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Studies of Nucleation Phase of Mn-doped Cadmium-Selenide (CdSe) Quantum Dots Via Photoluminescence Spectroscopy

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Abstract

In this paper, we predict the nucleation phase of as-synthesized manganese (Mn) doped cadmium selenide (CdSe) quantum dots (QDs) at an intrinsic physical size of 3 (± 0.1 – 0.9) nm via photoluminescence (PL) studies. The nucleation phase was analyzed at temporal evolution (16, 46 and 90 mins) and temperature (210, 215 and 220 ºC) below the CdSe QDs reaction temperature (210 and 215 ºC) to it reaction temperature (220 ºC). The PL spectra`s observed to be against the QDs ripening behaviour of QDs since there are no prominent red-shift of PL spectra`s. However, the intensity of PL spectra`s shows to be varied with different temperatures and times.

***Keywords*:** Cadmium selenide; Quantum dots; Manganese doped; Semiconductor; Coarsening effect

1. Introduction

Mn-doped CdSe QDs (zinc blende) was tremendously significant to the semiconductor research since Mn incorporation into CdSe QDs promised a high-density diluted semiconductor for spintronic application and provide good traps for excitation electrons which is significant for electronic and optoelectronic devices [1]. The bandgap tunability can be achieved by tuning the size of the QDs [2] to target a specific application requirement. Furthermore, the intrinsic optical properties of CdSe QDs is reported to be tailored by the introduction of transition metal dopant (i.e. Mn, Mg and Zn) [3, 4]. The integration of size variation and introduction of transition metal dopant in CdSe QDs system drew significant attention to the outcome analysis and how it can be manipulated to the specific application direction [5]. Come to realize that the size of QDs was extremely sensitive to the slight change in reaction temperature and reaction time, it is interesting for us to studies the actual nucleation phase of doped CdSe QDs using the ripening process.

2. Experimental

Mn-doped CdSe QDs were prepared using Mn-Cd and Se as precursors. 0.5g of Mn acetate and 0.5 g of CdO, 25 ml of paraffin oil and 15 ml of oleic acid were loaded in a three-neck round bottom flask. The mixture was placed into a glove box in vacuum condition. The solution was heated to 160 ◦C and stirred until the CdO was completely dissolved and a light yellowish homogeneous solution was obtained. Then, 0.079 g of Se in 50 ml of paraffin oil was carefully heated in a glove box under vacuum condition to 220 ◦C with rapid stirring in another three necks round bottom flask. The solution turned light orange and then wine red. Then about 5ml of Mn-Cd solution was swiftly injected into the Se solution during rapid stirring. The temperature dropped to 210 ◦C immediately after the injection, then rose to 220 ◦C. The heating process was immediately stopped after the injection.

The particles size determination of Mn-doped CdSe QDs was performed using High-resolution Transmission Electron Microscope (HRTEM) LEO LIBRA instrument operating at 120 kV. The structural studies of Mn-doped CdSe QDs samples are performed using Panalytical Empyrean X-ray Diffractometer equipped with graphite monochromatized Cu Kα radiation (λ= 1.54060 Å) irradiated with a scanning rate of 0.02°s-1, and usable range of 2º - 80º (2θ) and emission analyses are operated by Pelkin Elmer LS55 Series PL with Xenon discharge lamp.

3. Results and discussions

Mn-doped CdSe QDs samples are successfully synthesized with a physical size of 3 (± 0.1 – 0.9) nm (Fig 1). The XRD diffractogram shows three well-defined peaks were observed at 2θ = 24.7 º, 41.6 º, and 49.3 º correspond to (111), (220) and (311) planes respectively (Figure 2) is evidence of zinc blende structure QDs.

