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Development of DLC base schottky diode by FIB fabrication

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Abstract: In this study, we development of diamond-like carbon (DLC) base schottky diode by foucused ion beam (FIB) [1] fabrication. We performed Ga ion implantation in DLC films between metal electrodes by scanning a FIB. Materials of metal electrode were platinum (Pt), aurum (Au) and aluminum (Al). Fabrications of metal electrodes were used photolithography and each method (Pt: focused ion-beam assisted chemical vapor deposition (FIB-CVD) [2]; Au: ion spattering; Al: vacuum based deposition). I-V (current-voltage) characteristics of samples were measured by two probe method. As a results, Pt and Al showed schottky properties, and Pt and Au showed the double schottky properties.

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1.Introduction

DLC is a form of amorphous carbon with sp^2 and sp^3 bonding [3]. DLC has various attractive properties such as high hardness and wear resistance, low friction coefficient, high electrical insulation and gas impermeability. For utilize the DLC to electronic devices, we perform ion implantation into DLC film by focused ion beam (FIB) fabrication. The FIB has the following advantages for a sample fabrication. First, Ga^+ FIB could implant Ga^+ ions as acceptors impurity in carbon. Second, implantation dose amount could be easily controlled. Finally, FIB could perform etching and deposition of arbitrary configurations. In our preview research, [4] I-V characteristics of interface between Ga^+ ion implanted DLC and Pt electrode showed ohmic contact. Similarly Au electrode showed ohmic contact. On the other hand, Al electrode showed schottky contact. To fabricate schottky diode, we investigated electrical characteristics of the contact state between Ga^+ ion implanted DLC film and metal electrodes (Pt, Au and Al).

2.Experimental Method

We deposited intrinsic/insulation DLC (i-DLC) thin film on silicon substrate (size: 2cm × 2cm) by the ionized deposition method. Figure 1 showed diagrammatic illustration of ionized deposition method. [5] As conditions was negative bias voltage: 0.5 kV; filament current: 30 A; anode voltage: 60 V; reflector voltage: 20 V; pressure in chamber: 2.1×10^{-3} Torr; and fabrication time: 60 min.

Figure 2 shows process of sample fabrication. Metal electrodes were fabricated on intrinsic/insulation-DLC by photolithography. Pt electrode (thickness: 0.1 μm, height: 60 μm, width: 100 μm) were formed at the tip of one side of the electrode (size: 2mm × 1.5mm) by FIB deposition. The detailed method was as follows (Pt: FIB-CVD; Au: ion spattering; Al: vacuum based deposition). We performed Ga^+ ions implantation in to the DLC film. Furthermore, Ga^+ focused ion beam was irradiated to the surface of i-DLC films width dose amounts: 1.0×10^{17} ions / cm^2. Sizes of ion implanted part were height: 50 μm; width 450 μm. The surface of the DLC film was observed by scanning ion microscope (SIM). I-V (current-voltage) characteristics of these samples were measured by two probe method.

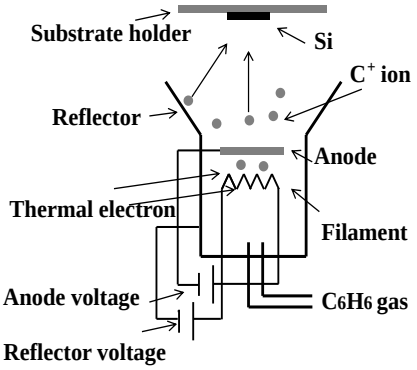
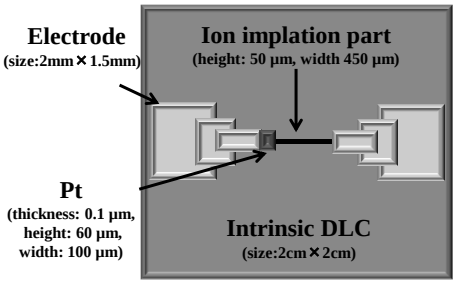
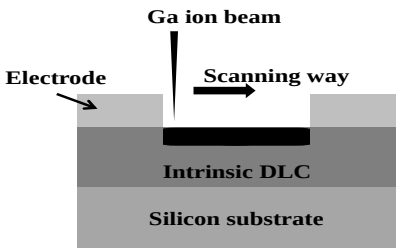


Fig.1 DLC deposition model



(a) Top view



(b) Cutaway view

Fig.2 Sample pattern diagram

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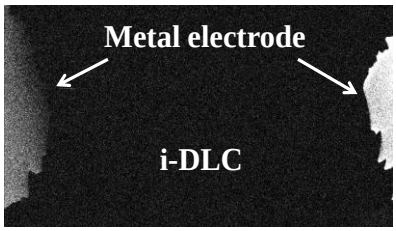
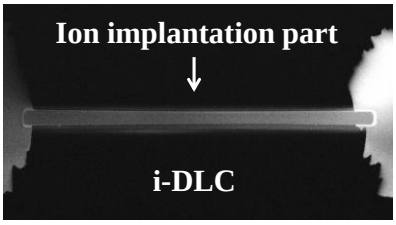
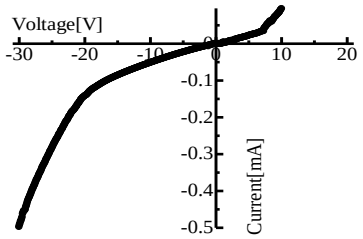


(a) Before the ion implantation

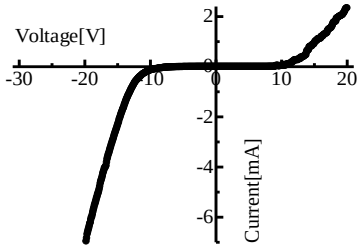


(b) After the ion implantation

Fig3. SIM images



(a) Pt and Al electrode



(b) Pt and Au electrode

Fig.4 I-V characteristics of each metal

3. Experimental Results and Discussion

Figure 3 showed scanning ion microscope (SIM) images of non implanted and ion implanted film. The i-DLC that insulative area is black as shown Figure 3. On the other hand, metal electrode that has conductivity properties is shown white. After ion implantation, beam scanning area showed slightly gray. It was found that i-DLC was changed to p-DLC from. Figure 4 showed I-V (current-voltage) characteristics of each metal electrode by two probe method. Figure 4 (a) was divided two properties. One was showed linear propertie in -20V to 8V. Another was showed exponential increase in outside linear area. Figure 4 (b), the breakdown voltage and the forward voltage value was similar. These results, Figure 4 (a) was showed combined schottky and ohmic properties. Figure 4 (b) showed double schottky properties just like a varistor. Originally, Pt and Au showed ohmic contact. However, the result showed the Schottky properties. As the cause, there is a Fermi level pinning by interface states and fixed charge at the interface. Ideal height of schottky barrier can vary greatly depending on the work function of the metal. However, even if the work function of the metal change, height of schottky barrier don't change. In this way seem to be pinned fermi level. This situation is termed "Fermi level pinning".

4. Conclusion

I-V (current-voltage) characteristics of Figure 4 (a) showed Schottky properties, and Figure 4 (b) showed double schottky properties. From this, Contact states between Pt and Al electrode and Ga ion implanted DLC showed shottky contact. The present result suggested that Pt and Al electrode with implanted in DLC films can be used as a shottky diode. But, contact states between Pt and Au electrode and Ga ion implanted DLC showed not ohmic properties but schottky properties.

Acknowledgment

A part of this study has been financially supported by the Nihon University Strategic Projects for Academic Research "N Projects".

Reference

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