Research Progress of Interlayer on Improving the Adhesion Between Diamond Coating and Cemented Carbide Substrate

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Abstract

CVD diamond coated carbide tools are well suited for processing composites, graphite, ceramics and non-ferrous metals and are therefore widely used. How to improve the adhesion between diamond coating and cemented carbide substrate has always been a key issue in the development of CVD diamond coated tools. By applying an intermediate layer, the graphitization of the cobalt binder phase is reduced, and the adhesion between the film and the substrate is improved, and a remarkable effect is obtained. This paper introduces the research progress of the middle layer in recent years, analyzes the shortcomings of the middle layer technology, and forecasts the future research trends.

Keywords

Diamond coating, cemented carbide, intermediate layer.

1. Introduction

The cobalt phase in the cemented carbide matrix has a strong graphitization effect, while the coefficient of thermal expansion between the cemented carbide and the diamond coating differs. The application of the intermediate layer will be an effective way to improve the adhesion between the diamond film and the cemented carbide substrate. In fact, the diamond film deposited on the surface of the cemented carbide not only faces the adverse effects of the binder phase, but also withstands the internal stress caused by the difference in lattice constant and thermal expansion coefficient from the matrix. The application of the intermediate layer on the surface of the cemented carbide can better block the graphitization of the binder phase on the one hand, and can also alleviate the sudden change of the physical properties of the cemented carbide substrate and the CVD diamond film on the one hand, thereby alleviating the stress concentration, thereby Improve the adhesion of the diamond coating.

2. Metal-based Interlayer

Na et al. prepared a pure metal tungsten and titanium intermediate layer on the surface of cemented carbide by DC magnetron sputtering, and then deposited a nano-diamond coating on the intermediate layer by microwave CVD. Through the friction test and indentation experiment of the prepared nano-diamond coating, they found that the adhesion of nano-diamond increased with the increase of the thickness of the intermediate layer, and the improvement effect of the tungsten intermediate layer on the adhesion of nano-diamond was better than that of titanium.

On the basis of cobalt removal, Kopf et al. sputtered an aluminum film on a cemented carbide substrate. During the deposition of diamond, cobalt reacted with aluminum to form a harmless compound, while the surface aluminum lifted the diamond. Nucleation density. However, the greater thermal stress leads to an improvement in the adhesion of the diamond. Subsequently, Kopf et al. attempted to add aluminum-containing components during the cobalt removal pretreatment and achieved a certain adhesion enhancement effect.

Tang et al. prepared a W/Al metal intermediate layer. The W film is used to improve the nucleation density of diamond, and the Al film is used to isolate the catalytic action of cobalt. The test results show that the nano-diamond film can be deposited under the process of depositing micro-diamond. The thickness of the W/Al metal interlayer is only 50-65 nm. The metal nano-diamond film usually means a large amount of non-diamond phase components. It is speculated that although the continuous diamond film can be deposited under the experimental conditions, the effect of cobalt is not affected.

3. Ceramic Interlayer

Hojman et al. tried to improve the adhesion of the diamond film by the CrN interlayer. They first prepared a 1.5μm metal chromium film on the cemented carbide substrate of YG10 by PVD sputtering process, and then nitrided it at high temperature to prepare CrN film. The characterization of the subsequently deposited diamond coating shows that the matrix binder phase can form an alloy phase with the metal chromium to enhance the adhesion between the intermediate layer and the matrix. At the same time, CrN itself can ensure the higher nucleation of diamond film growth.

Park et al. attempted to prepare a TiAl intermediate layer on YG6 cemented carbide. The results show that the addition of TiAlN component in the intermediate layer can produce better barrier effect on the binder phase, and the continuous adhesion of nanodiamond film is successfully prepared on the TiAl-based interlayer.

Polini et al. deposited CrN transition layer and Ti-based cermet transition layer by PVD method respectively. The adhesion of diamond coating deposited on CrN transition layer and Ti-based cermet transition layer was tested by friction experiment.The results show that Cr-based transition layer is better than Ti-based transition layer in improving the bond strength of diamond, and the diamond coating deposited on CrN transition layer shows excellent wear resistance, which is attributed to the carbide produced in the process of diamond deposition.

