

Synthesis and Optical Study of CdZnTe Quantum Dots

Faranak Asgari^{1*}, Shankar Lal Gargh², Karim Zare³

¹ Ph.D. Student, Department of Chemistry Science and Research Branch Islamic Azad University, Tehran, Iran

² Professor, Research Journal of BioTechnology, Sector AG/80, Scheme no.54, A.B.Road, Indore, India

³ Professor, Department of Chemistry Science and Research Branch Islamic Azad University, Tehran, Iran

Received: 1 January 2013; Accepted: 3 March 2013

ABSTRACT

The comparison of growth processes and fluorescent properties of CdZnTe semiconductor quantum dots that are synthesized in different concentrations of Zn²⁺ in water are discussed in this paper. The samples are characterized through absorption (UV) and photoluminescence spectra (PL). The results show that when the reaction time is prolonged, the absorption peak and fluorescent emission peak present obvious red shifts and the diameters of the Quantum dots continuously increase. Under the best reaction conditions, the highest quantum yield can be attained by using thioglycolic acid (TGA) as modifier when the reaction time is 300 min.

Keyword: Quantum dots; Modifier; Fluorescence; Photoluminescence; Thioglycolic acid; Emission.

1. INTRODUCTION

Research on semiconductor quantum dots has increased rapidly in the past few decades. Luminescent semiconductor quantum dots have been intensely studied due to their unique optical properties [1]. In particular, semiconductor Quantum dots are very attractive as biological labels because of their small size, emission tunability, superior photostability and longer photoluminescence decay times in comparison with conventional organic dyes [2-6]. These highly luminescent quantum dots have photophysical properties superior to organic dyes but the high temperature required to synthesize them can be

problematic for some applications [4, 5, and 7]. One of the major challenges is to obtain water soluble Quantum dots with a high PL quantum efficiency.

Arrested precipitation in water in the presence of stabilizers (e.g., thiols) is a faster and simpler method to synthesize water soluble Quantum dots and has been applied to several semiconductors potentially relevant to biolabeling (e.g., CdS, CdSe, CdTe). For CdS and CdSe, this yielded Quantum dots with defect related emission and a low quantum efficiency. For CdTe Quantum dots, both excitonic and defect related emission bands were observed. Although samples with no observable

(*) Corresponding Author - e-mail: faranak.asgari@gmail.com

trap luminescence were also obtained. In this study, we report a novel method that yields highly luminescent water soluble CdZnTe Quantum dots. The results show that when the reaction time is prolonged, the absorption peak and fluorescent emission peak present obvious red shifts and the diameters of the Quantum dots continuously increase [8].

2. EXPERIMENTAL

2.1. Materials

Cadmium chloride ($\text{CdCl}_2 \cdot 2.5\text{H}_2\text{O}$), zinc chloride (ZnCl_2), tellurium (Te reagent powder), and sodium borohydride (NaBH_4), Thioglycolic acid (TGA). All chemicals were received from Merck chemical company and used without any further purification. Deionized and distilled water were used in this work.

2.2. Characterization

A Varian Cary 100 spectrophotometer in the range of 200-800 nm was used to record the UV-Vis absorption spectra. The PL emission measurements were performed at room temperature on a photoluminescence spectrophotometer Ls-50B Perkin Elmer equipped with Xe lamp ($\lambda = 320$ nm) as an excitation light source. A JEON 360 Transmission Electron Microscope (TEM) operated at 100 W was

used to observe morphology and size of the synthesized Quantum dots.

2.3. Synthesis CdZnTe quantum dots

In a typical synthesis 2.5 mmol of $\text{CdCl}_2 \cdot 2.5\text{H}_2\text{O}$ and 5, 10, 15 weight percent of Zn^{2+} is dissolved in 110 mL of water, and 12 mmol of the thiol stabilizer (TGA) is added under stirring, followed by adjusting the pH to appropriate values by dropwise addition of 1M solution of NaOH. The solution may be slightly turbid at this stage. The reaction mixture is placed in a three necked flask fitted. Under stirring, NaHTe (a purple clear liquid generated by the reaction of 2.4 mmol of Te powder with 5 mmol NaBH_4 in 8 mL water and stirring then cooling in an icebath for 10 min) is passed through the solution together for 20 min. CdZnTe precursors are formed at this stage. The precursors are converted to CdZnTe quantum dots by refluxing the reaction mixture at 95°C under helium-gas conditions.

