| | |
|---|---|
| Title | 溶液プロセスを用いたバイオセンサ用アクティブマトリクス酸化物TFTアレイの作製 |
| Author(s) | 栗谷川，翔 |
| Citation | |
| Issue Date | 2020-03 |
| Type | Thesis or Dissertation |
| Text version | none |
| URL | http://hdl.handle.net/10119/16299 |
| Rights | |
| Description | Supervisor:高村　禅，先端科学技術研究科，修士（マテリアルサイエンス） |

## Fabrication of active matrix oxide TFT array for biosensor using solution process

Sho Kuriyagawa
(Yuzuru Takamura Lab.)
School of Material Science, Japan Advanced Institute of Science and Technology (JAIST)

Research on arraying biosensors for the purpose of multi-item measurement, position dependence, and density imaging has been advanced. The use of an optical imaging element, CMOS, or the like is advantageous for arraying many sensors. However, there is a disadvantage of high cost for large area applications. The solution process [1] [2], in which a material such as a semiconductor is formed using a sol-gel method or metal organic decomposition (MOD) method, enables fabrication of a relatively large-area and inexpensive active device. In this study, we fabricated an oxide TFT array as a biosensor switching application using a solution process. 576 TFTs (24 × 24 = 576) having gate insulating films, channels, and channel stoppers made from the solution were fabricated. To improve the ON / OFF ratio and leakage characteristics, which were the main technical issues in the past, the fabrication process and materials of the gate insulating film and the channel were optimized. As a result of the optimization, the ON / OFF ratio of $10^7$ (drain current value 1 pA-10 μA) and a leak current of 10 pA ($V_G$ = 10 V) were achieved.

*Keywords*: Solution process, Oxide TFT, Biosensor

### 1. Introduction

In recent years, demands for measuring a multi-item or detecting a several biomolecules have been increasing in a medical or agricultural scene. In the case where the items to be detected or measured are diversified, introduction of an inspection device specialized for each item increases costs and complicates work. Therefore, for the purpose of high throughput, research on integration of sensors using fine processing technology has been advanced. By using the microfabrication technology, a functional unit relating to a biosensor can be designed and fabricated in the same chip. Therefore, miniaturization of the measurement system, miniaturization of the sample, and high throughput can be expected.

The driving method of the integrated sensors is based on the premise that the detection results of the sensors do not interfere with each other. In the case of an electrochemical biosensor, a minute current due to a change in a sensing part is measured. When interference from the measurement system to each sensor occurs, a large error occurs in the result as compared with the measurement of a single sensor. In general, driving methods for arrayed circuits are classified into two types: a passive matrix driving method (Passive Matrix: PM type) and an active matrix driving method (Active Matrix: AM type). The PM type is excellent in mass production because of its very simple structure. But it has a problem in that the non-selected elements are driven by the sub-path. On the other hand, the AM type is desirable as a driving method for a biosensor-equipped device because the driving part is made independent by a switching element such as a TFT (Thin Film Transistor).

Thin film formation technology is important for fabricating devices with high integration and excellent characteristics. Generally, when fabricating a device, thin film formation by a vacuum process (a deposition method from a gas) is mainstream. This is because a high-purity thin film can be formed in an atmosphere in which gas molecules that can be chemically impurities are eliminated by vacuuming. However, it is not suitable for increasing the area of the device, so the cost is high. On the other hand, since the solution process forms a thin film under the atmospheric pressure, it is easy to increase the area of device fabrication, and commercial expectations are high.

Our group has successfully fabricated oxide TFT arrays using solution process. This result can make a significant contribution in terms of fabrication time and cost reduction as compared with the conventional case. In addition, the TFT array adopting the AM driving method can be expected to be applied as a switching device when multiple biosensors are mounted. However, there are many technical problems such as low ON/OFF performance, high leakage current, shift of the threshold voltage in the negative direction. In this study, we fabricated an oxide TFT array can use a biosensor by improving the TFT array fabrication process and optimized the materials.

## 2. Experimental

### 2.1. TFT structure

The oxide TFT arrays was fabricated using a solution process. Fig. 1 shows the cross-sectional structure of the TFT. A TFT was fabricated by five types of layers on a substrate. The gate insulating film, the channel, and the channel stopper, these three layers, were fabricated from a solution. The substrate was $SiO_2$ / Si (500 nm / 500 μm) cut into 2 cm × 2 cm. Fig. 2 is a top view of the TFT array. 24 × 24 = 576 TFTs were fabricated on one substrate.

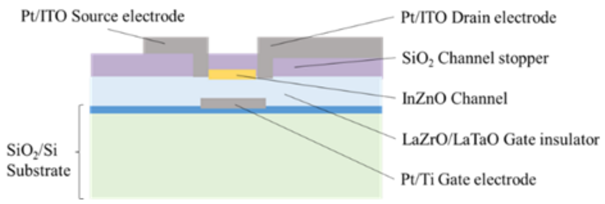


Fig. 1 Cross section of oxide TFT. The gate insulating film, the channel, and the channel stopper, these three layers, were fabricated from a solution.

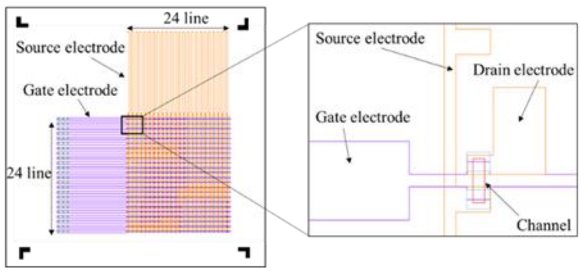


Fig. 2 Top view of TFT array. 576 TFTs were fabricated on one substrate.

