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EGFET-Based biosensor using parasitic BJT effect

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1. Introduction

The planar FET based sensor has been served as basis for chemical and biological detection which can be monitored electrically. Therefore, the ion-sensitive-FET (ISFET) which is the simplest FET based sensor has broadly used for detecting chemical species [1]. But, this widely used sensor has been facing the Nernst limit that means the 59 mV/pH which is maximum sensitivity in ISFET. To solve this problem, various metal-oxide insulators were used to overcome this problem [2]. Despite intensive studies, the sensitivity of ISFET still placed under Nernst limit. Therefore, the improving sensitivity is one of issues in biosensor application.

To solve this problem, the single transistor latch process which uses the parasitic BJT effect in silicon-on-insulator (SOI) structure can be breakthrough.

In this work, we realize high performance fully depleted (FD) SOI ISFET with titanium extended gate. And also, we suggest novel ISFET operation method using parasitic BJT effect to enhance the sensitivity.

2. Experimental details

EGFET devices were fabricated on SOI wafers. The thickness of top silicon layer and buried oxide layer is 100 and 200 nm, respectively. After patterning the active region, the gate oxide with a thickness of 5 nm was grown using thermal oxidation at 880 ˚C. A highly conductive in situ phosphorus-doped poly-Si film of 100 nm thick was deposited for gate electrode using low-pressure chemical vapor deposition at 650 ˚C. A gate region was defined by photolithography and dry etching processes. N^+-type source/drain (S/D) junctions were formed by a plasma doping system at 450 ˚C using PH_3 gas. A rapid thermal annealing process(RTA) process was carried out at 950 ˚C for 30s in mixed N_2/O_2 ambient for S/D activation. After RTA process, we deposited titanium for extended gate using e-beam evaporation system. After define the extended gate, a post-RTA annealing process was performed at 450 ˚C for 30min in a mixed 2% H_2/N_2 ambient using the conventional furnace system to improve interface states. The channel length and width of fabricated EGFET were 2 and 20μm.

3. Results and discussions

Fig. 1 shows the schematic diagram of fabricated EGFET. We attached PDMS chamber on the extended gate and injecting pH solution in it.

Fig. 2 shows the I_D-V_G characteristics of EGFET. When the drain voltage approach 3.7 V, the drain current abruptly increase from subthreshold region to saturation region. And also, the subthreshold swing approaches a value of 0 mV/dec. This abrupt change comes from latch process by parasitic BJT in SOI structure [3].

Fig. 3 shows the sensitivity characteristics of EGFET using parasitic BJT. We use the latch up voltage for reference voltage. During pH change from 4.2 to 10.2, the parallel shift of latch voltage was observed. It means that this parasitic BJT method can be applied for sensing operation. The measured sensitivity has 97.67% linearity and latch voltage shift 37 mV/pH

Fig. 4 shows the reliability of EGFET. To observe hysteresis characteristics, we sequentially changed pH solution as 4.2→7→10.6→7→4→10.6. The Ti extended gate was exposed for 5min in each pH solution. The latch voltage of EGFET was very stable during cyclic pH change. And also, we exposed the Ti extended gate to pH solution for 10^4 s to observe drift characteristics. After 10^4, the latch voltage shift was almost 0 mV. The fabricated EGFET shows very stable characteristics for non-ideal effect.

Fig. 5 shows the real-time sensing characteristics by parasitic BJT operation method. This novel operation is very suitable for detecting specific marked target. Because, the steep subthreshold characteristic leads large current difference by small potential change as shown in inset of Fig. 1. We use the pH 7 for initial state. And -140 mV and 3.7 V were constantly induced reference electrode and drain, respectively. When we replace the pH solution from 7 to 6, the source current was drastically increased to 52 μA. This large current difference was occurred by latch voltage shift. In pH 7, the bias of reference electrode was placed before latch state. But, in pH 6, the gate bias was placed on after latch state. The parasitic BJT operation converts the small potential change to large current difference. And we can control the sensing area by adjusting bias condition of reference electrode.

4. Conclusions

The FD SOI based ISFET with Ti extended gate were fabricated and analyze sensing characteristics. And also, we adapted novel operation method using parasitic BJT effect. The EGFET shows parallel shift of latch voltage by value of pH solution. The linearity and sensitivity were 97.67% and 37 mV/pH, respectively. During non-ideal effect experiment, fabricated EGFET shows very stable characteristic. The suggested operation method using parasitic BJT effect shows the large current difference. This EGFET and parasitic BJT operation method can be promising technique for detecting specific marked target.

