Vacuum 83 (2009) 510–514

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Preparation of various DLC films by T-shaped filtered arc deposition and the effect of heat treatment on film properties

Masao Kamiya [a,b], Hideto Tanoue [a], Hirofumi Takikawa [a,*], Makoto Taki [c], Yushi Hasegawa [c], Masao Kumagai [d]

[a] Department of Electrical and Electronic Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan
[b] Technology Development Department, Itoh Optical Industrial Co., Ltd., 3-19 Miyanari, Gamagori, Aichi 443-0041, Japan
[c] Research and Development Office, Onward Ceramic Coating Co., Ltd., Wa-13 Yoshihara, Nomi, Ishikawa 929-0111, Japan
[d] Material Technology Division, Kanagawa Industrial Technology Research Center, 705-1 Shimoimaizumi, Ebina, Kanagawa 243-0435, Japan

Keywords:
T-shape filtered arc deposition (T-FAD)
Various diamond-like carbon (DLC)
Tetrahedral amorphous carbon (ta-C)
Heat resistance

ABSTRACT

Different types of diamond-like carbon (DLC) films (ta-C, a-C, ta-C:H and a-C:H) were prepared on super hard alloy (WC-Co) substrate using a T-shape filtered arc deposition (T-FAD) system. At first, the film properties, such as structure, hydrogen content, density, hardness, elastic modulus, were measured. Ta-C prepared with a DC bias of −100 V showed the highest density (3.1 g/cm^3) and hardness (70–80 GPa), and the lowest hydrogen content (less than 0.1 at. %). It was found that the hardness of the DLC film is proportional to approximately the third power of film density. The DLC films were then heated for 60 min in an electric furnace at 550 °C in N_2. Only the ta-C film hardly change its structure, although other films were graphitized. The 200-nm thick ta-C film was then heated for 60 min through the temperature range from 400 to 800 °C in N_2 with 2 vol.% of O_2 and the film structure found to be stable up to 700 °C. The substrate was oxidized at 800 °C, indicating the ta-C film had a thermal barrier function up to that temperature.

1. Introduction

Amorphous carbon, well known as diamond-like carbon (DLC), is an interesting material and has attracted more and more attention recently. Many properties change depending on the sp^2/sp^3 ratio, hydrogen (H) content, and amorphousness. DLC is typically classified into four types: hydrogen-free tetrahedral amorphous carbon (ta-C), hydrogen-free amorphous carbon with lower tetrahedral fraction (a-C), hydrogenated ta-C (ta-C:H), and hydrogenated a-C (a-C:H) [1,2]. For example, ta-C has higher electrical resistivity, although a-C is conductive since it is somewhat graphitized. It is necessary to choose the appropriate type of DLC for the specific application. In recent years, ta-C has especially been the focus in various application fields [2]. One of the applications is utilization at high temperature, such as a protective coating for press molds [3]. Therefore, the high-temperature stability of the film should be investigated.

DLC film can be prepared by a variety of methods, including plasma CVD [4], ion beam plating (hot filament-assisted ionized-gas deposition) [5], balanced and unbalanced magnetron sputters [6], and cathodic vacuum arc deposition [7]. Cathodic vacuum arc deposition is only one method to prepare four kinds of the DLC mentioned above. However, the problem is that micron and/or sub-micron droplets are emitted from the cathode spot of the vacuum arc discharge and adhere to the film. In order to remove the cathode droplets from the cathodic arc plasma, the filtered arc method [8] has been developed, where the cathodic plasma is magnetically transported through a curved or bent duct. The droplets are trapped at the duct wall, when they are in molten form. However, since the droplets emitted from the graphite cathode are in the solid phase, filtration by the conventional filtered arc system is practically difficult. One of present authors has recently developed the T-shape filtered arc deposition (T-FAD) system [9,10], in which the droplets are separated from the plasma at the 90-degree bent position. In the present study, different types of DLC films were prepared by T-FAD. The principal properties of the films were analyzed, and the heat resistance of the films was investigated.

2. Preparation of various DLCs and characterization

Fig. 1 depicts the T-FAD system. The carbon plasma was generated between the graphite cathode and stainless steel anode, and clean carbon plasma transferring to the process chamber was

* Corresponding author. Tel./fax: +81 532 44 6727.
E-mail address: takikawa@eee.tut.ac.jp (H. Takikawa).

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doi:10.1016/j.vacuum.2008.04.016