Cabral et al. prepared a silicon carbide transition layer on a cemented carbide tool substrate by CVD using tetramethylsilane as a silicon source, and continued to deposit a high quality diamond coating. The cutting performance of the transition layer on the diamond coated tool was studied. The effect of the study found that the transition layer reacted with the cemented carbide matrix to form a silicon-cobalt compound, which has a better effect of blocking the diffusion of cobalt, so the tool has better adhesion properties compared to PCD cutters and conventional acid. A conventional diamond-coated tool that has been pretreated and prepared by a two-step alkaline process, which exhibits the lowest cutting forces and the highest cutting life.

Tang Bin et al. studied the difference in the improvement of adhesion of diamond interlayers prepared by SiC intermediate layers prepared at different deposition temperatures. It was found that the SiC interlayer deposited at 600 °C consisted of loosely packed nano-SiC spheres. When the deposition temperature rose to 850 °C shell-like SiC particles and graphite were deposited, and when the temperature rose to 950 °C. The SiC intermediate layer exhibits SiC particles and graphite particles in rapeseed. Studies have shown that the SiC intermediate layer deposited at 850 °C has the best effect on the adhesion of diamond film.

4. Composite Interlayer

Konyashin et al. used the PVD method to prepare a gradient TiCN intermediate layer: TiCN was in contact with the cemented carbide substrate, and then the C and N concentrations were gradually decreased, and finally pure Ti was formed on the surface layer of the intermediate layer. In this way, diamond microcrystals are implanted on the surface layer by laser ablation, thereby increasing the bonding force between the diamond coating and the intermediate layer and the nucleation density of the diamond. The indentation test shows that the bonding strength between the diamond coating and the intermediate layer is high, and the diamond crystallite has a great influence on the adhesion. In the test of processing silicon-aluminum alloys, it was found that the tool life using this process was increased by three times.

Raghuveer et al. used a method of embedding a discontinuous diamond layer by first depositing discontinuous diamond grains on a cemented carbide substrate and then applying a TiN/TiC transition layer. In this way, the thermal expansion coefficient of the TiN/TiC transition layer and the matrix can be effectively alleviated, and the exposed diamond grains can be used as seed crystals for subsequent diamond deposition, thereby effectively increasing the nucleation density of the diamond. The TiN/TiC transition layer mechanically locks the two layers of diamond, significantly increasing the adhesion of the diamond film to the substrate.

Polini et al. used a PVD process to prepare a CrN/Cr composite transition layer on the surface of a cemented carbide substrate. They use the FluidizedBed pretreatment process to improve the surface morphology of the substrate and improve the mechanical locking effect between the nanodiamond film and the substrate. Studies have shown that the CrN of the bottom layer in the CrN/Cr composite transition layer can effectively block the penetration of the binder phase, and the upper metal layer can effectively form a bond with the diamond, thereby improving the adhesion of the diamond. However, the thickness of the composite transition layer is relatively thick, reaching several micrometers, which easily causes passivation of the coating tool.

Lu et al. deposited two composite intermediate layers of Cr/CrN/Cr and Ti/TiN/Ti on the cemented carbide substrate, and used scratch test to study the relationship between the thickness of diamond film deposited on the intermediate layer and adhesion. Studies have shown that the adhesion of diamond film increases with the increase of film thickness, which is linear. Further, the adhesion of the diamond film deposited on the titanium-based intermediate layer is inferior to that of the diamond film deposited on the chromium-based intermediate layer.

Wei Qiping et al. used a reactive sputtering process to prepare a gradient graded W/WC composite transition layer on YG13 high cobalt cemented carbide substrate, and studied the effect of the deposition temperature of the prepared diamond on the composite transition layer and diamond coating. Indentation experiments show that the W/WC gradient composite transition layer can effectively improve the nucleation density and adhesion of diamond, and the adhesion of diamond coating increases with the increase of substrate temperature.

5. Conclusion

Due to its good toughness and impact resistance, high cobalt cemented carbide is suitable for processing difficult-to-machine metals with high impact toughness requirements. The development of diamond-coated tools based on high-cobalt carbide substrates will significantly improve tool durability and improve tooling quality. Although great progress has been made in the deposition of diamond coatings on cemented carbide substrates, the adhesion of diamond coatings deposited on high cobalt cemented carbides has yet to be improved. The application of the intermediate layer technology to deposit high-quality, high-adhesion diamond coating on the high-cobalt cemented carbide substrate is of great significance for the improvement of tool durability and processing quality.

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