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Effect of gas introduction position on substrate etching by means of Ar-dominated graphite-cathodic-arc plasma beam in μT-FAD

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ABSTRACT

Substrate etching by means of Ar-mixed graphite-cathodic-arc plasma beam was investigated in a newly-developed compact-type μT-FAD. The surface level and roughness change were measured as a function of the Ar gas flow rate, when Ar gas was introduced into the arc generation zone and in the vicinity of the substrate. When Ar gas was introduced to the arc generation zone, the etching rate was lower but the surface was relatively not roughened. When Ar gas was introduced in the vicinity of the substrate, the etching rate was higher but the surface was roughened. At the same gas flow rate (and pressure), the substrate was etched more than three times faster when Ar gas was introduced into the arc generation zone than to the vicinity of the substrate. After measuring the discharge and plasma conditions, the results were considered to be caused by the difference in the amount of plasma transported to the substrate.

1. Introduction

Filtered-arc deposition (FAD) [1–7] shows excellent performance in obtaining super-smooth thin films without incorporation of macro-droplets emitted from the cathode spot of the cathodic vacuum arc. One of the applications is preparation of hydrogen-free diamond-like carbon (DLC) film [8–13]. The authors have developed a T-shape filtered-arc deposition system (T-FAD) which is available for industrial production use and recently a compact-type T-FAD for R&D in the laboratory or for users requiring quick on-site use. The compact type is named micro T-FAD (μT-FAD).

In general, prior to coating DLC film or other functional films, the substrate is treated or etched as a pre-treatment by bombardment of argon (Ar) ion, generated by using RF plasma or ion gun, in order to obtain higher adhesion strength of the film. However, especially in case of a μT-FAD system, in order to market the system at a lower price and smaller size, an RF power supply or ion gun set would not be used. From this point of view, we have developed a new technique to etch a substrate using an Ar-dominated plasma beam, which is generated by introducing Ar gas into the graphite-cathodic vacuum arc in T-FAD [14]. A problem remaining to be addressed is at which position Ar gas should be introduced, near the substrate or in the vacuum arc generation zone.

In the present study, using μT-FAD, the effect of the position at which Ar gas is introduced on substrate treatment was investigated. The result was discussed from the standpoint of the basic properties of a filtered cathodic arc.

2. Experimental details

Fig. 1 depicts a schematic diagram of μT-FAD. The cathodic arc plasma was transferred to the process chamber through the T-shaped filter duct under magnetic and electric fields. Macro-particles (so-called droplets) emitted from the cathode spot were separated from the plasma beam at a corner of the T-duct. The major differences between T-FAD and μT-FAD are the following dimensions: duct diameter, 110 and 60 mm; distance between cathode to the substrate, 830 and 580 mm; and cathode diameter, 64 and 30 mm, respectively.

Experimental conditions were as follows: cathode, graphite; base pressure, less than 4×10^{-3} Pa; air leakage of the system, 3.5×10^{-6} Pa m^3/s; Ar gas flow rate, 0 to 7.0 ml/min (corresponding process pressure, 0.004 to 0.43 Pa), regulated with a mass flow controller; arc current, DC 30 A; duct bias, +10 V; substrate bias, DC −400 V; and time of plasma irradiation to the substrate, 10 min. The

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