Extended Abstracts of the 2006 International Conference on Solid State Devices and Materials, Yokohama, 2006, pp. 900-901

C-9-7

Liquid Sensing by Nano-Gap Device with Treated Surface

Takaaki Hirokane, Hideaki Hashimoto, Daisuke Kanzaki, Tatsuya Takegawa, Satoru Morita, Shinichi Urabe, Kenta Arima, Junichi Uchikoshi and Mizuho Morita

Department of Precision Science and Technology, Graduate School of Engineering, Osaka University,
2-1, Yamada-oka, Suita, Osaka 565-0871, JAPAN
Phone: 06-6879-7274, Fax: 06-6879-7274
thirokane@pm.prec.eng.osaka-u.ac.jp

1. Introduction

Recently, the development of the device with a new sensing mechanism, which offers high-throughput bioassay for DNA sequences, becomes important for genetic research or clinical diagnostics. We have fabricated the device based on an electron response and have succeeded in the detection of ultrapure water [1,2].

In this paper, we describe the surface condition dependence of liquid sensing for a nano-gap device. We also discuss the mechanism of ultrapure water sensing by capacitance-voltage (C-V) and conductance-voltage (G-V) measurements.

2. Experimental

Figures 1(a) and 1(b) show the schematic of the sensing device structure with Al/n-Si/nano-gap/p-Si/Au structure and the image of nano-gap device obtained by near-infrared ray transmission measurement, respectively. Thermal SiO_2 film as a spacer was formed on n-type Cz Si (100) wafer in wet oxygen gas at an atmospheric pressure. The SiO_2 film thickness was approximately 200 nm, as measured by ellipsometry. The SiO_2 film was patterned by photolithography to define gap region. The SiO_2 film was etched to leave the form of 1 mm^2 square. The distance between the square islands was 1 mm. This patterned wafer and cleaned p-type Si (100) wafer were stacked with the surfaces facing each other. The stacked wafer was heated in nitrogen gas to achieve the strong bonding of wafers. The width of a gap was confirmed to be approximately 200 nm by using scanning electron microscope. To form contact electrodes, aluminum (Al) and gold (Au) were evaporated on the back side surface of n-Si and p-Si, respectively. We prepared three-type devices. First device was used as fabricated. Second device had the Si sensing surface covered with the SiO_2 film of 10nm thickness by thermal oxidation. Third device had the Si sensing surface treated with HF cleaning followed by dropping H_2O_2 solution into nano-gap. The electric characteristics of ultrapure water were measured by using the three-type nano-gap sensing devices.

3. Results and Discussion

It has been observed by FT-IR and near-infrared light transmission measurement that the ultrapure water penetrates into the nano-gap [1,2].

Figure 2 shows the change of C-V and G-V characteristics at 100 Hz by dropping ultrapure water into the nano-gap. The C-V and G-V curves have a peak at approximately 0.5 V for the as-fabricated device. It is considered that the C-V and G-V peaks are arisen from capture and emission of electrons through states of water [1].

Figure 3 shows the change of C-V and G-V characteristics at 100 Hz for SiO_2-covered device by dropping ultrapure water into the nano-gap. No peak is observed in the curve of C-V and G-V for SiO_2-covered device. It is considered that capture and emission of electrons is interrupted by SiO_2 on Si surface. These results support the model based on capture and emission of electrons.

Figure 4 shows the change of C-V and G-V characteristics at 100 Hz for H_2O_2-treated device by dropping ultrapure water into the nano-gap. The curve of C-V and G-V for H_2O_2-treated device has a peak at approximately 1.4 V. The peak of C-V and G-V for H_2O_2-treated device was observed at a different voltage from the as-fabricated device. The peak was shifted depending on the surface condition of the nano-gap device. It is considered that the oxide voltage is increased for the constant applied voltage by the surface condition. On the other hand, the curve of C-V and G-V for HF-cleaned device is hardly changed by ultrapure water dropping. This suggests that the water does not penetrate into the nano-gap with HF-cleaned Si surface because the surface is hydrophobic. The water penetrates into the nano-gap with as-fabricated or H_2O_2-treated Si surface because of the hydrophilic surface.

4. Conclusion

We have demonstrated that the surface condition dependence of ultrapure water sensing supports the model based on capture and emission of electrons through states of water. It is important that the sensing surface is hydrophilic and the oxide film on the sensing surface is thin for high sensitive detection of liquid at low applied voltage.

References

[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.

[2] S. Morita, T. Hirokane, T. Takegawa, S. Urabe, K. Arima, J. Uchikoshi and M. Morita, *Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials* (2005) 828.

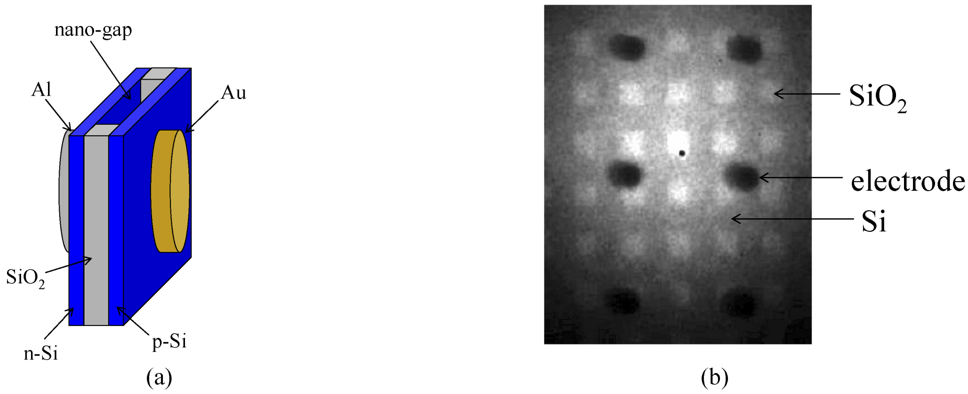

Fig.1 (a) Schematic diagram of nano-gap device and (b) image of nano-gap device by near-infrared ray transmission measurement.

