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ZnO thin films prepared by pulsed laser deposition

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ABSTRACT

Zinc oxide (ZnO) thin films were deposited on soda lime glass substrates by pulsed laser deposition (PLD) in an oxygen-reactive atmosphere. The structural, optical, and electrical properties of the as-prepared thin films were studied in dependence of substrate temperature and oxygen pressure. High quality polycrystalline ZnO films with hexagonal wurtzite structure were deposited at substrate temperatures of 100 and 300 °C. The RMS roughness of the deposited oxide films was found to be in the range 2–9 nm and was only slightly dependent on substrate temperature and oxygen pressure. Electrical measurements indicated a decrease of film resistivity with the increase of substrate temperature and the decrease of oxygen pressure. The ZnO films exhibited high transmittance of 90% and their energy band gap and thickness were in the range 3.26–3.30 eV and 256–627 nm, respectively.

1. Introduction

Zinc oxide (ZnO) is a highly interesting II–VI semiconductor material suitable for optoelectronic applications because of its wide band gap (3.27 eV at 300 K [1]), high chemical stability, and good photo- and piezoelectric properties. It is widely used in device development such as surface acoustic wave devices [2], gas sensors [3], optical devices [4], and solar cells [5]. In solar cell device technology, it is commonly used as window layer because of its transparency to the solar radiation spectrum centered at 1.5 eV. Various transparent conducting oxides (TCOs) such as ITO [6] and SnO_2 [7] have been reported for solar cell device development in this configuration, however ZnO [8–10] is considered to be the most promising TCO material in view of its low financial cost and excellent material properties.

Several techniques have been applied in ZnO film deposition, including sputtering [11], thermal evaporation [12], chemical vapour deposition (CVD) [13], sol–gel [14], molecular beam epitaxy (MBE) [15], and pulsed laser deposition (PLD) [16].

Among these, PLD is more efficient than other methods since it can be used to deposit high quality films at lower substrate temperatures. In fact, the lower deposition temperature in PLD techniques is counterbalanced by the high energy of the ablated particles in the laser-produced plasma plume [17]. Other advantages the PLD technique offers are: deposition in controlled reactive gas pressure and relatively high deposition rates. All these taken together enable sufficient control of film composition, and film properties.

In the present work, undoped ZnO thin films were deposited on glass substrates by PLD and the influence of substrate temperature and reactive gas pressure (O_2) on the structural, optical and electrical properties of the deposited films was investigated.

2. Experimental procedure

ZnO films were deposited on soda lime glass substrates. Before deposition, the substrates were cleaned in an ultrasonic bath with acetone for 10 min. A UV pulsed KrF excimer laser operated at 248 nm with pulse frequency 10 Hz, pulse duration 10 ns, and fluence 2.6 J/cm^2 was used to evaporate the metallic Zn target. The target consisted of a metallic Zn disk (Aldrich 99.9% purity), with diameter 2.5 cm and thickness 0.5 cm, and was placed at a distance of 5 cm from the substrate. To avoid fast drilling, the target was mounted on a vacuum compatible, computer-controlled *xy*-stage and performed a meander-like movement. The deposition chamber was initially evacuated to a base pressure 10^{-4} Pa. The soda lime glass substrate was tightly mounted on a resistively heated round metallic plate and kept overnight at the desired temperature using a stabilized DC current power supply. The temperature was continuously monitored by a Ni–NiCr thermocouple (Philips 2 AB I 15) that was placed inside and at the center of the heated plate just 1 mm beneath the substrate. During the deposition, the substrate temperature was constant within 1 °C as the thermo voltage was continuously recorded by an m-voltmeter. At a fixed deposition time of 2 h, ZnO films were deposited at substrate temperatures of

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