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Study of the Effect of pH on the Optical Properties of the CdTe Quantum Dots

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Abstract

This research aims to study the effect of different pH values on the growth of CdTe nanoparticles during specific times. The reflux method has been used as a method for preparing CdTe quantum dots. A difference in absorbance and intensities of peaks at pH 10.5 and 11.5 was observed during the reaction period. The growth rate of the NPs (nucleation) was irregular at low pH values. Optical examinations showed that the best growth rate of NPs was at pH value 12.

Keywords: CdTe, Refluxing method, quantum dots, aqueous method, NPs, pH, UV-vis

دراسة تأثير الاس الحامضي على الخصائص البصرية للجسيم النقطي الكمومي CdTe

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الخلاصة:

يهدف هذا البحث إلى دراسة تأثير تغير درجات الأس الهيدروجيني على نمو الجسيمات النانوية CdTe خلال أوقات معينة. تم استخدام طريقة الارتداد كطريقة لتحضير النقاط الكمومية لـ .CdTe لوحظ اختلاف في امتصاصه وشدة القمم عند الأس الهيدروجيني 10.5 و 11.5 خلال فترة التفاعل. معدل نمو) NPs التنوي) غير منتظم عندما ينخفض الرقم الهيدروجيني. أظهرت الفحوصات البصرية أن أفضل معدل نمو لـ NPs يصبح عندما يرتفع الرقم الهيدروجيني إلى 12.

1. Introduction:

Quantum dots (QDs) refer to nanoparticles (NPs) in which electrons are confined from three directions. They have luminous properties different from the rest of the nanomaterials [1, 2]. Quantum dots have attracted attention in nanotechnology instead of the macroscopic semiconductors because of their unique properties and the possibility of their manipulation according to the required application. For example, NPs have a water-repellent surface and poor surface stability compared to the interior of the nanomaterial due to the activation energy [3, 4]. As a result, NPs have been used in many applications such as light-emitting devices [5], transfer energy [6], displays [7] biological and medical applications [8].

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Cadmium telluride (CdTe) is a semiconductor formed in the form of QDs nanomaterial according to the preparation method. It has a direct energy gap of about 1.53 eV, making it widely used in many applications such as solar cells, biological sensors, and other applications [9-11]. Recently, many studies have reported the different methods used to prepare CdTe such as the aqueous method using microwave irradiation [12], and the ultrasonic thermal synthesis [13]. The aqueous synthesis is currently being used because it is inexpensive, less toxic, and biosynthetic [14].

This paper tries to prepare CdTe simply and inexpensively in a single vessel. Cadmium acetate dihydrate (Cd (Ac_2) .$_2H_2O$) was used as a source of Cd. It was coated with 3-mercaptopropionic acid 3MPA to pave the atoms with a Te source taken from potassium tellurite ($KeTeO_3$). And sodium brohydrate ($NaBH_4$) for rapid reduction of Te to Te^{-2} and preventing its diffusion. The effect of different values of pH (10.5, 11.5, and 12) on the optical properties of the NPs was studied.

2. Experiment:-

2.1 Chemical Materials

The materials used are: Cd (Ac_2) .$2H_2O$ (95%) (From Germany, Merck KGaA), $KeTeO_3$ (95%) (From India), NaOH (from India), $NaBH_4$ (95%) (From India, Alpha Chemika), 3-MPA (99%) (From Sigma Aldrich), and deionized water. All materials were used without purification.

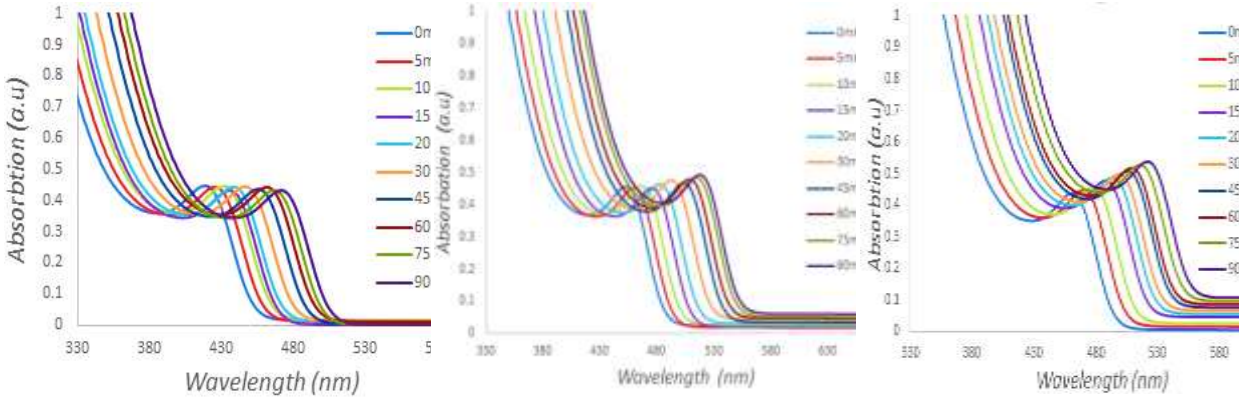
2.2 Preparation Method

The QDs were prepared using the same method used by Ncapayi et al. [15], using the refluxing method, and at a temperature of 1000C, inside a 250ml three necks flask. The 1M sodium hydroxide (NaOH) solution was used to modify the acidity to obtain the desired properties. During the growth process (reaction), 2ml of the prepared liquid was drawn at different time intervals (0min (the moment the reaction reaches the desired temperature), 5min, 10min, 15min, 20min, 30min, 45min, 60min, 75min, and 90min) to study and monitor the growth of NPs inside the prepared solution. Then, 8 ml of ethanol was added to the drawn-out solution to stop the reaction immediately and to remove any the remnants of unnecessary salts. After this, the solution was centrifuged at a speed of 5000 rpm for ten minutes to complete the separation process finally, the useless solution was removed, and 2ml of deionized water was added inside the tube and put in an ultrasonic device to break up the insoluble particles to obtain a complete dissolved solution. UV-Visible spectrophotometer was used to study the photoluminescence spectra of the prepared quantum dots.

