Solid State Science and Technology, Vol. 19, No2 (2011) 144-149
ISSN 0128-7389

SYNTHESIS OF HIGH-LUMINESCENCE CdSe QUANTUM DOTS AT VARIOUS TEMPERATURES

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ABSTRACT

The aim of this paper is to investigate the effect of temperatures on the optical properties of CdSe quantum dots (QDs). High-luminescence CdSe QDs were synthesized using wet chemical method via thermal decomposition reaction of organometallic cadmium and selenium as precursors in a hot solvent mixture. Cadmium precursor was prepared in the three-neck flask with the mixture of CdO, 1-octadecene and oleic acid as a stabilizer. 1 mL of selenium precusor which was prepared earlier was quickly injected into the flask at the temperature between 260^{o}C to 310^{o}C. CdSe quantum dots were grown for 45 seconds and then immediately collected. The resulting QDs were isolated by centrifugation and redispersed in hexanes. The optical properties of quantum dots were characterized using Photoluminescence spectrometer (PL) and UV-Vis Spectrometer. When the QDs exposed under the UV-lamp, it radiated light from green to red colour, indicating an increment in the size as the growth temperature increased. PL test revealed that the emitted wavelength of QDs were in the range of 500 nm to 650 nm with the narrow peak. UV-VIS spectrometer characterization support the PL characterized about the emission and excitation of electron which contributed the information on energy gap of the QDs. The effect of temperatures on the improvement of the optical characteristics of CdSe QDs will be discussed.

Keyword: CdSe quantum dots; photoluminescence; red-shift; absorption; energy gap;

INTRODUCTION

In past two decades, nanomaterials have been of much interest in research due to their novel electronic, magnetic, optical, chemical and mechanical properties, and thus making them highly attractive for many important technology applications [1-4]. From the various types of nanomaterials, semiconductor nanocrystals or quantum dots (QDs) have been the most intensively studied because of quantum confinement effect [1-3].

Typically, QDs sizes ranging between 1-10 nm in diameter. When quantum confinement effect occurs, the size of nanoparticles reduces (close to or smaller than the dimensions of the exciton Bohr radius within the corresponding bulk material), these nanoparticles behave differently from bulk solid [1, 2]. As a result, the electrical and optical properties of nanoparticles deviate substantially from bulk solid. Quantum confinements are responsible for the remarkable attractive optoelectronic properties exhibited by QDs, including their high emission quantum yields, size tunable emission profiles and narrow spectral bands [1-5]. Moreover, size-dependent properties of QDs that provide in tunability absoption and emission throughout the ultraviolet (UV) and near-infrared (IR) leads to new applications in science and technology [5-6].

The synthesis of CdSe quantum dots (QDs) has generated tremendous interest because of potentials in applications from LED to solar-cell and bio-labeling [7, 8]. In literature, many synthetic routes have been reported, including organometallic precursor route, non-organometallic precursor, microwave irradiation route, slovothermal routes and sonochemical method [1-6]. The organometallic precursor route was the most popular method for preparation of high quality CdSe QDs [9. 10] in term of ease to manipulation for controlling the size and shape of nanoparticles [3].

Recently, there have been many reports on the production of high quality QDs. Unfortunately, most of them required complicated system for preparing such as in vacuum or argon conditions [3-6, 9]. Herein we report a facile approach to synthesize stable and high quality CdSe QDs in pure air by using organometallic precursor. Reaction temperature is one of the important parameters in preparation of QDs. Thus, the influence of temperatures in controlling the size and optical properties of CdSe QDs was investigated with the objective to optimize the preparation process.

EXPERIMENTAL DETAILS

A typical procedure for synthesis of CdSe QDs is as follows. At room temperature, 0.013 g of cadmium oxide was dissolve in 0.6 ml of oleic acid and 10 ml of 1-octadecene. This mixture is called cadmium precursor. Then cadmium precursor was slowly heated up to 260 ^{o}C. At this temperature, 1 ml of selenium precursor, which was prepared previously by mixing 0.03 g of selenium powder in 0.4 ml tri-n-octylphosphine (TOP) and 5 ml 1-octadecene, was quickly injected into the cadmium precursor. The timing of growth QDs was recorded. After 45 seconds, the solution wes collected and transferred into ice-cooled glass vial to abruptly retard the growth of QDs. The resulting QDs were isolated by centrifugation and redispersed in hexanes, producing a clear QDs suspension solution with yellow color. To obtain the effect of temperature on the optical properties of QDs, the different temperature in the range of 260 – 310 ^{o}C were used for injected selenium precursor.

