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Development of line glow discharge plasma device for preparation of DLC films
DLC 成膜に向けた大気圧線状グロー放電プラズマ装置の開発

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Line glow discharge plasmas (LGDPs) at atmospheric pressure were generated for preparation of large-area amorphous carbon films using a mixed gas of He as a carrier gas and CH_4 as a precursor. The dielectric barrier discharge was produced by the high-voltage, high-repetition bipolar pulse applied between the parallel-plate electrodes with two quartz glasses as dielectric barrier. The LGDP with a length of approximately 170 mm was extracted on the stainless-steel substrate by applying pulsed bias-voltage to the substrate. An amorphous carbon film with the same length as the LGDP was synthesized by the LGDP at atmospheric pressure

1. Introduction

Diamond-like carbon (DLC) films have physical and chemical properties for applications such as high mechanical hardness, low friction, chemical inertness, electrical insulation, optical transparency, and biological compatibility [1]. DLC films can be produced by utilizing different kinds of discharge plasmas at low pressure, resulting in low deposition rates, typically, at most 0.05 μm/min [2] and also the requirement of costly vacuum systems.

Atmospheric pressure glow discharges are attractive for various material processing because of rapid deposition rate due to the use of high-density plasma and the cost reduction by removing the associated vacuum system. The deposition of DLC films at atmospheric pressure has been achieved by nanopulse plasma [3], dielectric barrier discharge (DBD) [4] and the torch-type plasma [5]. For preparation of large-area amorphous carbon film, the line glow discharge plasma (LGDP) was produced with a high-voltage, high-repetition bipolar pulse using the three-electrode configuration [6]. In this experiment, a high-voltage pulse source was used for production of DBD plasma and also LGDP, so that the stability and current density of LGDP was controlled.

In this paper, we study on the stable generation of LGDP using two independent high-repetition bipolar pulses which are synchronized each other for production of DBD and LGDP, respectively.

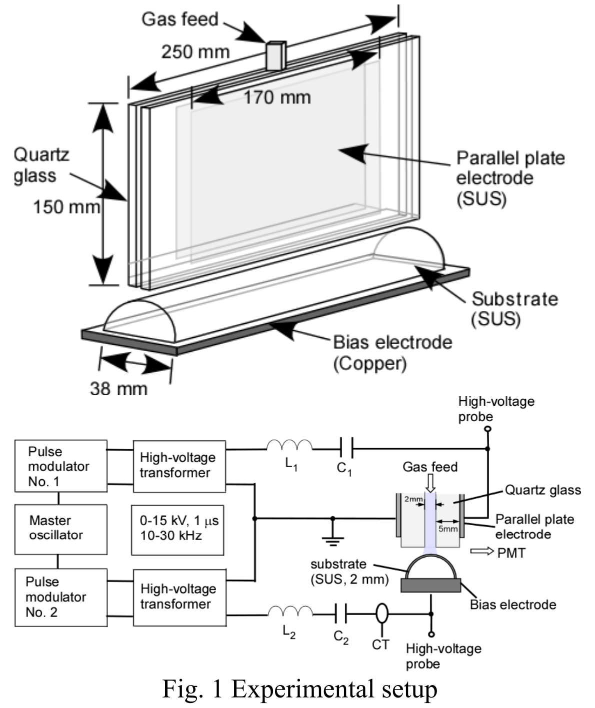

Fig. 1 Experimental setup

The first result of the preparation of amorphous carbon film is shown.

