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Photoconductivity Properties of Diamond-Like-Carbon Deposited by Ion Plating Method

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Abstract: In this study, we report on the photoconductivity properties of Diamond-Like-Carbon, which synthesized by ion plating method, to apply the high-biocompatibility optical-device. Voltage-current properties of DLC films with Au electrodes-contact shows schottky characteristic, and resistivity of the film was decreased by infrared light irradiation (940nm).Carrier density of the films was obtained by measurement of hall effect and this value was increased 2.00×10^{16} to 3.74×10^{16} by light irradiation.

1. Introduction

Growth technology of semi-conductive devices is contributed to drastic developments for a modern society. This technology will be applied to the biological sensor for assisting five senses such as artificial arms, eyes, and ears in the future. However, almost semi-conductive materials (i.e. Si and Ga) are not suitable for biological compatibility. Carbon based materials such as SiC and diamond are prefer to biological compatibility, however, growth systems were very expensive because of high energy gap. In order to obtain the biological sensors, we focused on the diamond like carbon (DLC). DLC has good ability such as abrasion-resistant, corrosion-resistance, and high hardness. The most striking feature of DLC is that energy gap can control 0.8 to 3.3 eV[1], so, DLC film with low energy gap can be performed optical responsively by infrared light irradiation. In this study, we have attempted to grow the DLC films, and investigated the photoconductive property by infrared light irradiation.

2. Experimental method

2-1 Growth of DLC films by ion plating method

Fig. 1 showed schematic apparatus of the ion plating method[2]. Quartzes substrate or silicon (*n*-type Si: 1-10 Ω-cm) substrates of (20 × 20 mm) were set on the rotation stage in a vacuumed chamber (0.4 mtorr). Thermal electrons were generated by heating filament (filament current: 30 A). Benzene (C_6H_6) gas as a DLC source was flown into the chamber, and carbon ions (C^+) were grown by collision between the C_6H_6 and thermal electrons. C^+ were attracted to a quartzes or Si substrates by applying negative voltage (0.5kV), and DLC films (thickness: 500 nm) were obtained on the substrate. Crystallization of DLC films were measured by Raman spectroscopic analysis.

2-2 *V-I* characteristics of DLC films.

Au electrodes, which distance was 5 mm, were patterned on DLC films deposited by D.C. sputtering method. Monochromatic light (940 nm) were irradiated t o the DLC films. *V-I* characteristics were measured by two prove method.　(Electronic voltmeter: Keithley, type 2400).

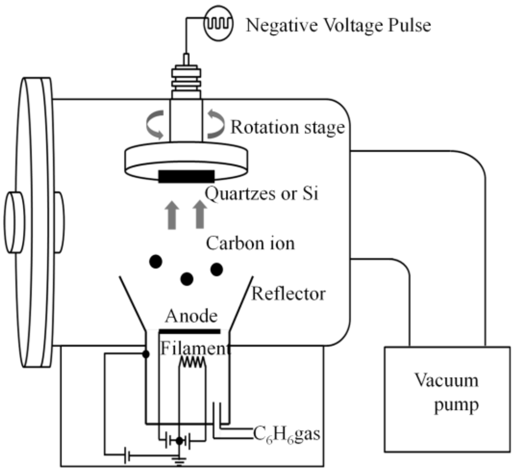

Figure 1. Schematic apparatus of ion plating method

2-3 Measurement of carrier density by hall effect

Fig. 2 shows a structure for hall effect measurement. Au electrodes were deposited to the four corners of DLC films by D.C. sputtering. We applied electric current (I = 0.02 μA) and magnetic fields (B = 1.5 kG) to the sample. Then, Hall voltage V_H was measured by digital multi-meter (Electronic voltmeter: Keithley, type 2400). The carrier density n was calculated by (1), (2).

$$\Delta R = \frac{|V_H|}{I}\ [\Omega] \quad (1)$$

$$n = \frac{B}{e \cdot d \cdot \Delta R}\ [\mathrm{m}^{-3}] \quad (2)$$

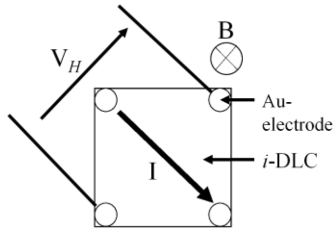

Figure 2. Structure of hall effect mesurement

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3-1 Raman spectroscopic analysis

Fig. 3 shows Raman spectrum of the DLC films. Raman spectrum was separated to four peaks (G-peak: 1550 cm^{-1}, D-peak: 1350 cm^{-1}, C=C: 1500 cm^{-1}, C-C binding: 1150 cm^{-1}). Crystallization of the DLC films was performed by G/D peak rate of the film was 2.4.