The photoluminescence and optical absorption properties of the CdSe quantum dots were tested using Perkin Elmer LS 55 Luminescence Spectrometer and Perkin Elmer Lambda 900 UV/VIS/NIR Spectrometer.

RESULTS AND DISCUSSION

CdSe quantum dots have been successfully prepared using the present technique. After the injection of selenium precursor into the hot-solution of cadmium precursors, the colour of the solution drastically changed to light-brown and further to dark-brown as the reaction period elapsed. The change in colour can be directly related to the progression of the quantum dots growth during the reaction time. The temperature of injection also allied with the growth process of CdSe QDs. When the temperature of precursors mixed was very high, the growth rate of nanoparticles also very high.

The illumination of the colloidal solution with UV-lamp (365 nm) surprisingly gave different luminescence that range from green emission for the lowest growth temperature period to dark-red for the highest growth temperature. It showed that the quantum dots obey red-shifted order.

Figure 1 presents the optical absorption spectra of the colloidal quantum dots for different temperatures (260, 275, 290 and 310 ^{o}C) at the growth time of 45 s. It can be clearly seen that the absorption peak of the quantum dots was red-shifted with the increment of the temperature, hence the decrease in the energy gap of the resulting quantum dots. Table 1 shows the resulting energy gap that can be calculated from the absorption peak.

As the absorption spectrum reveals the change in the energy band gap, which is decreasing with the increasing temperature, it also infers the increasing of the size of quantum dots when the temperature of precursor increased. From the Figure 1, the entire sample shows that the first exciton peak was very sharp. This shows that the size distribution of particles were very small hence most of the electrons will get excited over a smaller range of wavelength [11].

Table 1: The resulting of energy gap with different temperature

Temperature (^{o}C)	Energy Gap (eV)
260	2.143
275	2.066
290	1.999
310	1.937

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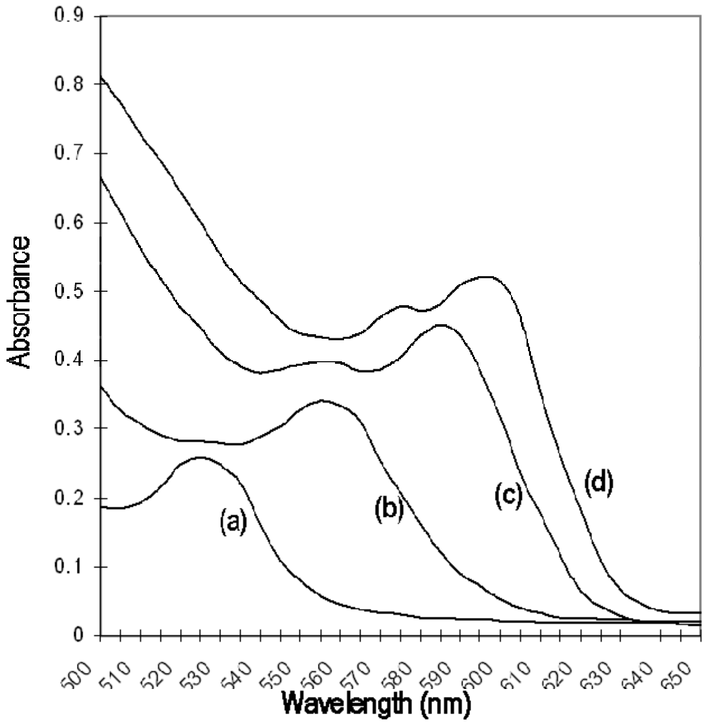

Figure 1: The UV-Vis absorption spectra for the different temperature ranging (a) 260 ^{o}C, (b) 275 ^{o}C, (c) 290 ^{o}C and (d) 310 ^{o}C

