The effect of thermal treatment on the structure and surface plasmon resonance of Ag-coated ZnO nanoparticles by sol-gel method

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ABSTRACT

Zinc oxide (ZnO) is an n-type II-VI semiconductor with a hexagonal wurtzite structure, a wide band gap (3.3 eV) and a higher exciton binding energy (60 meV), and has been applied in the field of ultraviolet or visible optoelectronic devices, photocatalyst, gas sensors, solar cells. On the other hand, silver (Ag) nanoparticles show the variable surface plasmon resonance (SPR) properties by controlling the particles shape, size, and density. In this study, the ZnO nanoparticles were fabricated by sol-gel method at the ambient environment. Subsequent baking was conducted at the 500℃ in air. The Ag nanoparticles were coated on the ZnO surface by surface decoration process and baked in the lower pressure condition (~10^{-3} torr) at several temperatures (100, 300, and 500℃).

XRD patterns showed that peaks of (100), (002), (101), (102), (110), (103) planes belonged to the pure ZnO nanoparticles as the wurtzite structure. The peak of (111) plane at 38.1°appeared at the baking temperature of 300 and 500℃ indicating that the Ag metal and its grain size increased with the increasing baking temperature. The TEM images and SAD patterns indicated that the Ag-coated ZnO nanoparticles kept the same crystal structure with a prominent facets (002) of the ZnO and (111) of the Ag nanoparticles.

The PL spectra displayed a tendency of blue shift in the UV light emission of 3.18 to 3.2eV and 3.08 to 3.1eV, respectively, while the Ag nanoparticles size increased. The former was the intrinsic emission, and the latter was caused by the V_O^+. Raman spectra revealed the peaks at 99cm^{-1} (E_2^{low}), 331cm^{-1} (multiphonon), 439cm^{-1} (E_2^{high}), and 580cm^{-1} (E_1 LO). The intensity of E_2^{low} mode showed the apparent increasing as the baking temperature increased. However, the intensity of multiphonon, E_2^{high}, and E_1 LO mode revealed the opposite tendency. The binding energy in XPS analysis of the $Zn2p_{3/2}$ and $Zn2p_{1/2}$ were observed at 1021.3 and 1044.8eV, respectively. In addition, the deconvolution of $Ag3d_{5/2}$ showed 368.5 (Ag^0) and 367.4(Ag^+)eV. The ratio (Ag^0/Ag^+) increased with the increasing baking temperature, meaning more Ag metals on the Ag-coated ZnO nanoparticles. The UV-Vis spectrum revealed the noticeable peak centered at λ=420nm due to the SPR effect of Ag nanoparticles, and showed the red shift to λ=460nm as the Ag nanoparticles size increased.

Keywords: Ag-coated ZnO nanoparticles, surface plasmon resonance, photoluminescence

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