Surface-plasmon-enhanced visible light emission of ZnO/Ag nano-grating structures

Minji Gwon, Eunsongyi Lee, and Dong-Wook Kim *
Department of Physics, Ewha Womans University, Seoul 120-750 Korea
**E-mail: dwkim@ewha.ac.kr*

Ki-Ju Yee
Department of Physics, Chungnam National University, Daejeon 305-764 Korea

Surface plasmon polaritons (SPP) are resonant interactions between the surface charge oscillations and the electromagnetic waves at the metal/dielectric interface. They generally arise from interactions between photons and electrons at the interface and exhibit various unique characteristics, including localization of electric fields at the interface and drastically increased density of modes near the resonance condition. Such properties provide the possibility of guiding light in subwavelength metallic structures and enhancing the light emission and absorption. Thus, the SPs have attracted considerable research attention due to scientific interest and applications in optoelectronic devices.

ZnO, with a direct bandgap of 3.37 eV, has been widely used as a transparent conducting electrode and is a strong candidate for ultraviolet light-emitting devices and photodetectors. Periodic nanostructures can bridge the SPP photon momentum gap and modify the optical properties of the dielectric layers. ZnO/Ag thin films can be used as back reflectors in silicon thin film solar cells. It is interesting to investigate how the grating structures can influence SPP-photon coupling and resulting optical properties of ZnO/Ag layers.

ZnO/Ag thin films were deposited on one-dimensional periodic structures, with the periodicity of 1000 and 1400 nm, fabricated by nanoimprint lithography (Fig. 1). The ZnO/Ag grating structures exhibited multiple peak features in visible-range photoluminescence (PL). Whereas a ZnO/Ag planar thin film showed two major PL peaks in UV and visible region (Fig. 2). Moreover the PL intensity of the periodic structures was 100 times larger than that of the planar counterpart. These results could be understood as a result of SPP-exciton interaction. The grating structures also exhibited quite distinctive features in reflectance from the planar samples. There were several reflectance dips, which were caused by photon-induced SPP excitation via the grating coupling. Thus, the PL peaks, well matched with the reflectance dips, represent the excited SPP energies, determined by the grating periodicity. Finite-difference time-domain simulations supported all the experimental results.

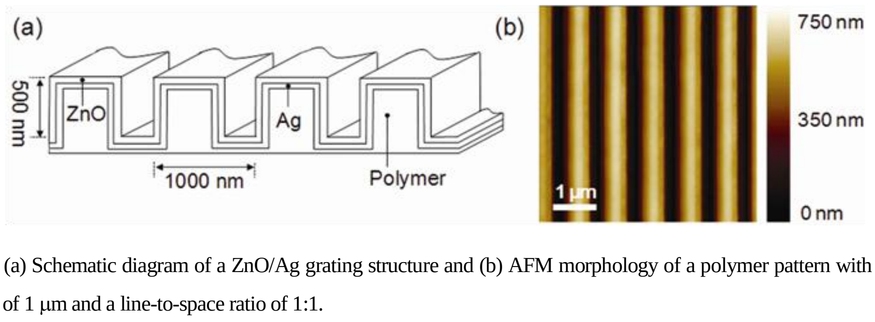

Fig. 1. (a) Schematic diagram of a ZnO/Ag grating structure and (b) AFM morphology of a polymer pattern with a period of 1 μm and a line-to-space ratio of 1:1.

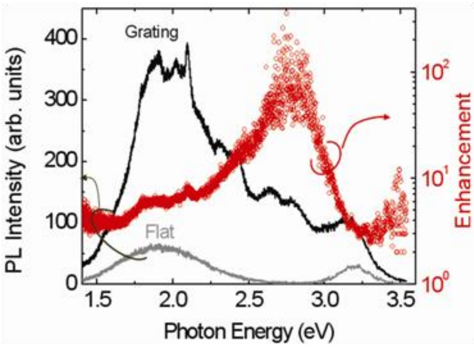

Fig. 2. PL spectra of a ZnO/Ag planar thin film and a ZnO/Ag grating structure. Enhancement indicates the ratio of the PL intensity of the grating structure to that of the planar thin film.

Acknowledgments

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References

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