Absorption measurement of Zn atom density during ICP-assisted magnetron sputter-deposition of Al-doped ZnO thin films

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Abstract

This paper reports the outlines of hollow cathode (HCD) lamp absorption system for the density measurement of sputtered metal atoms in the inductively coupled plasma (ICP) assisted sputter-deposition process of Al doped ZnO thin films. As a result, absorbance of about 6.5% was obtained, which corresponds to the Zn atom density of 1.5×10^{12} cm^{-3}.

Introduction

For the last few years, we have been investigating oxide thin film deposition process by using inductively coupled plasma (ICP) assisted sputtering, and we have succeeded in depositing high quality AZO thin films with resistivity of around 10-3 Ω cm. To understand the basic mechanism, however, a lot of information on the number density of gas phase species in various electronic states are required. This paper reports the outlines of HCD lamp absorption system.

Principle of absorption spectroscopy

Integral of absorption coefficient profile $k(\nu)$ over the entire frequency range is theoretically given by the following equation

$$\int k(\nu)d\nu = \frac{\lambda^2 g_u AN}{8\pi g_l} \qquad (1)$$

where λ: wavelength of absorption line, g_u and g_l: statistical weights of upper and lower levels, A:transition probability. Absorbance α that can be experimentally determined is given by [1]

$$\alpha \equiv \frac{I_{in} - I_{out}}{I_{in}} = 1 - \frac{\int f_s(\nu)\exp[-k_0 f_a(\nu)l]d\nu}{\int f_s(\nu)d\nu} \qquad (2)$$

where $f_s(\nu)$ and $f_a(\nu)$: line profiles of light source and absorber, k_0: absorption coefficient at line center, i.e., $k(\nu) = k_0 f_a(\nu)$. In low pressure sputtering condition, line profiles are approximated by Gaussian function with Doppler width $\Delta\nu_D$. Eventually, atom density is given by the equation

$$N = \left(\frac{8\pi g_l}{\lambda^2 g_u A_{ul}} \cdot \frac{\sqrt{\pi}}{2\sqrt{\ln 2}} \cdot \Delta\nu_D \right) k_0 \qquad (3)$$

Figure 1 shows a relation between absorbance α versus optical thickness $k_0 l$, which was calculated on Zn I 307.6 nm line for various gas temperature of absorber when source gas temperature is fixed 300K. Since the absorption coefficient at line center k_0 for the 307.6 nm line absorption is very small, we find that 10% absorption requires the Zn density of 2×10^{12}cm^{-3} if the absorption length is 0.3 m. To lower the detection limit, we need to utilize the most sensitive absorption line at 213.9 nm.

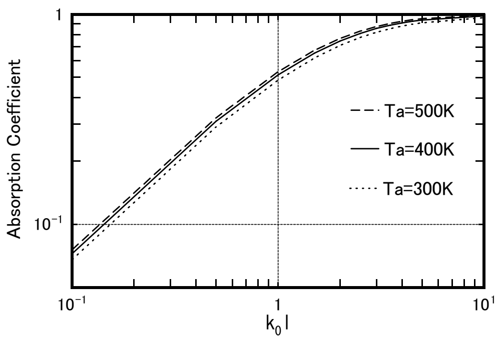

Fig.1 Relation between absorbance and optical thickness calculated for Zn I 307.6 nm line.

Experimental

Preliminary measurement was done using a set up shown in Fig. 2.The light discharged from HCD Lamp is converted into the collimated beam with the lens of f=100mm, and it is made for plasma to pass through the quartz window, and focused again with a lens. After the focused light enters into the spectroscope by the optical fiber, and it converts it into an electric signal with the photoelectric multipliable tube, it is multiplied and recorded with the oscilloscope. Then the density is calculated by comparing the transmitted light intensities of the HCD lamp for the presence of the electrical discharge for deposition.

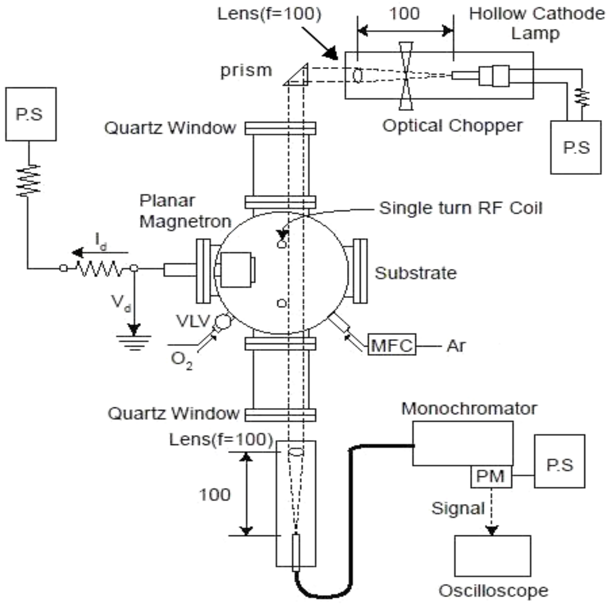

Fig.2 Experimental setup for the absorption measurement of sputtered zinc atoms using a hollow cathode lamp.

Results

Absorption measurement was done using the Zn I 307.6 nm line for the condition of ICP-RF power of 200W, target RF power (target voltage times target current) of 100W, and working pressure of 30 mTorr. As a result, absorbance of about 6.5% was obtained, which corresponds to the zinc atom density of 1.5×10^{12} cm^{-3}.

Conclusions

Absorbance of about 6.5% was obtained, which corresponds to the zinc atom density of 1.5×10^{12} cm^{-3}.

References

[1]A. Kono, S. Takashima, M. Hori, T. Goto: Pla. Phy. Lett. 76 (2000) 469.