X-ray Photoelectron Spectroscopy (XPS) Analysis of Undoped ZnO and ZnO:Er Thin Films

Iwan Sugihartono*), Esmar Budi, and Agus Setyo Budi
Jurusan Fisika, FMIPA Universitas Negeri Jakarta
**) Email: isugihar@hotmail.com*

ABSTRACT

Undoped ZnO and ZnO:Er thin films were deposited on *p*-type Si substrates by ultrasonic spray pyrolisis (USP). Undoped and ZnO:Er thin films have been analyzed by using X-ray Photoelectron Spectroscopy (XPS). The results show that the XPS spectrum has two Er peak at ~157 eV and ~168 eV. The XPS Zn 2p spectrum of undoped ZnO and ZnO:Er thin films have binding energy for Zn $2p_{3/2}$ (~ 1021 eV) and Zn $2p_{1/2}$ (~1045eV) were found no shift in binding energy after the incorporation of Er. Meanwhile, after Er incorporates into ZnO, the O 1s spectrum is composed two peak of binding energy (BE) at ~530.5eV and the shoulder about 532.5 eV.

Keywords**:** ZnO thin films, ZnO:Er, XPS, binding energy

INTRODUCTION

ZnO is a material semiconductor which has wide band gap energy 3.34 eV and large exciton binding energy 60 meV (Teke, et al, 2004). Nevertheless, ZnO has asymetry problem. It is regarding with the existence of native defects which make ZnO very difficult to be n-type semiconductor. Due to its character, many effort to elaborate ZnO properties has been reported.

XPS is one of the most powerful surface analytical techniques. Basic principle of XPS can be explained that the photon energy (x-ray photon) in and absorbed by atom in molecular or solid hence leading ionization and the emission of core electrons in certain shell (Chen, et al, 2000). Therefore, determination of the chemical state of elements on the surface is of great theoretical and practical interest. The chemical shifts of the binding energy values of the core electron lines represent the most easily accessible and interpretable information on the changes in the chemical state.

In this paper, undoped and ZnO:Er thin films have been grown by USP tecnhnique. Furthermore, the films were characterized by X-ray Photoelectron Spectroscopy (XPS).

EXPERIMENTAL DESIGN

Undoped ZnO and ZnO:Er thin films were deposited on *p*-type Si substrates with a carrier concentration of ~10^{19} cm^{-3} by ultrasonic spray pyrolisis (USP) (Iwan, et al, 2012). Zinc acetate dehydrate [$Zn(CH_3COO)_2.2H_2O$] and erbium (III) acetate hydrate [$Er(C_2H_3).xH_2O$] were chosen as host and dopant precursors, respectively. The zinc acetate (0.02 mol/ml) was mixed with the erbium (III) acetate hydrate (1 wt%, 4 wt% and 8 wt%) and diluted in de-ionized water (Iwan, et al, 2012). The aerosol of the precursor solution was generated by a commercial ultrasonic nebulizer (frequency of 1.65 MHz), and injected onto a Si substrate heated at 450^{o}C. Furthermore, the surface of ZnO:Er films has been etched by Ar^{+} ion prior to the XPS measurement.

RESULTS AND DISCUSSION

X-ray photoelectron spectroscopy (XPS) was employed to identify the chemical states of the Er in ZnO:Er films. XPS study of the Er (4d) proves the existence of Er in all the ZnO:Er films (Iwan, et al, 2012), as shown in Figure 1. The atomic concentration of Er in ZnO:Er is determined quantitavely use area under peak as intensity divided by factor which relates with atomic cross section. Yet, ZnO:Er(1wt%), ZnO:Er(4wt%), and ZnO:Er(8wt%) films are estimated to be 0.72at%, 1.12at%, and 1.17at%, respectively. The XPS spectrum shows two Er peak at ~157 eV and ~168 Ev (Iwan, et al, 2012). The peak at ~157 eV indicates due to Auger electron effect (Netzer, et al, 1981). Furthermore, with the increase of Er atomic concentration (1.17at%), the $4d_{5/2}$ state peak at ~168 eV could be clearly observed.

Figure 2 shows the XPS Zn 2p spectrum of undoped ZnO and ZnO:Er thin films. The Zn $2p_{3/2}$ (~ 1021 eV) and Zn $2p_{1/2}$ (~1045eV) were found no shift in binding energy after the incorporation of Er. Those two peaks indicate that there is no shift binding energy of Zn 2p and the chemical state of Zn remains the same after incorporation of Er. On the other hand, the formation of O 1s spectrum before Er incorporate into ZnO has single peak at ~532 eV.

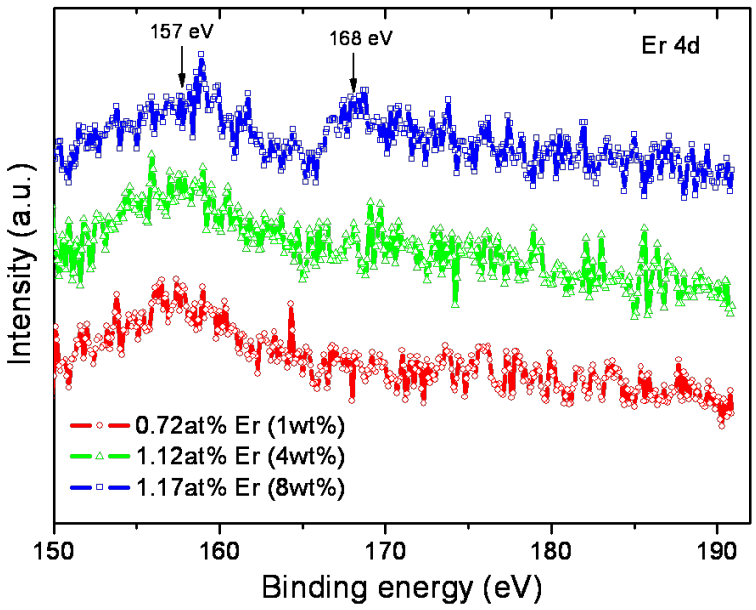

Figure 1. Binding energy of Er 4d (Iwan, et al., 2012)

