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Dependence of Electric Signal Transmission in Seawater utilizing Diamond Solution Gate FET on the NaCl Concentration

Teruaki Takarada[1], Kaito Tadenuma[1], Shuto Kawaguchi[1], Yu Hao Chang[1], Yukihiro Shintani[1], Hiroshi Kawarada[1, 2]

[1] Faculty of Science and Engineering, Waseda University.
3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan
Phone: +81-3-5286-3391 E-mail: teruaki_mrr@moegi.waseda.jp
[2] The Kagami Memorial Research Institute for Materials Science and Technology, Waseda University
2-8-26 Nishiwaseda, Shinjuku-ku, Tokyo 169-0051, Japan

Abstract

Electric seawater wireless communication has been researched utilizing diamond Solution Gate FET (SGFET) and Si ion sensitive (IS)FET. This communication method consists of three components: a gate electrode as a transmitter, SGFET as a receiver, and solutions as a medium. SGFET receives AC electric signals applied on the gate electrode via solution. We investigated the effect of ion concentration in electrolyte solution on the signal transmission between transceivers. As a result, SGFET responded to AC signals at least 10 MHz frequency with 3.5% NaCl solution and 25% NaCl solution up to 4 m distance. Also, the responses were higher on the high concentration solution medium than the low concentration solution medium. Thus, our new seawater wireless communication method utilizing SGFET is affected by the ion concentration of electrolyte solution as a communication medium.

1. Introduction

Seawater wireless communication has recently attracted much attention in fields such as scuba diving, autonomous underwater vehicles, and seabed resource explorations. These fields need mobile wireless communications where high data transfer rates and mobility are favored because their transceivers are moving. Several seawater communication methods have been researched such as electromagnetic waves, acoustic waves, and optical waves, but these methods are not suitable for mobile wireless communication; electromagnetic waves experience high attenuation in the seawater; acoustic waves exhibit high propagation delay and low data rate; optical waves require a transparent medium and high precision in pointing lasers at the receiver [1]. On the other hand, electric seawater communications have advantages of low attenuation, high data rate, and isotropic distribution due to the high electrical conductivity of seawater [2,3].

We have reported diamond solution gate FETs (SGFETs) which can operate in electrolyte solutions since 2001 [4]. The diamond surface is directly immersed in solutions and the drain current (I_{DS}) is remotely controlled by electric signals (V_{GS}) applied on the gate electrode via solution. Utilizing the gate electrode as a transmitter and SGFET as a receiver, we proposed a new electric seawater wireless communication method [5]. Diamond SGFET can respond to AC electric signals v_G applied on the electrically independent gate electrode which indicates successful wireless communications.

In this work, we measured the effect of solutions' ion concentration on the SGFET response to investigate the factors that affect signal transmission.

2. Experimental methods

Fig.1 shows the cross-sectional view of the diamond SGFET. The channel surface of SGFET was directly immersed in a solution to form a capacitance of the electrolyte double layer. Fig.2 shows a schematic view of the experimental system utilizing diamond SGFET. This communication system consisted of three components: a gate electrode as the transmitter, an SGFET as the receiver, and electrolyte solution as the communication medium. The gate electrode was applied with frequencies from 100 kHz to 10 MHz and 1 V amplitude square wave electric signals (v_G). The drain electrode of SGFET was connected to a load resistance (R_L) and applied a supply voltage (V_{DD}). Deionized water, 3.5% NaCl solution (equivalent concentration of seawater), and 25% NaCl solution (equivalent concentration of salt lakes) were filled into a cylindrical tube (diameter = 2.5 cm), and the distance between the gate electrode and the channel of SGFET was gradually increased from 0.2 m to 4 m. Then, drain-source voltage v_{DS} and load resistance voltage v_{RL} as outputs were measured on each solution and distance.

3. Results and Discussion

Fig.3 shows the output characteristics of diamond SGFET at 1MHz input voltage v_G on each solution concentrations. The output characteristics show that SGFET responds to v_G with 3.5% and 25% NaCl solutions. The output signals were observed as differential pulses responding to the input square v_G potential change with an amplitude of 1V. Fig.4 shows the amplitude of differential pulses V_{peak} on each distance and solution concentration. V_{peak} on each distance were higher on the high concentration (25% NaCl solution, e.g. 40 mV at 4m and 1 MHz) than the low concentration (3.5% NaCl solution, e.g. 14 mV at 4m and 1MHz). On the other hand, in the deionized water, V_{peak} were less than 10 mV at more than 1 m in distance. Therefore, in high concentration electrolyte solutions, the electric signal easily transfers in this system because of its high conductivity. These results show that sodium and chloride ions forming electrolyte in the solutions as a transmission medium has greatly related to the signal transmissions of this seawater wireless communication method. However, the switching characteristics at 10 MHz remain observable at 4 m in NaCl solutions, which suggests a longer communication range is available for this system.

4. Conclusion

We investigated the effects of NaCl solution concentration on the seawater wireless communication method using diamond SGFET. It is confirmed that responses of SGFET are affected by ion concentration of electrolyte solution as a communication medium. Also, this communication method has a possibility of operating in natural seawater at least 4 m in propagation distance.