3. RESULTS AND DISCUSSION

3.1. Optical properties of CdZnTe quantum dots

Figures 1, 2, 3 show photoluminescence (PL) spectra and absorptions (UV) of a size series of CdZnTe quantum dots. The spectra were measured on as prepared CdZnTe colloidal solutions which

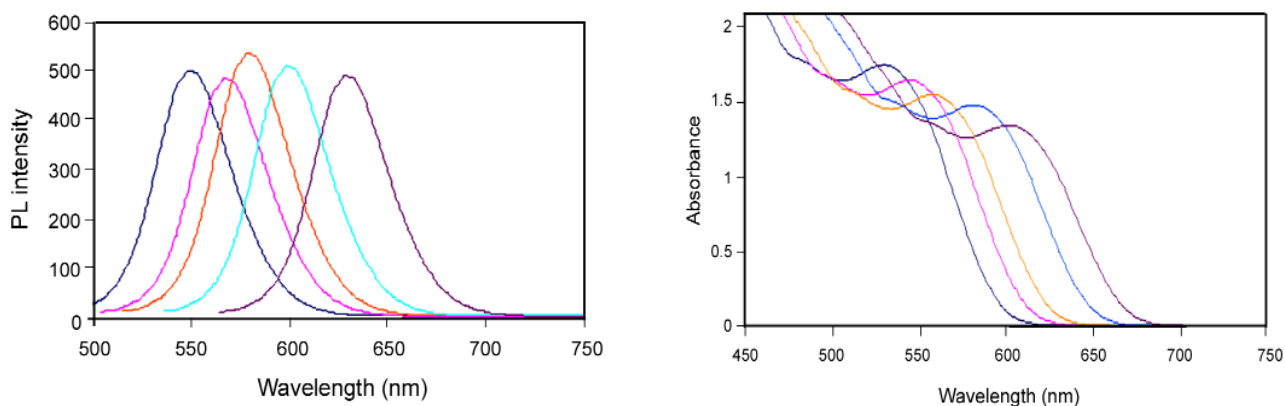


Figure 1: Fluorescence spectra and absorptions of CdZnTe (5%) quantum dots prepared at different reaction times.

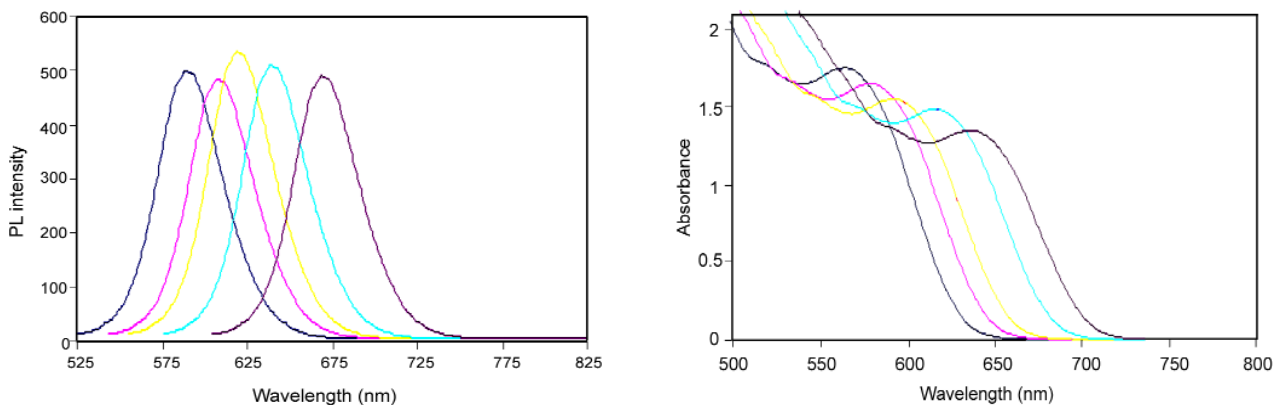


Figure 2: Fluorescence spectra and absorptions of CdZnTe (10%) quantum dots prepared at different reaction times.

