Sensitivity Enhancement of Metal-Oxide-Semiconductor Tunneling Temperature Sensor with Al_2O_3/SiO_2 Dielectric Stacks

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Introduction

Owing to rapid development of semiconductor manufacturing technology and increasing demands for electronic devices with high speed performance, the dimensions of transistors shrink drastically. The numerous transistors integrated on a chip generate heat and give rise to serious power dissipation and overheating problem. Hence, temperature monitoring of integrated circuit is of importance in order to prevent the irreversible device failures. Metal-oxide-semiconductor (MOS) tunneling diode with Al/SiO_2/p-Si structure has been reported as an on-chip temperature sensor by detecting saturated substrate injection current variation [1],[2]. In this work, we demonstrated that the stacked Al_2O_3/SiO_2 MOS(p) tunneling temperature sensor exhibits reliable temperature detecting capability. Compared to Al/SiO_2/p-Si structure, the saturation current sensitivity can be enhanced by using stacked Al_2O_3/SiO_2 gate dielectrics. In addition, the fabrication is CMOS process compatible and low-temperature processing (<400 ℃).

Results and discussion

For the MOS(p) tunneling diode, the substrate injection current is principally provided by generation-recombination mechanism and shows highly temperature dependent. The minority carriers (electrons) generated from depletion region tunnel through the oxide layer, and then are collected by Al electrode. When the tunneling rate is large enough, the current saturates due to the insufficient supply of minority carriers from the substrate. From the sensor point of view, it prefers that the device can operate at lower voltage. In other words, the substrate injection current should saturate as soon as possible. At subjection injection condition, schematic energy band diagrams of SiO_2 and Al_2O_3 MOS(p) tunneling diodes with the same effective oxide thickness are shown in Fig. 1(a) and 1(b), respectively. For the Al_2O_3 MOS(p) tunneling diodes, the substrate injection current saturates easier since the conduction band offset of Al_2O_3 is smaller than that of SiO_2. Fig. 2 shows the J-V curves of the Al_2O_3 MOS(p) tunneling diode with an effective oxide thickness (EOT) of 2 nm at elevated temperatures. When the device is positively biased, the saturated substrate injection current increases with elevated substrate temperature. The saturation current also remains stable when the gate voltage exceeds the critical value. Furthermore, it is clearly observed that the increase of current is over two decades.

In order to investigate the sensitivity of MOS(p) tunneling temperature sensor, current gain can be defined as the ratio of gate current at elevated temperature(T > 30 ℃) and gate current at 30 ℃(i.e., $I_{G\_T℃}/I_{G\_30℃}$). Fig. 3 shows the comparison of the current gain between the Al_2O_3 and SiO_2 MOS tunneling temperature sensors. For the MOS(p) diode with stacked Al_2O_3/SiO_2 structure (red lines), the sensitivity (current gain) is enhanced obviously. Furthermore, the gate current saturates earlier due to the conduction band offset of Al_2O_3. The results suggests that the MOS(p) tunneling temperature sensor with stacked Al_2O_3/SiO_2 gate dielectrics can be operated at lower voltage with improved performance.

References

[1] Y.-H. Shih and J.-G. Hwu, IEEE Electron Device Lett., **22,** 299 (2001).
[2] Y.-H. Shih, S.-R. Lin, T.-M. Wang, and J.-G. Hwu, IEEE Trans. Electron Device, **51**, 1514 (2004).

Acknowledgments

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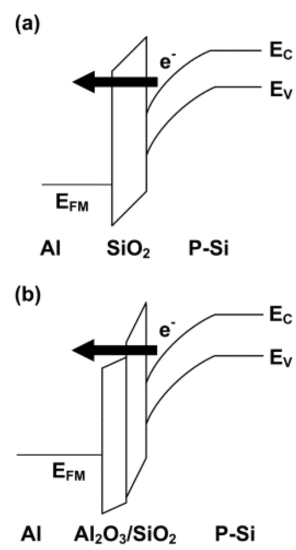

Fig.1 Schematic energy band diagrams of SiO_2 and Al_2O_3 MOS(p) tunneling temperature sensors.

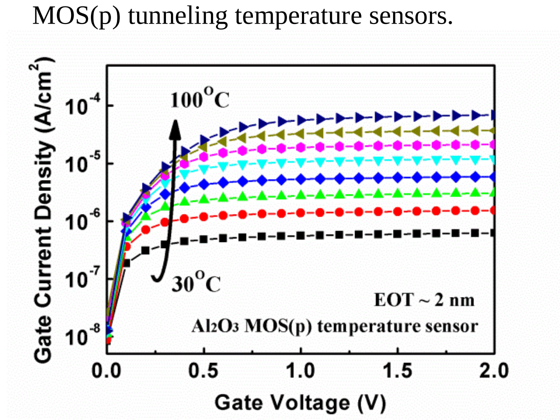

Fig.2 Gate current density versus gate voltage curves of Al_2O_3 MOS(p) tunneling temperature sensor at elevated temperatures.

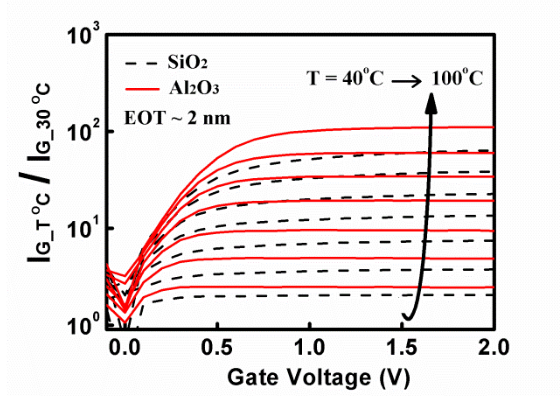

Fig.3 Comparison of current gain versus gate voltage curves of SiO_2 and Al_2O_3 MOS(p) tunneling temperature sensors.