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Common-Gate Boron-Doped Diamond (BDD) Solution Gate FET Application for PH Sensor

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Abstract

In this study, we employed Boron Doped Diamond (BDD) Solution Gate FET to be operated with common gate configuration setup. Reference gate electrode was requisite in SGFET measurement system in previous work[1]. However, in this present work we eliminate the use of external gate electrode (grounded) to simplify the system measurement. The SGFET was immersed in carmody buffer solutions in metal vessel. Both Source and Drain were applied with voltage bias within diamond potential window. Furthermore, the metal vessel was grounded. We introduce the I-V characteristics of common-gate SGFET for the first time which is comparable to typical Field Effect Transistor (FET) characteristics. Later, the pH sensitivity of the SGFET was measured using same configuration in carmody buffer solution from pH 2 to pH 12. The pH sensitivity of the common-gate measured in metal vessel was appear to be reverse sensitivity and the pH sensitivity across the pH for voltage and current was 27mV/pH and 0.83µA/pH respectively.

1. Introduction

Novel material diamond well known with its unique properties such as wide potential window, physical inertness and chemical stability. To date, numerous studies have attempted to use diamond as biosensor and chemical sensors transducer. Kawarada and team has develop Solution Gate FET (SGFET) using diamond as substrate for biosensor application[2] as replacement to silicon based ISFET which is introduced by Bergveld [3].The SGFET shows better sensitivity and simple fabrication [4].

Both of ISFET and SGFET require an external gate electrode such as Ag/AgCl gate electrode to induce ions in electrolyte [2], which make the measurement only possible in laboratory. So far there is no study has examined to simplify the SGFET system. The objective of present study is to investigate the common gate configuration for diamond SGFET. In this study, the reference gate electrode was grounded as shown in Figure 1(a). To totally eliminate the use of Ag/AgCl gate electrode, metal vessel gate was used as replacement. The measurement was respect to gate instead of source. We investigate the Current-Voltage (I-V) characteristics of the SGFET and pH sensitivity to verify the functionality of this system.

2. Experimental Details

The Boron Doped Diamond (BDD) was prepared in Microwave Plasma Chemical Vapor Deposition (MPCVD).The conductivity of the BDD was confirm to be around 30kΩ.Pure Aurum(Au) was evaporated on the BDD surface through a metal mask to form source and drain contact pad. The covered area is known as channel area and measured 0.2mm and 5mm for width and length respectively. Conductive paste was used to connect pair of wire to source and drain. Finally, source and drain metal pad was covered using epoxy resin. The channel area of BDD SGFET was electrochemically oxidized to improve the sensitivity of the pH sensor. I-V characteristics and pH sensitivity evaluation of BDD SGFET was done using Keithley Instrument source-measure unit in carmody buffer solutions varies pH. The BDD SGFET was measured in vessel cup which connected to ground as depicted in Figure 1(b) below.

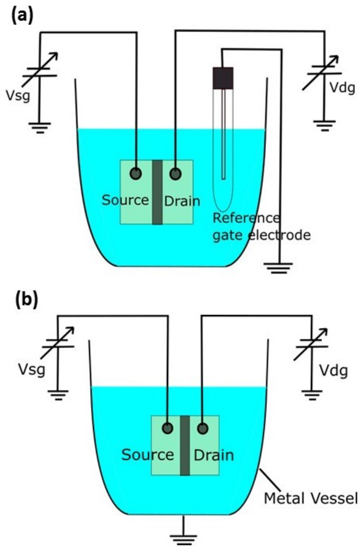

Figure 1: Common Gate configuration using (a) Ag/AgCl reference gate electrode and (b) Metal vessel gate

2. Results and Discussion

The discussion of the results begin with current-voltage (I-V) characteristics of common gate as shown in Figure 2. The present findings suggest that common gate I-V characteristics is comparable to FET characteristics as measured in typical common-source as depicted in Figure 2a.

