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Synthesis of Highly Transparent ZnO Quantum Dots

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ABSTRACT
Synthesize of optically and high luminescence of ZnO quantum dots in this work. XRD pattern show pure ZnO QDs and are genuinely polycrystalline with a hexagonal wurtzite structure. A typical TEM image of the material showed that particles are spherical in shape and their average size is (4) nm. No quantum dots with a diameter less than 2 nm or larger than 6.5 nm are found. PL spectrum of ZnO QDs is composed of an ultraviolet (UV) emission centered at about 360 nm and a broad green emission centered at about 475 nm.

Introduction

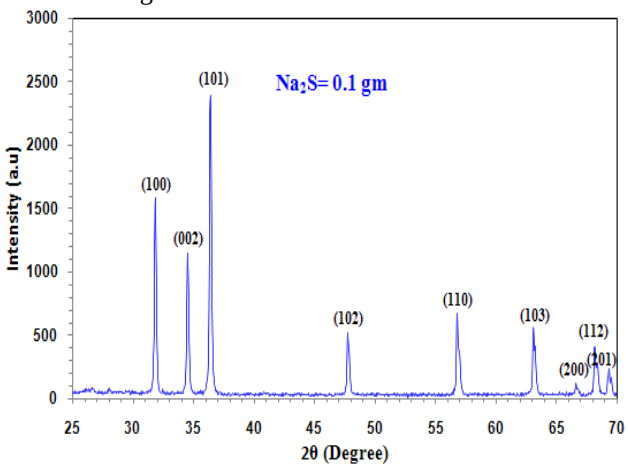
Quantum dots are a special class of materials, which are nanocrystals of inorganic semiconductors composed of atoms of periodic groups of II-VI, III-V, or IV-VI. The term quantum dots was first coined by Mark A. Reed in 1988 and developed in the early 1980s by Louis Brus at Bell laboratories, along with Alexander Efros and Alexei I. Ekimov of the A. F. Ioffe Physical Technical Institute. Quantum dots (QDs) exhibit unique properties which include broad excitation and narrow size-tunable emission spectra (usually 20–40 nm full width at half maximum intensity), negligible photobleaching, and high photochemical stability [1]. II-VI compound semiconductor have been found to be an unique host materials for doping optically active impurities, which exhibit efficient luminescence at room temperature [2]. Zinc oxide (ZnO) is a direct semiconductor with a wide bandgap of 3.4 eV and high binding exciton energy of 60 meV, which show excellent luminescent properties under electron beam and UV (365 nm) excitation [3]. Synthesis of semiconductor quantum dots and their dif- ferent applications as various electronic and optoelec- tronic devices including different kinds of sensors are the frontier research areas at present [4]. ZnO is an n-type semiconductor by nature due the presence of intrinsic defects such as oxygen vacancies and Zn interstitials. ZnO micro and nanoparticles have attracted great interest owing to their unique and fascinating chemical, electrical, mechanical, optical and piezoelectric properties. Due to its unique electrical and optical properties ZnO is considered as liable material for variety of applications in the visible and near ultraviolet (UV) spectra [5]. The nanostructures of ZnO material have been investigated intensively recently. In fact, ZnO shows the richest nanostructure morphologies of all materials. Among these ZnO nanostructures, nanowire, nanorod, nanopin, nanoring, nanodisk and quantum dots (QDs) have been fabricated and investigated. Significance of the exciton effects becomes more prominent in nanostructure materials especially in zero dimensional nanostructure, i.e. QDs. Hence, QDs are expected to have many interesting and useful properties for opto-electronic applications [2].

Experimental Section:

Synthesize ZnO quantum dots using 0.4 gm of zinc acetate dihydrate $Zn(CH_3COO)_2.2H_2O$ was add to 100 ml isopropyl alcohol C_3H_9O with continuous stirring for 30 minutes and 70°C heating temperature. The effect of sodium sulphide (Na_2S) addiation was investigation in the work by add different weight (0.1, 0.15 and 0.2) gm of sodium sulphide to the mixture solution followed immediately by the addition of 10 ml TEA under continuous stirring for 5 hours. ZnO colloidal solution was obtained. After each synthesis, the obtained white cloudy dispersion was centrifuged at 6000 rpm for 1 hour and washed three times with methanol and finally dried at 50°C for 7 hours in a vacuum oven.

Result and Discussion

XRD pattern of the prepared ZnO QDs at different Na_2S addiation is shown in figure (1).. It is seen from figure (1) that peaks appears at 31.766°, 34.412°, 36.245°, 47.475°, 56.601°, 62.583°, 66.368°, 67.958 and 69.103° corresponding reflecting planes are (100), (002), (101), (102), (110) , (103), (200), (112) and (201) respectively. The diffraction patterns detect good polycrystalline quality without any perceivable changes from pure ZnO QDs with a hexagonal wurtzite unit cell structure and lattice constant of a = 3.197Å and c = 5.208Å which is reported in JCPDS (36-1451) card number for bulk ZnO. The XRD patterns of all the samples indicated enhanced intensities for the peaks corresponding to (101) plane, indicating preferred orientation along the c-axis.



