Research Communication

An interesting experimental observation of O_2 pressure effect on the surface roughness of ZnO thin films prepared by PLD technique

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Nowadays, most of the principal optical devices, like light generators, detectors, transmitters, splitters, etc, have been demonstrated. Currently, research is focused on reducing the dimensions of these devices and implementing them as structural elements in integrated optical systems. Hence, new techniques need to be developed for fabricating such systems with dimensions of the individual element down to the micrometer range [1].

ZnO has great advantages for light emitting diodes (LEDs) and laser diodes (LDs) over the currently used semiconductors. Recently, it has been introduced that ZnO as II–VI semiconductor is promising for various technological applications, especially for optoelectronic short wavelength light emitting devices due to its wide and direct band gap. The most important advantage is the high exciton binding energy (60 meV) giving rise to efficient exciton emission at room temperature [2].

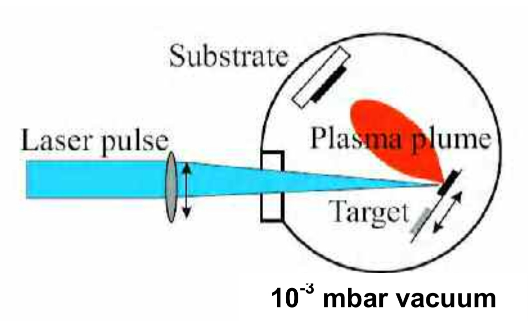

Fig. (1) Schematic diagram of a typical laser deposition set-up

A number of different techniques can be employed for the deposition of oxide materials, including electron beam evaporation (EBV), chemical vapor deposition (CVD), molecular beam epitaxial (MBE), ion-assisted deposition (IAD) and sol-gel methods [3].

Recently, pulsed laser deposition (PLD) proved to be a favorable technique for the deposition of Zinc oxides at different technological conditions on different substrates. That supposed to result in the different structural and micro structural properties and different surface morphology of the nanostructures to be obtained. Also, the optical properties of ZnO are known to be sensitive for its structural quality [4]. PLD offers many advantages compared with other techniques: reduced contamination due to the use of light, control of the composition of deposited structure and in situ doping .The oxygen pressure plays an important role in the film roughness. In this paper, we report the results on the deposition of ZnO thin films obtained at different O_2 pressure by PLD technique. We also investigated the influence of the O_2 pressures on the morphological properties (average Root Mean Square (RMS)) in term of AFM measurements of the films.

Ablation of the target was achieved using an Nd:YAG Second Harmonic Generation (SHG) laser (λ=532nm, pulse duration=7ns and repetition rate of 10Hz). In order to deposit one film, 10min (300 pulses) were applied. We used a set of samples of ZnO purity (99.9999%) and its alloys such as $Mg_xZn_{1-x}O$, $Cd_xZ\ n_{1-x}O$, Al_2O_3, etc). The experimental condition used for our depositions are given in Table (1).

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Table (1) Growth parameters

Target	ZnO and its alloys
Substrate	Glass
Substrate-target distance (cm)	4
Fluence (J/cm^2)	1
Substrate temperature (°C)	200
Spot size (mm^2)	0.99
Vacuum pressure(mbar)	10^{-3}
Deposition pressure(O_2) (mbar)	10^{-2}, 10^{-1}, 10
Number of pulses during deposition	300

At 10^{-2}mbar, the surface of the deposited sample appears very smooth and dense, while the others are relatively rough. The average RMS roughness value for the deposited films increased with the O_2 pressure as shown in Fig. (2). The RMS value of the surface at O_2 pressure $5x10^{-2}$ mbar is 50nm. At high O_2 pressure $5x10^{-1}$mbar the surface roughness was found to be 67nm. The roughness is increasing because of the grain formation which can be described as follows. After initial free expansion from the target surface, the mean free path of the ablated particles is reduced in the presence of gas. More specifically, at higher ambient pressure, more collisions and scatterings occur. The particles then lose energy to the level adequate for forming ionic complexes or molecules. If these clusters reach the substrate surface, small grains, start to grow as they become the nucleus. Most of the ablated particles can reach the substrate in the state near the single atoms if the ambient pressure is extremely low. On the other hand, the surface roughness with small grain size is recommended to be as a gas sensitive element [5].

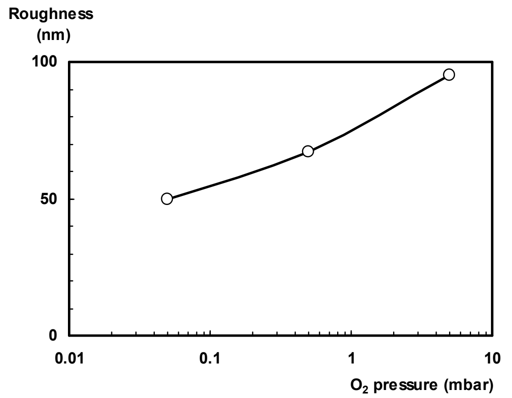

Fig. (2) Dependency of surface roughness of ZnO thin films prepared by PLD on the O_2 pressure inside the deposition chamber

Conclusions

In the foregoing section, we have seen that a high quality semiconductor nanostructure can be fabricated using PLD. A relatively smooth surface and a high crystalline quality, which are appropriate for good optoelectronic devices and applications, were obtained at oxygen pressure of $5x10^{-2}$mbar. But at vacuum of $5x10^{-1}$ mbar, a very low crystalline and a rough surface were obtained. This surface characterization is important for applications in gas sensors and catalysis.

References

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