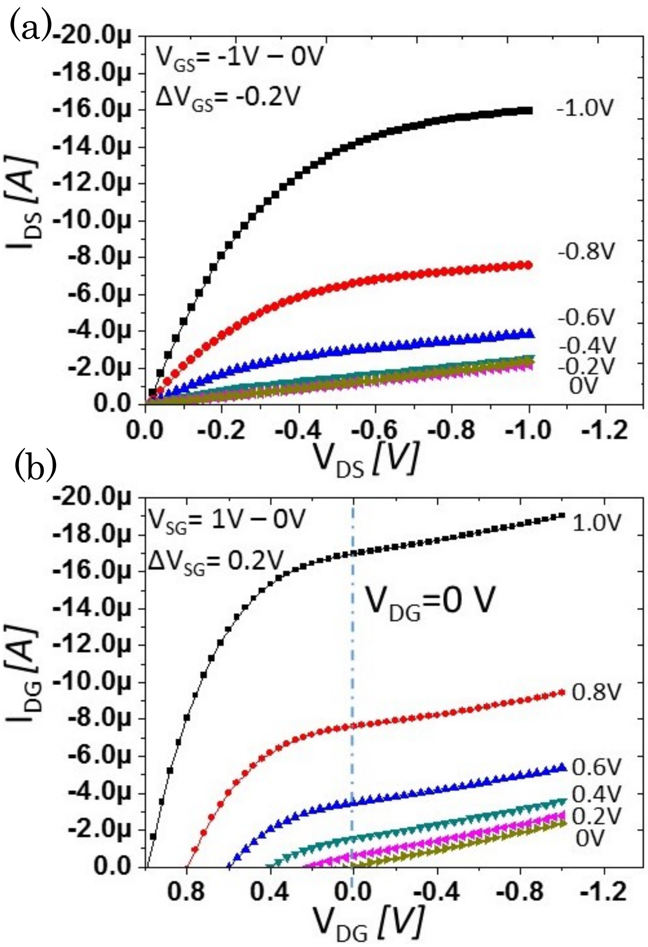

Figure 2: I-V Characteristics of (a) Common-source and (b) Common-Gate configuration measured in vessel

Nevertheless, the saturation region of the common-gate occurs at Vdg=0V. Our finding revealed that the SGFET measured as common-gate is normally off and operating in enhancement mode.

We also investigated the pH sensitivity of the device using common-gate configuration setup in wide range Carmody Buffer Solutions from pH2 to pH12. PH sensitivity across the pH are 27mV/ and 0.83μA/pH as exhibit in Figure 3(a(ii)) and 3(b) respectively. Interestingly, the pH sensitivity of the BDD SGFET measured in vessel cup with common-gate configuration was appear to be reverse sensitivity compare to pH sensitivity measured using Ag/AgCl gate electrode as shown in Figure 3(a(i)) . In Figure 3(b), there is clear trend of decreasing current as the pH number increase. This findings was contrary to a study conducted by Sasaki[5]. The pH sensitivity of vessel gate is higher than the diamond SGFET channel, hence explained the reverse sensitivity. Diamond SFGET channel facing each other across electrolyte. Electric double layer capacitance in one side has opposite polarity each other.

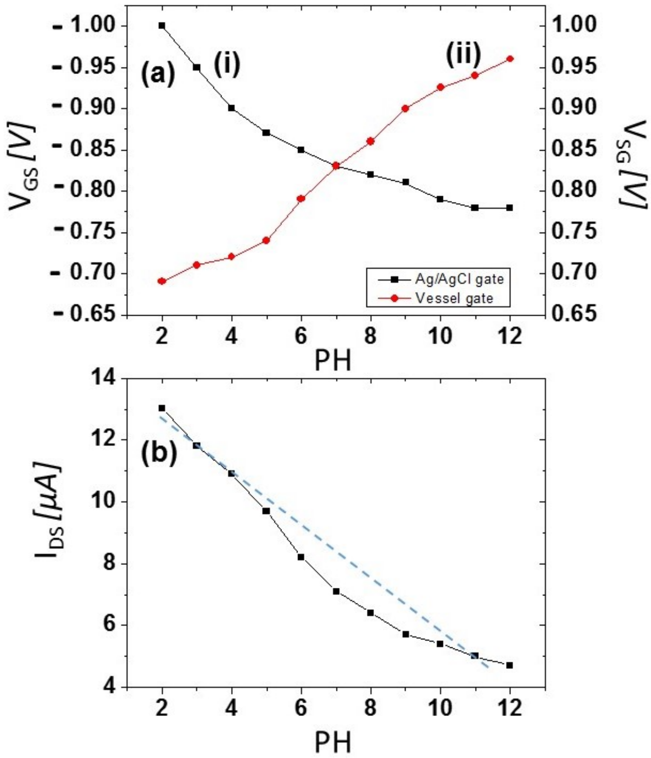

Figure 3: pH sensitivity of (a(i)) Ag/AgCl gate (a(ii)) Common-gate in metal vessel and (c) Current sensitivity across pH measured in metal vessel

3. Conclusions

The purpose of this study to explore the new potential of BDD SGFET as pH sensor. The presented data has shown that the BDD SGFET can be operated without external gate electrode. Thus, the implementation of common-gate SGFET as pH sensor is possible to simplify current system to measure ion activities in electrolyte.

Acknowledgements

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