Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 450–451

A-7-2

Electrolyte-Solution-Gate Diamond FETs Operated in Cl Ionic Solutions

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1. Introduction

Diamond has many advantages for electrochemical applications, such as wide potential window, chemical stability, and biocompatibility. Because of these properties of diamond, it is expected that diamond can be applied to electrochemical electrode, chemical sensor, and biosensor. On the other hands, on the hydrogen-terminated (H-terminated) surface, undoped diamond indicates surface p-type conductivity. Utilizing these properties of diamond, we have fabricated electrolyte-solution-gate diamond field effect transistors (FETs), where the H-terminated diamond surface is directly exposed to electrolyte solution. These FETs show FET operation in electrolyte solutions of pH1-13 [1].

2. Experimental

Polycrystalline diamond films have been synthesized on Si substrate by microwave plasma assisted chemical vapor deposition (CVD). The diamond surfaces have been terminated by hydrogen to obtain the surface p-type conductivity. To prepare the electrolyte-solution-gate FET structures on the polycrystalline diamond films, gold has been evaporated through the metal mask on H-terminated diamond surfaces to form source and drain electrodes. Afterwards Ar^+ ions have been implanted for device isolation. Finally, the wires have been bonded on the metal electrodes and electrodes have been covered with the epoxy. In this structure, the gate region of the diamond surface has been exposed in electrolyte solutions. The Ag/AgCl reference electrode has been used as the gate electrode. Schematic of electrolyte-solution-gate FET is shown Fig.1. These FETs have been biased within the potential windows.

3. Results

The Ids-Vds characteristics of these devices show the channel pinch-off and the drain current saturation in KOH solutions (pH8-13). The threshold voltages of FET were obtained to be constant in KOH solutions having different pH value of 8-13 [1]. Also we have obtained static characteristics for the electrolyte solution gate FETs in pH1-5 HCl strong acid solutions and 10^{-1}-10^{-5} M KCl solutions. The Ids-Vds characteristics were those of high quality FETs in the two kinds of solutions. The threshold voltages depend on the concentration of HCl and KCl solutions. The Ids-Vgs characteristics in 10^{-1}-10^{-6} M KCl solutions is shown in Fig.2, where the threshold voltages shift about 30 mV by the one digit change of molar concentration of KCl solution. From these results, it has been confirmed that FET operates in strong acid solutions (pH1-5), and the threshold voltage shift by the concentration of Cl^- ions in the HCl and KCl solutions.

4. Conclusion

The electrolyte-solution-gate diamond FETs have been fabricated. In this structure, H-terminated diamond surface has been exposed in electrolytes. The Ids-Vds characteristics of these FETs indicate good FET operations in strong acid and alkaline solutions. In KOH solutions, the threshold voltages of FET are constant regardless of pH value. In HCl and KCl solutions, the threshold voltage shift by the concentration of Cl^- ions. The FET is suitable for highly sensitive Cl^- ion sensor.

[1] H.Kawarada *et al.*, physica status solidi (2001) (in press)

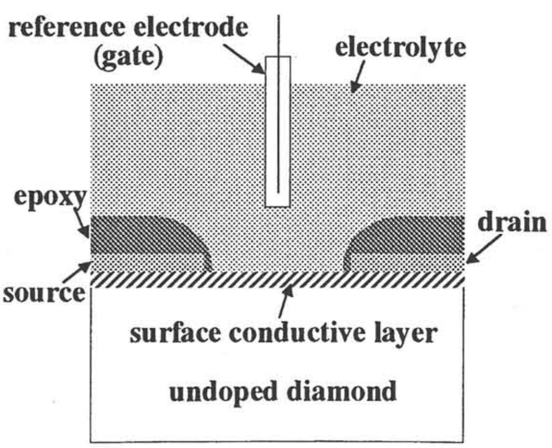

Fig.1 Schematic of electrolyte-solution-gate FET

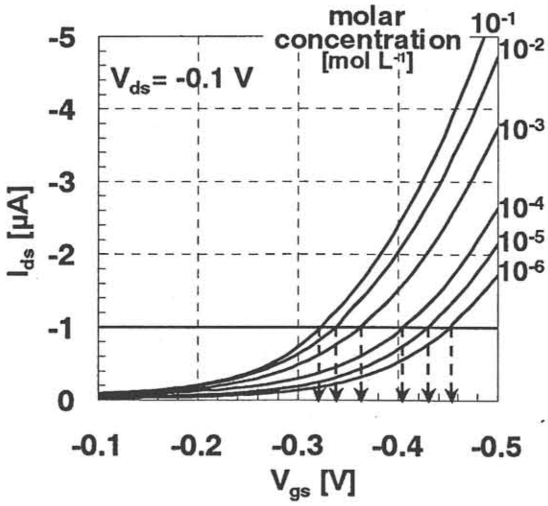

Fig.2 Ids-Vgs characteristics (KCl solutions)