

CHAPTER 4 COBALT DEPLETION TECHNIQUES FOR TUNGSTEN CARBIDE SUBSTRATES

*Tuty Asma Abu Bakar, Izman Sudin, and
Engku Mohamad Nazim Engku Abu Bakar*

4.1 INTRODUCTION

The interest in coating materials has increased significantly over the past 15 years. Diamond is the hardest known material, exhibiting a Vickers hardness in the range of 70–100 GPa depending on crystallographic orientation and purity (Zhang et al., 2024). In addition, it features exceptionally high thermal conductivity and a low friction coefficient. The synthesis of polycrystalline diamond films via Chemical Vapor Deposition (CVD) has opened new opportunities to utilize synthetic diamond in innovative protective coating applications, combining high hardness and low friction to reduce wear (Ashkinazi et al., 2022; Dias et al., 2024).

The most suitable substrate for producing diamond-coated components is Co-cemented tungsten carbide (WC–Co). Direct deposition of CVD diamond onto WC–Co parts and cutting tools yields components with exceptional abrasion resistance, while retaining the high fracture toughness of the underlying cemented carbide substrate (Su et al., 2025). Consequently, diamond coatings on WC–Co substrates

are increasingly used in engineering applications designed to withstand demanding wear conditions (Takahashi et al., 2017).

Chemical Vapor Deposition (CVD) diamond coatings can significantly prolong the lifetime of WC–Co cutting tools, particularly when machining highly abrasive non-ferrous alloys, composites, and ceramics (Behera et al., 2020). However, the presence of the cobalt (Co) binder typically 6–10% content detrimentally affects deposition, as Co suppresses diamond nucleation and promotes the formation of non-diamond carbon phases (e.g., graphitic layers with poor adhesion).

The WC–Co system remains well-balanced in its overall properties, offering a range of WC grades via adjustments to Co content (5–30%), grain size (0.5–50 μm), and carbide additives, thus tailoring hardness, toughness, strength, abrasion resistance, and thermal conductivity. To promote coating adhesion, chemical pretreatments such as Murakami's reagent etching and acid etching have been used to remove the Co binder from the substrate surface. However, these treatments can significantly reduce the substrate's mechanical properties and toughness (Veillere et al., 2011). The main challenge remains achieving strong adhesion between diamond coatings and the WC–Co substrate without compromising substrate integrity.

4.2 COBALT REMOVAL IMPROVED DIAMOND COATING GROWTHS

The presence of Co, typically at levels of 6–10% in cemented carbide substrates, has a detrimental influence on the deposition process. Binder materials such as Co can suppress diamond growth, favoring the formation of non-diamond carbon phases (i.e., graphitic deposits with poor adhesion). A high Co content in the substrate has been reported as the primary cause of poor adhesion. Studies have demonstrated that the presence of Co in cemented carbides affects both the nucleation and growth of diamonds on the substrate, as well as the adhesion between the coating and the substrate. In fact, diamond coatings deposited by

CVD on WC–Co generally exhibit low adhesive-bonding strength. The poor adhesion is primarily attributed to:

- (1) The mismatch of thermal expansion coefficients, which generates large thermal stresses at the interface.
- (2) The interaction between carbon and the thin layer of cobalt on the tool surface.

To address these issues, various pre-treatments—such as chemical etching and vacuum evaporation have been employed to reduce the Co content at the substrate surface, thereby improving the adhesion between the coating and the substrate

4.3 TYPE OF PRE-TREATMENT PROCESS FOR COBALT REMOVAL

Various methods have been employed to promote adhesion, particularly through chemical pretreatment aimed at removing the Co binder from the substrate surface. However, coating adhesion remains a critical issue. Chemical pretreatments are designed to modify the surface of the cemented carbide, and two main approaches can be envisioned. The first is to dissolve the Co binder from the substrate surface while simultaneously increasing surface roughness. This is necessary because Co tends to diffuse to the surface and attack the growing diamond crystallites, thereby suppressing their growth and favoring the deposition of a graphite film. Thus, it is essential to remove Co from the cemented carbide surface.

Examples of chemical pre-treatments for Co removal include acid etching, cobalt etching, the use of interlayer materials, and WC–Co heat treatment. These methods can reduce the formation of a graphitic carbon layer and improve the adhesion of the diamond coating to the substrate.