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Development and Status of Tool Coating

Liu Qian[1*], Yaqian Zhang[1], Shiyong Zhang[1], Li Zhuang[1], Jifu Zhang[1]
[1]Tianjin Key Laboratory of High Speed Cutting and Precision Manufacturing,
Tianjin University of Technology and Education
Tianjin, China

Abstract: **With the development of modern machining technology, the use of cutting fluid is removed in the process of cutting workpiece, and it is gradually developing towards the direction of green, so that the cutting becomes more satisfied with the machining accuracy of the workpiece and improves the machining efficiency of the workpiece. Although the dry cutting without cutting fluid has been adopted by the majority of machine tools, there are many shortcomings that need to be improved. For example, dry cutting will aggravate the friction between the tool and the workpiece surface, reduce the tool life and increase the cutting cost. Therefore, the development of tool coating has become the mainstream direction of today's society. By designing experiments, changing the process and coating on the cutting tools, we can compare domestic coated tools, uncoated tools and experimental preparation of coatings to test which cu tting tools are more suitable for today's harsh cutting conditions. This paper mainly introduces the development of coatings in recent years from two aspects of hard coating and superhard coating.**

1 INTRODUCTION

In the development of advanced manufacturing technology, high-strength steel, wear-resistant cast iron, high-temperature alloy and other difficult to machine materials are also emerging, which puts forward a high demand for cutting tools. However, with the increasingly severe cutting tool conditions, the coating technology of cutting tool surface is developing. In the emergence and development of tool coating, superhard materials, high-speed cutting and finishing machining are developed As a result, the tool coating can adapt to these complex working conditions, greatly reduce the production cost and improve the service life of domestic and imported cutting tools. Over the past 30 years, coating technology has made great progress. The coated cemented carbide blade has developed from the first generation and the second generation to the third and fourth generation products. The application of tool coating greatly improves the wear and heat resistance ability of the cutting tool when cutting workpiece, as well as the hardness of the tool itself, prolongs the service life of the tool and reduces the production cost. In the development process of tool coating, the first tool coating on the market is hard film CrN and tin coating. As the initial typical tool coating, it can not only be used for tool surface strengthening, wear-resistant parts surface treatment and mold surface, but also widely used in furniture decoration, mechanical bearings and aerospace machinery (as shown in Figure 1-1).

Figure 1-1 application of hard coating in various fields

2 DEVELOPMENT AND STATUS OF TOOL COATING

2.1 Hard coating

(1) Metal nitride coating: almost all the nitrides of transition metals meet the H ü GG rule, and generally have B1 NaCl structure (tin, ZrN, HFN, VN, CrN, etc.) or hexagonal structure (NbN, Tan, etc.). Tin and CrN coatings are the earliest and most widely used metal nitride coatings. On this basis, ternary and multi-element alloying are carried out, and the multilayer structure coating, nano multilayer structure coating and nanocrystalline composite coating of metal nitride are prepared, so that the performance is continuously improved and optimized. In tin and CrN structures, Ti and Cr atoms are arranged in a face centered cubic lattice, while N atoms form a typical B1-NaCl structure in the octahedral space.

(2) Metal carbide coating: the metal carbide coating materials under use and research mainly include group IV carbide (TIC, ZrC, etc.), group V carbide (VC, NBC, TAC) and group VI carbide (Cr-C, Mo-C, W-C), etc. Generally speaking, the hardness of metal carbides is higher than that of corresponding metal nitrides, because there are obvious covalent bonds in the coating structure of metal carbides. Among metal bonds, ionic bonds and covalent bonds, covalent bonds have higher hardness and perform better than metal bonds and ionic bonds in performance.

(3) Metal boride coating: the research of transition metal boride coating in advanced manufacturing technology is far less than the current popular nitrides and carbides. Although the hardness of borides is similar to that of corresponding carbides, some borides show higher hardness due to higher degree of covalent bond, but the brittleness of borides is very high, This shortcoming limits its application in actual machining parts.

(4) Metal oxide coatings: some metal oxide coatings studied in machining are often used as hard protective coatings on various parts, such as Cr_2O_3、TiO_2、Al_2O_3、ZrO_2、Ta_2O_5 coatings because of their excellent chemical stability, high hardness and good thermal stability. Because of its various crystalline forms, each metal oxide coating will form different crystal systems at different temperatures and show different characteristics. Therefore, it has a very wide market in industrial applications.

