Photothermal spectroscopy of ZnO thin film

T. Toyoda, K. Okonogi

► To cite this version:

T. Toyoda, K. Okonogi. Photothermal spectroscopy of ZnO thin film. Journal de Physique IV Proceedings, 1994, 04 (C7), pp.C7-369-C7-372. 10.1051/jp4:1994786 . jpa-00253317

HAL Id: jpa-00253317

<https://hal.science/jpa-00253317>

Submitted on 1 Jan 1994

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Photothermal spectroscopy of ZnO thin film

T. Toyoda and K. Okonogi

*Department of Applied Physics and Chemistry, The University of Electro-Communications,
1-5-1 Chofugaoka, Chofu, Tokyo 182, Japan*

Abstract: Photothermal spectroscopy using thermistor is applied to study the heat generation of sputtered ZnO thin film together with the optical absorption character. It shows that the increase of signal intensity of heat generation is different from that of optical absorption. The width of the exponential changes for the total rate of optical energy absorption is larger than that of the heat generation just below the fundamental absorption edge.

1. INTRODUCTION

Many applications of ZnO thin films to acoustoelectric and electrooptic devices have been developed. Highly conductive ZnO thin films have been actively investigated in recent years because of their potential applications as transparent electrodes for optoelectronic devices[1]. A number of publications have been appeared that are concerned with the optical properties of ZnO thin films. Although several investigations have been carried out on the optical absorption and reflection[2], there are few investigations using photothermal measurements. We present here the experimental results of direct detection of the temperature changes in ZnO thin film made by sputtering method by using a simple photothermal spectroscopy apparatus (PTS)[3].

2. EXPERIMENTAL

The cell for PTS measurements is described elsewhere[3-6]. We employed a thermistor as a sensor for temperature measurements(i.e., resistance changes). PTS involves placing a thermistor in close contact with the sample and measuring temperature changes during sample irradiation with monochromatic light. In order to eliminate the effect of temperature changes of surrounding air, a differential thermistor arrangement was

used to compensate for changes in ambient temperature. Neither thermistor was irradiated directly by the exciting beam during the experiment. The light source was a 500 W short arc xenon lamp. PTS measurements were carried out over the range from 350 nm to 500 nm. ZnO thin film was prepared by using rf sputtering method on SiO₂ glass. The temperature of the SiO₂ glass was kept at 120 °C. The ratio of Ar and O₂ gas at 0.003 Torr was 1:1. The velocity of the sample formation was approximately 0.3 μm/h. The thickness was determined by the direct SEM observation and weight of the sample. The sample thickness was approximately 6.5 μm. X-ray diffraction pattern showed that it crystallized in the hexagonal wurzite lattice (c-axis direction) in which the oxygen ions were arranged in closet hexagonal packing and the zinc ions occupied half of the tetrahedral interstitial positions. SEM observation showed that it was fiber structure.

3. RESULTS AND DISCUSSION

In order to determine and make sure the energy gap E_g for the ZnO thin film by rf sputtering method, $(\alpha h\nu)^2$ is plotted as a function of photon energy $h\nu$ in Fig.1. α is the optical absorption coefficient determined by transmittance and reflectance measurements. Extrapolating a linear portion to $(\alpha h\nu)^2 = 0$, the direct allowed energy gap E_g of ZnO thin film at room temperature can be obtained as 3.12 eV which is in good agreement with the reference[2]. Figs.2 and 3 show the PTS signal intensity and total rate of optical energy absorption, $1-T-R$ (T and R are transmittance and reflectance, respectively), of sputtered ZnO thin film as functions of photon energy in the form of semilog plots. The plots of the logarithms of the PTS and $1-T-R$ versus photon energy approach straight lines below the fundamental absorption regions (R1 and R2 in Figs.2 and 3). An empirical relation for the dependence of photon energy of the PTS and $1-T-R$ signals below the fundamental absorption edge are expressed by $\exp(h\nu/E_1)$. E_1 is the parameter which shows the width of exponential

Fig.1. Photon energy dependence of $(\alpha h\nu)^2$ (α and $h\nu$ are optical absorption coefficient and photon energy, respectively) for ZnO thin film made by rf sputtering method.

Fig.2. Photon energy dependence of the photothermal signal intensity for sputtered ZnO film in the form of semilog plot.

Fig.3. Photon energy dependence of the total rate of optical energy absorption, 1-T-R, for sputtered ZnO thin film in the form of semi-log plot.

change. In order to study increases and changes of both the PTS and 1-T-R signals near and at the fundamental absorption edge, the parameter E_1 is derived for R1 and R2 regions in Fig.2 and 3. Fig.4 shows the E_1 of PTS and 1-T-R for two regions (R1 and R2) in Figs.2 and 3. The values of E_1 of 1-T-R measurements in two regions are larger than those of PTS measurements, suggesting that the width of exponential change in the former are larger than those of the latter. It also shows that there is a dif-

Fig.4. Inverse logarithmic slope, E_1 , of the photothermal spectrum and total rate of optical energy absorption, 1-T-R, for sputtered ZnO thin film.

ference between PTS and 1-T-R spectra and therefore there is a different yields of thermal deactivation in the photon energy region concerned. At present, the experimental results cannot be adequately explained and clarification of the nature of the photothermal effect in ZnO thin film is left to future experimental and theoretical investigations. In the future, a study of relationships between sample preparation (for example, the temperature of SiO₂ glass substratum, ratio of Ar and O₂ gases and gas pressure etc.) and photothermal spectra are needed to clarify the nonradiative processes in sputtered ZnO film formation.

REFERENCES

- [1] Valentini A., Quaranta F., Penza M. and Rizzi F.R., J. Appl. Phys. **73** (1993) 1143-1145.
- [2] Heiland G. and Mollwo E., Solid State Physics, Vol. 8 (Academic Press, New York, 1958) pp. 191-323.
- [3] Brilmyer G.H., Fujishima A., Santhanam K.S.V. and Bard A.J., Anal. Chem. **49** (1977) 2057-2062.
- [4] Fujishima A., Masuda H. and Honda K., Anal. Chem. **52** (1980) 682-685.
- [5] Brilmyer G.H. and Bard A.J., Anal. Chem. **52** (1980) 685-691.
- [6] Fujishima A., Maeda Y. and Honda K., Bull. Chem. Soc. Jpn. **53** (1980) 2735-2741.