and then the multi-compound coating, until the nanostructured coatings. Nano-coating due to its special super-hard effect has caused the industry's concerns, which has become the hotspot of the coating research in the future [1, 2]. Nano-multilayer is a coating system which is alternately arranged by two thicknesses of layers of different materials on the nanometer scale. Nanocomposite films are thin-film materials which are composed of two-phase or solid material in the above two-phase thin-film materials, including at least one phase is nanocrystalline. Nano-coating has caught more and more people's attention because of its unique physical and chemical properties [3, 4]. Fig. 1 is a nano-multilayer structure formed by the two materials. By two or more materials to the nanometer level thickness of alternate soking forms multilayer structure films, in the direction of the thickness, it has the periodicity of nanometer level. For A-B two materials of the formation of the nano-multilayer films, the sum of the thickness of two adjacent layers is called modulation period T (T= $L_A + L_B$), and their thickness are called modulation ratio R (R= $L_A - L_B$). Generally the multilayer that the thickness is less than 100nm is called nano-multilayer [5, 6].

This article chooses TiN, TiAlN that through certain modulation ratio prepared the coating of nano-multilayer films. Because of two coating of TiN, TiAlN are more commonly used at present, and but TiN's temperature resistance is worse, the hardness is also lower; although TiAlN's temperature resistance and hardness are higher, the brittleness of the films is higher, and the binding force of matrix is worse. In order to improving the performance of the two single coating, using the technology process to composite made nano-multilayer films to increase the performance of the traditional coating, which is a good choose.

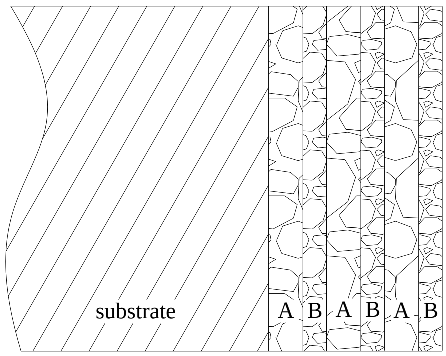

Fig. 1. Nano-multilayer films.

2. The preparation of nano-multilayer films

In this article, the preparation of nano-multilayer films is used the AF-550 equipment which Qingdao Wolfer Beschichtung Technick GMBH imports from Germany WOLFER. The equipment is used an advanced multi-arc cathode are technology, coating equipment has four groups of different target, each group of target include three types of same target (size is ϕ 100×16). So preparing composite coating can complete in a charging, and do not need to change another target.

The preparation of nano-multilayer films has an influence on modulation period, modulation ratio, working pressure and deflection pressure and other factors. The author based on many years of work experience and review of the literature, he determined argon's working pressure is 0.5Pa, deflect voltage is -70V, coating temperature is 450-500°C. The selection of the other process parameters is shown in Table 1. For comparison, at the same time, prepared TiN, TiAlN single-layer coating total thickness are 3 μ m.

Sample plates is used in high speed steel SKH-51, the size is ϕ 20×3, after quenching and tempering the matrix hardness is HRC63-64, and before coating sample surface is strictly polishing and claening. After coating is used respectively the spectrum tester (XMDVM-T2.1-W) which Germany produces, nanohardness tester HM2000 (FISCHER) which Germany produces and the American MTS company's XP nano-hardness tester in surveying thickness, hardness and the binding force between the layer and the matrix. It is explain that where the binding force is used a measurement method which European coating is commonly used. This method is divided a measurement method which European coating is commonly used. This method is divided to HF0, HF1 …, HF6 of the binding force, and HF0 binding force is best. Though the indentation which is blown up under microscope compares with the standard map, the binding force belongs to which level.

Table 1. The experimental parameters of preparing TiN/TiAlN nano-multilayer films.

Sample numbers	1#	2#	3#	4#	5#	6#
Modulation period (nm)	15	20	25	30	35	40
Modulation ratio (L_{TiN}:L_{TiAlN})	1:2					
The total thickness of coating (μ m)	3					

Table 2. Three kinds of coating performance comparison.