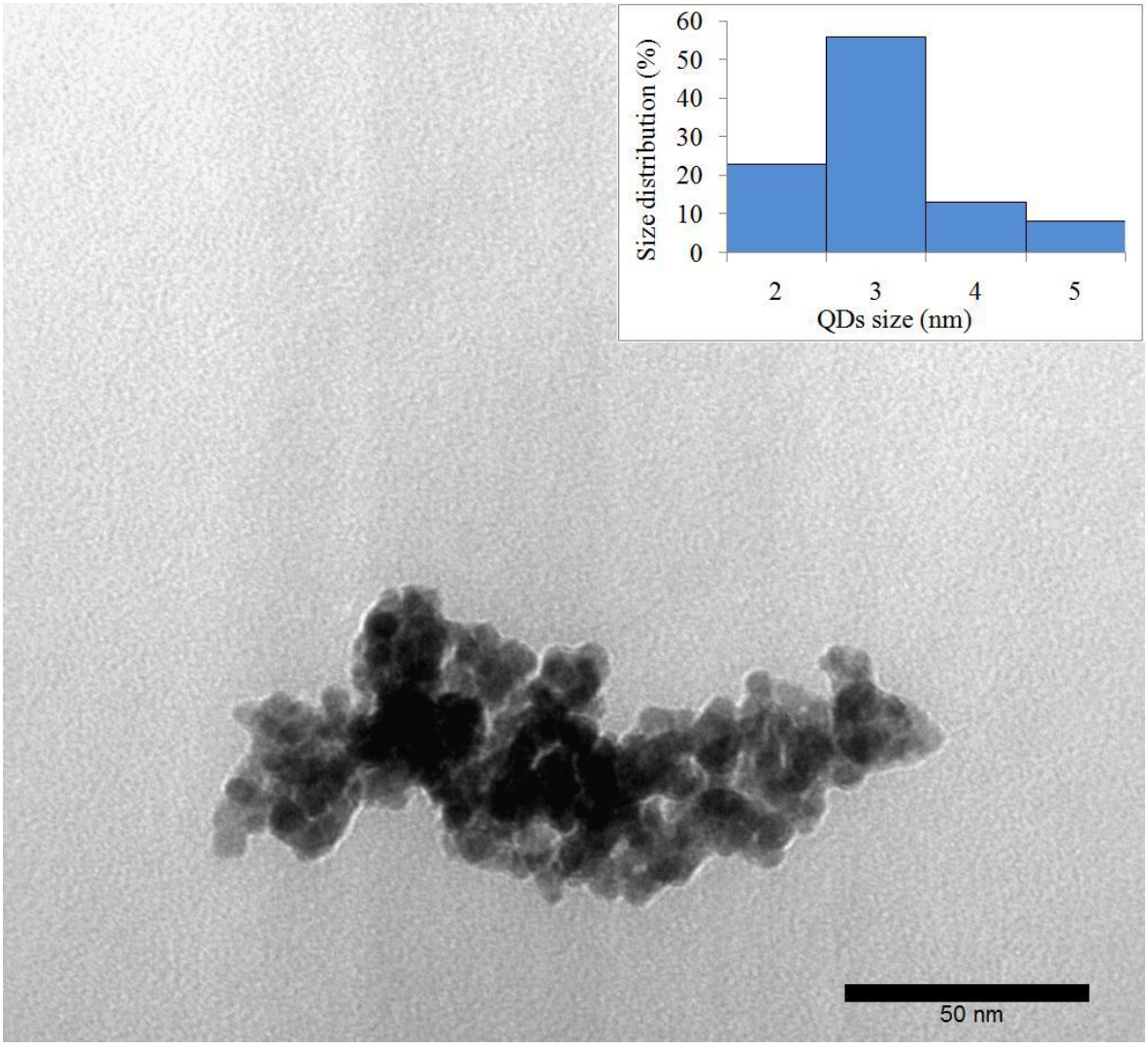

Figure 1: HRTEM image of Mn-doped CdSe QDs with QDs size distribution (insert) at immediate temporal evolution.

