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IGZO Substrate for pH Detection in LAPS with High Photo Response

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Abstract

A structure of niobium oxide (NbO_x) directly on In-Ga-Zn oxide (IGZO) semiconductor layer on commercial ITO/glass substrate is proposed for pH sensing in light-addressable potentiometric sensor (LAPS). pH sensing performance can be both evaluated by capacitance-voltage (C-V) and photovoltage-voltage (PV-V) measurements. pH sensitivity could reach to about 58 mV/pH and photovoltage is about 8 times higher than 300um p-Si.

1. Introduction

LAPS had the advantages of 2-dimensional chemical image which is more powerful for biology and chemistry sensing. [1] Due to its wide energy band gap in IGZO, no visible light absorption is observed for high lighting efficiency. [2] In the meantime, α-IGZO was proposed as the channel material of thin-film transistors (TFTs) on polyethylene terephthalate (PET) substrate with a Hall mobility exceeding 10 $cm^2V^{-1}S^{-1}$. [3] NbO_x was already verified as a good pH sensing membrane for LAPS. [4] Therefore, a new structure of NbO_x/IGZO on ITO glass fabricated by low-temperature process was proposed to check pH sensing properties and also compare to P-type Si substrate.

2. Experiment

IGZO and NbO_x were deposited by rf sputter on commercial ITO/Glass substrates after acetone and methanol clean. In:Ga:Zn:O atomic ratio in IGZO target is 1:1:1:4 and purity is 99.9%. The flow rate of Ar/O_2 was set as 24/1 in sccm for reactive rf sputtering with the power at 200 W and 250°C. The thickness of IGZO layer was controlled to 350 nm by deposition time verified by an ellipsometer measurement. Nb target with 99.9% purity was used to sputtering with flow rate of Ar and O_2 for 20 and 5 sccm, respectively. The power is 200 W until NbO_x thickness of 45 nm. Finally, a polydimethylsiloxane (PDMS) container with 1x1 mm^2 opening was used to attach on NbO_x. [4] Detail process flow and picture of chip are shown in Fig. 1(a) and (b), respectively. C-V and PV-V measurement and setup is shown in ref. [4] in detail. UV-vis and atomic force microscope (AFM) were also used to investigate film quality.

3. Results and discussion

UV-vis was carried out both for IGZO/ITO/glass and ITO/glass are investigated to confirm the wavelength of inject light source as shown in Fig. 2. The difference of absorption in 370 nm which is the wavelength of LED used in measurement is 18%. As shown in Fig. 3 (a) and (b), Rq in ITO/glass and NbOx/IGZO/ITO/glass is 4.68 and 4.99 nm in AFM analysis, respectively. Fig. 4 shows the measured photo- voltage versus bias voltage by different frequency. Maximum frequency of C-V measurement could be 10 kHz. As shown in Fig. 5, C-V curve measured at 3 kHz was shifted to more positive substrate bias in lower pH value of buffer solution. pH sensitivity of 54.7 mV/pH can be calculated by linear fitting between output voltage of 0.6 normalized capacitance. In PV-V measurement, different frequency of ac signal applied in light source is presented as shown in Fig. 6. From 1 to 10 kHz, PV is slightly reduced by higher frequency. As shown in Fig. 7, pH sensitivity and linearity is 58.5 mV/pH and 96.4% by calculating bias measured in different pH buffer solution from PV-V curves. Similar performance can be seen in C-V and PV-V measurements. In final, to test the photo efficiency, PV-V curve of NbO_x/IGZO and Si_3N_4/SiO_2/P-type Si substrate is measured as shown in Fig. 8. Photovoltage of NbO_x/IGZO LAPS with 5 times higher than Si_3N_4/SiO_2/P-type Si LAPS is observed. Therefore this developed device structure with low temperature and easy process could be used in pH sensing application.

4. Conclusions

A new structure of NbOx/IGZO/ITO/glass is fabricated in low temperature process, which is proven to have pH sensitivity of 58.5 mV/pH without room light interference. This structure could be applied in LAPS with UV light source for higher photo response and better signal-to-noise ratio.

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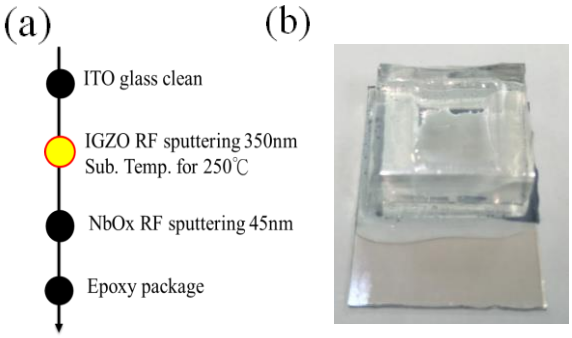

Fig. 1 (a) Process flow and (b) picture of NbOx/IGZO/ITO/glass LAPS.

