IGZO 반도체 박막 기반으로 제작한 포토트랜지스터의 특성 분석

터르쇼이 게르게이, 이재윤, TUKHTAEV ANVAR, ZHAO HANLIN, ISAMADDINOV SHUKHRAT, BERDIEV JONIBEK ELMURODOVICH, WANG XAIOLIN, 최병근, 김용환, 김성진*

충북대학교 전자정보대학

tarsolyger@protonmail.com, rnjsxnrn@naver.com, anvarjon20@gmail.com, z374644892@hotmail.com, isamaddinov19940328@gmail.com, jonkax7777@mail.ru, wxl0412@gmail.com, minhakim@chungbuk.ac.kr, k.yh@korea.kr, and ksj@chungbuk.ac.kr*

Analysis of phototransistors fabricated based on IGZO semiconducting films

Gergely Tarsoly, Jae-Yun Lee, TUKHTAEV ANVAR, ZHAO HANLIN, ISAMADDINOV SHUKHRAT, BERDIEV JONIBEK ELMURODOVICH, WANG XAIOLIN, Choi Byung Geun, Yong-Hwan Kim, and Sung-Jin Kim* Sung-Jin Kim*

College of Electrical and Computer Engineering, Chungbuk National University

요 약

Amorphous indium gallium zinc oxide (IGZO) is a widely studied semiconductor that has been applied as active layer in electronic devices such as transistors, memristors, etc. Due to its wide bandgap, it has a low absorption in the visible range, enabling its utilization in transparent circuit. Here, we discuss methods that can be utilized to enable the absorption of light in the IGZO thin film, leading to photoelectronic applications.

Ⅰ. Introduction

Currently, even though most of the semiconducting industry is focused on fabricating silicon based electronic devices, research is ongoing to develop novel materials for specific applications. Metal oxide semiconductors such as In_2O_3, Ga_2O_3 or indium gallium zinc oxide (IGZO) has been popular research topics due to their intrinsic n-type charge transport and wide bandgap, that allows their use in transparent electronics, such as display backplanes. Moreover, it is possible to fabricate photodetectors for different purposes by adding a photoactive material layer [1], increasing gap states by increasing the disorder in the material [2]. Previously, we have shown how the interface between IGZO and the photoactive layer has to be optimized [3]. Here, we present our results using a gradient annealed IGZO + IGZO bilayer for photo electronic applications.

Ⅱ. Body

Amorphous IGZO films deposited using radio frequency sputtering offers reproducible characteristics, however without any post-deposition treatment, the defects in the film result in less-than-optimal electrical performance. On the other hand, for optoelectronic applications, the localized trap sites generated by the film defects can be utilized for the trapping of photogenerated charges, leading to enhanced photoresponse. Indeed, based on our experiments, we have found that the transistor devices based on pristine IGZO films exhibit large current increase under illumination. When the films undergo thermal treatment at 300 °C, the electrical characteristics are highly improved, but the photoresponse behavior is diminished. To combine the

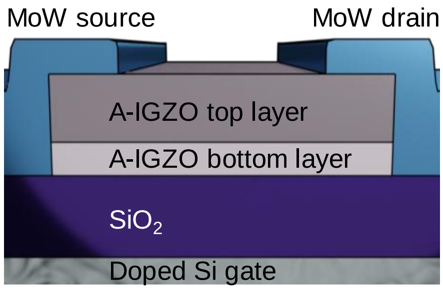

Fig.1. Schematic structure of the device with gradient annealed layers

high photoresponse of the devices fabricated using pristine IGZO or IGZO annealed at lower temperatures with the better electronic characteristics of the devices with high-*T* annealed IGZO films, we developed a gradient annealing method. The method is based on the deposition of a thin, 20 nm IGZO film, that is annealed at high temperature, and a thick, 40 nm IGZO film deposited separately on top, and annealed at a lower temperature. The structure of the device is shown in Fig. 1.: the bottom layer serves as an electron transport layer, and the top layer serves

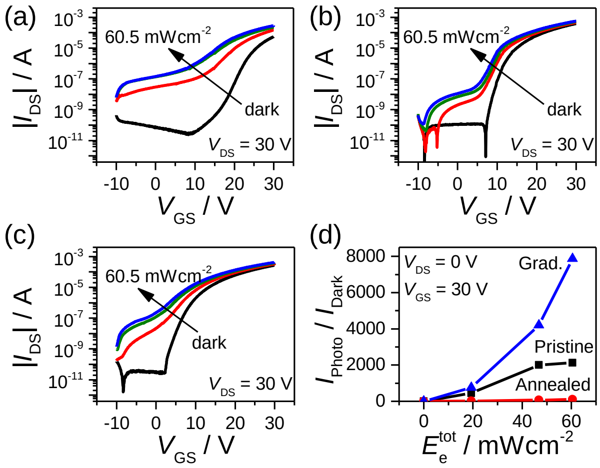

Fig. 2. Transfer curve of the device with (a) pristine, (b) annealed and (c) optimized gradient annealed layer in dark and under illumination at different irradiances and (d) the photocurrent ratio in the transistor off state for devices with 300 °C annealed, pristine and gradient annealed IGZO thin films.

as the photogeneration layer.

The transfer characteristics of the device with pristine IGZO and one with 300 °C fully annealed IGZO layer were evaluated under dark and illumination of 19.4, 46.8 and 60.5 mWcm^{-2} irradiance by a LED lamp and are shown in Fig. 2. (a) and (b). The transfer curves confirm the superiority of the annealed devices in terms of electrical characteristics, and the higher photo response in the device with pristine IGZO.

The gradient annealing fabrication process was optimized by first varying the annealing temperature for the bottom layer with using pristine top layer, and then varying the annealing temperature of the top layer while using a fixed bottom layer type. It was found, that the IGZO film annealed 300 °C used as the bottom layer provided the best electrical characteristics, and the pristine IGZO film as the top layer provided the best photoresponse characteristics. The transfer curve of the optimized device with gradient annealed IGZO is shown in Fig. 2. (c) in dark and under illumination by a LED lamp.

Comparing the performance of the optimized device to the devices with pristine and fully annealed films reveal that the photoresponse of the gradient annealed device in the off state is significantly improved as the device has a low off current in dark similar to that of the fully annealed device, and a high current under illumination, similar to that of the device with pristine layer (Fig. 2. (d)).

Ⅲ. Conclusion

In our work, we developed the gradient annealing method to fabricate transistors for optoelectronic applications using amorphous IGZO bilayer films. The process with regards of the annealing temperatures was optimized, and both the electric and optoelectronic properties of the optimized device were evaluated and were found to be improved due to the gradient annealing method.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2020R1A6A1A12047945)

참 고 문 헌

[1] J. Li, F. Zhou, H.-P. Lin, W.-Q. Zhu, J.-H. Zhang, X.-Y. Jiang and Z.-L. Zhang, *Superlattices Microstruct.*, 2012, **51**, 538-543

[2] J. Chung, Y. J. Tak, W.-G. Kim, B. H. Kang and H. J. Kim, *ACS Appl. Mater. Interfaces*, 2019, **11**, 38964-38972.

[3] G. Tarsoly, J-Y. Lee, Y. J. Jeong, S. Pyo, S-J. Kim *J. Mater. Chem. C*, 2022,**10**, 12621-12629