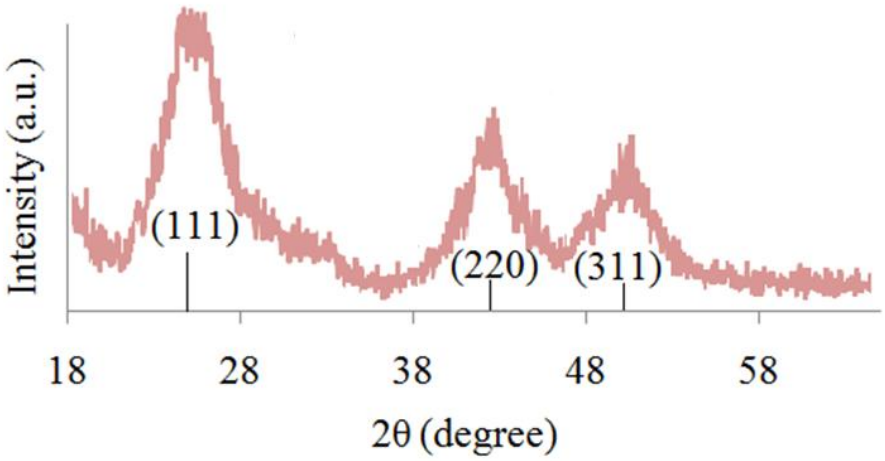

Figure 2: XRD patterns of Mn-doped CdSe QDs sample

Background pre-scan of paraffin liquid (figure 3) gives excitation wavelength at 217nm. While pre-scan of Mn-doped CdSe QDs gives excitation wavelength at 314 and 527 nm. Hence, excitation wavelengths at 527 nm were chosen as a background for the PL analysis. Overlapping of both paraffin liquid and QD PL at 314nm shows two significant peaks for the PL of the QD at around 440 and 465 nm, as well as broad peaks around 500nm.

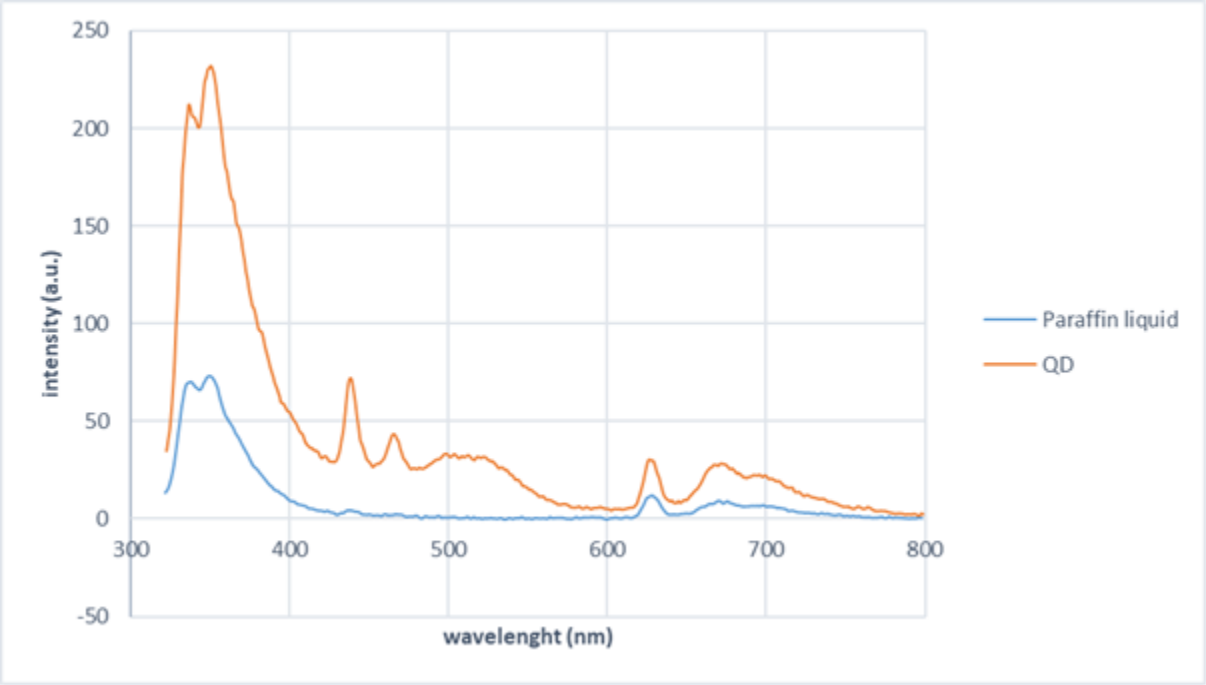

Figure 3: PL of paraffin liquid overlapping against PL of Mn-doped CdSe QDs

Based on the graphs in Figures 4, 5 and 6 observed that PL of QDs shows a uniform decreasing in fluorescence intensity values at around 527 nm peaks when reaction times are taken into consideration. 16 mins reaction time shows the highest fluorescence intensity value compared to 46 mins and 90 mins regardless of the reaction temperatures. The longer the reaction times, the lower the fluorescence intensity for all three reaction temperatures. On the other hand, the highest PL intensity value is recorded at a reaction temperature of 210 ºC, while the lowest is recorded at 215 ºC based on figure 5. There is no significant uniform trend going up from 210 to 220 ºC. However, no prominent red-shift was observed in this temporal evolution analysis; thus, it is predicted that no coarsening of QDs occur below the CdSe QDs theoretical reaction temperature (220 ºC).

