Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 704-705

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Nano-Gap Device for Liquid Sensing

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1. Introduction

Many groups have explored new sensing devices for various applications. Furthermore, the device with a new sensing mechanism is requested for development of application fields.

In this paper, we describe a new device with nano-gap for liquid sensing. We observe for the first time peaks due to water sensing in capacitance (C)–voltage (V) and conductance (G) –voltage (V) characteristics of a nano-gap device.

2. Experimental

The nano-gap device that has Au/p-Si/nano -gap/n-Si/Al structure was fabricated. A thermal oxide film was formed on n-type Si(100) wafer in wet oxygen gas at an atmospheric pressure. The oxide thickness was about 200 nm. The oxide film was patterned by photolithography to define the gap region. The wafer and a cleaned p-type Si(100) wafer were stacked with the surfaces facing each other. The stacked wafers were heated to achieve strong bonding of the wafer.

3. Results and Discussion

Figure 1 shows the change of G-V and G-V characteristics at 100 Hz for a nano-gap device by water dropping into the gap. C-V and G-V curves after water dropping have a peak at 0.7 V.

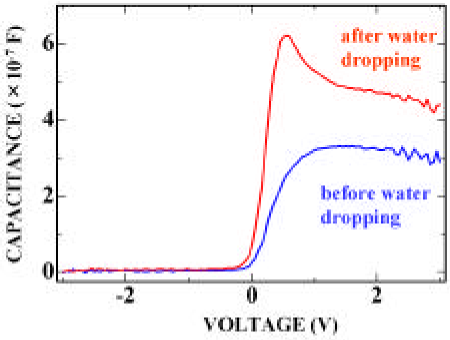
Differences of G-V and G-V characteristics at 20, 50, 100, 200 and 500 Hz by dropping water are shown in Fig.2. The difference of characteristics is obtained by the subtraction of the curve before water dropping from that after the dropping. The peak height in C-V is increased at lower frequency, while the peak height in G-V is increased at higher frequency.

FTIR spectral change after water dropping into nano-gap space is shown in Fig.3. FTIR spectra have absorption peaks due to water at 1645 and 3450 cm^{-1}. It is confirmed that water is introduced into nano-gap by the dropping. Peaks due to water at 700 and 2125 cm^{-1} are not observed for water in nano-gap, while the spectrum of water dropped on the outer surface of Si has the peaks. It is considered that hydrogen bond between water molecules is weakened in nano-gap space.

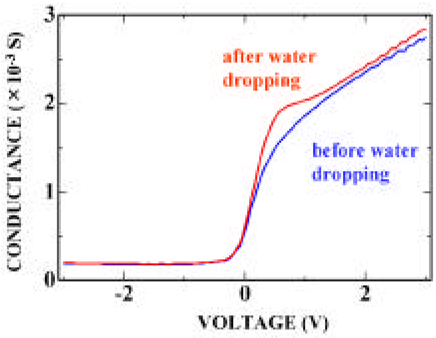
The peak in C-V and G-V curve can be explained by capture and emission of electrons through the states of water as illustrated in Fig.4, because the behavior of the peak for voltage or frequency resembles that of the peak due to capture and emission of electrons through the SiO_2/Si interface traps in C-V and G-V curve of a Metal/Oxide/Silicon diode.

4. Conclusion

We observe for the first time G-V and G-V peaks arised from capture and emission of electrons through the states of water. The sensing of water shows that a new nano-gap device has possibility to be useful for biological sensors.



(a)



(B)

Fig.1 (a) Capacitance-voltage and (b) conductance-voltage characteristics at 100 Hz for nano-gap sensor before and after water dropping.

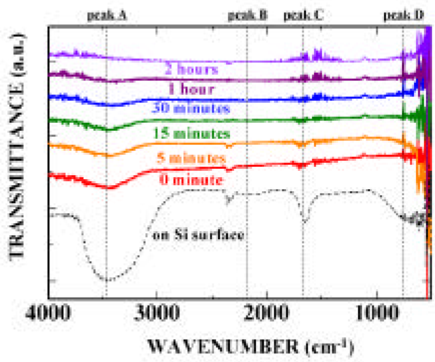
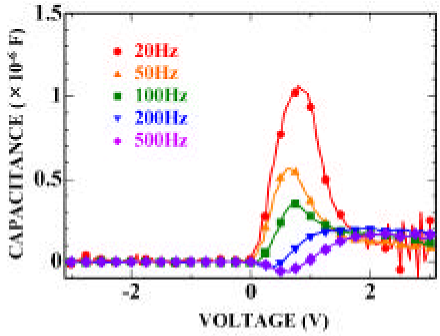
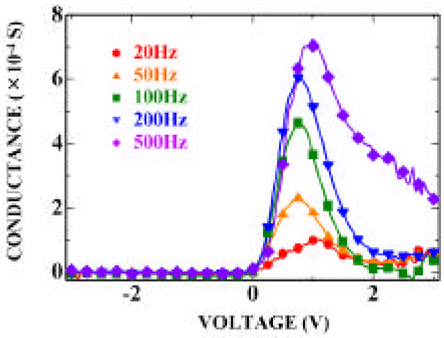


Fig.3 FTIR spectra of water in nano-gap space for times after water dropping. FTIR spectrum of water dropped on outer surface of Si is shown as a reference.



(a)



(b)

Fig.2 (a) Difference of capacitance-voltage and (b) difference of conductance-voltage characteris-tics at 20, 50, 100, 200 and 500 Hz for nano-gap sensor by dropping water.

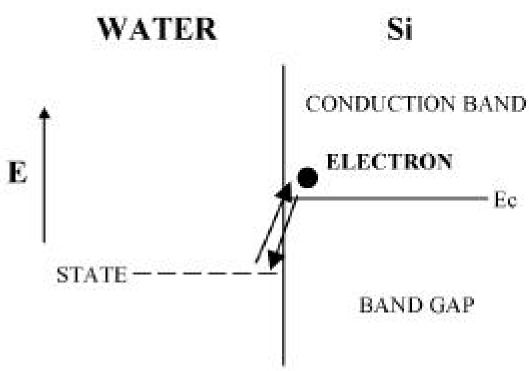


Fig.4 Illustration of capture and emission of electrons through the states of water.