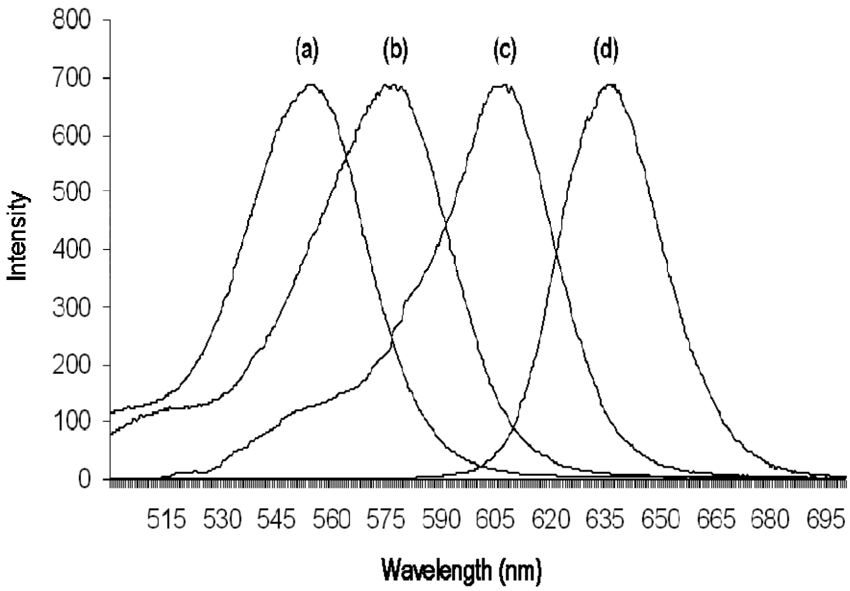

Figure 2: The photoluminescence spectra for the different temperature ranging (a) 260 ^{o}C, (b) 275 ^{o}C, (c) 290 ^{o}C and (d) 310 ^{o}C

Figure 2 shows the quantum dots giving a red-shift in the photoluminescence peaks. Our result also showed that the intensity of the emission decreased with the increasing temperature of the cadmium precursor. This might be attributed to the increase in the non-radiative recombination of electrons and holes on the surface of the quantum dots as the size increase [6]. The differences in the photoluminescence of the quantum dots can be directly associated with the change in the quantum dots size due to obeying the red-shifted order.

From the Figure 2, the photoluminescence spectrum shows that the particles of quantum dots at time collected of 45 second were emitted at the ranging of 540 – 625 nm which is agreeable with the absorption peak displayed as shown in Figure 1. From the photoluminescence results a typical quantum yield of the CdSe quantum dots is in the range of 36 % – 58 %. It also confirmed that the photoluminescence peak was red-shifted when the temperature increased. The visible light corresponds to a wavelength range of 400 - 700 nm and a color range of violet through red. Table 2 shows the relationship between the increasing temperature with the wavelength that the particle emitted and the visible color.

Table 2: The relationship between increasing temperatures, emission wavelength and color light

Temperature (^{o}C)	Wavelength (nm)	Visible Color
260	550	Green
275	577	Yellow
290	599	Orange
310	625	Red

From Table 2, its shows that the variations of temperature give the different color of the quantum dots which is green, yellow, orange and red. The growth rate at low temperature was relatively slow thus it was well suited to prepare small size of nanoparticles with emission from green to yellow light. While, at the higher temperature, the growth rate markedly accelerated and the larger sizes of nanoparticles were obtained.

CONCLUSION

In conclusion, the facile method for the synthesis of highly-luminescence CdSe quantum dots was presented and the effect of temperature on optical properties of this nanocrystal was discussed in this paper. The results show the growth rate of CdSe quantum dots increases leading to larger particles at higher growth temperature. The size of CdSe quantum dots can be finely controlled via simply varying growth temperature from 260^{o}C to 310^{o}C or reaction time. The preparation of CdSe nanocrystal possessed strong luminescence with quantum yield increment up to 56% with the narrow peak of emission spectra. The CdSe quantum dots may find an extensive usage on LED and organic-hybrids OLED devices.

ACKNOWLEDGEMENT

The authors would like to thank the Universiti Kebangsaan Malaysia for the Zamalah Research University (RU) and Ministry of Higher Education (MOHE) for the grants of UKM-ST-07-FRGS0024-2010.

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