Highly luminescent ZnO Thin Films Obtained by VUV-assisted Sol-Gel Processing

INOEL[1], Graduate School of Science and Engineering[2], Yamagata Univ.

○Lina Sun[1], Kyota Uda[2], Tsukasa Yoshida[2] and Yoshiyuki Suzuri[1]

E-mail: sunlina@yz.yamagata-u.ac.jp

Zinc oxide (ZnO), as a wide band gap (3.37 eV) semiconductor, are useful materials for wide range of applications in thin-film transistor (TFT), photovoltaics, photocatalysts, sensors, and so on. Large exciton binding energy (60 meV) at room temperature (RT) makes ZnO a promising luminescent material especially in optoelectronic devices such as UV lasers and light emitting diodes (LED). Among them, ZnO nanocrystals (quantum dots) has attracted increasing attention because their optical properties can be tuned by varying the crystal size. However, its nanoscale crystallites tend to aggregate to undergo Ostwald ripening due to their high surface energy. To stabilize them, surface modification are usually necessary. At the same time, the whole processes for nanocrystal synthesis and film fabrication become complicated.

Here, we report a simple novel photochemical sol-gel conversion approach for one-step preparation of ZnO thin films with an average nanocrystals in about 2-3 nm size (inset in Fig. 1a), by employing vacuum ultraviolet (VUV) light irradiation in dry N_2. Systematic characterization is performed to understand the surface chemistry and the optical properties of ZnO nanocrystals. Thus obtained ZnO films show unique absorption peak at 292 nm (4.25 eV) (Fig. 1a) and strong tunable photoluminescence in the range of 386-496 nm when expose to UV light, from violet, blue to bluish-green upon increasing time of VUV irradiation (Fig. 1b). Clearly blue-shifted absorption peaks of the VUV treated samples are indicative of quantum-confinement effect, as contrasted to the broad character of the annealed film, which originates from band structure of bulky ZnO. The extension of VUV time only results in increase of absorbance, with no change of the peak wavelength, indicating population increase but no crystal growth by Ostwald ripening during the VUV irradiation. Therefore, the color change of the emitted light should be associated with the change of defect state distribution, rather than the size effect. However, such photoluminescence from defects was fairly strong to be clearly recognized by naked eyes, so that the university logo could be patterned by photomasking VUV to be seen under black light was demonstrated (inset in Fig. 1b).

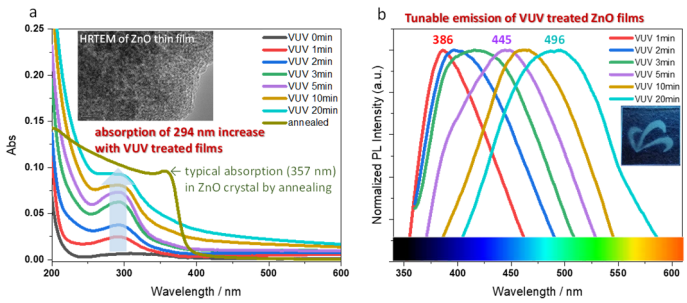

Fig. 1. Absorption (a) and Photoluminescence spectra excited at 325 nm (b) of ZnO thin films as a function of VUV irradiation time. HRTEM image of ZnO sample obtained by VUV irradiation for 5 min is shown as an inset in (a); the university logo of VUV patterned ZnO thin film under blacklight is shown as an inset in (b).