Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.734-735

P7-14

Photodetector Characteristics of Metal-Oxide-Semiconductor Tunneling Structures with Transparent Conductive Tin Oxide Gate

Motonori Chikamoto, Hideaki Hashimoto, Kosuke Horikoshi, Akihito Shinozaki, Satoru Morita, 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
E-mail: h.hashimoto@pm.prec.eng.osaka-u.ac.jp

1. Introduction

The integration of optics on a silicon (Si) substrate through metal-oxide-semiconductor (MOS) compatible processes is becoming important for optical interconnects, image sensors or monolithic optical biosensors [1]. The MOS tunneling structure has used as a photodetector [2]. However, the indium tin oxide sputtering process has been reported to degrade photodetector performance.

In this study, we have examined the photodetector characteristics of MOS diodes with tin oxide (SnO_2)/ultrathin silicon dioxide (SiO_2)/n-Si structures.

2. Experimental

The wafers were n-type Si (100) with a resistivity of 6-12 Ω・cm. The wafers were cleaned by following processes: rinsed with O_3 ultrapure water, cleaned with $HF/H_2O_2/H_2O$/surfactant solution under megasonic irradiation, rinsed with O_3 ultrapure water, etched with dilute HF solution, and rinsed with ultrapure water. Ultrathin SiO_2 films were formed to be approximately 3 nm by thermal oxidation. The thermal oxidation of Si was carried out at 900 ℃ in oxygen gas of an atmospheric pressure. SnO_2 powder was evaporated on an SiO_2 film, and after cleaning with O_3 ultrapure water, SnO_2 electrode was formed by thermal oxidation of the evaporated film. The oxidation was carried out at 215℃ in oxygen gas of an atmospheric pressure. The photodetector characteristics of SnO_2 gate MOS diode was examined by comparing with those of Al gate MOS diode. The photo current of MOS diodes was measured by using halogen lamp or He-Ne laser (wavelength:632.8nm) with dark filters.

3. Results and Discussion

Figure 1 shows the transmittance versus wavelength for the SnO_2 film formed in this experiment. The transmittance of the evaporated film at visible light wavelengths is less than 10%. The transmittance can be increased to approximately 40% by thermal oxidation.

Figure 2 shows the current density-voltage characteristics of SnO_2 gate and Al gate MOS diodes. The photo current was measured under halogen lamp light irradiation. The difference between photo and dark current densities of SnO_2 gate MOS diode is observed at negative gate voltages. The comparison of SnO_2 and Al gate MOS diodes indicates that the photodetector performance is not degraded by the SnO_2 formation process.

Figure 3 shows the current density-voltage characteristics of SnO_2 gate and Al gate MOS diodes for various light intensities. The photo current was measured by controlling the light intensity of the He-Ne laser using dark filters. The electron tunneling current through the ultrathin SiO_2 film from SnO_2 to n-Si is increased at negative gate voltages by light irradiation. It is considered that the increase in electron tunneling current is mainly due to the increase in oxide voltage with the formation of inversion layer by photoexcitation [3].

The difference between photo and dark current densities as a function of light intensity for SnO_2 and Al gate MOS diodes is shown in Fig.4. For the light intensity of 0.32 nW/cm^2, the current difference of SnO_2 gate MOS diode is approximately 100 times compared with that of Al gate MOS diode at the gate voltage of –1.5 V. It is confirmed that the MOS tunneling diodes for n-type Si have high gains as phototransistors.

4. Conclusions

We have demonstrated the photodetector characteristics of the MOS tunneling structures with SnO_2 gate. These results are useful for the development of photodetectors fabricated by MOS compatible processes.

References

[1]K. Misiakos, E. Tsoi, E. Halmagean and S. Kakabakos, Tech. Dig. Int. Electron Device Meet. (1998) 25.
[2]C. W. Liu, W. T. Liu, M. H. Lee, W. S. Kuo and B. C. Hsu, IEEE Electron Device Lett. **21** (2000) 307.
[3]S. Morita, A. Shinozaki, Y. Morita, K. Nishimura, T. Okazaki, S. Urabe and M. Morita, Jpn. J. Appl. Phys. **43** (2004) 7857.

