Effect of substrate bias on electrical property of ZnO films deposited by magnetron sputtering

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Abstract : Nominally undoped (intrinsic) ZnO thin films were deposited by magnetron sputtering system with utilization of substrate bias on silicon at 450^{0}C. Oxygen gas was selected as sputtering gas. The deposited thins were evaluated with X-ray diffraction (XRD) for their microstructure analysis and Hall effect in Van der Pauw configuration for their electrical property. The XRD shows that the magnitude and polarity of substrate bias significantly influence the microstructure and electrical properties.

Key words : Intrinsic ZnO film, substrate bias, Magnetron sputtering

1. Introduction

One of recent interests of crystal materials is focused on ZnO. ZnO has large exciton binding energy of 60 meV, direct wide electron energy bandgap of 3.37 eV and microstructure similarity to GaN. With these properties, also together with other properties, ZnO shows its light-emission potential which can be used as photoelectronic devices. It is pivotal to grow high quality ZnO films to manufacture light-emitting devices based on this material. Theoretically, group I and group V elements can be used as acceptor dopants for mono-doping in ZnO; N is the best dopant of group V elements [6]. Magnetron sputtering is often used to grow thin film for its ease of operation and is also used to grow ZnO. Usually, due to the characteristics of sputtering plasma, metal Zn and ceramic ZnO are used as DC sputtering target and RF sputtering target respectively to grow ZnO films. RF magnetron sputtering with ceramic ZnO as a target has an advantage over DC magnetron sputtering with metal Zn as the target in growing high quality ZnO. In this study, RF magnetron sputtering was used to grow high quality ZnO films and ceramic ZnO is used as the RF magnetron sputtering target. Through analysis of XRD spectra and Hall effect, it is confirmed that the microstructural and electrical properties are substantially influenced by substrate bias.

2. Experiments

ZnO films were deposited on Si (100) by RF magnetron sputtering. Before deposition, n-Si (100) (resistivity about 20 ohm.cm) wafer was ultrasonically cleaned sequently in acetone, methanol and DI water, then was etched in HF (2%) to eliminate SiO_2 on Si surface. And then DI water was used to clean Si surface with an ending of N_2 dry. After that the Si wafer was installed in sputtering chamber. The details of deposition condition is listed in Table 1.

Table 1. The deposition condition of intrinsic ZnO thin films.

parameter	condition
Target	ZnO ceramic (5N)
Substrate	Si(100)
Sputtering gas	O_2
Base pressure	$8x10^{-6}$ Torr
Working pressure	10 mTorr
RF power	150 W
Temperature	450 ^{0}C
Time	150 min
Substrate bias	-60, -30, 0, +30, +60 V