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Development of Tool Coating

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***Abstract*: With the continuous development of society and the continuous progress of science and technology, people put forward more and more requirements for processing quality and material types. The cutting environment of cutting tools is becoming increasingly harsh, and the traditional coated cutting tools are more and more difficult to meet the needs of people. In order to keep pace with the times, researchers have been exploring continuously to improve the coating structure by doping a variety of functional alloy elements, so as to prepare high hardness, super wear-resistant, high wear-resistant, high-performance coatings, self-lubricating and high temperature oxidation resistant tool coating. This paper focuses on the improvement of coatings in recent years.**

1 INTRODUCTION

As a kind of material surface modification technology, coating technology can effectively solve the contradiction between high hardness, wear resistance, high bending strength and impact toughness of cutting tools. Based on the above, compared with uncoated tools, coated tools can allow higher cutting speed and improve cutting efficiency; the friction coefficient between coating materials and processing materials is small, Moreover, it can effectively isolate the tool matrix from the workpiece material, and the tool integrity is high, which can effectively reduce the cutting force of the tool and improve the service life of the tool. Traditional transition metal nitride coatings, such as tin, CrN, have been widely used since their research and development. With the rapid development of today's industry, the demand for high strength and high hardness materials such as titanium alloy, cemented carbide and high-speed steel is gradually increasing. In order to improve the traditional coating tools, it is difficult to meet the process requirements of high-speed cutting and dry cutting In order to meet the needs of social development and improve the machining efficiency of cutting tools, the internal structure of the coating is gradually complex. New coatings with high thermal stability, chemical stability and oxidation resistance at high temperature have become an important direction of coating development.

2 DEVELOPMENT OF TOOL COATING

2.1 Binary coating

As the first industrial coating material, tin has mature preparation technology and good metal and non-metallic properties, which has been widely promoted in the field of cutting processing. In addition, due to its unique appearance color, tin coating has been widely concerned in the material decoration industry. The thermal expansion coefficient of TiN coating and steel is similar, so it can effectively adhere to the steel [1], and the chemical stability of tin coating itself is high, and it is not easy to react with processing materials. The oxidation temperature of TiN coating is 550℃-600℃ [1-3]. The TiO2 produced by cutting on the prop surface can play a lubricating role, reduce the cutting force and reduce the cutting temperature.

As a typical representative of transition metal nitride coating, CrN has high hardness, good wear resistance and the adhesion strength between coating and substrate, which greatly improves tool life and machining efficiency. It is widely used in tool cutting and various mechanical parts (0.19-0.20). Compared with tin, CrN coating has a slightly lower hardness, but its friction coefficient is lower. Cr2O3 protective film is formed on the surface of coated tool during cutting, The oxidation temperature can reach 700℃ and the oxidation resistance and corrosion resistance of the internal coating are better than that of tin coating[4]. The Cr metal coating with high brittleness, poor wear resistance and carcinogenic is replaced in industrial application[5].

2.2 Ternary coating

With the continuous improvement of cutting speed and harsh working environment, the traditional binary coating tool has been more and more difficult to meet the industrial progress. It is found that doping al into CrN, tin and other coatings can effectively improve the mechanical and Tribological Properties of the coating, and further improve the oxidation resistance of the coating at high temperature.

TiAlN coating has been widely used in dry cutting, high speed cutting and NC machining due to its high thermal hardness, thermal fatigue and high temperature oxidation resistance[6]. Al element doping in the coating can replace part of Ti, which can strengthen the solution, cause lattice distortion, increase dislocation and effectively improve the hardness of the coating. The working temperature of TiAlN coated tools can be as high as 1470 ℃, which is due to the fact that Al element is easy to react with O to form stable Al2O3 film, which can act as a chemical and thermal barrier and effectively protect the internal coating from further oxidation. The density and high temperature oxidation resistance of TiAlN coating can be effectively improved by increasing the content of Al in TiAlN coating[7].