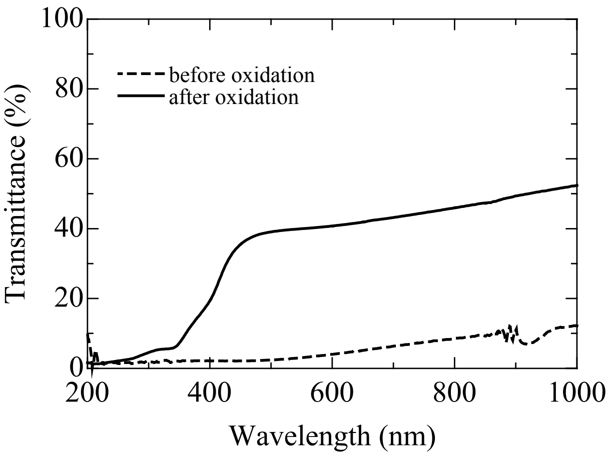
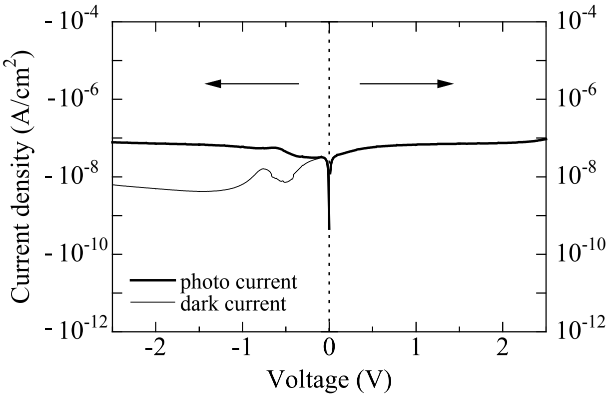


Fig.1 Transmittance versus wavelength for SnO_2 film.



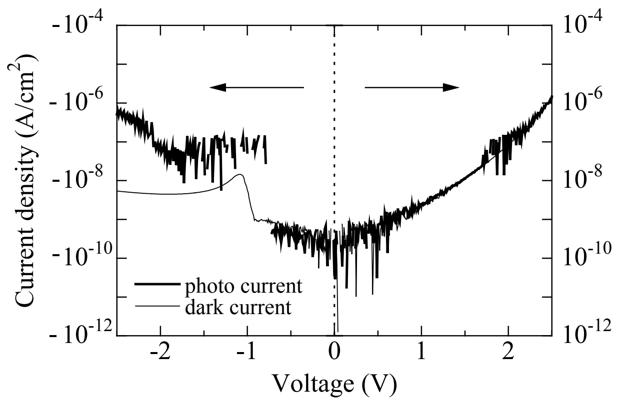
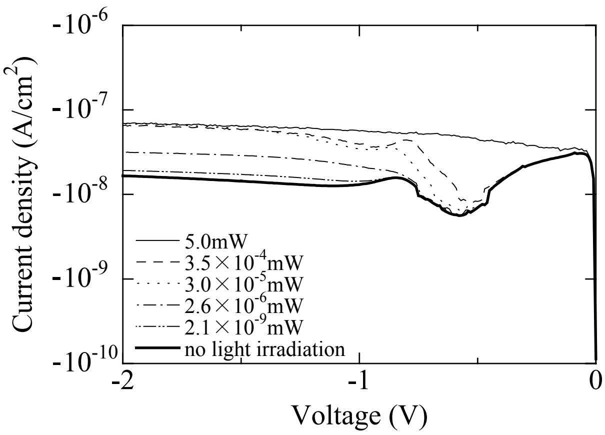


Fig.2 Photo and dark current density-voltage characteristics of (a) SnO_2 gate and (b) Al gate MOS diodes.



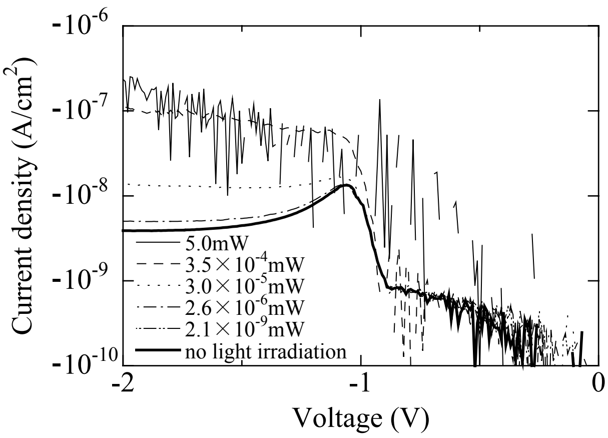


Fig.3 Photo current density-voltage characteristics of (a) SnO_2 gate and (b) Al gate MOS diodes for light intensities.

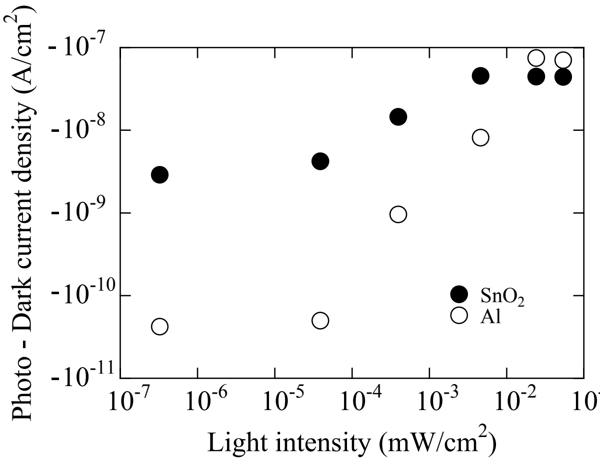


Fig.4 Difference between photo and dark current densities as a function of light intensity for SnO_2 and Al gate MOS diodes.