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Development of Nano-Gap Device for Biosensor

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1. Introduction

Highly sensitive biosensors are of importance in diagnosis of genetic diseases and detection of infectious agents. Various types of biosensors have been developed over the years. A device with a new sensing mechanism is expected to develop application fields.

In this paper, we describe a new sensing device with nano-gap fabricated by the wafer bonding method. We characterize ethanol or ultrapure water, which is generally used as DNA menstruum or DNA conservation solution, by the capacitance-voltage (C-V) and the conductance-voltage (G-V) measurements of nano-gap device.

2. Experimental

Figure 1 (a) illustrates the sensing device with Al/n-Si/nano-gap/p-Si/Au structure. Thermal oxide was formed on n-type Si (100) wafer in wet oxygen gas at an atmospheric pressure. The oxide thickness was approximately 200 nm, as measured by ellipsometry. The thermal oxide film was patterned by the photolithography to define gap region. This wafer and cleaned p-type Si (100) wafer were stacked with the surfaces facing each other. The stacked wafer was heated in nitrogen gas ambience to achieve the strong wafer bonding. The width of a gap was confirmed to be approximately 200 nm by using scanning electron microscope. Metal electrodes were formed on the outside surfaces of the stacked wafer by evaporation. The electric characteristics of ethanol or ultrapure water were measured by using the nano-gap sensing device.

3. Results and Discussion

Figure 1 (b) shows the image of nano-gap device obtained by near-infrared light transmission measurement when ultrapure water was dropped into the nano-gap. It is seen that the nano-gap structure has been fabricated and the ultrapure water penetrates into the nano-gap.

Figure 2 shows the change of C-V and G-V characteristics at 100, 200 and 500 Hz by dropping ultrapure water into the nano-gap. The G-V changes have a peak at approximately 0.5 V for frequencies, while the capacitance is decreased by the dropping. It is considered that the G-V peaks are arisen from the capture and emission of electrons through the states of wafer [1]. The peak arisen from the electron capture and emission is also observed in the C-V changes for the other sample device [1]. The characteristics in which the peak is observed are conjectured to depend on the parasitic resistance or capacitance of a sample device. Further investigation is necessary to extract the conductance and capacitance due to the electron capture and emission from the total conductance and capacitance.

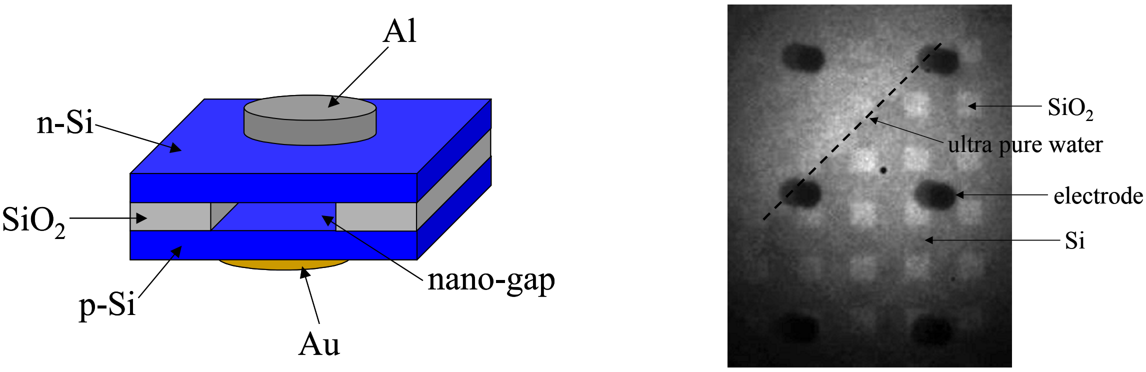
Figure 3 shows the change of C-V and G-V characteristics at 100, 200 and 500 Hz by dropping ethanol into the nano-gap. The C-V and G-V characteristics at 100 and 500 Hz are hardly changed by ethanol dropping. The G-V change at only 200 Hz has a broad peak at approximately 0.5 V. It is seen that the G-V peak depends on frequency. The results in Figs. 2 and 3 suggest that ethanol or ultrapure water can be identified from the frequency dependence of G-V peak. From the frequency dependence of G-V peak, it is considered that the energy states of ethanol is discrete compared with that of ultrapure water.

