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Effect of pretreatment of substrate on synthesized diamond films on Tungsten Carbide substrate by flame combustion

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Abstract

A flame combustion method enables the synthesis of diamond using acetylene-oxygen gas flame combustion in ambient air. Recently, tungsten carbide (WC) has been used as cutting tools in the machining industry. To obtain diamond films and to achieve good adhesion on the WC substrate, diamond films were synthesized by flame combustion method. However, synthesized diamond films delaminate as a result of thermal stress during cooling. In this study, as a pretreatment of the substrate to prevent the delamination, a chemical processing was performed. The WC substrate was pretreated by chemical etching to roughen the surface. The substrate was etched in an ultrasonic bath using Murakami's reagent. Another processing was performed using an acid solution of hydrogen peroxide, in order to remove cobalt from the substrate surface. The pretreatment periods were varied. Moreover, the effect of the pretreatment of the substrate on synthesized diamond films by flame combustion was investigated.

Keywords: Diamond films; Flame combustion; Tungsten carbide; Pretreatment of substrate

1. Introduction

Owing to its excellent properties, namely, high thermal conductivity, high hardness and high wear resistance, diamond is widely used in the industry, such as in the manufacture of cutting and polishing tools. Diamond films have

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long been considered a coating material of dental cutting tools [1]; thus, diamond has been extensively studied for use as a coating material of medical devices [2].

Recently, tungsten carbide (WC) is used as cutting tools in the machining industry and dental machining applications. WC is very hard and brittle and is prone to wear and fracture during cutting. Worn and failed tools have to be discarded, with resource and environmental penalties. It is thought that if diamond films can be directly synthesized on the WC surface and good adhesion can be achieved, surface improvement in terms of the high hardness and ultimately in terms of wear resistance can be realized. The CVD method in which the diamond was deposited on the WC surface has been developed. There were many problems such that adhesive strength between the synthesized film and the substrate surface was low and density of diamond nuclei on the surface was low. Thus, it was difficult to synthesize the diamond films on the WC surfaces. Moreover, the experimental equipment of the CVD method was very large, and the synthesis speed was very slow.

The flame combustion method enables the synthesis of diamond using acetylene-oxygen gas (C_2H_2/O_2) flame combustion in ambient air [3, 4]. It has various advantages over other methods, such as high synthesis speed and the safety and low cost of the equipment used; these advantages are desirable in the industrial market. However, to date, the factors affecting diamond synthesis remain to be determined and no means of precisely controlling this method has been established. Moreover, during cooling, most diamond films delaminate as a result of thermal stress. We previously synthesized diamond films on a Molybdenum (Mo) substrate surface by the flame combustion method [5-7]. In previous report, diamond films were synthesized on WC surfaces by flame combustion [8]. However, it was difficult to synthesize the diamond films on the WC substrate surface. Therefore, in order to synthesize the diamond films and prevent film delamination, a step synthesis method for the WC substrate surface was proposed. In this method, the film surface temperatures was changed during the synthesis.

In this study, to obtain good quality diamond films and to achieve good adhesion on the WC substrate, diamond films were synthesized by flame combustion using a mixture acetylene and oxygen gas. We have pointed out that pretreatments on the substrate surface affects synthesis. A chemical pretreatment on the WC substrate surface was performed to prevent delamination. The WC substrate was pretreated by chemical etching to roughen the surface. The substrate was etched in an ultrasonic bath using Murakami’s reagent. After the WC substrate was pretreated by Murakami’s reagent treatment, another processing was performed using an acid solution of hydrogen peroxide, in order to remove cobalt (Co) from the WC substrate surface. Diamond films were synthesized on pretreated substrate surfaces. The pretreatment periods were varied. Moreover, the effect of the pretreatment of the substrate on synthesized diamond films on the WC substrate by flame combustion was investigated. Optimal pretreatment condition was investigated and determined. The films synthesized by this method were analyzed, and the results were discussed. The results showed that diamond films were deposited on the WC substrate surfaces by the this method.

2. Experimental details

2.1. Substrate

Tungsten carbide (WC) was used as the substrate for synthesizing diamond. The WC substrate had a disk-shaped with diameter of 10 mm and thickness of 3 mm. As a pretreatment to prevent the delamination, chemical processing was performed. Furthermore, as growth nuclei for the diamond synthesis, diamond seed particles of about 0.25 μm in diameter were dispersed in acetone, the WC substrate were added, and seed attachment processing was performed for 30 minutes with an ultrasonic syringe. Many diamond seed particles were attached on the substrate surface by the pretreatment.

2.2. Experimental equipment

The experimental equipment is shown in Fig. 1. A 100 × 100 × 55 mm^3 copper rectangular box was used for cooling. Cooling water was poured into this box and the film surface temperature was kept constant at 1273 K or 1223K. A noncontact infrared radiation thermometer was used to measure the film surface temperature during the synthesis. As a support for cooling, a tungsten (W) rod of 10 mm in diameter was set vertically at the center of the