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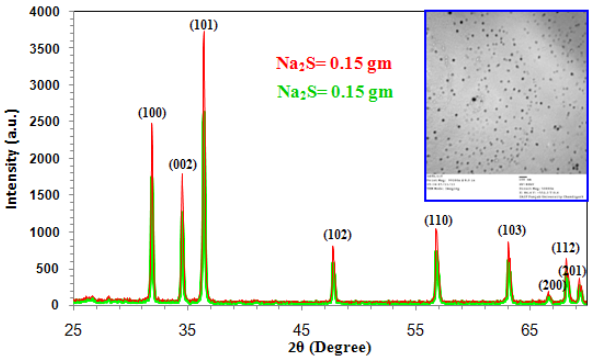

Figure 1. XRD of ZnO quantum dots at different Na_2S addition

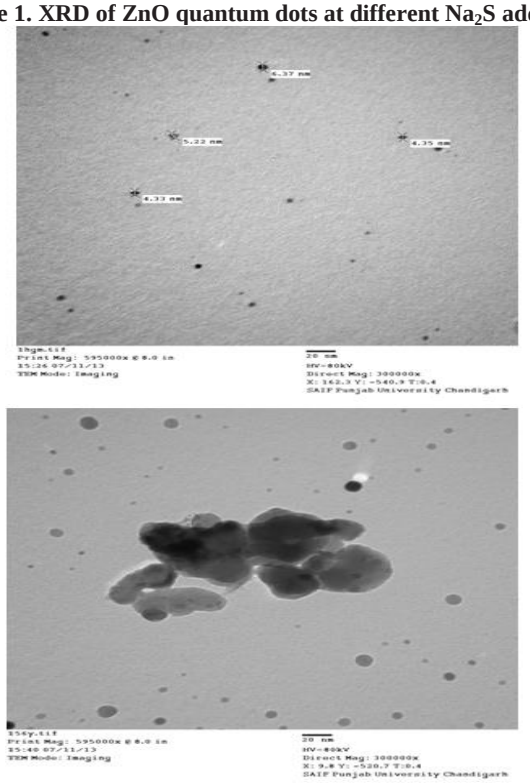

Figure 2. HRTEM micrograph of ZnO quantum dots with ave. particle size 4 nm

Microstructural investigations of the prepared ZnO quantum dots are performed by high resolution transmission electron microscopy (HRTEM) at 80 kV acceleration voltage. TEM images support the growth in particle size of QDs. A typical TEM image of the material showed that particles are spherical in shape and their average size is (4) nm (Figure 2). No quantum dots with a diameter less than 2 nm or larger than 6.5 nm are found. ZnO nanostructures exhibit novel optical and electronic properties due to the quantum confinement of excitons and phonons in nanostructures. The phenomenon of quantum confinement arises once the diameter of the particle is of the same magnitude as the wavelength of the electron wave function. Quantum confinement generally results in widening of the band gap, i.e. the gap between the conduction band and the valence band, increases as the size of the nanostructure decreases. It is because of the quantum confinement effect that quantum dots of the same material with different sizes exhibit various colors. ZnO QDs having sizes < 6.5 nm experience strong quantum confinement in all the dimensions, *i.e.* movements of electrons and holes are restricted in all three directions. Thus, the density of states for this zero dimension (0D) system will be delta functions. Small spatial correlation between electrons and holes produce a significant change in the optical properties of these quantum dots [1].

Figure (3) shows the room temperature photoluminescence (PL) spectrum curve of ZnO QDs is composed of an ultraviolet (UV) emission centered position at about 360 nm and a broad green emission centered position at about 475 nm.

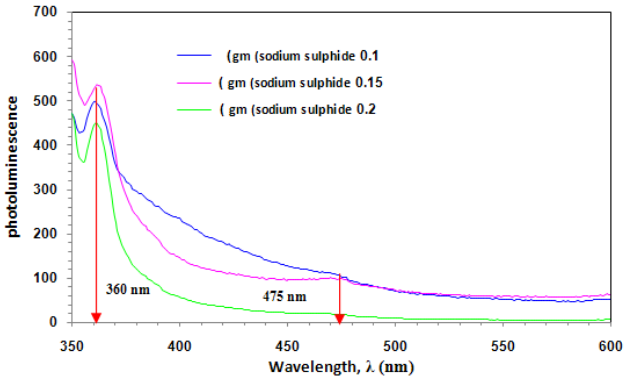

Figure 3. PL with wavelength of ZnO quantum dots at different Na_2S addition

Conclusions

ZnO quantum dots prepared in this work at different Na_2S addition. XRD results show polycrystalline ZnO QDs with a hexagonal wurtzite structure. HRTEM image of the material showed that no quantum dots with a diameter less than 2 nm or larger than 6.5 nm are found. PL spectrum of ZnO QDs is composed of an ultraviolet (UV) emission centered at about 360 nm and a broad green emission centered at about 475 nm.

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