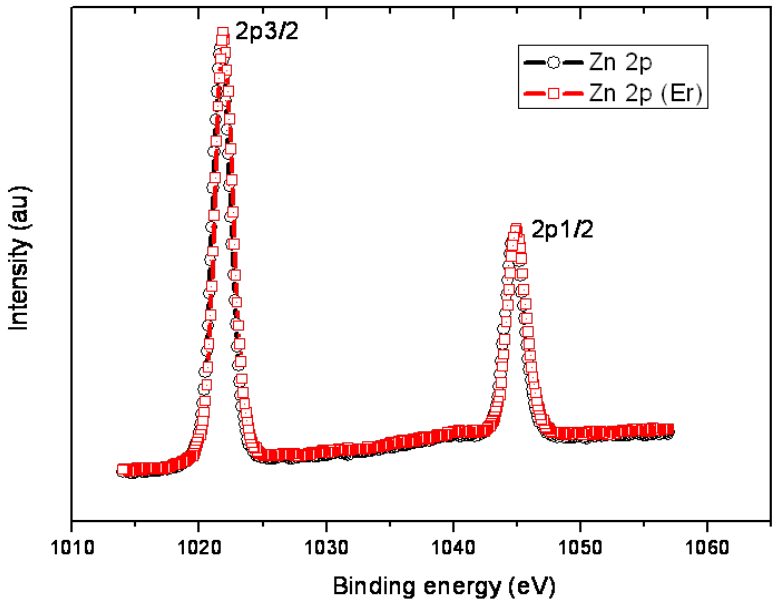

Figure 2. Binding energy of Zn 2p

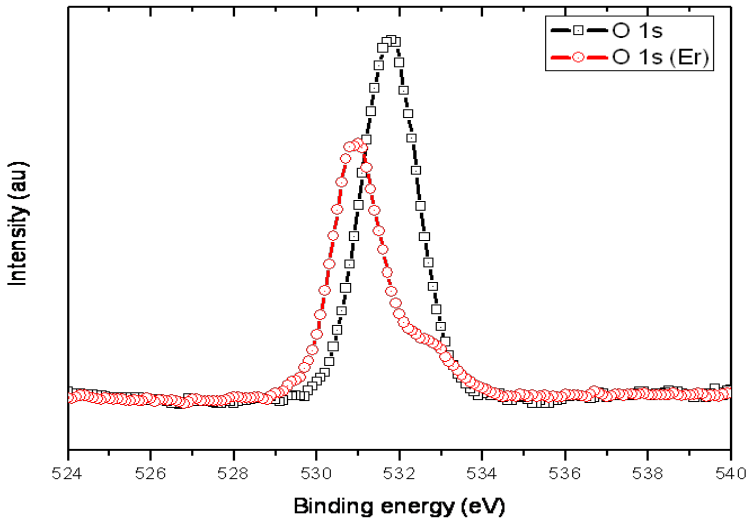

Figure 3. Binding energy of O 1s

Figure 3 shows the O 1s spectrum after Er incorporates into ZnO. The O 1s spectrum is composed two peak of binding energy (BE) at ~530.5eV and the shoulder about 532.5 eV.

The appearance of shoulder indicated there is a residual oxygen on the thin film surface or oxidized Er.[2] Moreover, the spectrum at the peak ~1021 eV and O 1s spectrum at ~530.5 eV corresponds to the chemical bonding structure of ZnO thin film (Shuji, et al, 2000; Islam, et al, 1996).

CONCLUSIONS

In conclusions, the XPS spectrum shows two Er peak at ~157 eV and ~168 eV. The XPS Zn 2p spectrum of undoped ZnO and ZnO:Er thin films have binding energy for Zn $2p_{3/2}$ (~ 1021 eV) and Zn $2p_{1/2}$ (~1045eV) were found no shift in binding energy after the incorporation of Er. Meanwhile, after Er incorporates into ZnO, the O 1s spectrum is composed two peak of binding energy (BE) at ~530.5eV and the shoulder about 532.5 eV.

REFERENCES

Chen, M., X. Wang, Y.H. Yu, Z.L Pei, X.D Bai, C Sun, R.F Huang, L.S Wen, Applied Surface Science.158, 134-140 (2000).

Islam, M.N., T. B. Ghosh, K. L. Chopra, and H. N. Acharya, Thin Solid Films **280,** 20-25 (1996).

Iwan, S., S. Bambang, J. L. Zhao, S. T. Tan, X. W. Sun, G.Q. Lo, H. M. Fan, L. Sun, S. Zhang., Physica B: Condensed Matter. **407**, 2721-2724 (2012).

Netzer, F.P., E. Bertel, and J. A. D. Matthew, *J. Phys. C: Solid State Phsyics* **14,** 1891 (1981).

Shuji, K., K. Tooru, M. Takitaro, Z. Xinwei, I. Hideo, and A. Yoshinobu, Journal of Applied Physics **88,** 7129-7136 (2000).

Teke, A., Ü. Özgür, S. DoÄŸan, X. Gu, H. Morkoç, B. Nemeth, J. Nause, and H. O. Everitt, Physical Review B 70, 195207 (2004).