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Effect of Hydrogen in Zinc Oxide Thin-Film Transistor grown by MOCVD

Jungyol Jo[1], Ogweon Seo[2], Euihyuck Jeong[1], Hyunseok Seo[1], Byeonggon Lee[3], and Yearn Ik Choi[1]

[1]Department of Electrical and Computer Engineering, Ajou University, Suwon, 443-749, Korea
Phone: 82-16-302-6503 E-mail: jungyol@ajou.ac.kr
[2]NFC, Samsung Advanced Institute of Technology, Suwon, Korea
[3]CDA Co., Ltd., Yangjaedong, Seochogu, Seoul, Korea

I. Introduction

Recent trends show that next generation light emitting device in display system will be made of organic light emitting diodes (OLED). If OLED is employed, the driver circuit needs significant modification, since OLED requires more current than conventional TFT-LCD. Zinc oxide (ZnO) has attracted considerable attention for its utilization in display and optoelectronic devices due to high mobility and wide bandgap. There have been many reports about ZnO TFT fabricated by laser-ablation and sputtering methods [1]. Although they showed excellent performance, these methods have a limit for the size of the substrate. For display application, ZnO should be grown on a large-area glass or ploastic substrate, and MOCVD is a good candidate for this purpose. We studied ZnO TFT grown by MOCVD at temperatures below 400^{o}C. We investigated material aspects of ZnO, as well as current-voltage characteristics of ZnO TFT. We found that hydrogen plays an important role in MOCVD grown ZnO. Mobility of 15 cm^2/Vsec was observed, indicating that MOCVD can be a useful growth method of ZnO film.

II. Experimental Results

ZnO usually shows n-type behavior, but the high electron concentration makes it difficult for TFT application. To be optimized for ZnO TFT, it is essential to control doping precisely. It is believed that hydrogen and defects are the origin of n-type behavior [2]. We investigated unintentionally doped hydrogen in our ZnO film grown by MOCVD.

Our ZnO films were grown at temperatures between 200℃ and 400℃. Our MOCVD system has a horizontal reactor operating at atmospheric pressure. For ZnO sources, diethylzinc (DEZ) and oxygen were used. ZnO films were grown on silicon substrates, which have 1100Å thick oxide. SEM (Scanning Electron Microscopy) images of our films showed that grain size increased when growth temperature was increased from 200℃ to 400℃. X-ray diffraction is shown in Fig. 1, and (002) peak of wurtzite structure is marked as an arrow. The (002) peak becomes stronger as growth temperature is increased from 200℃ to 400℃. As expected, an increase in crystallinity is observed with increasing growth temperature.

After MOCVD growth, we made TFT structure (channel length= 15 μm, width= 500 μm) by using Al evaporation and shadow mask. Fig. 2 is current-voltage characteristics of TFT grown at 300℃. It shows 15 cm^2/Vsec mobility measured at room-temperature. TFT's grown at 400℃ showed lower mobility of 5 cm^2/Vsec. This is different from general case where higher growth temperature improves mobility. Fig. 3 shows gate voltage dependence measured in the same device. It shows that turn-off is not complete, possibly due to defects in the channel.

In order to understand details of ZnO defects, we investigated gas concentrations. Fig. 4 is results of SIMS (Secondary Ion Mass Spectroscopy) for films grown at (a) 250℃ and (b) 400℃. In our horizontal reactor, faster reaction at higher temperature means insufficient source supply at the substrate, and this is the reason why higher temperature sample (a) shows smaller thickness.

The data in Fig. 4 show that our ZnO films have significant amount of hydrogen and carbon concentrations, which depends on growth temperature. Sample grown at 400℃ shows lower H concentration than the sample grown at 250℃. The origin of H and C must be DEZ, because it is the only material containing them. Fig. 4 shows that more H is incorporated into the film when growth temperature is lower, with carbon showing the same behavior. Due to higher burning rate of H and C at higher temperature, we can expect lower concentration of H and C at the substrate. We think that the higher mobility in Figs. 2 and 3 (grown at 300℃) is due to higher hydrogen concentration. Fig. 3 also shows that threshold voltage and turn-off characteristics should be improved for practical application.

III. Conclusions

We demonstrated that high mobility ZnO films can be grown by MOCVD. SIMS results showed that hydrogen incorporated during MOCVD growth is responsible for the n-type behavior. It also showed that hydrogen concentration depends on growth temperature. Although our TFT showed 15 cm^2/Vsec mobility, threshold voltage and turn-off characteristics should be improved. We hope that optimum TFT performance can be obtained by controlling H and C incorporation during growth.