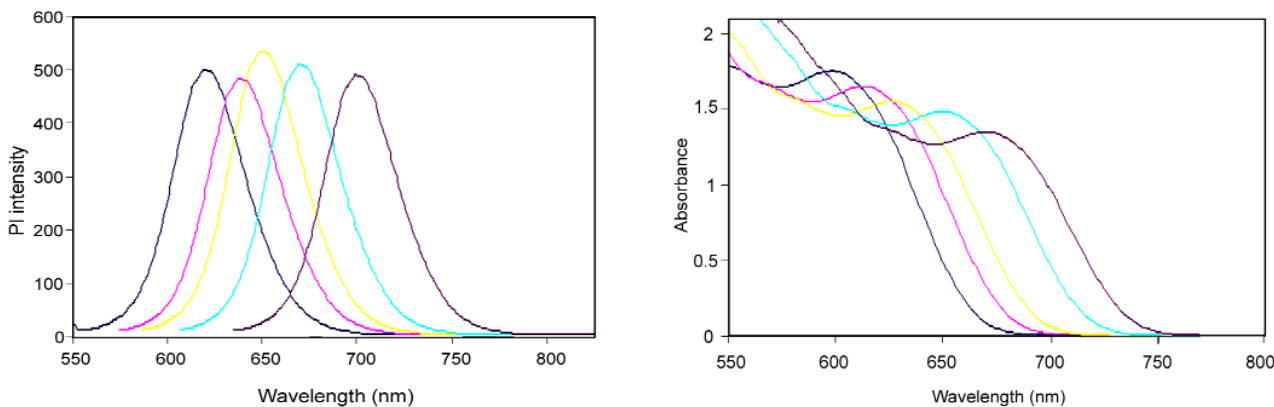


Figure 3: Fluorescence spectra and absorptions of CdZnTe (15%) quantum dots prepared at different reaction times.

were taken from the refluxing reaction mixture at different intervals of time. A clearly resolved absorption maximum of the first electronic transition of CdZnTe Quantum dots appears which shifts to longer wavelengths as the particles grow in the reaction process. The size of the growing CdZnTe Quantum dots is further controlled by the duration of reflux and can be easily monitored by absorption and PL spectra. The PL excitation spectra also display electronic transitions at higher energies when the heating time is extended from 30 min to 300 min in the presence of thioglycolic acid is used as the stabilizer. PL technique allows detection of the luminescence emitted by particles with selected size.

3.2. Morphology study and structure analysis of CdZnTe quantum dots

Figure 4 shows typical XRD patterns obtained from powdered precipitated fractions of CdZnTe quantum dots synthesized when the stabilizer is TGA. Five distinct diffraction peaks were observed values of 24.0°, 39.2°, 46.3° and 56.8° respectively, corresponding to the (111), (220), (311) and (400) crystalline planes. Figure 5 shows TEM obtained from powdered precipitated fractions of CdZnTe quantum dots. This distribution of spherical image shows a well homogenized quantum dots. Figure 6 shows the band gap of the Quantum dots decrease and the diameters of the Quantum dots continuously increase.