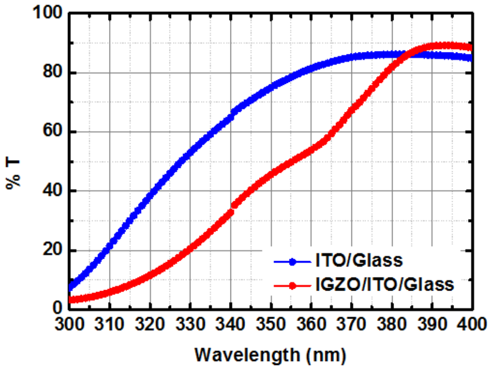

Fig. 2 UV-VIS comparison between ITO/glass and IGZO on it.

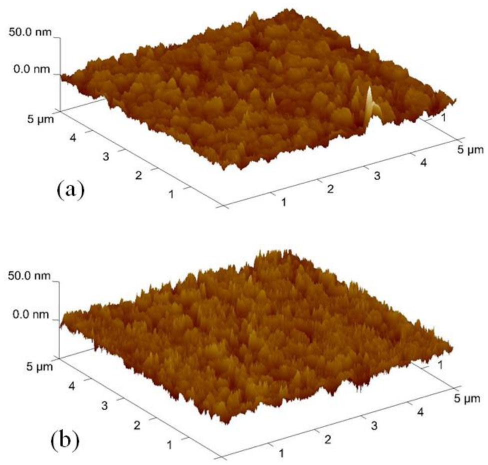

Fig. 3 Surface roughness by AFM for (a) ITO/glass and (b) NbOx/IGZO/ITO/glass.

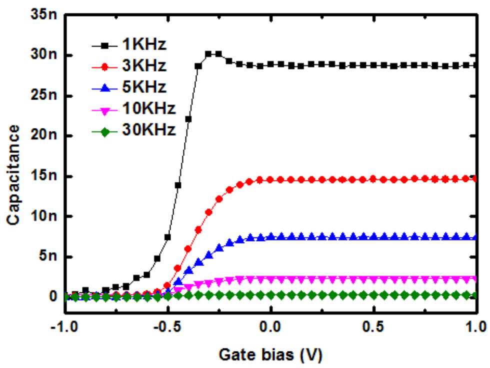

Fig. 4 Capacitance-voltage curves at different frequency.

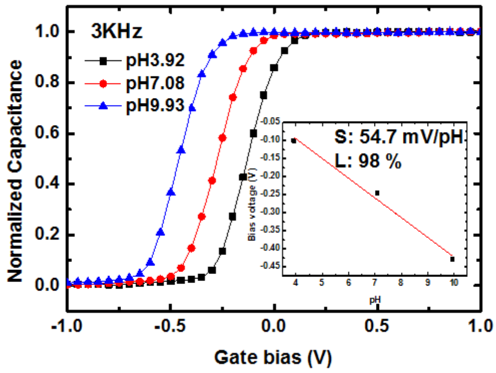

Fig. 5 pH response of C-V curves in buffer solution of pH 4, 7 , and 10. pH sensitivity and linearity is shown in the inset.

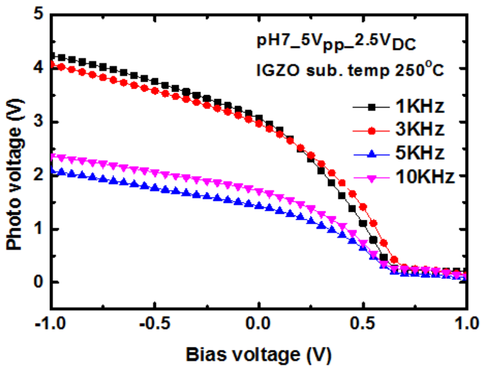

Fig. 6 Photovoltage-voltage curves at different frequency.

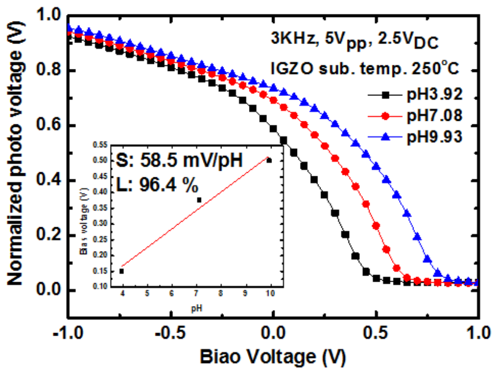

Fig. 7 pH response of PV-V curves in buffer solution of pH 4, 7 , and 10. pH sensitivity and linearity is shown in the inset.

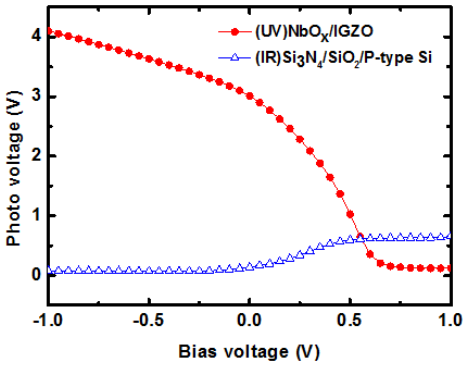

Fig. 8 PV-V curves in buffer solution of pH 7 of NbO_x/IGZO and Si_3N_4/SiO_2/P-type Si