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Effect of Substrate temperature on the defect related emission of ZnO thin films prepared by pulsed laser deposition

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1. Introduction

Zinc Oxide (ZnO) has attracted much attention in research activities with potential applications such as light emitting diode, spintronic device, transparent conductive electrodes, laser and solar cells due to its wide band gap (˜3.37 eV) and large exciton binding energy (˜60 meV) [1,2]. There are several deposition techniques used to grow ZnO thin films, including chemical vapour deposition (CVD) [3], magnetron sputtering [4], spray pyrolysis [5], the sol-gel method [6] and pulsed laser deposition (PLD) [7]. In the case of PLD prepared films, the degree of orientation is influenced by the deposition conditions such as temperature, background gas composition and pressure, and kinetic energy of the plume particles [7]. The trivalent rare earth (RE3+) doped ZnO belong to one kind of novel optical materials and have drawn an increasing amount of attention [8]. Terbium doped ZnO (ZnO:Tb3+) thin films were prepared by PLD at different substrate temperatures. In the present work, the effects of substrate temperature on the structure, optical and luminescence properties of ZnO:Tb3+ thin film were investigated in detail. A correlation was found between the defects (confirmed by X-ray photoelectron spectroscopy) and the Photoluminescence (PL) results.

1. Results

Figure 1 shows the XRD patterns of the ZnO thin films deposited on Si substrates at different substrate temperatures ranging from room temperature (RT) to 400°C. According to the XRD patterns, all ZnO films were oriented along the (002) plane. This is in line with the characteristics of the hexagonal ZnO wurtzite where the c-axis is perpendicular to the substrate plane [9]. The PL spectra of the ZnO films grown at the different substrate temperatures are shown in figure 2. It is worth noting that the films mainly exhibit emission in the UV region. The strong near-band edge emission at room temperature is due to free exciton recombination. Generally in ZnO, the visible light emission is ascribed to the structural defects [10] such as zinc vacancy (VZn), oxygen vacancy (Vo), interstitial zinc (Zni), interstitial oxygen (Oi) and antisite oxygen defects (OZn) [10]. The PL spectra of the ZnO:Tb3+ thin films are characterized by three different types of transitions, the one is due to exciton recombination emission, the second is due to defect level emission and the third is due to the Tb3+ f-f transitions. For the emission due to the Tb3+ ions, a green emission peak at 543 nm and a few minor peaks at 489 and 622 nm were detected. These peaks represent the 5D4-7F5, 5D4-7F6, and 5D4-7F3 transitions of Tb3+, respectively [10].

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