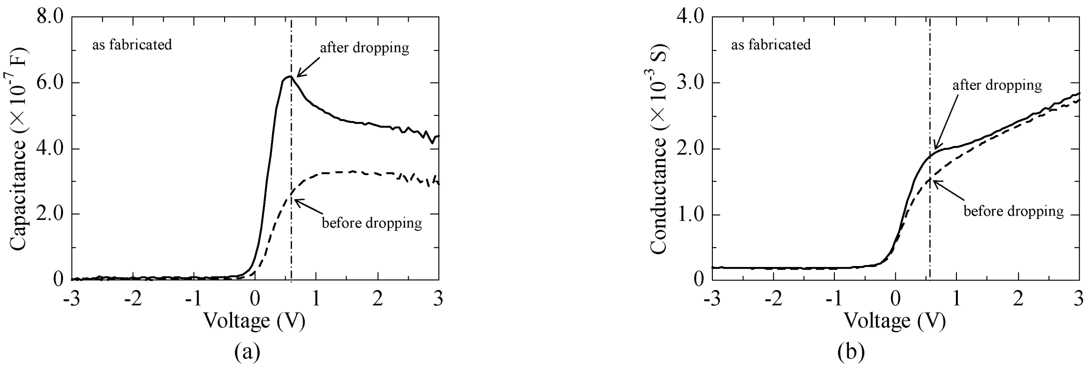

Fig. 2 (a) Capacitance-voltage and (b) conductance-voltage curves at 100 Hz for as-fabricated nano-gap device before and after ultrapure water dropping into nano-gap.

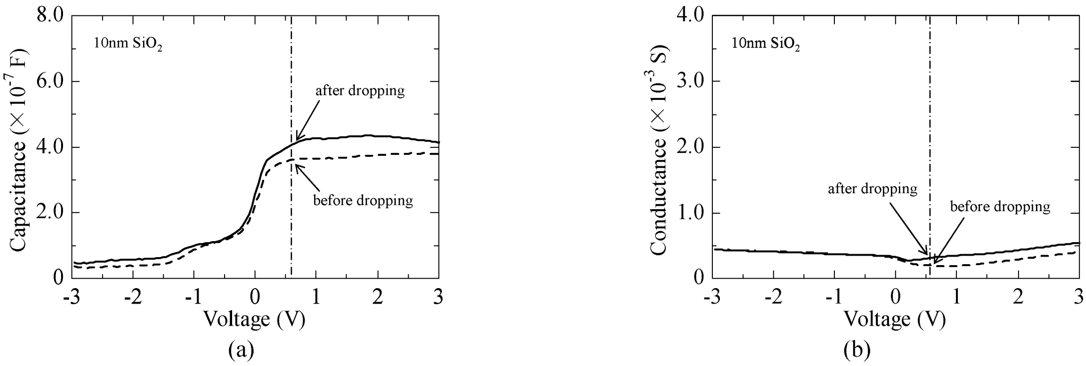

Fig. 3 (a) Capacitance-voltage and (b) conductance-voltage curves at 100 Hz for nano-gap device covered with 10nm-thick SiO_2 film before and after ultrapure water dropping.

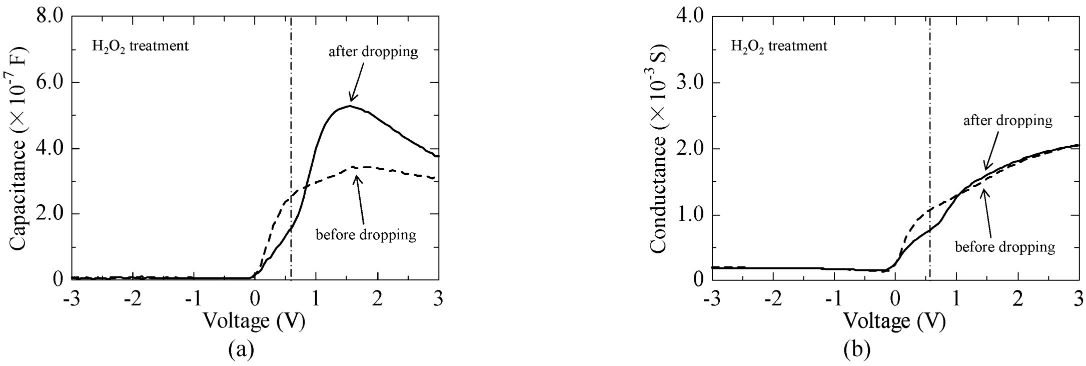

Fig. 4 (a) Capacitance-voltage and (b) conductance-voltage curves at 100 Hz for nano-gap device treated with H_2O_2 before and after ultrapure water dropping.