Development of X-Shaped Filtered-Arc-Deposition (X-FAD) Apparatus and DLC/Cr Film Preparation

Hideto Tanoue, Hiroki Hikosaka, Yasuhiro Iwasaki, Hirofumi Takikawa, *Member, IEEE*, Tateki Sakakibara, *Member, IEEE*, and Yushi Hasegawa

***Abstract*—An X-shaped filtered-arc-deposition (X-FAD) apparatus was developed in order to prepare hydrogen-free tetrahedral amorphous carbon (ta-C), which is a kind of diamond-like carbon (DLC), and metal film as a binding interlayer on the superhard alloy using a plasma beam irradiated from the same direction. First of all, the droplet-reduction performance was verified, and then, the appropriate duct-bias voltages and deposition rate were measured. Optima of duct biases for chromium (Cr) and DLC were found to be +25 and +15 V, respectively. From the result of X-ray diffraction analysis, it was found that Cr film that is prepared at a higher substrate-bias voltage was well crystallized and has less internal stress. The appropriate substrate bias for preparing ta-C was −100 to −200 V. DLC film was also prepared with substrate heating. It was found that ta-C could be prepared at a substrate temperature of less than 200 °C, and the film was graphitized at higher temperature. By following these results, 2.5-μm-thick ta-C film was prepared on a superhard alloy with an interlayer by X-FAD.**

***Index Terms*—Binding interlayer, chromium (Cr) film, diamond-like carbon (DLC), hydrogen-free tetrahedral amorphous carbon (ta-C), X-shape filtered-arc-deposition (X-FAD) system.**

I. Introduction

DIAMOND-LIKE CARBON (DLC) films and amorphous hydrogenated or nonhydrogenated forms of carbon are metastable amorphous materials characterized by attractive mechanical, optical, electrical, chemical, and tribological properties [1]–[3]. Nonhydrogenated and sp^3-rich tetrahedral amorphous-carbon (ta-C) films are expected to be used for hard protective coating. For example, ta-C film is considered as the perfect coating on dry-machining tool for an aluminum alloy because of its good antiadherent properties without a lubricant [4]. A coating more than 1 μm thick is necessary for long durability of cutting tools. However, it is known that adhesion of ta-C film to the superhard alloy is not good because of the difference in internal stress between substrate and film [5]. One of the solutions is the employment of a binding interlayer between the ta-C film and superhard alloy.

A DLC film can be prepared by various methods, whereas only vacuum-arc deposition can be used to prepare and mass-produce ta-C film. However, the vacuum-arc cathode emits not only plasma particles (electrons, ions, and neutrals) but also macroparticles (so-called droplets) of cathode material [6]–[8]. The authors have been developing a filtered-arc-deposition (FAD) system with a T-shape filter duct (T-FAD), which has efficient droplet-reduction function [9], [10]. However, it is difficult to deposit thick ta-C film directly on a superhard alloy substrate with this apparatus. Therefore, we newly developed an X-shape FAD (X-FAD) apparatus with a filter duct, which has a shape that was a fused form of a T-FAD for preparing DLC film and a crank-shape filter FAD (Crank-FAD) for preparing droplet-free metal-interlayer [11]. A double-source FAD with separate duct has been developed for revolving substrates [12], although X-FAD with a common duct exit can be applied with a stationary substrate as well.

In this paper, the X-FAD system is described and the duct bias is optimized. Cr film is prepared by Crank-FAD part in X-FAD, and then, droplet-removal performance, crystalline structure, and deposition rate were analyzed. Influence of substrate temperature on the structure of DLC film prepared by T-FAD part in X-FAD is investigated. Effectiveness of X-FAD in preparing thick ta-C film on the superhard alloy is examined last.

II. Experimental

The X-FAD system is depicted in Fig. 1. The system has two cathodic-arc-plasma sources. One of the cathodes is graphite (C) and the other is chromium (Cr). The C-plasma source is shown in the upper center part of Fig. 1 and the Cr-plasma source in the left part. The X-FAD apparatus consists of a T-FAD and a Crank-FAD. C- and Cr-plasmas were transported to the substrate through a common exit of the plasma transportation duct. The plasma-beam scanner is located at the duct exit in order to coat a wide area. Two aligner coils were placed in the chamber in order to focus the plasma beam and control the incident angle of the ions to the substrate. In this experiment, the scanner and aligner coils were adjusted for a coating area that is 150 mm in diameter.

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H. Tanoue, H. Hikosaka, Y. Iwasaki, and H. Takikawa are with the Department of Electrical and Electronic Engineering, Toyohashi University of Technology, Aichi 441-8580, Japan (e-mail: takikawa@eee.tut.ac.jp).

T. Sakakibara is with Gifu National College of Technology, Gifu 501-0495, Japan.

Y. Hasegawa is with Onward Ceramic Coating Company, Ltd., Ishikawa 929-0111, Japan.

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