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# Effect of voltage on diamond-like carbon thin film using linear ion source

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ABSTRACT

Diamond-like carbon (DLC) films were deposited by the linear ion source (LIS)-physical vapor deposition condition changing the anode voltages from 800 V to 1800 V and bias voltages from 0 V to −200 V and characteristics of the films were investigated using Nano-indentation, Micro Raman spectroscopy, Field Emission-Scanning Electron Microscope (FE-SEM), Residual stress tester, Time-of-Flight Secondary Ion Mass Spectroscopy (TOF-SIMS) and X-ray Photoelectron Spectroscopy (XPS). The residual stress and hardness increased relatively with increasing the ion energy up to anode voltage of 1400 V and −100 bias voltage respectively. From the Micro Raman analysis, the content of $sp^3$ carbon in $sp^3/sp^2$ ratio was increased with increasing the anode voltage. From these results, residual stress and hardness of DLC films are increased as increase of anode voltages due to the enhancement of 3-dimensional cross-links between carbon atoms and dangling bond. Also, the internal compressive stress is increased with increasing the voltages. Therefore, the optimum anode and bias voltage are considered to be around 1400 V and −100 V respectively in these experimental conditions.



## 1. Introduction

Diamond-like carbon (DLC) coatings have excellent physical properties such as low friction, high wear resistance, and high hardness. In mechanical engineering, low friction signifies a lower loss of energy, higher reliability, and better wear resistance. These properties make DLC films interesting for industrial applications, for example, in biotechnology and molds, tools, and mechanical parts [1,2]. DLC films have an amorphous structure, unlike that of diamond or graphite. The bonding structures include $sp^3$ (diamond-like or tetrahedral bonds), $sp^2$ (graphite-like or trigonal bonds), and $sp^1$ hybridized C–C bonds. The relative ratios of such bonds can be adjusted in DLC films by using different deposition methods or process conditions, giving rise to films with various physical and chemical characteristics. Various deposition methods have been reported for DLC coatings, such as pulsed laser deposition, ion-beam sputtering, and radio frequency microwave chemical vapor deposition; the results suggest that the properties of the films can be tailored by deposition parameters such as the precursor material and deposition method [14]. However, films formed with these deposition methods have low productivity, and their mechanical properties such as adhesion and hardness are not good enough because of the lack of ion straight and the low ion density in the deposition areas.

The DLC thin film was deposited by a linear ion source (LIS). This source is compared to how long the process of coating. In addition, the discharge current value shows a good stability, and the film has 95% or more of the attributes of a uniform thin film.

In this article, a DLC thin film was deposited using LIS physical vapor deposition (PVD) with acetylene and argon. The anode voltage was varied from 800 to 1800 V, and the bias voltage was changed from 0 to −200 V, in order to determine the optimum deposition conditions in terms of bonding strength, hardness, and residual stress.

## 2. Experimental

Fig. 1 shows a schematic diagram of the deposition system used in the present experiments. Cr inter layers of thickness 400 nm were deposited on polishing AISI 4140 substrates by sputtering, and DLC thin films were deposited on the Cr buffer layers by a linear ion source. During film deposition, the anode and bias voltages were varied from 800 to 1800 V (no bias voltage) and from 0 V and −200 V (1400 V anode voltage), respectively (Table 1). The other control factors were fixed (flow rate of $C_2H_2$: 60 sccm, current: 0.6 A). The structures of the DLC thin films were characterized by micro Raman spectroscopy (RENISHAW in bin) with a He–Cd laser (λ = 633 nm) in the wavelength range 1000–2000 $cm^{-1}$. In addition, the films were analyzed by X-ray photon spectroscopy (XPS) using an Al source at a beam power of 200 W. The hardness was measured by nano-indentation (MTS-XP) tests. The cross-sections of the specimens were studied by field-emission scanning electron microscopy (Hitachi-S4800), and a residual stress tester (J&L TECH) was used to observe the residual stresses of the specimens. The hydrogen content