References

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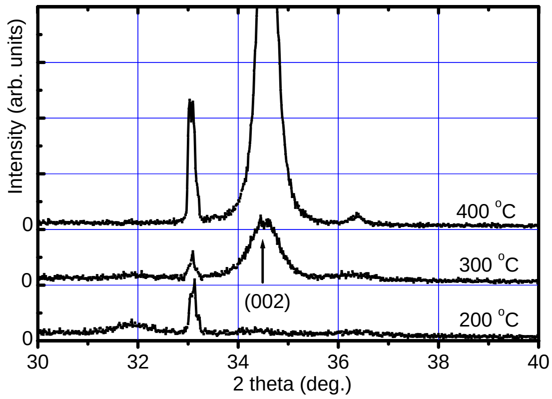

Fig. 1. X-ray diffraction from ZnO films grown at different temperatures. The arrow indicates wurtzite (002) peak position, 34.422°.

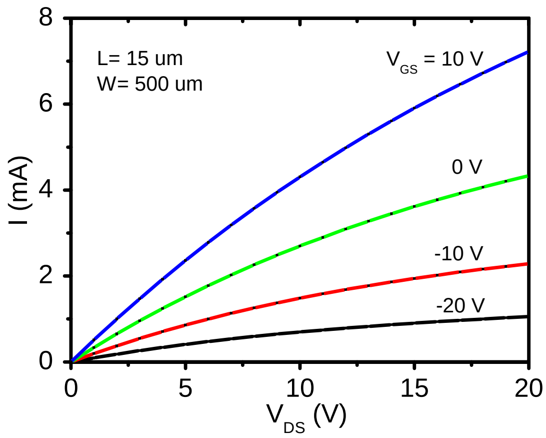

Fig. 2. Current-voltage characteristics of ZnO TFT, grown at 300℃.

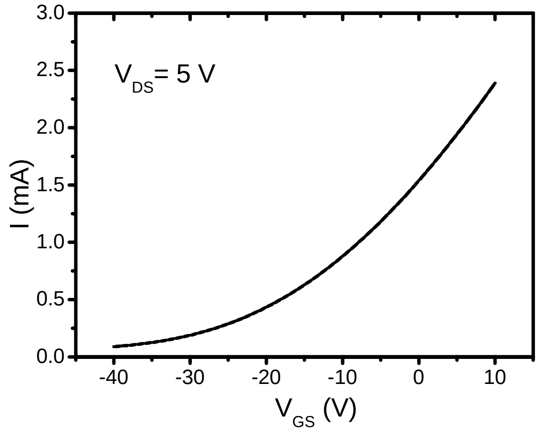

Fig. 3. Current change by gate voltage. The device is the same one used in Fig. 2.

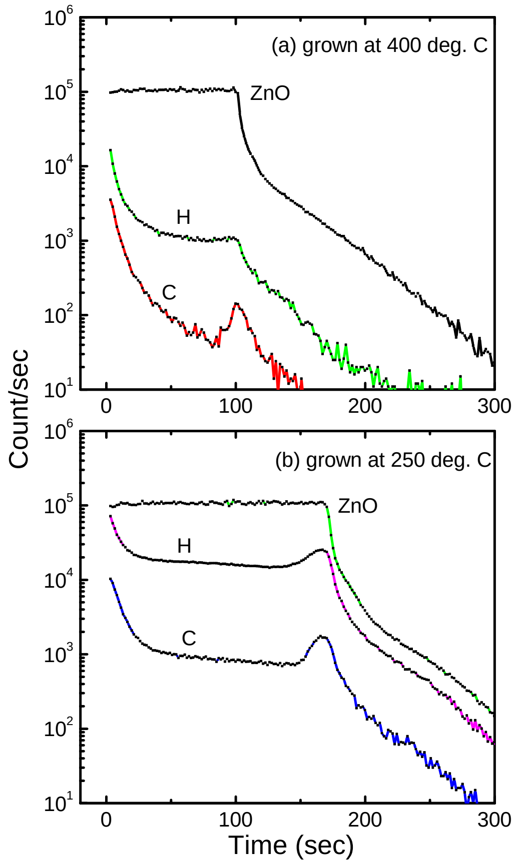

Fig. 4. SIMS profiles of hydrogen and carbon in ZnO.