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The internal structure of AlCrN coating changes gradually with the change of the atomic content ratio of Al and Cr, and with the increase of Cr content, the coating gradually changes from cubic structure to hexagonal structure. Under high temperature cutting conditions, Cr2O3 is formed on the coating surface When the cutting temperature rises to 900 ℃, the coating can still maintain high hardness, the adhesion strength between film and substrate and wear resistance[8]. Balzers company prepared and launched the ultrathin and high hardness AlCrN coating. When the temperature was 1000 ℃, the hardness of the coating was still as high as 27Gpa, with high red hardness. Compared with TiCN and TiAlN, the cutting life of the coating was significantly improved[9].

2.3 Nanocomposite coating

The nano-composite coatings of Me-Si-N and Me-B-N were prepared by doping Si, B and other elements into the metal nitride (MeN) coating. The microstructure of the coating was composed of fine nano-crystalline MeN/MeBX contained in amorphous SiNY/BN. The existence of amorphous SiNY/BN effectively inhibited the growth of coating grains [10]. Compared with the polycrystalline coating with the same composition, the nano-composite coating shows better mechanical and tribological properties, which is due to the fine grain size and high hardness in the coating, the good plasticity of the soft amorphous phase, the high cohesive energy of the interface between the two phases, and the thermodynamic separation trend of the crystal phase and the amorphous phase; the dislocation can not be formed in the fine nano-crystalline, and the thin amorphous layer between the grains can effectively resist at high temperature, the amorphous phase SiNY/BN can effectively prevent oxygen atoms from penetrating into the coating along the grain boundary defects, which can effectively improve the oxidation resistance of the coating. Therefore, the nano-composite coating with high hardness, good toughness and good wear resistance can be applied to the cutting field of cutting tools with bad cutting environment, so as to give full play to its excellent mechanical and tribological properties. The specific nano-composite structure is shown in the figure.

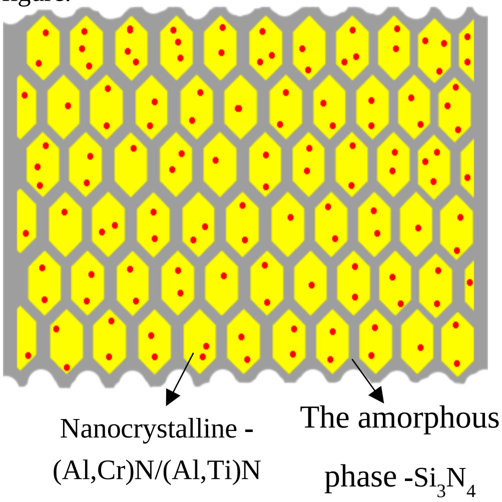

Fig1. The specific nano-composite structure

2.4 Multilayer composite coating

Multilayer composite coating refers to a coating system formed by the superposition of two or more layers of single-layer films with different components or structures as a group of repeating units. The multilayer coatings mainly include three types: Metal/ metal, metal/nitride (carbide, boride), nitride (carbide, boride)/nitride (carbide, boride) [11] In the same coating system, different modulation period and modulation ratio significantly affect the microstructure of the coating, and also have a greater impact on the mechanical and tribological properties of the multilayer coating. The purpose of multilayer structure modification is to coordinate the advantages of two or more kinds of thin film materials, so as to achieve the purpose of improving the overall coating performance[12]. The relevant research shows that the cracks produced by the hard brittle layer will deflect at the interface or be buffered in the soft layer, so as to effectively improve the toughness of the coating. According to Hall-Petch theory, the smaller the grain size in a certain range, the higher the hardness of the coating; according to the Koehler modulus difference strengthening theory, when the dislocation passes through the interface with different elastic modulus, the hardness mechanical properties of the coating are strengthened. Liu et al[13] prepared W/ZrB2 nano- multilayer coatings by RF magnetron sputtering system with W and ZrB2 monolayers with similar thermal expansion coefficients. The results show that when the modulation period is 30 nm, the maximum hardness of the coating is 41.5 GPA, which is much higher than that of single-layer w (19.7 GPA) and ZrB2 (32.6 GPA). On the one hand, the hardness enhancement mechanism is due to the large difference of elastic modulus between the two monolayers, and on the other hand, the thin monolayer can effectively inhibit the generation of dislocations and the growth of columnar crystals. The cross section morphology of W/ZrB2 nano-multilayer coating is shown in the figure.