Coating types	Binding force	harding (HV)	thickness (μ m)
TiN	HF2	2500	3.0
TiAlN	HF2	3500	3.0
TiN/TiAlN nano-multilayer films (modulation period is 30nm, modulation ratio is 1:2)	HF0	3800	3.0

3. Experimental results and analysis

Figs. 2 and 3 respectively show that the modulation period has an effect on the binding and hardness of nano-coating. With the changing of the modulation period on the general trend, the binding force, the hardness first increased and then reduced. When the modulation period, the binding force and the hardness of nano-multilayer films respectively are HF0, HV3800, the performance achieves a more rational condition.

It is concluded that the modulation ratio is a certain, with the modulation period increased, the thickness ratio of TiN, TiAlN gradually increased, when the corresponding coating of the strength and hardness will be increased correspondingly. But when the thickness increases to a certain extent, the interlaminar stress in the coating is larger, resulting in the brittleness is larger, so the binding force and the hardness are worse. Table 2 is the performance test results of TiN, TiAlN and TiN/TiAlN nano-multilayer films. Data in the table can be seen, when the modulation period of nano-multilayer films is 30nm and the modulation ratio is 1:2, the binding force and microhardness are much higher than that of TiN, TiAlN. It is shows that nano-multilayer films have more advantage than the single layer.

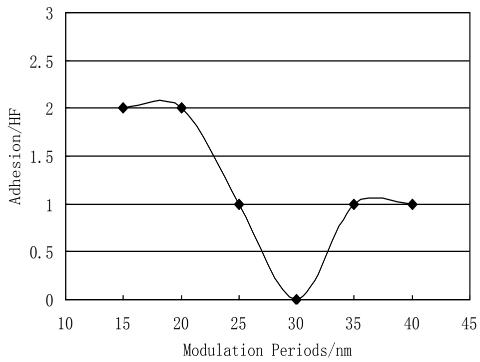

Fig. 2. The modulation period has an effect on the binding force of nano-multilayer films.

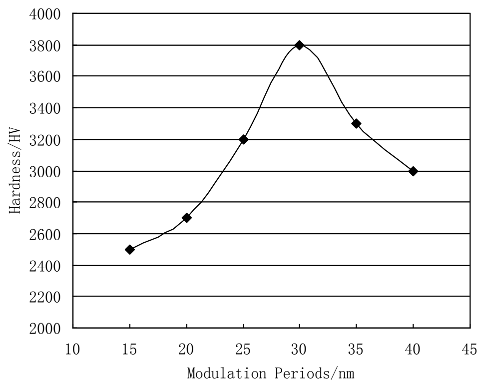

Fig. 3. The modulation period has an effect on the hardness of nano-multilayer films.

Using the simple model to analyze in the following, nano-multilayer films are formed after the layer-by-layer deposition in the perparation process, what can not only decrease the interlaminar stress, but also prevent the crack progation in the following using. Fig. 4, 5 respectively is crack in the nano-multilayer films and single-layer film expansion in the diagram. Coating in the process of their work are generally cracking in the surface, and then gradually inivard expansion, when it extended to the coating and the joint surface of the substrate, when the crack runs through the entire coating, resulting in the coating flaking. From the graph crack propagation route to seeing, the path of crack propagation in the nano-multilayer films is much larger than the single-layer, it shows that in the same coating thickness, the life of the nano-multilayer films is higher than the single-layer. The reports which a lot of internal interfaces which are parallel to the matrix in the nano-multilayer films can hinder crack propagation, ande provide dislocation motion’s resistance, at the same time increasing the toughess, hardness and strength of the film are also improved in the liternature is consistent.

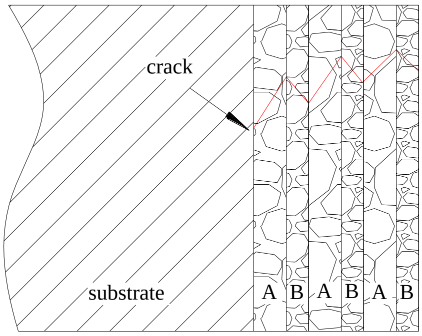

Fig. 4. Crack propagation paths in nano-multilayer films.

