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UV detection of n-type Ultrananocrystalline Diamond/Hydrogenated Amorphous Carbon Composite Films by Coaxial Arc Plasma Deposition

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Abstract

N-type ultrananocrystalline diamond/hydrogenated amorphous carbon composite (UNCD/a-C:H) films were deposited in nitrogen and hydrogen mixed gas atmospheres by coaxial arc plasma deposition (CAPD) with graphite targets. The n-type conduction of the films was thermally confirmed. A heterojunction diode with p-type Si exhibited typical rectifying action. Under illumination, photocurrent is clearly detected at reverse voltages.

1. Introduction

Ultrananocrystalline diamond/hydrogenated amorphous carbon composite (UNCD/a-C:H) is a new candidate carbon semiconductor, and the application to electrical devices has received much attention. It has been known that nitrogen-doping for diamond is ineffective for realizing n-type conduction at room temperature because nitrogen form a deep donor level of 1.7 eV below the bottom of the conduction band in diamond. For a-C:H, n-type conduction is realized by nitrogen doping, however it is difficult for the carrier density to be controlled widely. On the other hand, it has been reported that nitrogen doping makes an enhancement in the carrier density possible by nitrogen doping in addition to the induction of n-type conduction, for UNCD/a-C:H films prepared by chemical vapor deposition (CVD) and pulsed laser deposition (PLD) [1-3]. UNCD/a-C:H is a new candidate material for the potential application in electric and optoelectric devices. It has been experimentally demonstrated that p-type UNCD/a-C:H films deposited by PLD with boron-blended graphite targets exhibit an excellent photodetection performance for UV light[4]. On the other hands, there have few reports on the application of nitrogen-doped UNCD/a-C:H films to optoelectric devices. In this work, heterojunction photodiodes comprising nitrogen-doped UNCD/a-C:H films deposited by coaxial arc plasma deposition (CAPD), and silicon substrates were prepared and their photodetection performance was studied.

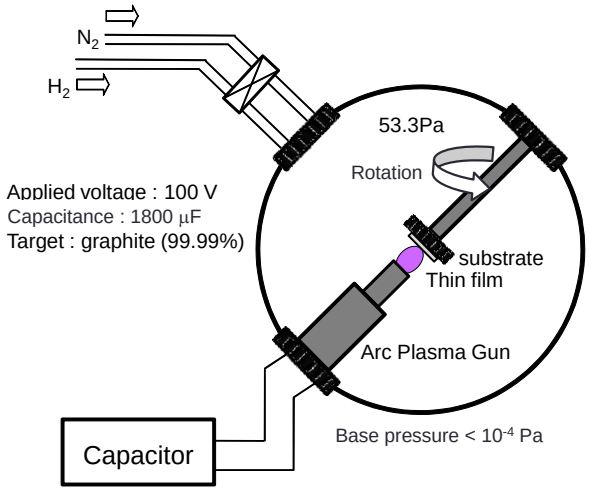

Figure 1. Schematic of coaxial arc plasma deposition (CAPD)

2. Experimental

n-Type UNCD/a-C:H films were deposited on p-type silicon and quartz substrates at a substrate temperature of 550 ºC in a nitrogen and hydrogen mixed gas atmosphere 53.3 Pa, as shown Figure 1. In order to vary the nitrogen content in the films, the nitrogen inflow rate was changed under the fixed hydrogen inflow rate of 10sccm. The electrical conductivity was measured by van der Pauw method using palladium ohmic electrodes, which were formed by sputtering. The n-type conduction was confirmed thermally, namely, from the Seebeck effects.