Nevertheless, it is interesting to observed the deterioration of PL intensities with overall increases of ripening temperature and the highest PL intensity recorded at 210 ºC. This may indicate that the reduction of quantum efficiency upon the post-heating process below 220 ºC, and the nucleation process may start at 220 ºC.

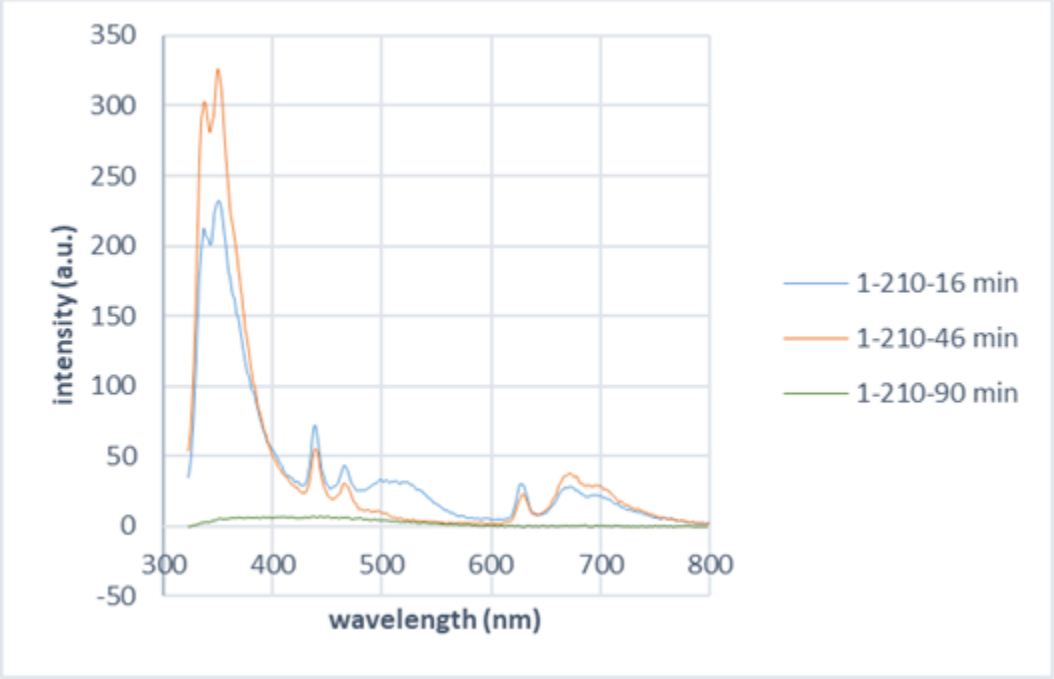

