29a-F1-7

Dependence on the Film Thickness of the Characteristics of ZnO Thin Films Grown Using High-Energy H_2O Generated by a Catalytic Reaction

Dept. Electrical Eng., Nagaoka Univ. Technol.,
°Kanji Yasui, Eichi Nagatomi, Naoya Yamaguchi, Souichi Satomoto, Takahiro Kato
E-mail: kyasui@vos.nagaokaut.ac.jp

Zinc oxide (ZnO) is a highly useful material for various applications such as short-wavelength optoelectronics, photoconductive devices, and transparent conductive electrodes. A wide variety of growth techniques, including molecular beam epitaxy (MBE) [1-3], pulsed laser deposition (PLD) [4-6], magnetron sputtering, and metal-organic chemical vapor deposition (MOCVD) [7-8], have been used for preparing ZnO films. Although MOCVD has many advantages for industrial applications, ZnO films deposited by conventional MOCVD techniques consume a lot of electric power for the reaction of source gases and for raizing the substrate temperature for the deposition of high-quality ZnO films. In order to save energy and resources, a more efficient reaction of the oxygen and metalorganic source gases during film growth is highly desired. In a previous paper, we reported a new growth method for preparing ZnO films by reacting dimethylzinc and high-energy H_2O generated from the Pt-catalyzed exothermic H_2 and O_2 reaction[9]. And we also reported that ZnO films with excellent crystallinity and optical properties[10, 11] were grown on a-plane (11-20) sapphire (a-Al_2O_3) substrates. In this paper, the dependence of electrical properties of the ZnO films on the film thickness is reported.

ZnO films with various film thicknesses were grown directly on a-Al_2O_3 substrates at 773K for 2-60 min without any buffer layer. Figure 1 shows the variation in electron mobility as a function of film thickness measured at room temperature (290 K). The electron mobility increased from 30 to 190 $cm^2V^{-1}s^{-1}$ with increasing film thickness from 0.1 μm to 2.8 μm. The electron mobility of the ZnO films 100 – 400 nm in thickness increases significantly with increasing film thickness. The increase in the mobility becomes slower when the film thickness becomes greater than 800 nm, and the mobility reaches the saturation point for thicknesses greater than 2000 nm. On the other hand, the electron concentration of the ZnO film 100 – 400 nm in thickness is on the order of 10^{18} cm^{-3}, and decreases to the order of 10^{17} cm^{-3} with increasing film thickness at greater than 500 nm. The mobility became less than 3×10^{17} cm^{-3} for the films greater than 1500 nm in thickness. Hydrogen and boron atoms were detected on the order of 10^{18} cm^{-3} and 10^{17} cm^{-3}, respectively, by secondary ion mass spectroscopy. These atoms are considered to be donor impurities in the ZnO films grown in this study.

Acknowledgment
This work was supported in part by a Grant-in-Aid for Scientific Research (No. 24360014) from the Japan Society for the Promotion of Science.

1) M. Sano et al., *Jpn. J. Appl. Phys.*, **42,** L1050 (2003).
2) H. Tampo et al., *Appl. Phys. Lett.*, **84**, 4412 (2004).
3) K. Miyamoto et al., *J. Cryst. Growth*, **265,** 34 (2004).
4) A. Ohtomo et al., *J. Cryst. Growth*, **214/215**, 284 (2000).
5) E. M. Kaidashev et al., *Appl. Phys. Lett.*, **82**, 3901 (2003).
6) A. Ohtomo et al., *Semicond. Sci. Technol.*, **20**, S1 (2005).
7) J. Dai et al., *Appl. Phys.* A, **89,** 645 (2007)
8) J. Dai et al., *J. Cryst. Growth*, **290**, 426 (2006)
9) K. Yasui et al., *MRS Proc.* **1315,** 21 (2011).
10) K Yasui et al., *The 59th JSAP Spring Meeting*, 2012, 17a-F2-1.
11) K Yasui et al., *The 73rd JSAP Autumn Meeting*, 2012, 13p-C9-6.

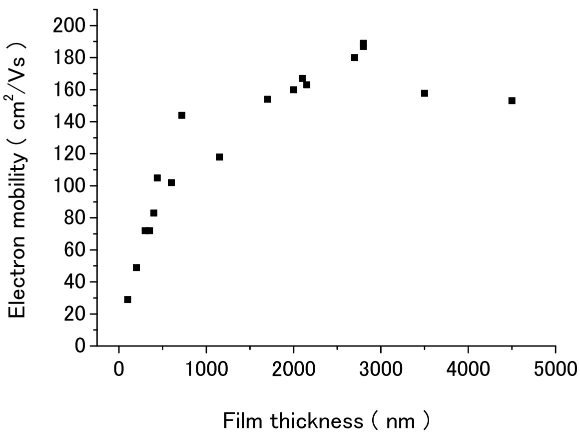

Fig. 1 Variation in electron mobility of ZnO films grown on a-Al_2O_3 as a function of film thickness