Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp1135-1136

Characteristic on H^+ and Ca^{2+} Sensor of HfO_2 Sensing Membrane with PVC Membrane

Chao-Hui Wei[1], Chia-Ming Yang[1,2,3,4] and Chao-Sung Lai[1,2,3,5,6*]

[1] Department of Electronic Engineering, Chang Gung University
[2] Department of Electro-Optical Engineering, Chang Gung University
[3] Biosensor Group, Biomedical Engineering Research Center, Chang Gung University, Taoyuan, Taiwan
[4] Department of General Surgery, Chang Gung Memorial Hospital, Linkou, Taoyuan, Taiwan
[5] Department of Nephrology, Chang Gung Memorial Hospital, Linkou, Taoyuan, Taiwan
[6] Department of Materials Engineering, Ming Chi University of Technology, New Taipei City, Taiwan

Phone: +886-3-2118800 ext.5607 E-mail: cslai@mail.cgu.edu.tw

Abstract

In this article, the hafnium oxide (HfO_2) films deposited by high power impulse magnetron sputtering were investigated as a sensing layer on extended gate field effect transistor for H^+ and Ca^{2+} ion detection. Results of H^+ sensitivity and linearity measurement is 59.41mV/pH and 99.83 %. A subsequent Ca^{2+} ion detection carried out on a poly vinyl chloride layered substrate showed a prominent sensitivity and linearity is 21.8 mV/pCa and 96.679 %.

1. Introduction

The replacement of Ion Selective Field Effect Transistor (ISFET) with extending gate FET (EGFET) structure has brought ion sensor. EGFET enables the isolation of the sensing membrane apart from the MOSFET part and offers numbers of advantages including cost-effective fabrication, simple structure, packaging simplicity, long term stability, resistance to light and temperature and also disposable gate.

As we know, the human body have many important ion element, both of hydrogen, potassium, calcium, sodium, magnesium and so on. Among them, calcium ion is the highest in human body and plays an important role in nerve central control and hormone release [1]. The calcium content in human cells is important in a certain range and many physical activities can be monitored by detection calcium ions. However the abnormal calcium concentration in serum are in connection with several diseases such as malignant tumors and hyperthyroidism.In this work, EGFET was modified with PVC selective membrane for Ca^{2+} ion detection. Results show that the Ca^{2+} ion selectivity PVC membrane have good selectivity for pCa solution. it means PVC does not react to other ion.

2. Experiment

Sensing membrane fabrication—The substrate was use ITO-PET, then HfO_2 thin film was power is 80 watt, the gas is N_2:O_2 1:5.

PVC modification on EGFET sensor—To from the PVC membrane, is mixed with tetrahydrofuran (THF) and three kinds of plasticizers: ionophone II, N-POE and NaTFPB. The mixture was then applied on the commercial EGFET. For pCa detection, phosphate buffer solutions of calcium were prepared in deionized water. pH solution was tested as control samples. The pCa value of the buffer solutions were adjusted by adding 0.1 M $CaCl_2$ and 0.9 M Tris in a range 10^{-1} to 10^{-5} M and monitored by Ag/AgCl reference electrode.

3. Results and discussion

Fig.1 demonstrated simple EGFET structure. Fig. 2 show the bare HfO_2 chip as a sensing membrane that measurement ranges from pH 2-12 detection I_D-V_{GS} curve and sensitivity. This substrate displayed an eventual shifting to the more positive direction as pH increasing and achieving a considerably high sensitivity at about 59.4 mV/pH and high linearity at about 99.79%. For the hysteresis effect, Fig. 3 shows the hysteresis curve of the HfO_2 EGFET in pH loop 7-4-7-10-7, loop time 25 min. We can observe that the hysteresis width is 7 mV and the hysteresis width of the acid solution is smaller than alkaline solution, and the ions diffuse speed different results in the different response [2]. The size of H^+ ion and OH^- ion are different, the diffusion speed of H^+ ions are faster than OH^- ions. Therefore, the hysteresis of the acid solutions is smaller than alkaline solutions [3].

Later on, the sensor is tested for a distinct Ca^{2+} ion detection. PVC selective membrane prepared in mixture with number of additional compounds show a signification improvement in pCa sensing with solution concentration ranges from 10^{-1} to 10^{-4} M that the high sensitivity 21.8mV/pCa and high linearity 96.679 % (Fig. 4). Fig. 5 show bare HfO_2 chip on pH detection, Ca^{2+} PVC on pCa, pH and pK. We found that the PVC membrane have a good selectivity for Ca^{2+} ion, because of PVC on pH and pK solution almost without sensitivity (summary of characteristic in Table I).

4. Conclusions

In this work, theHfO$_2$ as a sensing membrane on EGFET that Ca^{2+} ion detection PVC membrane and PVC selectivity for H^+ and K^+ is demonstrated.Future works may entail the use of other ionophores on the EGFET for important ions in human, such as Na^+ and Mg^{2+}.