2. Experimental setup

Figure 1 shows a schematic of experimental setup for carbon film deposition by the LGDP at atmospheric pressure, where the parallel-plate electrode (upper) and a cross-sectional view of the

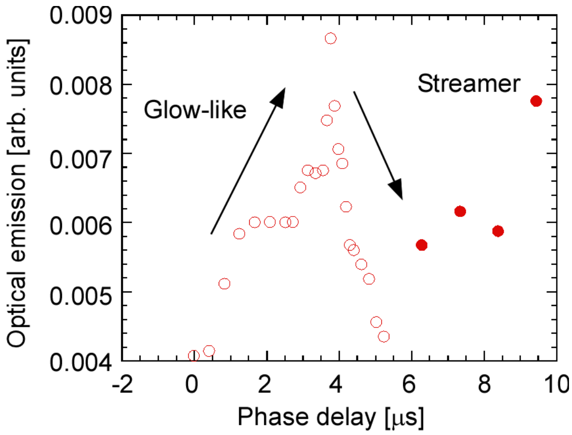

Fig. 2 Magnitude of the optical emission from the plasma as a function of the phase delay.

three-electrode configuration and electrical circuit (lower). The DBD source plasma was generated by a high-voltage, high-repetition bipolar pulse with a fast rise time using the parallel-plate geometry with a gap width of 2 mm. Two quartz glasses with the thickness of 5 mm and the width of 250 mm x 150 mm were placed between two electrodes made of stainless-steel (170 mm x 150 mm) to produce DBD. A mixed gas of He as a carrier gas and CH_4 as a precursor was supplied to the discharge region from the upper side of the parallel-plate electrodes. Applying another pulsed bias voltage to the gap between the parallel plate electrode and the bias electrode (stainless-steel substrate), the LGDP was extracted on the substrate for a film deposition. The pulsed bias voltage and bias current were measured with a high-voltage probe and a pulse CT, respectively. The light emission from the extracted plasma was observed by a photomultiplier tube (Hamamatsu Photonics, R960)

3. Experimental results

There is little diffused plasma on the substrate from the DBD without pulsed bias voltage. When the pulsed bias voltage was applied to the substrate, the uniform LGDP was observed in the gap between the parallel-plate electrode and the substrate. It is found in Fig. 2 that as the bias voltage is applied at several μs later, the bias current and optical intensity of LGDP become the maximum. As not shown here, when the voltage was increased, both intensities of bias current and optical emission were enhanced. Further increase in bias voltage led to the streamer discharge from the glow discharge.

Figure 3 shows the result of amorphous carbon film on the substrate prepared by the LGDP. Here, a half-cylinder substrate of stain-less steel (SUS304) is used, and the gap length between the parallel plated electrode and the substrate is 1 mm. It is confirmed that the width of 2 mm of the film is successfully prepared. Thus, amorphous carbon film with large area could be prepared by rotating a cylindrical substrate. The detail properties of the prepared film such as thickness, hardness, and Raman spectrum will be investigated.

4. Summary

The uniform LGDP at atmospheric pressure was generated by two independent high-voltage, high-repetition bipolar pulses using the three-electrode configuration. When the pulsed bias voltage was applied to the substrate at several μs later, the largest intensity of LGDP was observed. The amorphous carbon film was successfully prepared by the LGDP.

Acknowledgments

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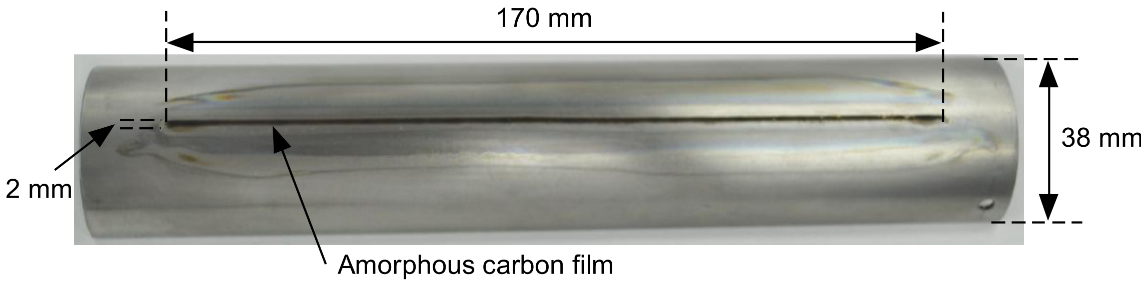

Fig. 3 Amorphous carbon film on the substrate prepared by the LGDP.