(5) Other hard coating, multilayer structure coating and gradient coating: in addition to the metal nitride coating, metal carbide coating, metal boride coating and metal oxide coating mentioned above, there are also high hardness and widely used intermetallic compound coating, such as TiAl and NiAl coating. In the protection of high temperature oxidation of blade, a kind of MCrAlY protection has emerged MCrAlY protective coatings mainly include nicocralysib coating, NiCoCrAlY coating and NiCrAlYSi coating.

2.2 Superhard coating

(1) Diamond coating: as is known to all, as the hardest material in nature, diamond is widely used in various fields and has broad prospects for development. It has been studied and applied in the fields of heat, light, electricity and sound. Table 1-1 shows the hardness comparison between diamond and other hard materials. Diamond atoms are arranged in tetrahedron, and diamond is the most typical atomic crystal among many material crystals. There is covalent bond in diamond, which is formed by each carbon atom and four adjacent carbon atoms. Each carbon atom has SP3 hybrid orbit. Among all kinds of diamond, the properties of CVD diamond coating are better than that of natural diamond, so it has been paid more attention.

Table 1-1 comparison of hardness between diamond and other hard materials

Material	Mohs hardness	Knoop hardness / GPa	microhardness / GPa
Diamond	10	60~102	80~120
Cubic boron nitride (c-BN)	9.8	44.1	75~90
Boron carbide (BC)		76.9	37~43
Silicon carbide (SIC)		24.3	
Tungsten carbide (WC)	9.5	21.5	
Corundum (α - Al_2O_3)	9	16~20	20.6
Quartz (SiO_2)	7	8.2	11.2

(2) Diamond like carbon (DLC) coating: it is a metastable amorphous carbon with a lot of SP^3 bond inside. There are a lot of SP2 and SP3 bonds in DLC coating, and the ratio of the two bonds varies in a wide range. The performance of diamond-like carbon (DLC) coating depends largely on its special structure. The advantages of DLC coating, such as low friction coefficient, high hardness and small thermal expansion coefficient, are due to the formation of a large number of SP3 hybrid atoms in the coating.

(3) Cubic boron nitride (c-BN) coating: there are four isomers of nitrogen and boron compounds: hexagonal boron nitride (h-BN) belongs to hexagonal system with layered structure, in which the lattice constant is similar to graphite crystal in daily life. Recent studies show that h-BN coating can be used in vacuum microelectronics manufacturing due to its good field emission characteristics; rhombic boron nitride is a kind of three-dimensional structure Cubic boron nitride (r-BN) belongs to the trigonal system, and its structure and properties are similar to that of hexagonal boron nitride.

(4) Carbon nitride CNx coating: there is diamond with the strongest hardness in nature, so it has been considered as the standard. However, in 1985, M.L. Cohen, a professor of physics at Berkeley University, predicted that the elastic modulus of β-C_3N_4 would exceed that of diamond, which opened up a new way for the future of material industry. However, the preparation of pure crystalline phase β - C_3N_4 is a very difficult work, and there is no clear answer to prove its existence. Therefore, the synthesis of crystalline CNx coating is still the goal of researchers.

(5) Boron carbon nitrogen (BCN) coating: it has two kinds of structure, cubic BCN (c-bcn) has excellent characteristics, hardness is close to diamond hardness, thermal stability is similar to cubic boron nitride; hardness and thermal stability of hexagonal BCN (h-bcn) are between diamond and hexagonal boron nitride, in structure, C atoms in hexagonal BCN (h-bcn)

replace cubic boron nitride and hexagonal nitride Boron carbon nitrogen (BCN) coatings, such as B_2C_5N, BC_3N and BC_2N, are formed by controlling the proportion of boron, carbon and nitrogen atoms in boron structure.

(6) Nano multilayer structure coating and nanocrystalline composite coating: these two coatings have a nanometer scale standard in thickness direction, and have periodic structure. Nano multilayer structure coating generally refers to the structural alternation of two different materials with different thickness on the nano scale, forming a nano coating system with certain rules, also known as superlattice coating. It is widely used in semiconductor materials and optical instruments, and has the prospect of developing into more fields.