4. Result

The current-voltage (I-V) curves diodes exhibit

typical rectification actions with rectification ratios of 3 orders of magnitudes at bias voltages range between -5 and 5 V, as shown in Figure. 2. The nitrogen-doped UNCD/a-C:H evidently acts as a n-type semiconductor. The capacitance-voltage (C-V) curves are shown in Figure. 3. The capacitance value is decreased with the reverse voltage. The depletion region in the diode certainly spreads under the reverse bias. The built in potential was estimated to be 0.3 eV. The UV detection characteristics of the heterojunction photodiode are shown Figure. 4. Their measurements were conducted in the dark and under illumination with a 254nm monochromatic lamp. Under illumination, photocurrent is clearly detected at reverse voltages. The photocurrent is evidently attributable to photocarriers generated in UNCD grains.

3. Conclusions

n-type UNCD/a-C:H films were prepared in nitrogen and hydrogen mixed gas atmospheres by CAPD, and their potential as a photovoltaic material was experimentally proved from the UV photodetection in the heterojunction diodes comprising the n-type UNCD/a-C:H films and silicon substrates.

Acknowledgements

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References

[1] T. Yoshitake et al, Jpn. J. Appl. Phys. 46 (2007) L936.

[2] S. Bhattacharra, et al., Appl. Phys. Lett. 79 (2001) 1441.

[3] S. Al - Riyami et al., Appl. Phys. Express. 3 (2010) 115102.

[4] S. Ohmagari et al., Jpn. J. Appl. Phys. 51 (2012) 090123.

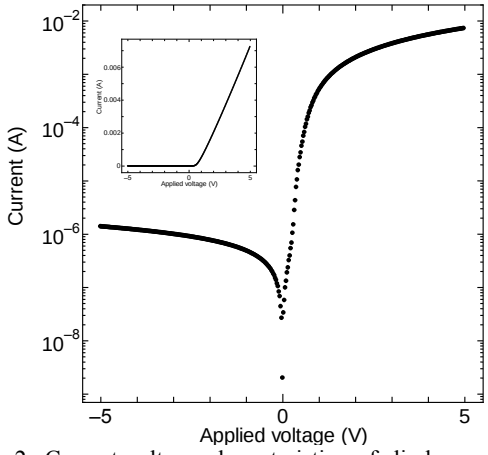

Figure 2. Current-voltage characteristics of diodes comprising p-type silicon substrates and n-type UNCD/a-C:H films deposited.

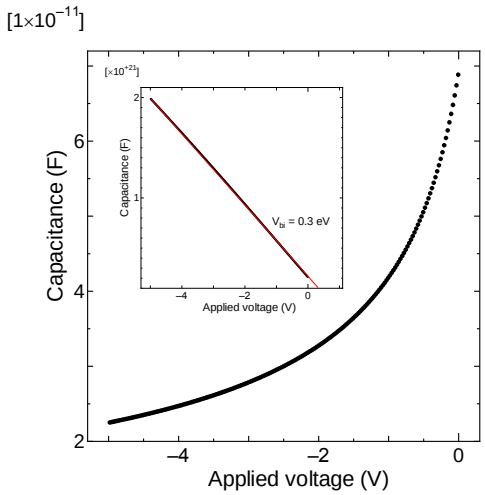

Figure 3. Capacitance-voltage characteristics of diodes comprising p-type silicon substrates and n-type UNCD/a-C:H films deposited.

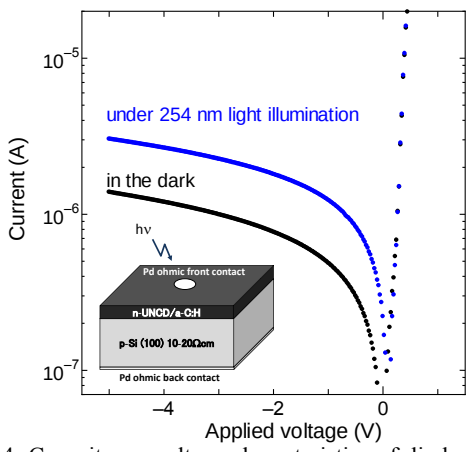

Figure 4. Capacitance-voltage characteristics of diodes comprising p-type silicon substrates and n-type UNCD/a-C:H films deposited.