4. Conclusion

We have demonstrated the sensing of ethanol or ultrapure water in the nano-gap by C-V and G-V measurements. The characterization of ethanol or ultrapure water used as a solvent of DNA solution shows the possibility of the nano-gap device to be applied for biological sensors.

Reference

[1] S. Morita, T. Takegawa, T. Hirokane, S. Urabe, K. Arima, J. Uchikoshi and M. Morita, *Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials* (2004) 704.



(a) (b)

Fig. 1 (a) Schematic diagram of nano-gap device structure and (b) image of nano-gap device structure by near-infrared light transmission measurement.

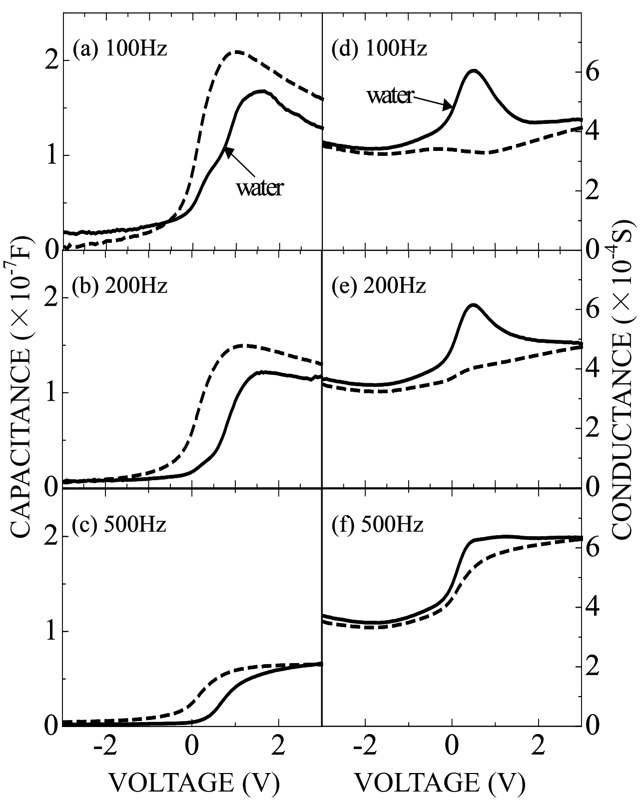


Fig. 2 (a)-(c) Capacitance-voltage and (d)-(f) conductance-voltage characteristics at 100, 200 and 500 Hz for nano-gap device before (broken line) and after (solid line) ultrapure water dropping.

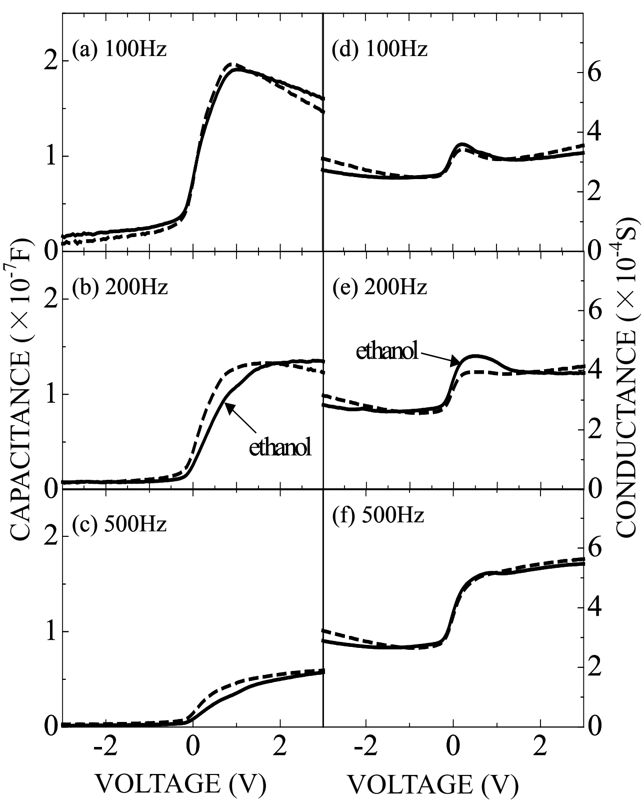


Fig. 3 (a)-(c) Capacitance-voltage and (d)-(f) conductance-voltage characteristics at 100, 200 and 500 Hz for nano-gap device before (broken line) and after (solid line) ethanol dropping.