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Experimental Investigation of ZnO Thin Film Formed by Use of Negative Oxygen Ion Plasmas and DEZn III

酸素負イオンプラズマと DEZn を用いた ZnO 薄膜生成実験 III
－基板温度依存性－

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In this paper, we present the first data of produced ZnO films with changing the substrate temperature. They are deposited by a PE-MOCVD method containing lots of negative oxygen ions. Two cases of substrate temperature, which are 200 and 300 °C, are tested. For both cases, light absorption is observed at approximately 340 nm. Apparent difference is, on the other hand, recognized in the measured XRD spectra.

1. Introduction

Although PE-MOCVD [1,2] has several advantages, the method usually needs to heat a substrate during the deposition process. Actually, even for a low temperature process of ZnO film, the substrate temperature is at least 200 °C [3,4], which is still too high to deposit on a flexible substrate. A new method of PE-MOCVD which proceeds at lower temperature is thus called for.

As described in companion papers [5,6], we have just initiated to investigate a PE-MOCVD method that contains lots of negative oxygen ions O^- in the oxygen source. In this paper, we present the first experiment performed by changing the substrate temperature. No other experimental parameters are changed at all.

2. Experimental Setup

2.1 *Substrate*

As for the substrate, we have used a small glass plate (Eagle XG, Corning Inc.). Since it is an insulator, we heat the substrate holder shown in Fig. 1 instead of the glass substrate. It is made of SUS316L and the diameter is 23 mm. The substrate is placed in the center hollow part. Inside the substrate holder, a tungsten wire (ϕ = 0.3) is wound non-inductively. The substrate temperature is measured by a type K thermocouple with ϕ = 1.6. By applying an electric current of 4.5 A in the tungsten wire, the substrate holder can be heated up to approximately 400 °C. DC bias potential V_b can be also provided directly to the substrate holder. The value of V_b is variable, but fixed to 20 V for the presented experiments.

Before starting each deposition, the glass substrate is cleaned ultrasonically with acetone and ethanol for 15 min. each.

2.2 *Zn source and other parameters*

As mentioned in Refs. 5 and 6, we have used diethyl zinc (DEZn) as Zn precursors. An afterglow oxygen plasma is produced by a pulsed 13.56 MHz RF discharge. Partial pressure of oxygen has been kept constant to 10 Pa. Those are summarized in Table I with other experimental parameters.

3. Results and Discussion

Figure 2 shows transmission spectra for cases where the substrate temperature is (a) 200 and (b) 300 °C. As recognized, for both cases, light absorption occur at λ < ~ 340 nm. These results indicate that ZnO is deposited successfully on both substrates. Regarding their XRD spectra, changes in the intensity of XRD spectra are seen in Fig. 3. For the case of (b), an apparent peak is seen at 2θ/θ ~ 34°. This result means that the thin film has the orientation of the c-axis, while no peaks in the case

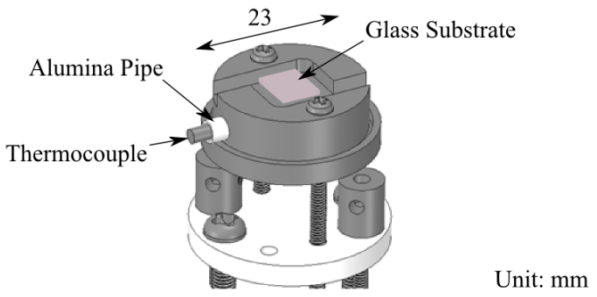

Fig.1. A schematic drawing of the substrate holder. Alumina pipe is used to insulate the thermocouple from the substrate holder.

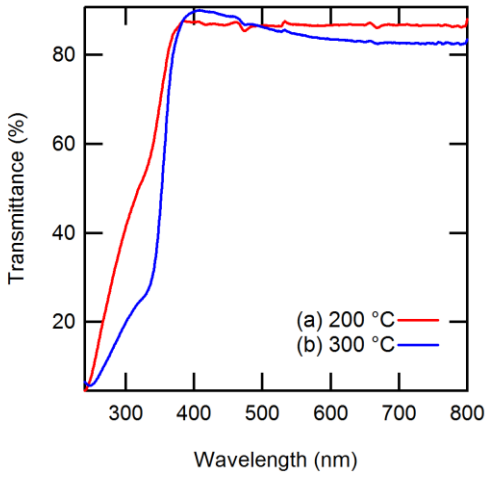

Fig.2. Dependences of transmission spectra of the ZnO films on the wavelength for cases where the substrate temperature is (a) 200 (the red curve) and (b) 300 °C (the blue curve).

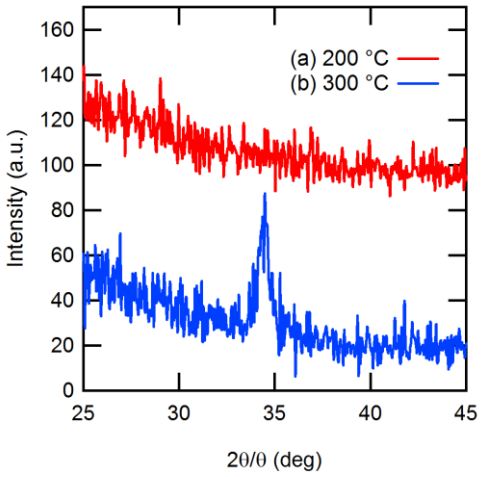

Fig.3. Changes in intensities of XRD spectra for cases of the substrate temperature is (a) 200 and (b) 300 °C.

Table I. Nominal experimental parameters.

Substrate	Glass (Corning Inc., Eagle XG)
Deposition time (min)	3
O_2 flow (sccm)	7
Oxygen partial pressure (Pa)	10
DEZn flow (sccm)	3.16
RF Power (W)	200
V_b (V)	20
Substrate Temperature (°C)	200, 300

of (a).

The obtained results suggest that ZnO thin film needs at least ~ 300 °C for the c-axis orientation even for the process having lots of O^-. However, in experiments, V_b (= 20 V) might be lower than the plasma space potential. For this case, any negative charged particles are repelled from the substrate holder. To address this question, potential distribution around the glass substrate will be measured. It is also unknown how a ZnO film is formed on the glass substrate when lots of O^- are contained in the process. Further studies are thus required.

4. Summary

To investigate a lower temperature ZnO process using O^-, we have initiated new experiments. In this study, with changing only the substrate temperature, ZnO thin films are deposited. No apparent difference is seen in transmission spectra, while a distinct difference is observed in the XRD patterns.

Acknowledgments

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