References

[1] S. Orrenius. et al. *Cell Biol*. 4, (7), *(2003) 552–565.*
[2] T. Mikolajick, et al. *Sens. & Actuat. B 44 (1997) 262–267.*
[3] Jung Chuan Chou, et al. *Sen.s & Actuat. B 86 (2002) 58–62.*

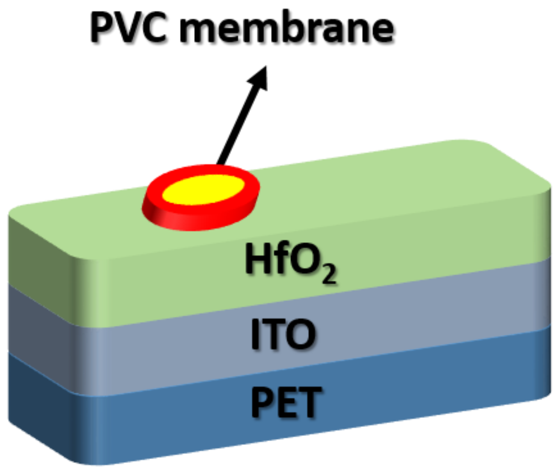

Fig. 1 EGFET simple structure demonstrated.

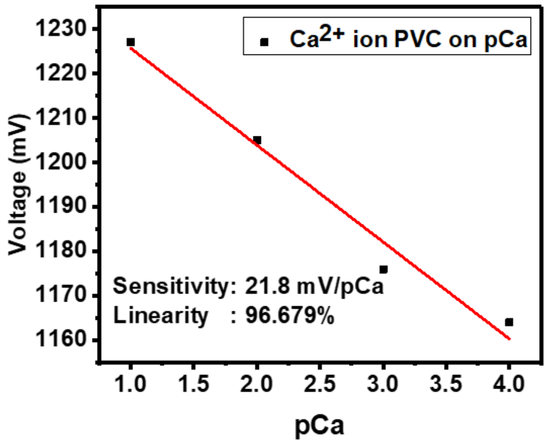

Fig. 4 The sensitivity of Ca^{2+} ion selectivity on pCa range from 1-4 solution.

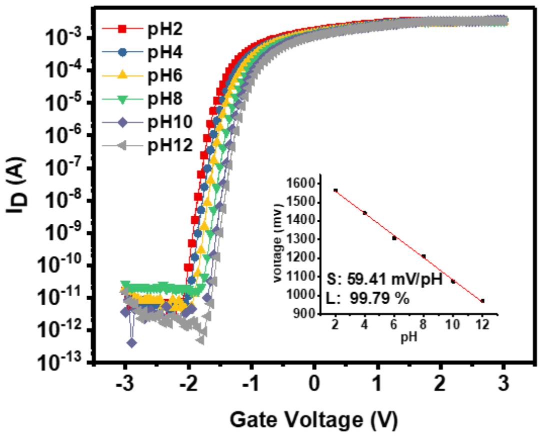

Fig. 2 I_D-V_{GS} curve results of range from pH 2-12 and sensitivity test on bare HfO_2 EGFET device.

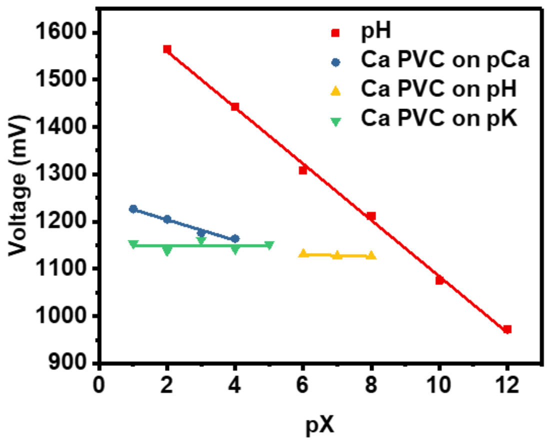

Fig. 5 The solution sensitivity and PVC selectivity on bare HfO_2, Ca^{2+} ion PVC on pCa , pH and pK solution.

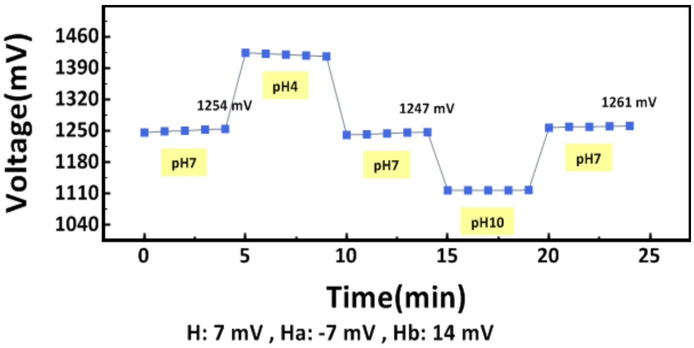

Fig. 3 The hysteresis width curve at loop pH 7-4-7-10-7 for the different loop time.

Table I. Summary of bare chip pH detection, PVC selectivity membrane on pCa, pH and pK solution sensitivity and linearity.

	Bare chip on pH solution	**Ca^{2+} PVC selectivity on pCa solution**	**Ca^{2+} PVC selectivity on pH solution**	**Ca^{2+} PVC selectivity on pK solution**
Sensitivity	59.4 mV/pH	21.8 mV/pCa	2 mV/pH	0 mV/pK
Linearity	99.79 %	96.679 %	5 %	3.3 %