第81回応用物理学会秋季学術講演会 講演予稿集 (2020 オンライン開催)

# The effect of elevated temperature on fluorocarbon thin film for pH sensing using boron-doped diamond solution-gate field-effect transistors

**Waseda Univ. [1], Kagami Memorial Research Institute for Material Science and Technology [2],**

**°Y.H. Chang [1], Y. Iyama [1], K. Tadenuma [1], S. Kawaguchi [1], T. Takarada [1], H. Kawarada [1,2]**

**E-mail: yu-hao.chang@ruri.waseda.jp**

pH sensing has played an important role in many substantial aspects of the society including chemical laboratory analysis, agriculture, and water qualities. However, existing pH sensors like the traditional glass pH electrode or ion-sensitive field-effect transistors (ISFETs) suffer problems and limitations such as fragility, drifting effect or hysteresis. To address the issues of these existing pH sensors, we have fabricated pH sensors utilizing diamond solution-gate field-effect transistors (SGFETs).

Diamond has many appealing properties including chemical inertness, biocompatibility, and simple chemical modification on the surface. These properties are favorable for biosensing applications, especially pH sensing. In addition, the lack of passivation layer as opposed to ISFETs has enabled direct sensing on the device's channel. Since 2001, we have reported diamond SGFETs where the semiconductor surface was directly immersed in electrolyte solution and the drain current was controlled by an electric double layer at the diamond surface[1]. Several studies utilizing different functional groups including hydrogen, oxygen nitrogen, and fluorine have been report[2,3,4]. We have also reported pH insensitive results by using fluorine-terminated diamond SGFETs where the diamond surface is dominated by C-F bonding[5]. Comparing with this C-F bonding, fluorocarbon thin film is composed of layers of C-CF, C-F, C-$F_2$, and C-$F_3$. In this work, we investigate the use of fluorocarbon thin film with boron-doped diamond (BDD) SGFETs for pH sensing for the first time.

Polycrystalline diamond substrate was first cleaned by immersing in a mixture of $HNO_3$ and $H_2SO_4$ at 200 °C for 30 minutes. A thin delta-boron doping layer was formed on the polycrystalline substrate before it was hydrogenated under 600 °C in a hydrogen atmosphere for 30 minutes. Source and drain electrodes were formed with Au, connected with wires by conductive paste, and sealed with epoxy resin to prevent leakage when placed in pH solutions. The fluorocarbon thin film was fabricated using the inductively coupled plasma – reactive ion etching (ICP- RIE) method. $I_{DS}$-$V_{DS}$ characteristics and pH sensitivity were procured by Keithley Instrument source-measure unit from pH 2-12. As shown in Figure 1 and Figure 2, the pH sensitivities were 67.4 mV/pH, higher than that indicated by Nernst equation, and 34.9/pH in acidic and alkaline pH regions, respectively. In future research, we hope to investigate the effect of elevated temperature and thickness of the film to fluorocarbon thin film BDD SGFETs.

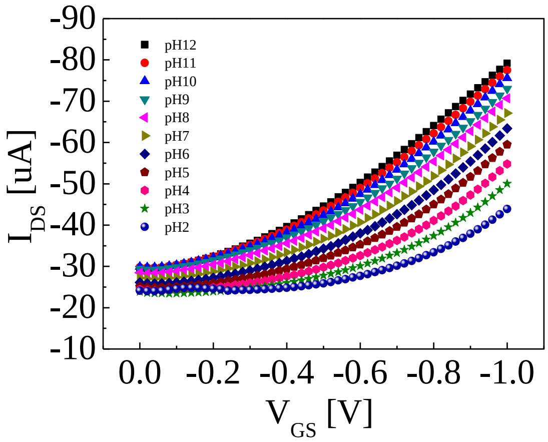


Figure 1. pH measurement from pH 12-2

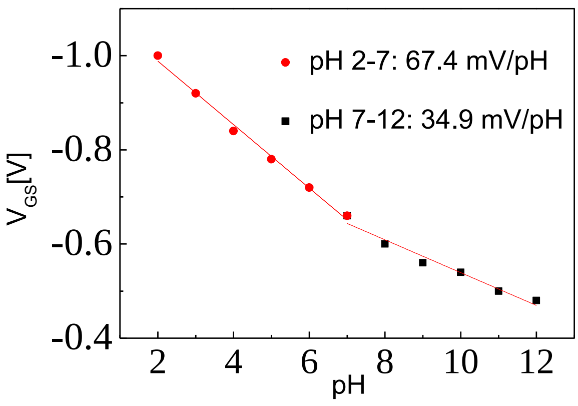


Figure 2. Analyzed pH sensitivities

## References

1. H. Kawarada, A. Ruslinda, *physica status solidi (a)* ,**2011**, 208, 2005.
2. M. Tachiki, *et al.*, *physica status solidi (a)*,**2003**, 199, 39.
3. S. Falina, *et al.*, *Sensors*, **2018**, 18, 2178.
4. K. Song, *et al.*, *Appl. Phys. Lett.*,**2007**, 90, 063901.
5. Y. Shintani, M. Kobayashi, H. Kawarada, *Sensors*, ***2017***, 17, 1040.