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Barrier Height of Au contact on p-Type Ultrananocrystalline Diamond/Hydrogenated Amorphous Carbon Composite Films

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Abstract

Ultrananocrystalline diamond (UNCD)/hydrogenated amorphous carbon (a-C:H) composite (UNCD/a-C:H) films have a specific film structure, wherein a large number of diamond nanograins are embedded in an a-C:H matrix. The UNCD/a-C:H films possess large optical absorption coefficients of more than 10^6 cm^{-1} in the photon energy range between 3 and 6 eV. These optical features are profitable for the application of thin-film based solar cell and UV photodetectors. Although the Metal-Semiconductor-Metal (MSM) geometry is suitable for photodetection by using single-layered UNCD/a-C:H film, the property of the film/metal interface hasn't been investigated in detail. In this study, a direct determination of barrier height of Au contact on p-type UNCD/a-C:H film was performed using X-ray photoelectron spectroscopy (XPS) and ultraviolet photoelectron spectroscopy (UPS). As a result, it was revealed that the down bending occurs on the film/Au interface, which indicates that depletion layer might appear on the surface of p-type UNCD/a-C:H by this structure.

1. Introduction

Ultrananocrystalline diamond (UNCD)/hydrogenated amorphous carbon (a-C:H) composite (UNCD/a-C:H) films, which are composed of a large number of diamond grains whose diameters are less than 10 nm embedded in an a-C:H matrix, are new candidates for photovoltaics. In our previous research, we have experimentally demonstrated that the production of n and p-type conduction accompanied by enhanced electrical conductivities is possible by doping nitrogen and boron, respectively.^[1,2] In addition, on the basis of the doping results, we have fabricated heterojunctions comprising boron-doped UNCD/a-C:H films and n-type Si and comprising nitrogen-doped UNCD/a-C:H films and p-type Si substrates, and demonstrated their photodetection.^[3-5]

Metal-Semiconductor-Metal (MSM) geometry is effective for photodetection by UNCD/a-C:H itself, however property of the film/metal surface have not yet well understood. UNCD/a-C:H film is carbon-based thin film that is flexibility controllable on sp^2/sp^3 structure and it bosses intermediate structure of diamond and DLC. In the single crystal diamond/metal interface, it tend to be pinned by the defect level. However it has the potential to eliminate a pinning and freely control a Schottoky barrier by inserting the UNCD/a-C:H film between them.

In this study, we investigated the barrier height between the film/Au interface by ultraviolet photoelectron spectroscopy (UPS) and X-ray photoelectron spectroscopy (XPS) as fundamental characteristic.

2. Experimental method

UNCD/a-C:H films were deposited on Si substrates at a substrate temperature of 550 °C in 53 Pa hydrogen atmospheres by a coaxial arc plasma equipped with graphite cathode targets. The inside of a CAPD apparatus was evacuated down to a base pressure of less than 10^{-4} Pa using a turbo molecular pump. An arc plasma gun equipped with a capacitor of 720 μF was operated at a voltage of 100 V and repetition rate of 5 Hz. Boron-doped films were prepared by employing boron-blended graphite targets. Direct determination of barrier height of Au contact on p-type UNCD/a-C:H film was performed using XPS and UPS. XPS were taken using Mg K α line with photon energy of 1253.6 eV was employed. An argon ion bombardment etching was carried out with an applied voltage of 1 kV.

3. Result and Discussion

After removal of the surface oxide layer by argon ion bombardment etching, we confirmed that the peak shift equivalent to band bending due to surface oxygen does not arise according to

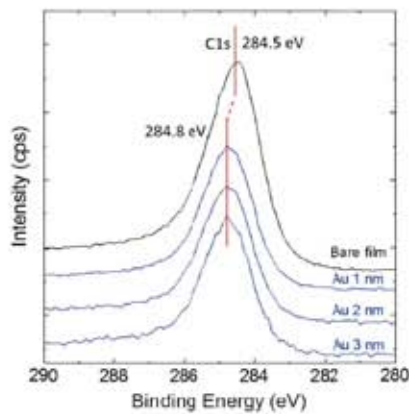


Figure 1. XPS spectra for Au contact on p-type UNCD/a-C:H

comparison of the XPS C1s spectrum. UPS were taken using synchrotron radiation with an incident photon energy of 40 eV at beamline 12 of SAGA Light Source.

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Figure 1 shows the XPS C1s spectra through Au on the film. The C1s core-level peak moved to a higher binding energy; a peak shift of 0.3 eV was observed by means of Au contact. The C1s core-level peak position did not appreciably change in each Au thickness.

Figure 2 shows the UPS spectra of the valance band edge for Au contact on p-type UNCD/a-C:H. The sharp increase in the signal at the Energy from Fermi level to valance band edge; $E_F - E_V$ of 0.26 eV was obtained.

Figure 3 shows a schematic of the proposed band diagram for Au contact on p-type

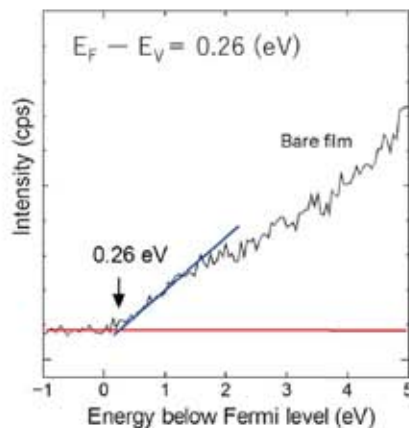


Figure 2. Valance-band edge from UPS characterization of Au contact on p-type UNCD/a-C:H

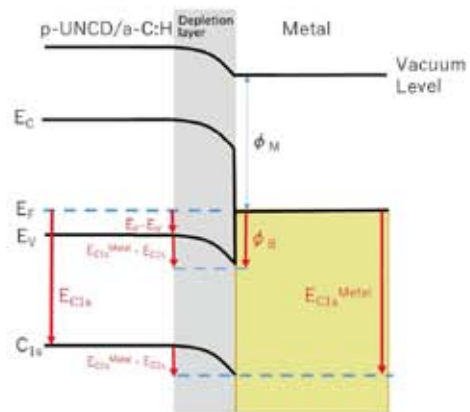


Figure 3. Schematic of the proposed band diagram for Au contact on p-type UNCD/a-C:H, showing band gap (E_g), Fermi level (E_F), conduction band minimum (E_C), valence band maximum (E_V), and C1s core-level (E_{C1s}).

UNCD/a-C:H showing C1s core level. We conclude that down bending was occurred in the film/Au interface, which indicated that the depletion layer might be realized by means of the structure. The film surface is not observed change in alignment even oxidized, there is a possibility that occurred different physical phenomena in contrast with single crystal diamond due to the numerous dangling bonds existing in the film.

5. Conclusion

C1s spectrum was shifted high energy side by Au contact. It attributed to that down bending was occurred in the interface of UNCD/a-C:H and Au, which indicates that depletion layer might appear on the surface by this structure. We investigated that the different physical phenomena in contrast with single crystal diamond due to the numerous dangling bonds existing in the film.

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