Influence of laser beam focusing on the structural, optical and electrical properties of pulsed laser deposited ZnO films

M. G. Tsoutsouva[1], I. Fasaki[2], C. N. Panagopoulos[1], D. Papadimitriou[3] and M. Kompitsas[2]

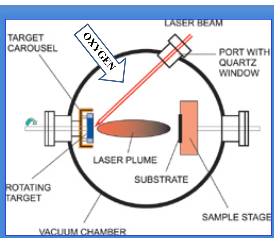
[1] Laboratory of Physical Metallurgy, National Technical University of Athens, Zografos, 15780, Athens, Greece
[2] Theor. and Phys./Chem. Institute, National Hellenic Research Foundation, 48 Vas. Konstantinou Ave., 11635, Athens, Greece
[3] Department of Physics, National Technical University of Athens, Zografos, 5780 Athens, Greece

Abstract

Zinc oxide (ZnO) thin films were deposited on soda lime glass substrates by pulsed laser deposition (PLD) in an oxygen-reactive atmosphere (20 Pa) and a constant substrate temperature (300 °C). A pulsed KrF excimer laser operated at 248 nm and pulse duration 10 ns was used to ablate the ceramic ZnO target. The structural, optical, and electrical properties of the as-deposited films were studied in dependence of the laser energy density (1.2 – 2.8 J/cm^2), by X-ray Diffraction, Atomic Force Microscopy, Transmission Spectroscopy, and the van der Pauw method respectively. The results indicated that the structural and optical properties of the ZnO films could be improved by increasing the laser energy density of the ablating laser. The surface roughness of the ZnO film was found to increase with the decrease of laser energy density and both the optical bang gap and the electrical resistivity of the film were significantly affected by the laser energy density.

Experimental Procedure

ZnO thin films were deposited in a high vacuum chamber that was initially evacuated to a base pressure at 10^{-4} Pa. A UV pulsed KrF excimer laser operated at 248nm with a repetition rate of 10 Hz and pulse duration 10 ns was used to ablate the target, a ceramic ZnO disc (99.9% of purity) with 1.2 cm in diameter and 0.5 cm thickness. To avoid fast drilling, the target was mounted on a vacuum compatible, computer-controlled XY-stage and performed a meander-like movement. The laser beam was focused through a 70 cm focal lens onto the target at a 45° angle of incidence. The substrates were microscope soda lime glass slides, and were cleaned for 10 min in an ultrasonic bath with acetone before being loaded into the chamber. They were placed parallel to the target surface at a distance of 5 cm. For all depositions, the oxygen pressure and the deposition time were fixed at 20 Pa in dynamic flow and 90 min, respectively. At a constant substrate temperature of 300 °C, five ZnO films were prepared with of 1.2, 1.8, 2.1, 2.4, 2.8 J/cm^2 laser energy density.



Results and Discussion

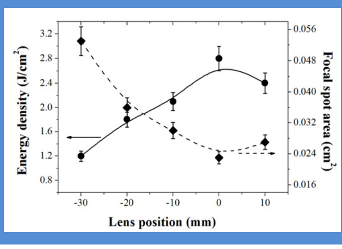


Figure 1: The measured laser spot area and the calculated laser energy density as a function of the relative lens position. The position 0 corresponds to the lens focal distance

Structural Properties

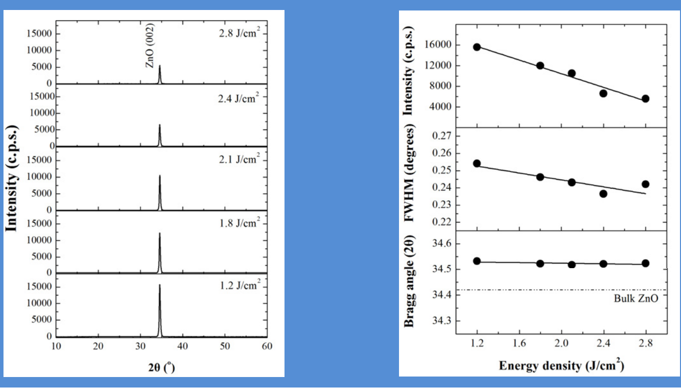


Figure 2: X-ray diffraction pattern of ZnO thin films deposited at various laser energy densities

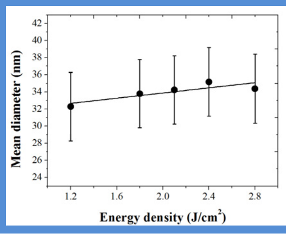


Figure 3: The mean grain diameter of the ZnO films grown at different laser energy densities

The FWHM value of (002) peak is observed to decrease with increasing energy density, resulting to an improved crystalline quality of ZnO films with larger grain size [1].

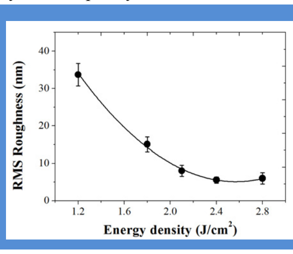


Figure 4: The root-mean-square (RMS) surface roughness of the deposited ZnO films as a function of the laser energy density

The increase of laser energy density leads to an increase in the plasma density and particles kinetic energy. When these particles arrive at the substrate surface, their kinetic energy is transformed into the energy of mobility and the particles diffuse on the growing surface and this results to a decrease of the surface roughness.

Optical Properties

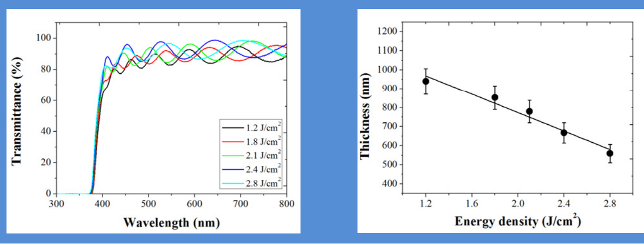


Figure 5: Transmittance spectra and thickness of the deposited ZnO films as a function of the laser energy density

For the selected experimental conditions all the produced ZnO films show high transmission up to 90% in the visible region. When moving closer to the target (defocusing), the laser spot area on the target increases and thus the film thickness increases. The thickness therefore scales with the increased spot area and consequently increases because the total number of atoms that arrives at the substrate increase [2].

Electrical Properties

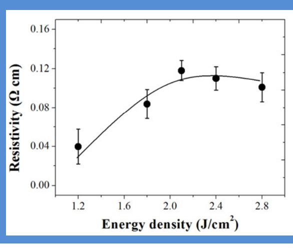


Figure 9: Resistivity of ZnO films as a function of laser energy density

At relative low values of the laser energy density, the crystal quality of ZnO film is poor, and consequently the carrier concentration (defects) is high. As the energy density increases, the carrier concentration decreases and seems to dominate the increased mobility that is probably due to the larger grains.

References

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[2] M. Liu, G. Sun, Z.G. Zhang, X.Q. Wei, C.S. Chen, C.S. Xue and B.Y. Man, Eur.Phys. J. Appl. Phys. 34 (2006) 73-76