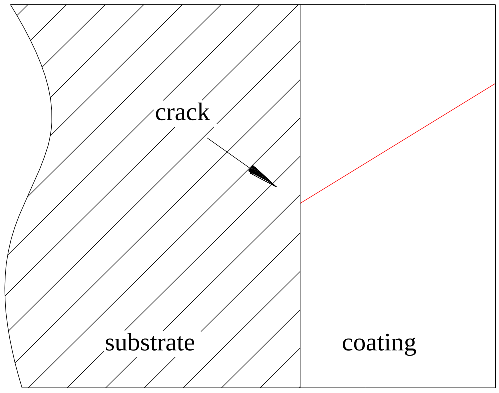

Fig. 5. Crack propagation paths in single-layer films.

4. Testing for cutting performance

In order to verify the actual cutting performance of nano-multilayer films, especially we choose two kinds condition on cutting tests: (1) Using the coating of carbide milling-tool on cutting test; (2) Using the coating of M42 high-speed steel drill on drilling test. Table 3 shows the relevant parameters on milling and drilling tests.

Table 3. Milling and drilling test parameters.

Name	D	Blade number	V_c	n	a_p	a_e	f_z	cooling	Machined materials
Milling (WC milling cutter)	12 mm	8	200 m/min	5310 r/min	10 mm	0.5 mm	0.02 mm	Compressed air	DIN1.2343 1800N/mm^2
Drilling (M4 drill)	6 mm	—	35 m/min	1856 r/min	15 mm	—	0.12 mm/r	Vegetable oil	DIN1.2379 720N/mm^2

During the milling test and the drilling test, milling cutter and drill should be treated by TiN, TiAlN and TiN/TiAlN nano-multilayer films respectively(modulation period is 30 nm, modulation ratio is 1:2). The average width of wear land of tool flank V_B =0.3 mm act as the standard of tool changing. Figs. 6 and 7 respectively show results of milling test and drilling test. Through the field milling and drilling test can be seen that TiN/TiAlN nano-multilayer films have better performance than the traditional single layer (TiN, TiAlN).

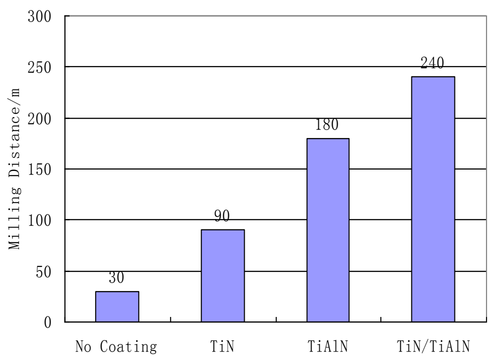

Fig. 6. Different coating milling test results.

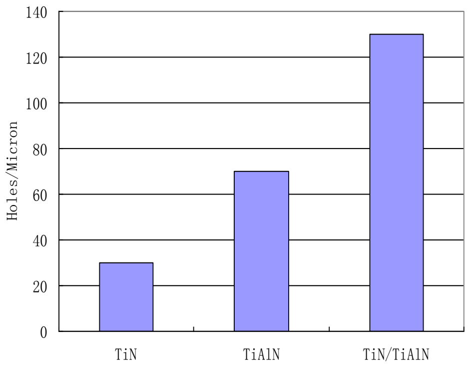

Fig. 7. Different coating drilling test results.

5. Conclusions

(1) When the modulation period of TiN/TiAlN nano-multilayer film is 30nm and the modulation ratio of 1:2 have better performance than the single layer: the binding force is HFO grade, the hardness is HV3800.

(2) TiN/TiAlN nano-multilayer films have excellent milling and drilling performance. In the same congditions, it can replace TiN/TiAlN multilayer films as a tool of superhard coating surface.

Acknowledgements

This work was supported by Creation Project from Shanghai Educational Committee (Project No.: 12Yz160) and Scientific Start-up Project for Introduction of Talent of Shanghai Institute of Technology (Project No.:YJ2011-04).

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