

# Effects of oxygen concentration on the electrical properties of ZnO films

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## Abstract

In this paper, electrical characteristics by various oxygen content in ZnO films were studied. To control the oxygen content of ZnO films, post-thermal annealing was performed in N<sub>2</sub> and air ambient, led to improve crystallinity and optical properties of ZnO films. The oxygen concentration was measured by Auger electron spectroscopy. The ZnO films having the deficiency of oxygen showed the electron concentrations between 10<sup>21</sup> and mid 6 × 10<sup>17</sup> cm<sup>-3</sup> and resistivity at 10<sup>-3</sup>–10<sup>-1</sup> Ω cm. On the other hand, when the oxygen concentration of the ZnO films was up to the stoichiometry with Zn, the ZnO films showed low electron concentration at ~10<sup>17</sup> cm<sup>-3</sup> and resistivity at 10 Ω cm.

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## 1. Introduction

Zinc oxide (ZnO) is currently considered as a promising material for very bright ultraviolet and blue optical devices, like light-emitting diodes (LED), laser diodes (LD), and photodiodes (PD) [1], because of its interesting characteristics, such as a large direct band gap of 3.37 eV at room temperature and a large exciton binding energy of 60 meV, which is 2.4 times higher than that of GaN. Furthermore, it is widely applied in transparent conductive contact and thin-film gas sensors, varistors, solar cells, and other devices. In practice, ZnO films can be deposited by various deposition techniques including molecular beam epitaxy (MBE), chemical vapor phase deposition (CVD), pulse laser deposition (PLD) and sputtering [2–5]. However, most of the deposited ZnO films tend to show many point defects, such as oxygen vacancy, zinc interstitial,

zinc vacancy, interstitial oxygen, and antisite oxygen. These point defects have an influence on structural, optical, and electrical properties of ZnO films [6–8]. Especially, the oxygen vacancies generate the free electrons in ZnO films due to oxygen nonstoichiometry [9] and are responsible for natural n-type of ZnO. Thus, it is of great significance to understand the properties of ZnO films with oxygen contents.

In this paper, the effects of oxygen content in ZnO films on the electrical properties of ZnO films were reported. To control oxygen concentration of ZnO films, several kinds of post-thermal annealing in N<sub>2</sub> and air ambient were performed. The relationship between the electrical characteristics and oxygen content of ZnO films was investigated.

## 2. Experimental procedure

ZnO films were deposited on SiO<sub>2</sub>/Si (1 0 0) substrates at room temperature by RF sputtering system. ZnO (4N) was used as the target. The vacuum chamber was evacuated to 10<sup>-5</sup> Torr, then Ar (50 sccm) gas was introduced through mass flow

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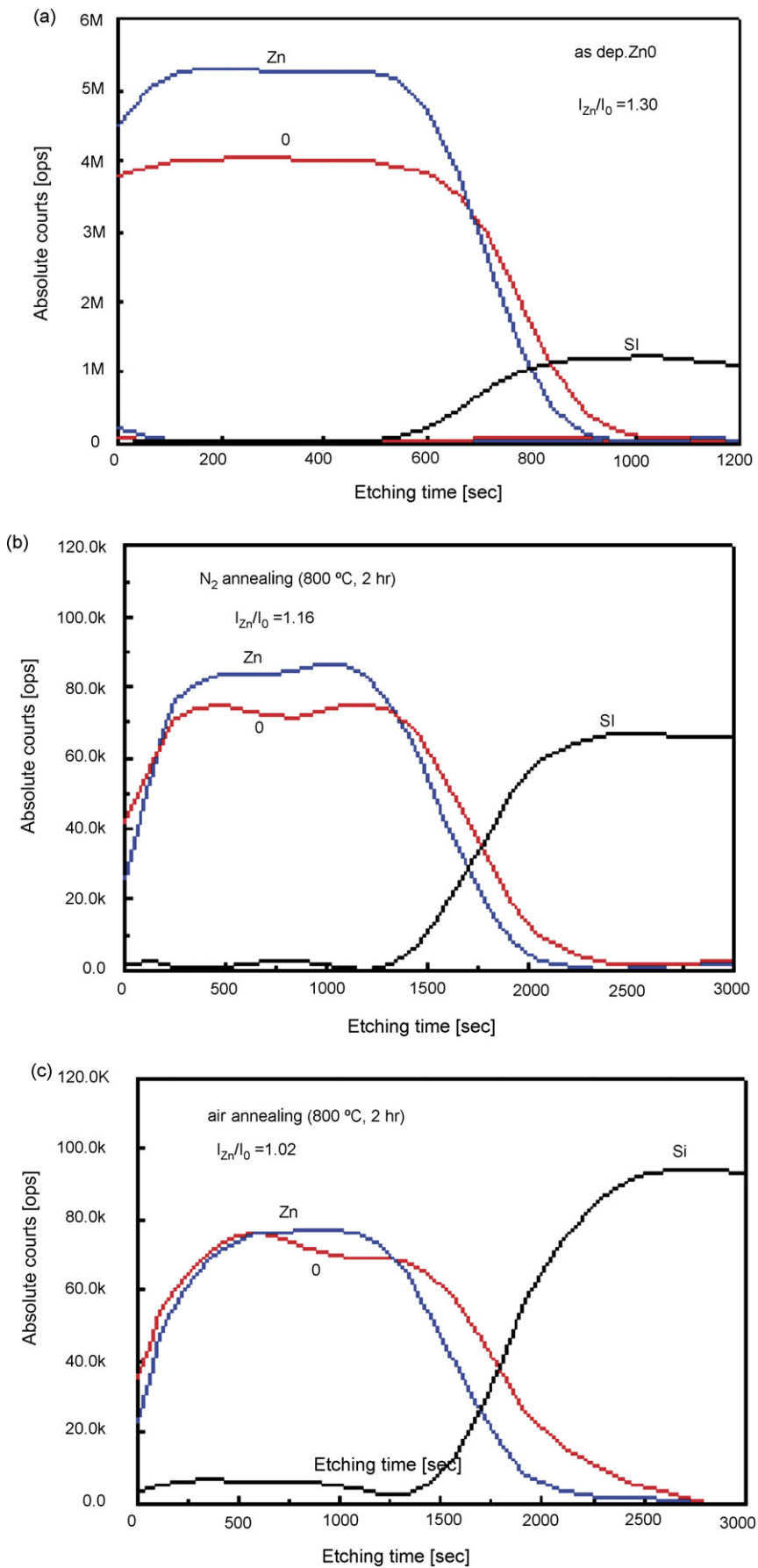


Fig. 1. Auger depth profiles of ZnO films with different annealing ambient. (a) *as dep.* ZnO (b) in  $N_2$  ambient, (c) in air ambient at 800 °C for 2 h.

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