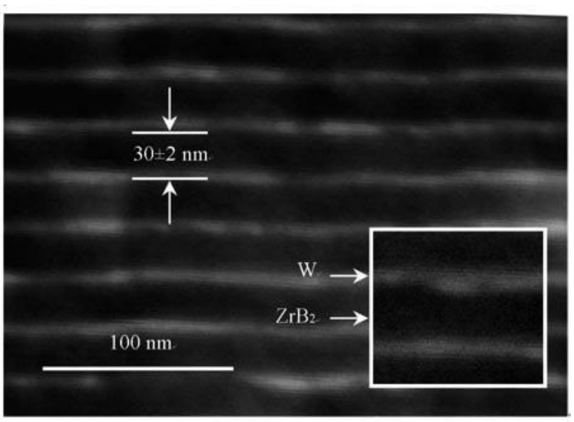

Fig2. The cross section morphology of W/ZrB2 nano-multilayer coating

2.5 High entropy alloy coating

In the 1990s, Professor Ye Junwei proposed that the alloy with five or more main elements with equal or close to equal atomic ratio is called high entropy alloy Alloys (HEAS) is a new kind of material which is obtained by introducing "chemical disorder" into multi principal component mixing. In order to expand the design range of alloy, the atomic fraction of each principal component is between 5% - 35% [14]. Its solution strengthening and dispersion strengthening effects can greatly improve the service performance of the alloy[15]. The performance enhancement of high entropy alloy can be attributed to four major effects[16,17]: (1) thermodynamic effect; (2) lattice distortion effect in structure; (3) hysteresis diffusion effect in dynamics; (4) cocktail effect in performance. Based on the above, new materials are developing rapidly in recent years. However, in the process of preparing high entropy alloy bulk materials, expensive elements such as Cr, Ni, Co, W, Mo, Ti are often added, resulting in the high processing cost [17]. However, the performance of many parts depends on their surface characteristics, and the preparation of high entropy alloy coating can obtain its excellent mechanical and tribological properties and greatly reduce the cost. The preparation of high entropy alloy coating has been widely received General concern. Some high entropy alloy films not only exhibit excellent properties similar to high entropy alloys, but also superior to bulk alloys in some properties.

In order to solve the problem that it is difficult to prepare the multi-element complex alloy target, the high entropy alloy coating with the required element composition is prepared by the interaction of multiple simple alloy targets. Based on the above, high entropy alloy coating is warmly sought after. Cheng et al [18] deposited alcrmotatizrn high entropy alloy coating by reactive RF magnetron sputtering in Ar/N2 mixed atmosphere. The results show that the hardness of the coating is as high as 40gpa, with low residual pressure stress (1.04gpa), high wear resistance and thermal stability. Relevant researchers have shown that nitrogen is introduced to form hard ceramic phase during the preparation of high entropy alloy coating, which can realize the preparation of high hardness coating. Moreover, Li Wei et al [19] Prepared alxfeconicrti high entropy alloy shows that the corrosion resistance of the alloy can be effectively improved by properly increasing the aluminum content in the alloy.

3 CONCLUSION

In the process of cutting, the coating can effectively avoid the direct contact between the tool substrate and the processing material, and play a thermal and chemical barrier effect. With the continuous innovation of coating technology, multi-layer and multi-scale coatings gradually appear in people's vision. At present, even in the high-speed and high-temperature cutting environment, coated tools can still maintain a higher cutting life.

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