3 CONCLUSION

In recent years, with the continuous upgrading of material preparation technology, new super strong and superhard materials are constantly emerging. With the promotion of high-speed and high-precision cutting, dry cutting, and turning instead of grinding and other new technologies, higher requirements will be put forward for cutting performance of cutting tools, and the tool coating with excellent performance is the necessary condition for realizing high-end and high-speed machining of cutting tools. In view of the above, in the design of tool coating, the combination strength, hardness, toughness, thermal and chemical stability, elastic modulus, thermal conductivity, thermal expansion coefficient and friction coefficient should be considered comprehensively to prepare multifunctional coating. With the development of low temperature and low pressure vapor deposition technology, especially the emergence of plasma and ion beam assisted deposition technology, the renewal of tool coating is promoted and the industrialization of new coated tool is promoted.

REFERENCES

[1] Zhang S H, Wang L, Wang Q M, et al. A superhard CrAlSiN superlattice coating deposited by multi-arc ion plating: I. Microstructure and mechanical properties [J]. Surface and Coatings Technology, 2013, 214: 160-167.

[2] Zhang J, Lv H, Cui G, et al. Effects of bias voltage on the microstructure and mechanical properties of (Ti,Al,Cr)N hard films with N-gradient distributions [J]. Thin Solid Films, 2011, 519(15): 4818-4823.

[3] Shan L, Wang Y X, Li J L, et al. Structure and mechanical properties of thick Cr/Cr_2N/CrN multilayer coating deposited by multi-arc ion plating [J]. Transactions of Nonferrous Metals Society of China, 2015, 25(4): 1135-1143.

[4] Jao J Y, Han S, Chang L S, et al. Bias voltage effect on the structure and property of chromium copper-diamond-like carbon multilayer films fabricated by cathodic arc plasma [J]. Applied Surface Science, 2010, 256(24): 7490-7495.

[5] Ye Y W, Wang Y X, Chen Het, et al. Influences of bias voltage on the microstructures and tribological performances of Cr-C-N coatings in seawater [J]. Surface and Coatings Technology, 2015, 270: 305-313.

[6] Qiu Y X, Zhang S, Lee J W, et al. Towards hard yet self-lubricious CrAlSiN coatings [J]. Journal of Alloys and Compounds, 2015, 618: 132-138.

[7] Chang H W, Huang P K, Yeh J W, et al. Influence of substrate bias, deposition temperature and post-deposition annealing on the structure and properties of multi-principal-component (AlCrMoSiTi)N coatings [J]. Surface and Coatings Technology, 2008, 202(14): 3360-3366.

[8] Lin J, Wu Z L, Zhang X H, Mishra B, Moore J J, Sproul W D. A comparative study of CrN_x coatings Synthesized by dc and pulsed dc magnetron sputtering [J]. Thin Solid Films, 2008, 517(6): 1887-1894.

[9] Park J K, Baik Y J. The crystalline structure, hardness and thermal stability of AlN/CrN superlattice coating prepared by D.C. magnetron sputtering [J]. Surface and Coatings Technology, 2005, 200(5): 1519-1523.

[10] Chen M. H, Chen W L, Cai F, et al. Structural evolution and electrochemical behaviors of multilayer Al-Cr-Si-N coatings [J]. Surface and Coatings Technology, 2016, 296: 33-39.

[11] Lewis D B, Reitz D, Wustefeld C, et al. Chromium nitride/niobium nitride nano-scale multilayer coatings deposited at low temperature by the combined cathodic arc/unbalanced magnetron technique [J]. Thin Solid Films, 2006 (503): 133-14.

[12] He X M, Baker N, Kehler B A, et al. Structure, hardness, and tribological properties of reactive magnetron sputtered chromium nitride films [J]. Journal of Vacuum Science & Technology A Vacuum Surfaces and Films, 2000, 18(1): 30-36.

[13] Chen H Y, Tsai C J, Lu F H. The Young's modulus of chromium nitride films [J]. Surface and Coatings Technology, 2004 (184): 69-73.

[14] Wang T, Zhang G J, Jiang B L. Microstructure, mechanical and tribological properties of TiMoN/Si 3 N 4 nano-multilayer films deposited by magnetron sputtering [J]. Applied Surface Science, 2015, 326: 162-167.

[15] ANDRIEVSKI R A. Nanostructured superhard films as typical nanomaterials [J]. Surface & Coatings Technology, 2007, 201(13): 6112-6116.

[16] RIZZO A, VALERINI D, CAPODIECI L, et al. Reactive bipolar pulsed dual magnetron sputtering of ZrN films: The effect of duty cycle [J]. Applied Surface Science,2018,427: 994-1002.