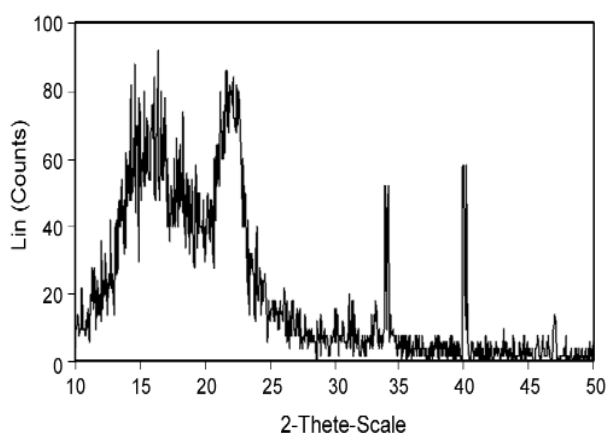


Figure 4: XRD pattern of the CdZnTe (5%) quantum dots.

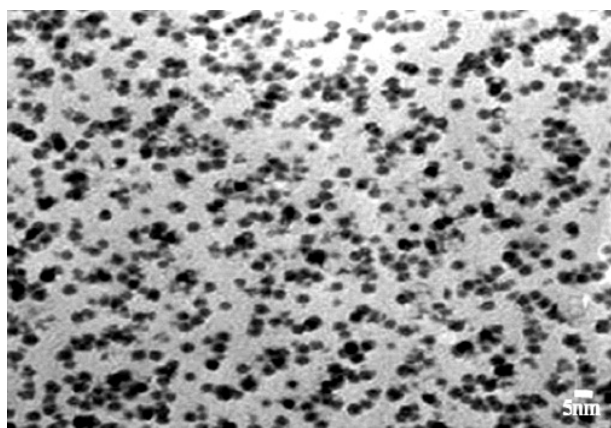


Figure 5: TEM of the CdZnTe (5%) quantum dots.

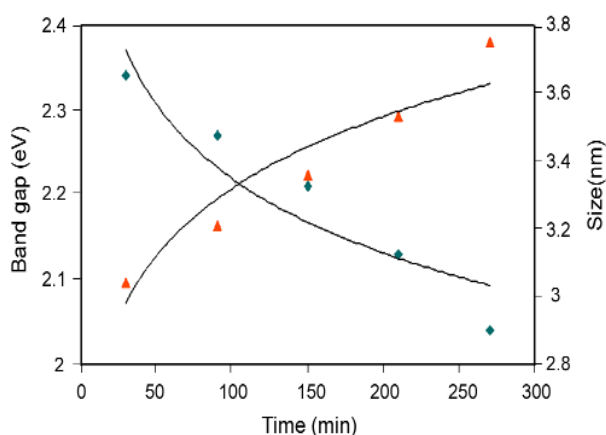


Figure 6: Band Gap and Size of CdZnTe quantum dots compared at different reaction times.

4. CONCLUSIONS

Water soluble CdZnTe Quantum dots have been reported in this paper with 0.8 nm in diameters. The Fluorescence spectra of CdZnTe quantum dots prepared at different reaction times functional groups of the thiol capping molecules of the quantum dots provide their water solubility. The method reported here is also very attractive for its simplicity compared to other methods for producing water soluble semiconductor Quantum dots. It also yields water soluble Quantum dots with photophysical properties superior to those presented by Quantum dots prepared directly in water.

REFERENCES

1. Chan W., Nie S., *Science*, **281**(5385) (1998), 2016.
2. Bruchez M., Moronne M., Gin P., Weiss S., Alivisatos A.P., *Science*, **281**(5385) (1998), 2013.
3. Alivisatos A.P., *J. Phys. Chem.*, **100**(31) (1996), 13226.
4. Colvin V.L., Schlamp M.C., Alivisatos A.P., *Nature*, **370**(1994), 354.
5. Klimov V.I., Mikhailovsky A.A., Xu S., Malko A., Hollingsworth J.A., Leatherdale C.A., Eisler, H.J., Bawendi M.G., *Science*, **290**(5490) (2000), 314.
6. Brus L., *J. Phys. Chem.*, **90**(12) (1986), 2555.
7. Meng L., Song Z.X., *Biochem. Biophys. Dev.*, **31**(2) (2004), 185.
8. Santra S., Yang H., Holloway P.H., Stanley J.T., Mericle R.A., *J. Am. Chem. Soc.*, **127**(6) (2005), 1656.