Figure 4: PL of sample 1 at 210ºC taken at different reaction times

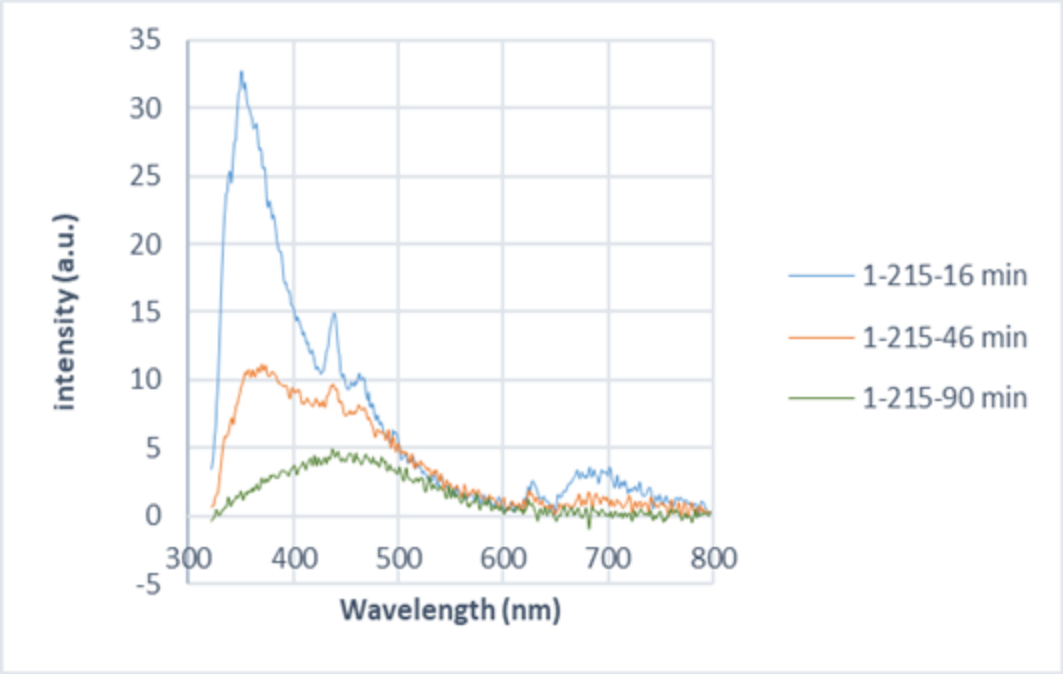

Figure 5: PL of sample 1 at 215℃ taken at different reaction times

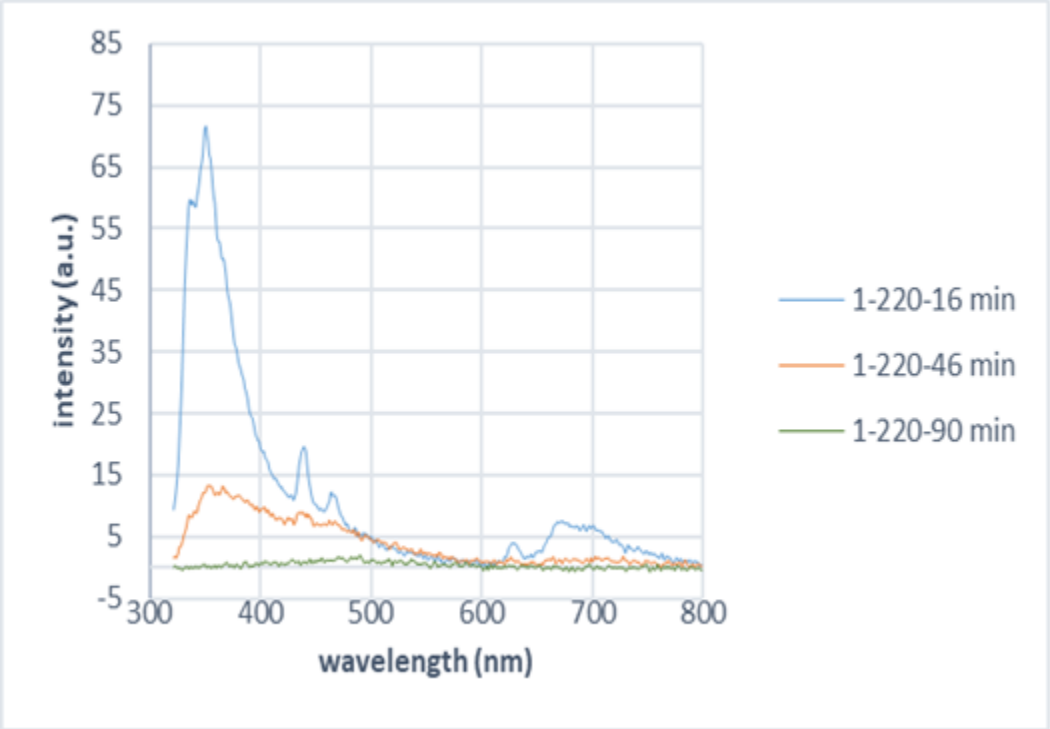

Figure 6: PL of sample 1 at 220℃ taken at different reaction times

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