Novel Synthesis, Properties and Applications of *Nano*structured Zinc Oxide

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1. Introduction

Zinc oxide (ZnO) nanoparticles have received much attention due to unique optical and photocatalytic properties [1- 4]. In this research, we have used the DC plasma to synthesize spherical, rod- and tetrapod-shaped ZnO nanoparticles **(**fig. 1) and investigated properties of the various nanostructures as photocatalytic, phosphor, ultraviolet (UV) and infrared (IR) light-absorbing, and short-wave light-emitting materials.

2. Experimental

In the present study, a novel DC plasma reactor operated at 70KW and atmospheric pressure was used to synthesize ZnO nanoparticles. Commercial zinc powders (Alfa Aesar) containing impurities of Cr, Fe and Pb less than 50ppm were used as the raw material. The Zn powders were fed into plasma flame through carrier gas and subsequently underwent vaporization, oxidation and quench processes. Doping nitrogen into ZnO nano-particles was achieved by introducing nitrogen gas into the plasma-forming and carrier gases.

The phase identity and crystallite size of the ZnO nanoparticles were determined using an X-ray diffractometer (XRD, Philip PW1700). A field emission scanning electron microscope (FE-SEM, LEO 1530) and a transmission electron microscope (TEM, Jeol 2010) were used for morphological observations of the ZnO nanoparticles. The optical properties of the nanoparticles were investigated by a photoluminescence (PL) spectrometer and a UV-visible spectrometer (HITACHI U-3010). In the PL experiment, the samples were optically pumped by frequency tripled Nd:YVO_4 laser (λ=355nm, FWHM~500ps,1kHz).

3. Results and Discussion

The crystalline structure of all the synthesized ZnO nanoparticles in the present study is hexagonal wurtzite structure. Average particle size of the spherical ZnO is about 31nm**.** While the tetrapod-like particles consist of four crystalline needles with a diameter and a length of about 30 nm and 100~200nm respectively. Shape of the crystalline needle is hexagonal in the cross section and the needle grew in the <001>direction. In the photocatalytic study, nitrogen-doped ZnO nano-particles with rod- and tertapod-like shapes were found to possess better photocatalytic ability under illumination of both UV and visible light. As to light-absorbing property, we found that ZnO nanorods synthesized in mixed plasma of nitrogen and hydrogen revealed a strong absorption of IR and UV light. Room-temperature photoluminescence spectroscopy (fig. 2) of the ZnO nanorods showed a UV emission peak at 380 nm, a green emission peak at 520 nm, and a weak near-IR emission peak at 750 nm. The UV emission was assigned to the near band-edge emission while the green and the near-IR emissions corresponded to the deep-level emission from different defects. In addition, the green emission peak of the nanorods subjected to annealing shifted with blue-shift in reductive annealing atmosphere and red-shift in oxidative atmosphere. Finally, discrete UV lasing modes were observed in the random-packed nanorods at room temperature, as shown in fig. 3. This may be attributed to recurrent light scattering that provides coherent feedback for lasing.

References

1. M.D. Driessen, T.M. Miller, V.H. Grassian, J. Mol. Catal. A: Chem. 131, (1998) 149-156
2. J. Villasenor, P. Reyes, G. Pecchi, J. Chem. Technol. Biotechnol. 72, (1998) 105-110
3. J. C. Johnson, K. P. Knutsen, H. Yan, M.t Law, Y. Zhang, Peidong Yang, and R. J. Saykally, Nano Lett., Vol. 4, No. 2, 197-204, 2004
4. M. H. Huang, Y. Wu, H. Feick, N. Tran, E. Weber, and Peidong Yang, Adv. Mater. 2001, 13, No. 2, 113-116

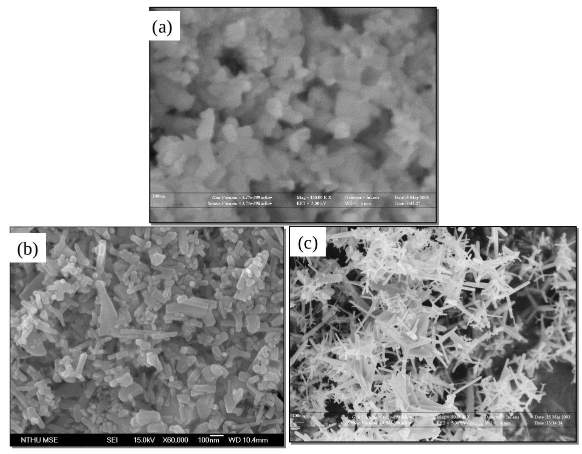

Fig. 1. FESEM micrographs of (a) spherical (b) rod-like (c) tetrapod-like ZnO nanoparticles.

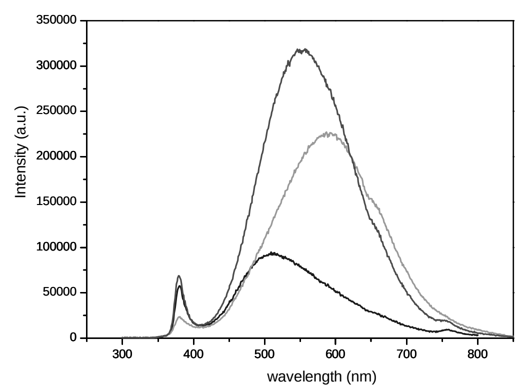

Fig. 2. PL emission spectra of the ZnO nanorods.

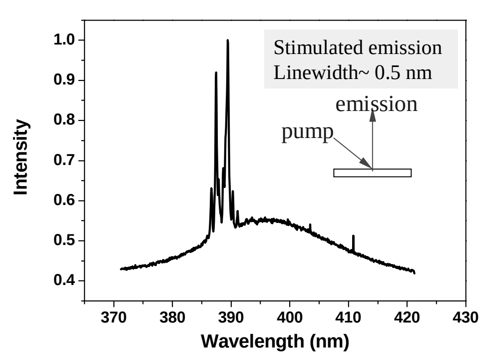

Fig. 3. Random lasing action of ZnO nanorods. Excitation intensity>30MW/cm^2