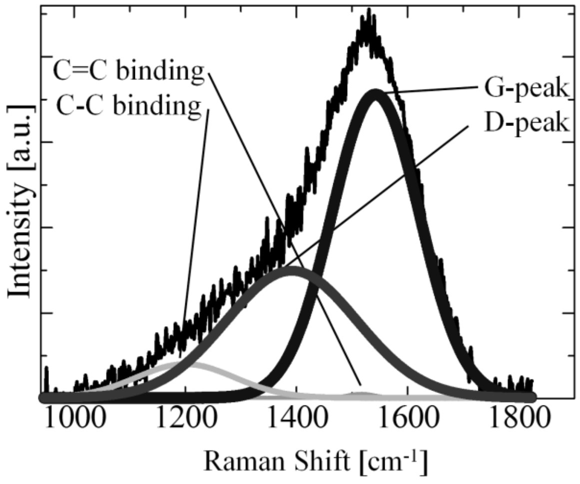

Fig. 3 Raman spectrum of DLC

3-2 *V-I* characteristics

Fig. 4 shows *V-I* characteristics of DLC films with Au electrodes. Current was increased non-linearly with increasing voltage. Therefor contact between the DLC film and Au electrode was Schottky. Current voltage of non-irradiation and 940 nm at 3V were 0.392 and 0,484 µA, respectively.

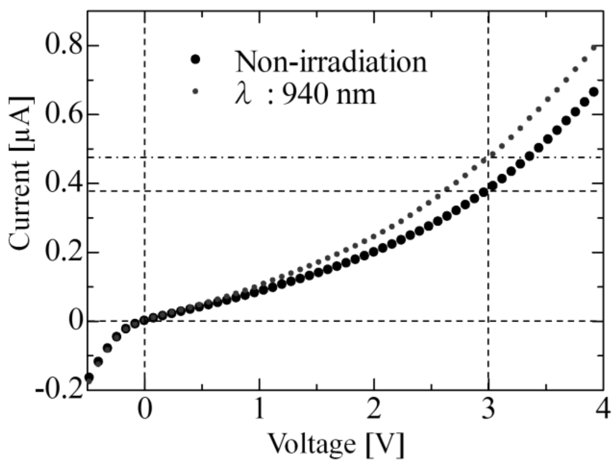

Figure 4. *V-I* characteristics

3-3 measurement of carrier density

Table 1 shows measurement results of V_H and *n*. Hall voltage of Non-irradiation sample was 1.87 eV. This voltage was decreased by monochromatic light irradiation. Moreover, these voltages were decreased with decreasing wavelength of monochromatic light. On the other hand, carrier density was increased from 2.00 × 10^{16} to 3.74 × 10^{16} m^{-3} by light irradiation.

Table 1. Number of hall effect

Wavelength λ [nm]	Hall voltage V_H [V]	Hall constant R [MΩ]	Carrier density n [m^{-3}]
Non-irradiation	1.87	93.5	2.00×10^{16}
940	1.00	50.0	3.74×10^{16}

4. Conclusion

In this study, we attempted to synthesized DLC films to apply the high biocompatibility optical device. *V - I* properties of DLC films with Au electrodes-contact shows schottky characteristic, and resistivity of the film was decreased by infrared light irradiation (940nm). Carrier density of the films was obtained by measurement of hall effect and this value was increased 2.00 × 10^{16} to 3.74 × 10^{16} by light irradiation. This results indicated that we successful DLC infrared light responsible device.

Reference

[1]. K. Takamichi, S. Kurumi, and K. Suzuki, “Fabrication of Nanoscale Electrical Circuits on Diamond-Like-Carbon Film by Scanning a Ga^+ Focused Ion Beam”, J. Nanoelectron Optoelrctron, vol. 7, No. 3, pp. 275-278 (2012).

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