Acknowledgements

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References

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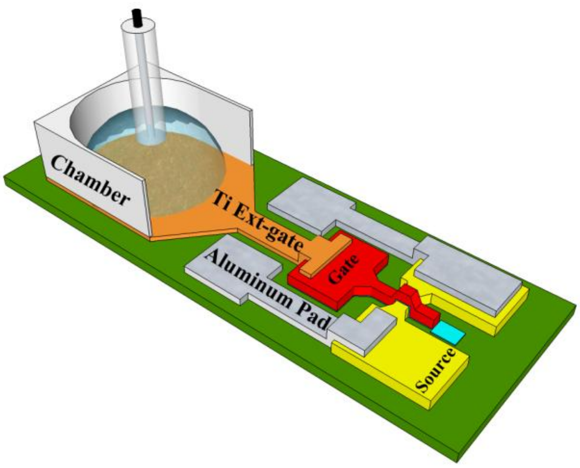

Fig. 1 Schematic diagram of ISFET with Ti extended gate.

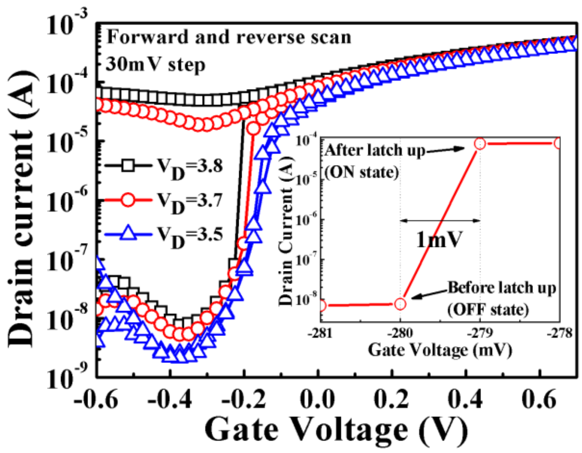

Fig. 2 I_D-V_G characteristic of EGFET. The abrupt increased drain current and hysteresis curve was observed under specific drain voltage.

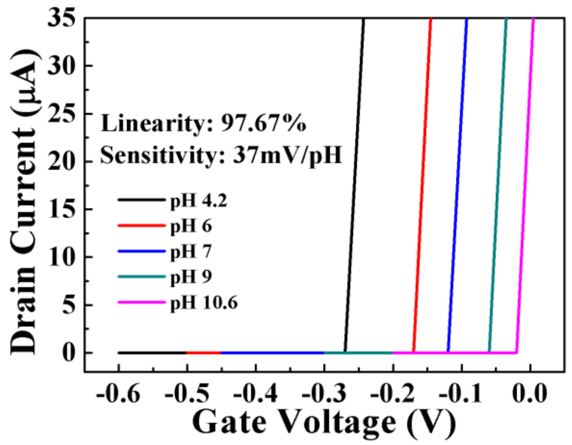

Fig. 3 the sensitivity characteristics of EGFET using parasitic BJT effect. The parallel shift of latch voltage was observed.

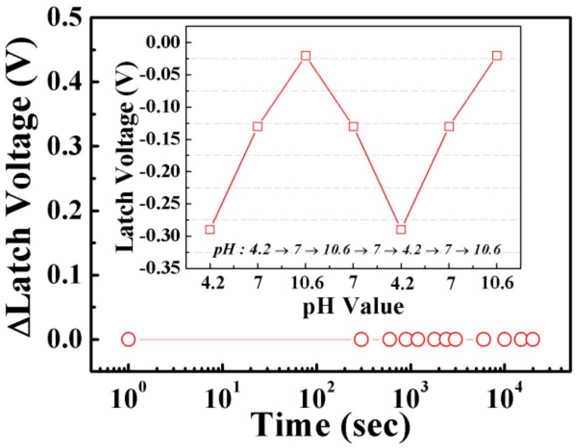

Fig. 4 The non-ideal effect of fabricated EGFET. The EGFET shows very stable characteristic while measurement.

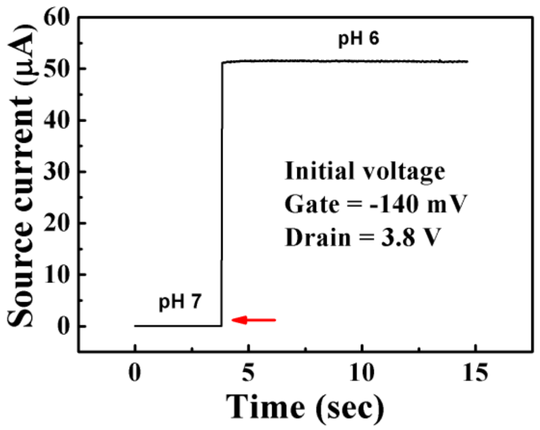

Fig. 5 Real-time sensing properties using parasitic BJT operation method. When the pH value was changed from 7 to 6, the EGFET shows the large current difference.