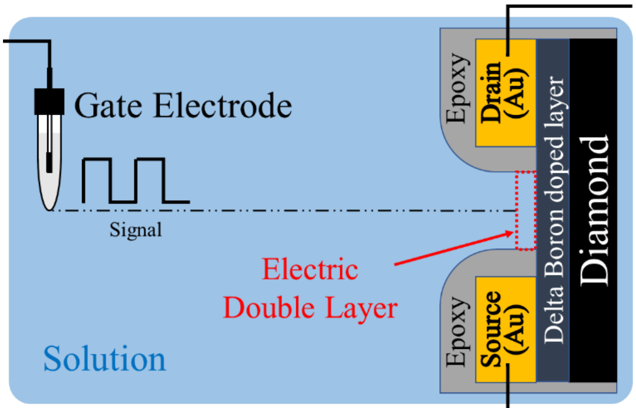

Fig.1 The cross-sectional view of the diamond SGFET with a gate electrode far from the channel. A signal from the electrode propagate to channel.

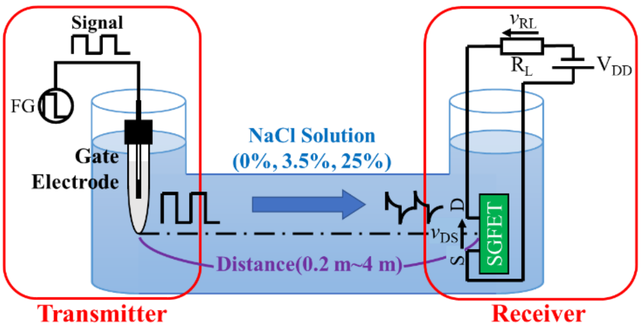

Fig.2 The schematic view of the experimental system utilizing diamond SGFET.

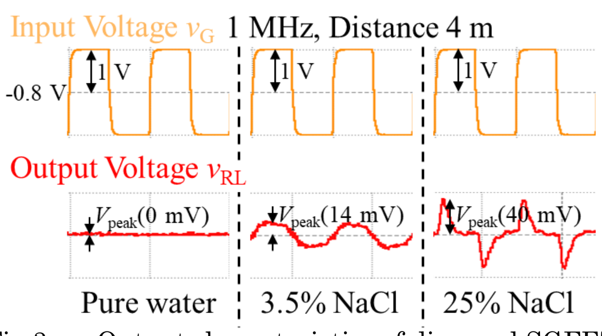

Fig.3 Output characteristics of diamond SGFET (Solution concentration changed)

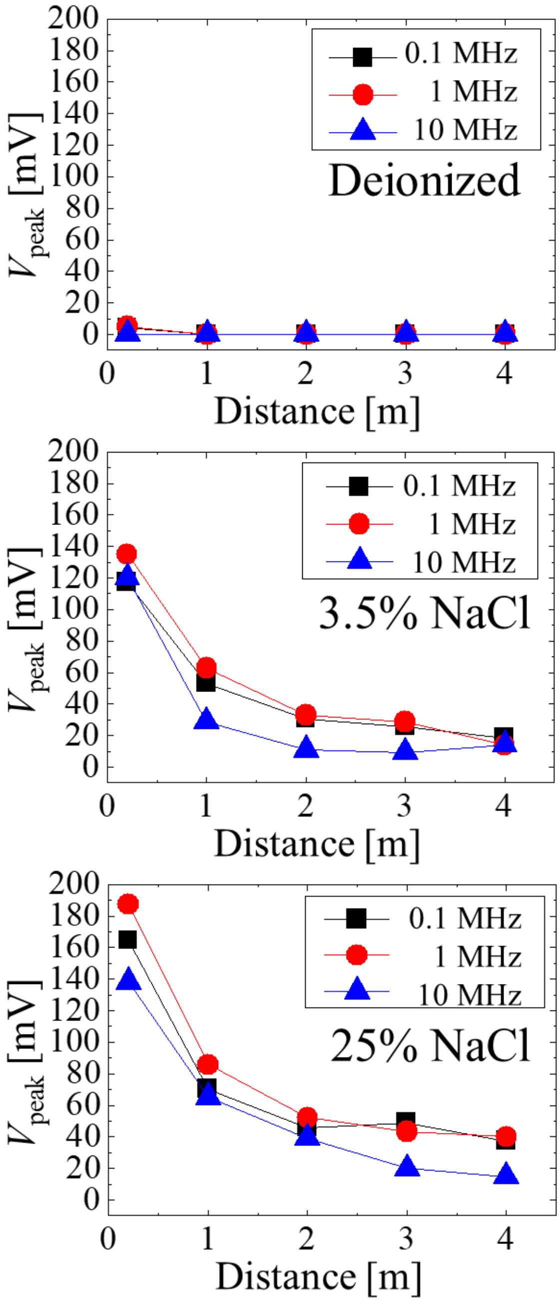

Fig.4 Solution concentration change of distance dependence of differential pulse amplitude V_{peak}

Acknowledgements

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