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Removal of Diamond-Like Carbon Film by Oxygen-Dominated Plasma Beam Converted from Filtered Carbon-Cathodic Arc

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Diamond-like carbon (DLC) film is sometimes removed using oxygen plasma in order to reuse workpieces such as cutting tools and press molds. In this study, an oxygen-dominated plasma beam was generated by converting the cathodic carbon arc plasma beam formed in T-shaped filtered-arc-deposition (T-FAD) in order to investigate the feasibility of using the plasma beam for the removal of DLC film. When the oxygen (O_2) gas flow rate was relatively high (50 ml/min) and the substrate was biased (DC −500 V), the plasma beam in front of the substrate was confirmed to contain a considerable amount of excited oxygen atoms, since an atomic oxygen spectral line (777 nm) emitted from the plasma beam had relatively strong radiation intensity. The plasma beam was irradiated on a tetrahedral amorphous carbon film, a hydrogen-free sp^3-rich DLC film, prepared on a hard alloy (WC with 6 wt % Co binder) substrate. It was found that a plasma beam generated with an appropriate O_2 gas flow rate and applied substrate bias was able to etch the DLC film proportionally to the treatment time. The surface was not roughened when the treatment time was 1.5 times longer than the intended time to remove a given thickness of DLC film.

1. Introduction

An amorphous hard carbon film containing a diamond-structure constituent, called diamond-like carbon (DLC) film, is a very attractive protective coating for dry cutting tools for aluminum alloy and press molds for glass forming.[1–3] In particular, in the latter case, a very expensive tungsten carbide (WC) mold is used. Therefore, it is desirable to remove the protective coating and reuse the same mold, from the perspective of production cost.[3] Popular hard coatings or protective coatings are metal nitride films, such as TiN and CrN. However, these films are difficult to remove. From this point of view as well, DLC film has an industrial advantage in that it is easy to remove by oxygen chemical and/or physical etching,[3–10] or with fluorine plasma,[10] or other means.[11] In the case of plasma etching, RF oxygen plasmas are widely employed,[3–7] and occasionally, DC or pulse plasma. An expensive oxygen ion gun is, in race cases, used for precision processes.[8,9]

The authors have developed a T-shape filtered arc deposition system (T-FAD) that is available for use in industrial production, and recently, they developed a compact-type μT-FAD for research and deveropment (R&D) in the laboratory or for users requiring quick on-site use. In order to market a smaller μT-FAD at a lower price, an RF power supply or ion gun set should not be used, but the DLC film removal feature should be provided. From this stand point, in the present study, the feasibility of a new technique to remove the DLC film in a filtered cathodic arc-plasma was investigated. We previously developed a substrate etching technique as a pre-treatment for DLC film preparation, in which an argon (Ar)-dominated plasma beam generated by mixing Ar gas and a filtered carbon-arc plasma is used.[12] In the prior technique, a cathodic arc has been used to produce Ar glow discharge for substrate etching with an additional separate anode and power supply, which is unnecessary for film preparation.[13] However, our technique does not require the extra-anode or power supply. In the present study, instead of introducting Ar gas for etching, oxygen (O_2) gas was mixed for the removal of DLC film in T-FAD. First, the optimum conditions for plasma transport and treatment were determined. Then, the removal performance was examined for tetrahedral amorphous carbon (ta-C), which is a hydrogen-free, sp^3-rich DLC film that possesses various superior properties, such as high density, high hardness, low friction and chemical inertness.[14]

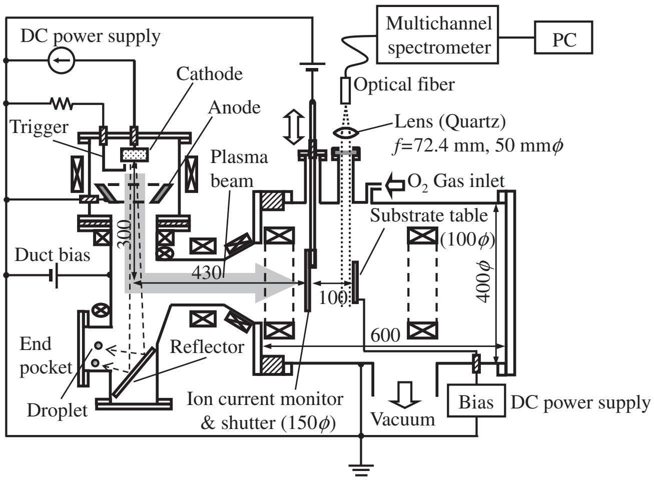

Fig. 1. Schematic diagram of T-shaped filtered arc deposition system (T-FAD).

2. Experimental Procedure

Figure 1 depicts the experimental setup of the T-FAD system used in this study.[12,15–19] The system is composed of an arc source, T-shaped filter, and a process chamber. A high-purity graphite cathode and a stainless anode were arranged in the arc source part, and the carbon cathodic arc plasma was generated between them. The plasma in beam

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