Research Progress of CVD Diamond Coated Carbide Tools

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Abstract

CVD diamond coated carbide cutting tools combine the excellent performance of diamond and cemented carbide, is the ideal materials for cutting and machining and have a bright future. In this paper, the characteristics of CVD diamond coating tools, common preparation methods of CVD coatings are reviewed. The methods to improve the bonding strength of the coating and substrate are mainly discussed.

Keywords

Diamond coating, Cemented carbide, Chemical Vapor Deposition (CVD) , Intermediate layer.

1. Introduction

Diamond is the hardest material in nature. Due to wear-resistant, high thermal conductivity and good chemical stability and many other excellent properties make it an ideal material for abrasive and cutting tools. However, the use of diamond alone is very brittle, can't be high-intensity processing, and single-crystal diamond tool due to high cost and impact resistance of the soft rib caused its application is limited.

2. Characteristics of CVD diamond coated cemented carbide tools

The combination of CVD diamond film and cemented carbide makes the tool not only show high hardness, wear resistance and thermal conductivity of diamond, but also have good impact resistance and strong toughness of cemented carbide. Compared with the carbide cutting tools, it has the advantages of long life, high precision, more suitable for high-speed machining, dry cutting to reduce environmental pollution and so on. Diamond coated cemented carbide tools can be widely used in processing non-ferrous metals, non-metallic, plastics, composites, wood, graphite and other materials.

3. The Preparation methods of CVD diamond film

Through the continuous exploration and improvement of our predecessors, the equipment and growth technology of CVD diamond coating have been rapidly developed. At present, many mature methods have been developed. The most common CVD diamond coating preparation methods are: hot filament CVD (HFCVD), microwave plasma CVD (MWPCVD).

(1) Hot filament CVD (HFCVD)

Hot filament CVD method is the most mature method of industrialization. The principle is the parallel arrangement of several tungsten or tantalum wire heated to about 2000 ℃. The thermal decomposition of methane and hydrogen in the vacuum reaction chamber to form atomic hydrogen and active carbon-containing groups will promote the formation of sp3 hybridized C-C bonds. Diamond nuclei are formed on the surface of the substrate and continue to grow to form diamond coatings. This method has been widely studied because of its low cost and suitable for industrialized production.

(2) Microwave Plasma CVD (MWPCVD)

Microwave Plasma CVD method is to use microwave equipment in the cavity to generate high-frequency microwave, to stimulate the violent oscillation of the plasma, and then produce a

large number of high-energy particles, through the hydrogen methane and other reaction gases of the constant impact of the ionization, so as to achieve rapid and efficient diamond nucleation and deposition. Deposition of substrate temperature is low, electrodeless discharge no metal pollution, so the crystallization of diamond coating and quality reproducibility are very good, is currently the formation of high-quality Diamond coating is a competitive method. The disadvantage is that the equipment cost is high, the deposition rate is low, and the film deposition area is small. Based on its more advantages is one of the future direction of development.

4. Improve the adhesion of coating and substrate

The lack of adhesion between CVD diamond films and cemented carbide substrates limits their application in industry. How to improve the adhesion of the diamond coating on the tool and ensure the excellent processing performance and service life of the CVD diamond coated tool has become an urgent problem for material scientists.

There are many factors that affect the bonding force between the diamond coating and the cemented carbide substrate, which are mainly as follows:

(1)Competitive growth in the deposition process led to the formation of non-diamond carbon at the interface;

(2)Due to the difference in thermal expansion coefficient caused by the higher thermal stress of the coating;

(3)Diamond growth defects caused by the formation of the higher coating stress;

(4)Cobalt matrix in the matrix at high temperatures led to the proliferation of lower nuclear rate and graphite at the interface, the presence of amorphous carbon.

Among these factors, the presence of binder phase Co and the difference of the thermal expansion coefficient between the coating and the substrate are the most important factors leading to the poor film-based bonding performance.

In order to improve the adhesion between the diamond coating and the cemented carbide substrate, a number of pre-treatment methods for the cemented carbide substrate have been developed, mainly in the following ways:

(1)Surface Decontamination

Through cleaning, grinding, sandblasting and other methods to purify the surface of the substrate, can remove impurities and oxide film, and improve the nucleation rate.

(2)Cobalt Removal Treatment

Acid-base two-step method, alkalis two-step method can significantly roughen the surface of the substrate to improve the diamond deposition quality and adhesion. But at present it can only be used in the cemented carbide with low cobalt content, and the effect of cemented carbide with high cobalt content is not satisfactory.

(3)Add the Intermediate Layer

At present, the most effective method is to add an intermediate layer between the substrate and the diamond film. This method is not only suitable for low-Co alloys but also for high-Co alloys.

The intermediate layer is added before the diamond deposition, a thin middle layer is prepared on the cemented carbide substrate by electrochemical, physical vapor deposition and chemical vapor deposition, which can reduce the mutation in the physical properties of the interface, reduce the thermal expansion coefficient of the difference so as to reduce thermal stress and at the same time can prevent carbon excessive infiltration into the substrate and prevent the diffusion of Co to the surface at high temperatures, thereby significantly improve the coating quality and adhesion. Therefore, the pretreatment method is especially suitable for cemented carbide with high co content. The selection of intermediate layer materials should follow the following principles: ①diamond nucleation rate is high; ②moderate thermal expansion coefficient; ③with the two heterogeneous materials, such as

diamond film and WC carbide, can form a strong bonds and have good adhesion on cemented carbide and diamond surface; ④react with Co to form stable compounds, or Itself can directly prevent Co diffusion to the surface layer and the diamond coating at high temperature; ⑤chemical stability, with a certain degree of mechanical strength.

5. Conclusion

At present, the research of CVD diamond coating tools mainly focuses on the deposition method and mechanism of CVD diamond, substrate pretreatment, intermediate layer, low temperature growth, high-speed and efficient growth, industrialization of diamond tools. There are still many fundamental issues that need to be solved in order to achieve the industrial application of CVD diamond coated tools. As a result, there is much more research to be done and future work can be done in the following areas:

(1) Increase the study of intermediate transitional layer. At present, the method of treating and removing co from the substrate surface can't fundamentally solve the difference of the bonding force between the diamond coating and the cemented carbide matrix, which leads to the majority of the current research on 6%~8% Co cemented carbide, and there is little research on the deposition of diamond on the higher Co content cemented carbide.

(2) By changing the diamond film deposition process conditions to get a smaller particle or nanometer diamond coating.

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