용액공정을 이용하여 제작된 SiInZnO 박막 트랜지스터의 전기적 특성 변화

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Variation of electrical properties in solution processed SiInZnO thin film transistors

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Abstract - We have investigated the effect of silicon contents (0~0.4 molar ratios) on the performance of solution processed silicon-indium-zinc oxide (SIZO) thin-film transistors (TFTs). Despites its solution processed channel layer, low annealed temperature below 200°C in air has been used for SIZO-TFTs.The V_{th} is shifted from -4.04 to 5.15 V as increasing Si ratio in the SIZO-TFTs. The positive shift of V_{th} as increasing Si contents in SIZO system indicates that Si suppresses the carrier generation in the active channel layer since V_{th} is defined as the voltage required accumulating sufficient charge carriers to form a conductive channel path..

1. Introduction

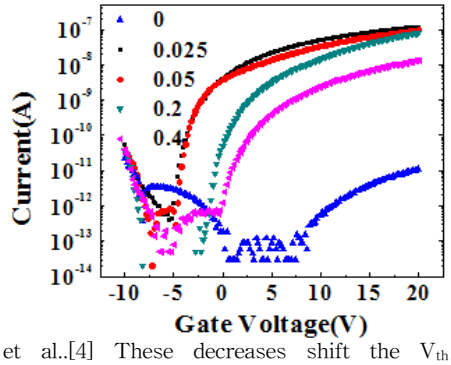
Recently, amorphous oxide semiconductors (AOS) have attracted as an active channel material of next generation display because they offer high mobility, low temperature process, good stability, and excellent transparency.[1] Therefore, AOS can be used in various applications such as panel display, sensor, and circuits. Inparticular, zinc oxide (ZnO) materials, such as indium zinc oxide (IZO), indium gallium zinc oxide (IGZO), and zinc tin oxide (ZTO) have much attentions as the promising candidates for thin film transistors (TFTs) due to their excellent electrical and optical properties.[2] Most active channel layers of ZnO-based TFTs are fabricated using the vacuum process, such as radio frequency-dc magnetron sputtering,[3,4] chemical vapor deposition,[6] atomic layer deposition,[7] and pulsed laser deposition,[5] because vacuum processed devices are showing good performances compared to those of solution processed devices. Nevertheless, ZnO-based TFTs are fabricated by the solution process, such as spin-coating, ink-jetprinting, and roll printing,[8,9] for the next generation displays because solution-processed TFTs have many benefits, such as low cost, high throughput, and easily controlled composition ratio.
At the solution-processed TFTs, annealing process has been necessarily required to reduce hysteresis, improve electrical stability, and bonds between cation and oxygen are generated during annealing.[3] Therefore, usually the solution-processed oxide TFTs require high annealing temperature process to fabricate thin films. But silicon indium zinc oxide (SIZO) is different compared with other oxide materials because required annealing temperature is relatively low.[1] In this paper, we focused on the effects of incorporated Si contents in IZO system using solution process with low annealing temperature.

2. Experiment

The precursor solution of SIZO was prepared by dissolving 0.5M mixture of zinc acetate dehydrate [$Zn(OAc)_2 \cdot 2H_2O$], indium nitrate hydrate [$In(NO_3)_3 \cdot xH_2O$], and silicon tetraacetate [$Si(OCOCH_3)_4$] in 2-methoxyethanol (2ME). Then ,monoethanolamine (MEA) was added as a stabilizer, and it was stirred at 60°C for 1h to form the SIZO sol-gel precursor. The molar ratio of In:Zn was fixed, and the content of Si was varied from 0 to 0.4 molar ratio. Using these precursor solutions, SIZO thin films were deposited on 200 nm thick SiO_2 / Si (n-typedoped) as an active layer by spin coating process. The SIZO precursor solution was spin-coated and baked at 300°C for 5 min to remove the organic solvents. The thickness of SIZO thin film channel layers was ~35 nm with different Si ratios. Next, the channel films were annealed at 200°C for 1h in air ambient. Finally, Ti(10nm)/Au(60nm) were patterned for the source and drain electrodes by evaporation and thermal deposition process. The width/length of active channel were 250/50 ㎛, respectably.

3. Result and Discussion

Fig. 1 shows the transfer characteristics of SIZO TFTs with varied Si contents. The V_{th} was shifted to the positive direction with increasing Si contents. Since V_{th} is defined as the voltage required to accumulate sufficient charge carriers to form a conductive channel path, the presence of less charge carriers due to Si contents requires channel formation at a higher gate bias, resulting in the V_{th} shift.[16] At the Si content of 0 molar ratio sample, transfer characteristics resembled those of an insulator since it is solution processed IZO-TFT baked at 300°C and annealed at 200°C. The Si ion can form stronger chemical bonds with oxygen than with Zn and In ions because the Si ion has a high ionic potential due to its +4 valence electrons. This characteristic of the Si ion results in the suppression of carrier generation by reducing oxygen vacancy formation.[17] Fig. 1 shows that the addition of Si causes the decrease of on-current and field effect mobility due to the reduced carrier concentration same as reported by



Moon et al..[4] These decreases shift the V_{th} toward a positive direction, which is controlled by carrier concentration in the channel.[19,20] Also, these systematic variations in the transfer curve including the V_{th} shift and the off-current reduction are possibly caused by the addition of Si. As Si content increasing, it is expected to suppress carrier generation through reducing oxygen vacancy formation and hence help to achieve lower on-current.

<Fig 1> Drain current versus gate-voltage transfer characteristics of solution-processed SIZO TFTs as a function of Si molar ratio.

4. Conclusion

In conclusion, we fabricated solution-processed a-SIZO TFTs and studied the effect of the chemical composition of Si in IZO based TFTs. We confirmed that the SIZO films baked at 300oC and annealed at 200°C were amorphous phase regardless of the Si / (In+Zn) composition ratio. The effects of varying the Si contents were significant in the a-SIZO TFTs. As the Si content increased, the V_{th} was shifted to positive direction from -4.04 to 5.15 V, and the on-current and the field effect mobility were decreased due to the reduced carrier concentration. The proper SIZO TFTs can be easily fabricated by controlling the Si molar ratio in the IZO based TFTs using low temperature solution process.

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