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# The I-V characteristics of a termination-controlled boron-doped polycrystalline diamond field effect transistor pH sensor for using at harsh environment

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Rapid and accurate sensing of pH in solution is of great interest for chemical and biochemical industry. Generally, pH sensing is carried out by using a glass electrode. Because of its high reliability, the glass electrode is recognized as a de-facto standard for pH sensing, and is widely used in laboratory and manufacturing process. However, in addition to its instability in fluorine-containing solution, alkaline error above pH10 is recognized as serious issue [1, 2, 3]. Furthermore, the glass electrode possesses fragile nature and difficulties in miniaturization. Thus, alternative pH electrode is still desirable. A diamond surface is an excellent candidate since it has superior robustness, high chemical inactivity, wide electrochemical potential window, and highly-flexible surface modification. In our previous study, it has been confirmed that electrolyte-solution-gate field-effect transistor (SGFET) utilizing non-doped diamond surface as gate channel is sensitive to various ions, and ion sensitivity can be controlled by partially modified surface atoms [4,5]. In terms of pH sensitivity, hydrogen-terminated diamond SGFET is insensitive to pH, whereas, diamond SGFET with partially oxygen- and/or nitrogen-terminated gate surface is sensitive to pH up to 45 mV/pH.

Here, we proposed a boron-doped polycrystalline diamond channel solution-gate FET. A hole accumulation layer induced by Boron-doping was employed for detection, on behalf of a hole accumulation layer induced by hydrogen termination in case of using a non-doped diamond. The boron-doped layers with the range from 10nm to 150nm thickness were employed as SGFET channels fabricated by microwave plasma chemical vapour deposition. Maximum drain current densities of 8micro-A/mm and transconductance of 0.027mS/mm were obtained with a SGFET of 500micro-m channel length and 8mm width, where 1.4V was applied for the gate voltage. Those properties are comparable to the hydrogen-terminated non-doped diamond SGFET with the same gate length. For oxygen treatment, boron-doped channel was exposed to UV under rich-oxygen condition. The coverage of oxygen was up to ca.30%, calculated by XPS. The oxygen-terminated FET indicated the pH sensitivity of ca.30mV/pH. The current–voltage characteristics related to the boron-doped FET structure (i.e. boron layer thickness, sheet career) and surface condition (i.e. oxygen coverage) were also studied.

In addition, we applied a differential FET measurement to realize an all-solid-state pH sensor. The characteristics of difference SGFET measurement were also evaluated by using a set of a partially amino- and/or oxygen-terminated SGFET (working electrode) and a hydrogen-terminated SGFET (REFET) in reference to Ag/AgCl or Pt (QRE). The detection of differential FET-IV led to minimize the influence of the polarization of QRE.

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