Printable Indium Oxide Thin-Film Transistor

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Abstract

Recently, the oxide semiconductor, which is possible to substitute for Si-based devices, has been studied for their advantages such as transparent, high carrier mobility and low cost. In many processes it was reported to make the oxide semiconductor. Besides, we tried the solution process for high productivity and used In2O3 to active layer of TFTs by sol-gel reaction. As a result, we obtained the advantages i.e. efficiency of the productivity, processing time and low cost. The performance of TFTs by solution process shows 0.02 cm2/Vs field effect mobility and 10^6 I_{on}/I_{off} ratio.

1. Introduction

Metal oxide electrical properties span have a vast range from metallic to semiconducting and to insulating, all of which are essential characteristics for thin-film transistor (TFT) components. Metal oxide-based TFTs are far from optimum where the majority of reported devices fabricated by vapor-phase deposition of the component layers. Low-pressure growth processes are expensive to scale for large areas and high throughput during solution-phase processes. Nevertheless, the metal oxide TFTs fabricated to date by semiconductor solution deposition techniques have generally exhibited marginal performance, i.e. low field-effect mobilities, low I_{on}/I_{off} ratios, and large operating voltages, all of which have preclude practical application. Among metal oxides, In_2O_3 is a promising n-type semiconductor having a wide band gap, high single crystal mobility, and good visible region transparency. We reported here the demonstration of solution-processed In_2O_3 TFTs using SiO_2 as gate dielectrics. We demonstrated that the combination of optimized film precursor stoichiometry enables high-mobility In_2O_3 film growth and excellent TFT performance.

2. Experiments

2.1 Preparation of In_2O_3 films

Indium chloride (99.9%, Aldrich), 2-methoxy ethanol (99%, Aldrich), and ethanolamine (99%, Aldrich) were used without further purification. $InCl_3$ (0.10 mmol) were dissolved in 2-methoxyethanol (10ml). And ethanolamine (1.0 mmol) added to the 2-methoxyethanol solution of $InCl_3$. These clear solutions were then stirred for 30 min at room temperature before spin-coating.

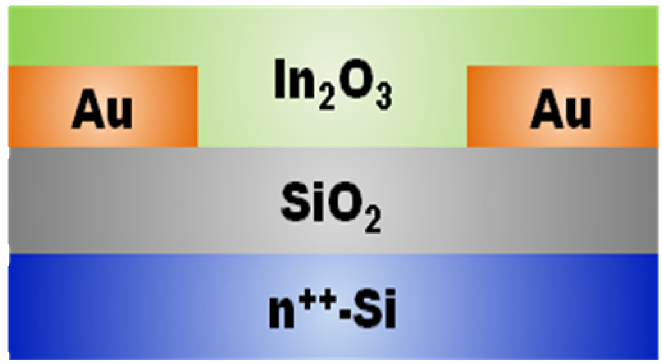


Figure 1. *Structure of In_2O_3 TFT device (SiO_2 thickness : 100nm, channel length : 2~20µm, channel width : 1mm)*

2.2 Fabrication of In_2O_3 TFT devices

SiO_2 coated Silicon wafer were sonicated with ethanol and dried with N_2 stream followed by oxygen plasma treatment. Au source and drain electrode of 50nm thickness were deposited by thermal evaporation affording channel dimensions of 2~20µm(L)×1mm(W). The In_2O_3 precursor solution was then spin-coated onto these substrates at the speed of 1500 rpm (Fig 1). Subsequently, the spin-coated films were annealed at 400~500℃ for 30~120 min and cooled at room temperature. This coating process was then repeated twice.

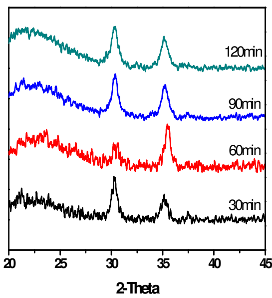
2.3 Characterization

We evaluated XRD pattern of the In_2O_3 thin-films, which were treated annealing along with the controlled conditions. In addition, we measured transfer and output curve of TFT devices on Si/SiO_2 substrate.

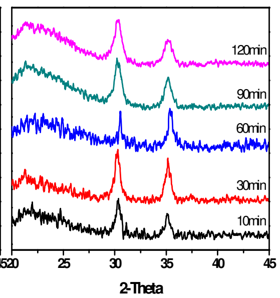
3. Results and discussion

3.1 XRD pattern of In_2O_3

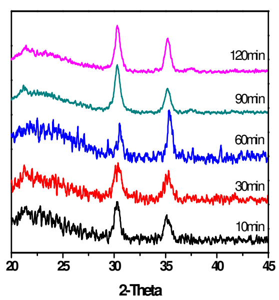
Fig 2 and Fig 3 shows the XRD patterns of spin-coated In_2O_3 thin films annealed at various temperature and time. The XRD patterns exhibit two broad and small peaks at $2\Theta=30°$ and 35°. In case of annealed at 400℃ for 60min, (2,2,2) reflection of 30° peak disappears, and the growth orientation associated with the higher carrier mobility (0,0,4) reflection of 35°.