### 2.2. Fabrication of oxide TFT array for switching biosensor using solution process

Fig. 3 shows the fabrication process of the oxide TFT array using the solution process. To improve the leak characteristics, a gate insulating film composed of a LaZrO 1 layer / LaTaO 4 layers was fabricated. First, 4 layers of LaTaO films were stacked, and a LaZrO film was stacked thereon. The solutions used for forming the gate insulating film were LaZrO 0.4 mol / kg, La: Zr = 1: 1 and LaTaO 0.2 mol / kg, La: Ta = 3: 7. An InZnO solution (0.2 mol / kg, In: Zn = 2: 1) was used for the channel. All films except the metal electrodes were deposited by spin coating and dried on a hot plate. Annealing was performed using a rapid thermal annealing apparatus (TPC-5000 ULVAC RIKO) or a hot plate. Etching by hydrochloric acid. (Pure-etch Hayashi pure chemical industry) was used to extract the gate electrode, and a plasma etching system (RIE-101iPH, SAMCO) was used to etch the channel and channel stopper. A maskless aligner (MLA150 HEIDELBERG-instruments) was used for photolithography. After the fabrication of the TFT array, $I_d$-$V_g$ measurement was performed using a semiconductor parameter analyzer (E5250A Agilent) and a measurement probe (TN-1910 Vector Semiconductor). For the purpose of switching biosensors, the target values were an ON / OFF ratio of about $10^6$ and a maximum leakage current value of 10 pA.

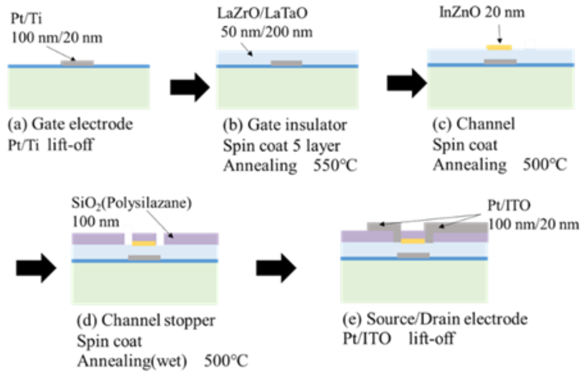


Fig. 3 Fabrication process of oxide TFT array

## 3. Result and Discussion

### 3.1 TFT array completed drawing

By using a maskless exposure system, an oxide TFT array could be fabricated in three days (Fig. 4). Unlike conventional contact aligners, the alignment speed is automatically adjusted in units of a few micrometers, greatly increasing the work speed. Since no photomask was used, contamination due to contact between the mask and the substrate was eliminated.

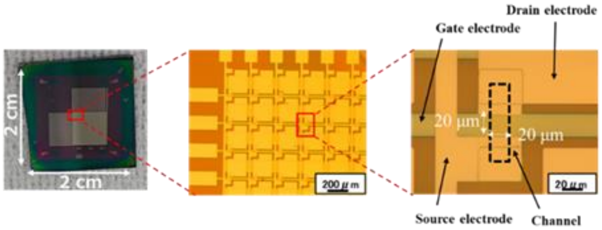


Fig. 4 Completed oxide TFT array

3.2 $I_d$-$V_g$ ($I_g$-$V_g$) measurement

Fig. 5 shows the result of TFT $I_d$-$V_g$ ($I_g$-$V_g$) measurement. With a voltage of 1.0 V applied between the source / drain electrodes, a voltage from -15 V to15 V was applied to the gate electrode. At this time, the drain current and the leakage current were measured. 25 TFTs were measured and their values were averaged. The target value was achieved with an ON / OFF ratio of $10^7$ (drain current value 1 pA-10 μA) and a maximum leakage current value of 10 pA ($V_G$ = 10 V). The maximum leakage current was improved by about two orders of magnitude as compared with TFT having 5 layers of LaZrO. The statistical value of the threshold voltage showed an average value of 0.62 V, a standard deviation of 0.311 V, and a standard error of 0.062.

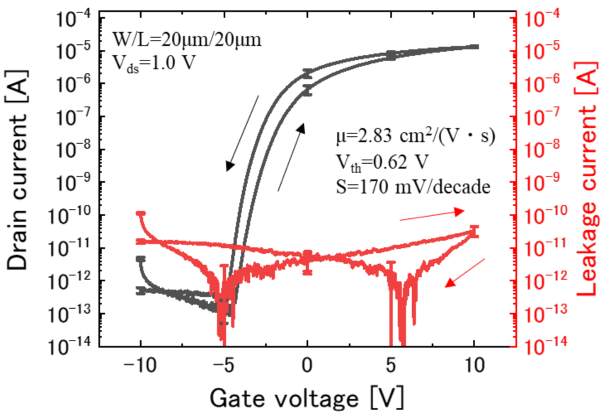


Fig. 5. Transfer curve of TFT

**4. Conclusion**

In this study, we developed a TFT array for switching biosensor using solution process. While maintaining an inexpensive and easy fabrication process, the performance as a switching element was sufficiently achieved. In the future, we contribute to the biomedical field through simultaneous detection and imaging of multiple biological materials using TFTs equipped with sensing elements.

**Reference**


[1] Phan Trong Tue, et al., IEEE ELECTRON DEVICE LETTERS,VOL.34, N al,DECEMBER(2013)pp.1536-1538

[2] Satoshi Inoue, et al., Phys. Status Solidi A 212,No.10,pp2133-2140(2015)