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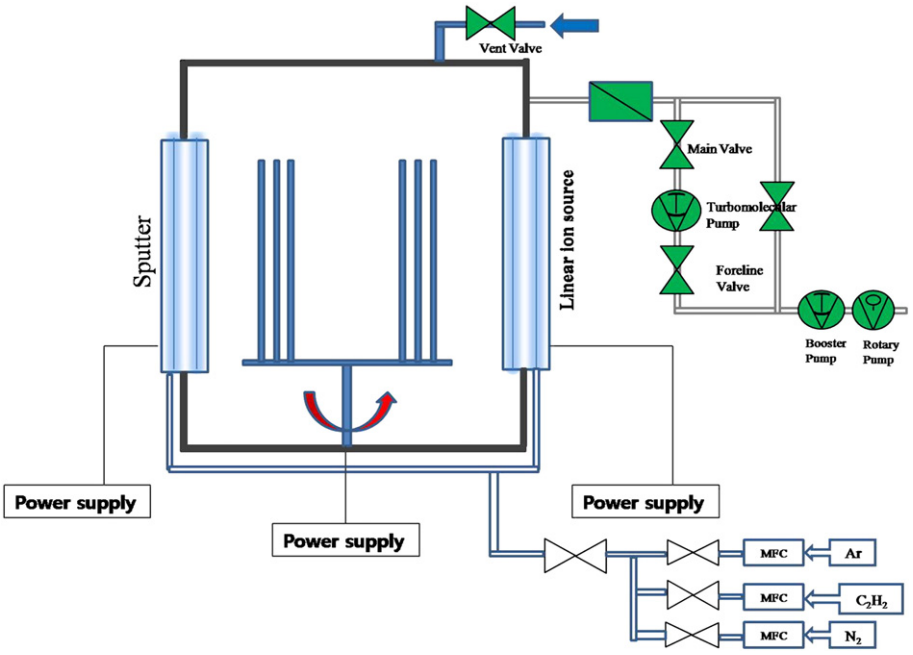


**Fig. 1.** Schematic view of the deposition system used in the present experiments.

**Table 1**
Specimens of DLC by various conditions such as anode voltage and bias voltage variable.

| Specimens | Source | Pressure | Power (W) | Current (A) | Anode voltage (V) | Bias voltage (−V) | Gas flow (sccm) | Time (min) | Temp. (°C) |
|---|---|---|---|---|---|---|---|---|---|
| Specimen 1 | LIS | $5\times E^{-5}$ | 480 | 0.6 | 800 | 0 | $C_2H_2$ 70 | 60 | 100 |
| Specimen 2 | | | 600 | | 1000 | | | | |
| Specimen 3 | | | 720 | | 1200 | | | | |
| Specimen 4 | | | 840 | | 1400 | | | | |
| Specimen 5 | | | 960 | | 1600 | | | | |
| Specimen 6 | | | 1080 | | 1800 | | | | |
| Specimen 7 | LIS | $5\times E^{-5}$ | 840 | 0.6 | 1400 | 0 | $C_2H_2$ 70 | 60 | 100 |
| Specimen 8 | | | 840 | | | 50 | | | |
| Specimen 9 | | | 840 | | | 100 | | | |
| Specimen 10 | | | 840 | | | 150 | | | |
| Specimen 11 | | | 840 | | | 200 | | | |

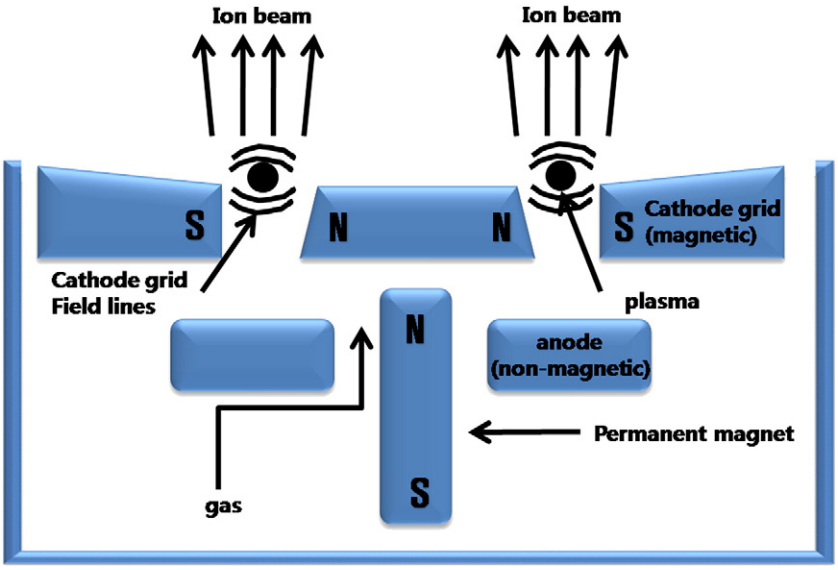


**Fig. 2.** The schematic image of linear ion source (LIS)-physical vapor deposition for the deposition of the DLC films.