(a)



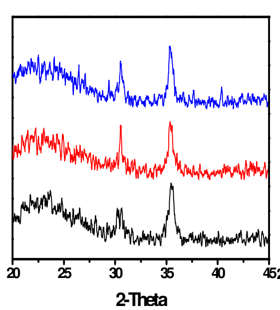
(b)



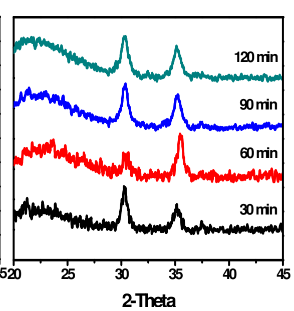
(c)

*Figure2. XRD pattern of In_2O_3 thin-films : **(a) annealed at 400 ℃** for**30~120** min. (b) annealed at 450 ℃ for 30~120 min**, (c) annealed at 500** ℃ for 30~120 min .*

In each different annealing time, (0,0,4) Peak is increased until 60 min, but decreased from 90 min. Finally, we obtained optimized annealing condition. Therefore, optimized Indium oxide precursors are evaluated by measuring the performance of TFT devices.



(a)

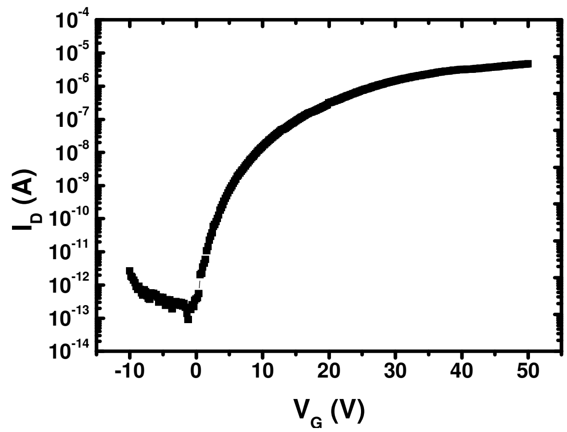


(b)

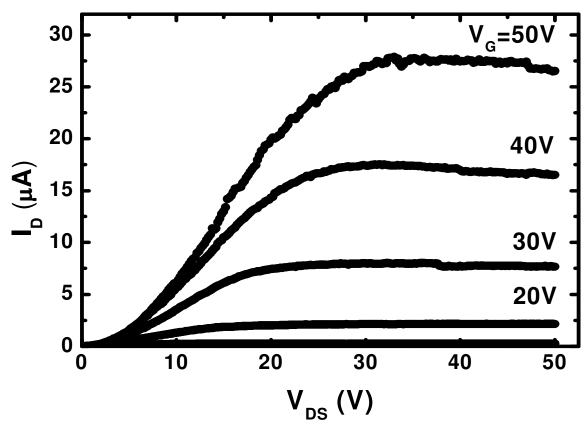
***Figure 3**. XRD pattern of In_2O_3 thin-films : (a) annealed at 400~500 ℃ for 60 min. (b) annealed at 400 ℃ for 30~120 min.*

3.2 Performance of TFT devices

After TFT fabrication, the devices were evaluated in ambient atmosphere. Fig 3 (a) shows transfer characteristics of I_D versus V_G at V_{DS}=50V for In_2O_3 TFT annealed at 400℃ for 60min. The In_2O_3 TFT exhibits the field effect mobility of 0.02 cm^2/Vs and the threshold voltage of 5.35 V. Fig 3 (b) reveals the drain current versus drain-to-source voltage output characteristics of the In_2O_3 TFTs annealed 400□ with various gate voltage. The results show the n-type semiconductor behavior with hard saturation.



(a)



(b)

***Figure 4**. Performance of In_2O_3 TFT (In_2O_3 thin-films were annealed at 400 ℃ for 60 min) : (a) transfer (b) output*

4. Conclusion

We have demonstrated solution-processed metal oxide TFT employing In_2O_3 as a semiconducting channel. The In_2O_3 thin films were fabricated by a simple and low-cost precursor solution process though spin-coating. The films were annealed at 400~500℃ for 30~120min. The TFTs are operated in enhancement mode and the device fabricated at 400□ for 60min has a field effect mobility of 0.02 cm^2/Vs, a threshold voltage of 5.35 V and an on-off current ratio higher than 10^6. In the further works, Metal oxide and PTCDI (3,4,9,10-perelenetetracarboxylic diimide) each modified Indium oxide thin film will deposited. And, performance of each TFTs will researched. As a result, optimized precursor will be obtained by comparison of the performance of each TFTs. Additionally, effiicient experimental method will be designed such as metal oxide loading.

References

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