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Fabrication of Boron-Doped Diamond Films on Cemented Tungsten Carbide

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Abstract

Diamond coating on cemented tungsten carbide (WC-Co) is quite difficult. Generally, in order to reduce reactivity of cobalt (Co) which is the binder of WC-Co, the pretreatment using the acid is carried out. To obtain boron-doped diamond (BDD), diborane (B_2H_6) and trimethyl boron ($B(CH_3)_3$) are often used as boron sources. This study is an attempt to deposit BDD directly on WC-Co by microwave plasma CVD using trimethyl borate ($B(OCH_3)_3$) as a safe boron source. WC-Co substrate was scratched with diamond powders and cleaned before loaded into the chamber. $B(OCH_3)_3$ was introduced into the chamber with hydrogen (H_2) carrier gas. Boride was formed on the substrate to reduce reactivity of Co. Then, BDD was formed continuously with using reactive gases of methane (CH_4) and H_2. As a result, the presence of boride was important to secure adhesion strength and deposit of BDD. It was possible to deposit BDD continuously with good adhesion without Co removal as a pretreatment.

Keywords: Boron-doped diamond, microwave plasma CVD, Cemented tungsten carbide, Adhesion

1. Introduction

WC-Co having heat resistance and abrasion resistance is widely applied to cutting tools as well as general tools. Generally, tungsten carbide (WC) particles are sintered together with a binder metal, but the kind and amount of the binder and the WC particle diameter are changed depending on the application. The pursuit of production efficiency made the processing conditions more stringent, in which it became common to coat Titanium (Ti) and Chromium (Cr) ceramic with physical vapor deposition (PVD) after selecting an appropriate WC-Co [1-2].

In recent years, the introduction of aluminum (Al) alloy and carbon fiber reinforced plastic (CFRP) has been increasing for the purpose of reducing weight mainly in the aerospace industry. However, adhesion and significant abrasion of the work piece on the tool surface have become a major issue. In this processing, ceramic coating cannot work and the only solution is diamond coating [3].

Although diamond coating is deposited by chemical vapor deposition (CVD), it is difficult to directly deposit diamond on WC-Co. This is because the catalytic function of Co serves as a binder of WC-Co, and in order to control this action, generally, pretreatment of removal with acid is performed [4]. On the other hand, it has been reported that without removing Co with acid, and by forming boride on the surface of WC-Co with the Plasma Enhanced (PE) CVD using B_2H_6, reactivity of Co is controlled and adhesion of nanostructure diamond improves [5]. Both B_2H_6 and $B(CH_3)_3$, which are commonly used as B sources, have toxicity, flammability and explosiveness, and they need to be managed by using special apparatus [6].

In this study, $B(OCH_3)_3$ with a little toxicity was used as a boron source. BDD was deposited on WC-Co directly using microwave plasma CVD with two steps formation of boride and deposit. It was inspected whether it was possible to secure the adhesion by forming boride on WC-Co surface even if it does not take Co of a binder out by the acid.

2. Experimental method

2.1 Deposition of diamond

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