3. Result and discussion:-

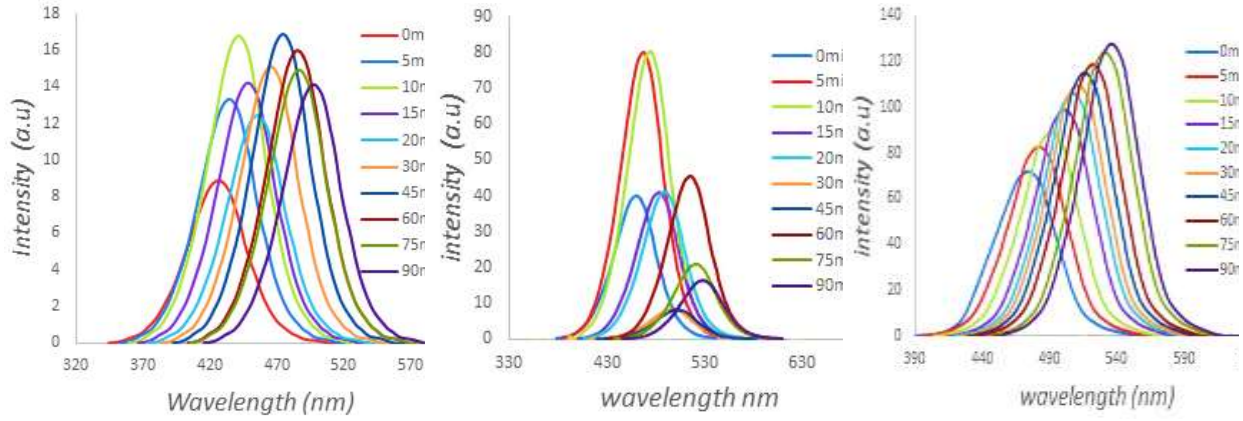
Figures 1 shows show the UV-Vis spectra, and Figure 2 shows the photoluminescence (PL) spectra of CdTe at different reaction times for different values of pH (10.5, 11.5, 12). Differences in absorbance and photoluminescence (PL) intensity can be noticed in Figure 1 (a and b) and in Figure 2 (a and b) at pH =10.5 and at 11.5 during the reaction period. This difference is attributed to the difference in the period of nucleation of each particle within the reaction solution. In other words, due to the difference in the speed of nucleation processes between one particle and another, i.e., there are incomplete (slow-growing) particles, and MPA incompletely encapsulates some particles. Therefore, diffences in the peaks absorbance and intensity were noticed [16, 17]. The decrease in PL intensity can also be attributed to the presence of precursors of $Cd^{+\ 2}$ ions in the reaction solution (non-reactive), which act as surface defects that capture electrons, thus decreasing the intensity of PL [18]. Therefore, when Cd^{+2} decreases inside the solution, the surface inertness increases intensities during the

reaction periods. It is possible that these ions were not completely reactive during the time the liquid was drawn out. From Figures (1c and 2c), the asymmetry of the distribution of both absorption peaks and PL peaks at pH = 12 is observed. It can attribute to the regularity of the nucleation or particle formation phases during the reaction periods [19]. Table 1 contains the information on NPs calculated from Figure 1 and Figure 2.



(a) **(b)** **(c)**

Figure 1: UV-Vis spectra of CdTe QDs at (a) pH=10.5, (b) pH=11.5, (c) pH=12 at different reaction time from 0min to 90min.



(a) **(b)** **(c)**

Figure 2: Photoluminescence (PL) spectra of CdTe QDs at (a) pH=10.5, (b) pH=11.5, (c) pH=12 at different reaction time from 0min to 90min.

Table 1: shows the optical properties of CdTe capped with 3MPA at different pH

PH=10.5				
Reaction Time (min)	*Wavelength (nm)*	*Intensity of peak (a.u)*	*Emission intensity (a.u)*	*Energy gap (eV)*
0	421	430	8.75	2.88
5	429	438	12.55	2.83
10	434	445	16.78	2.87
15	439	452	14	2.74
20	443	459	12.25	2.70
30	451	468	14.87	2.64
45	460	478	16.62	2.59
60	465	483	15.75	2.56
75	470	490	14.70	2.53
90	478	505	13.91	2.45

PH=11.5				
Reaction Time (min)	*Wavelength (nm)*	*Intensity of peak (a.u)*	*Emission intensity (a.u)*	*Energy gap (eV)*
0	456	463	39.01	2.67
5	464	472	80	2.62
10	470	478	78.27	2.59
15	479	486	39.89	2.55
20	486	492	40.03	2.52
30	495	500	8.13	2.48
45	500	505	7.96	2.54
60	512	519	44.33	2.38
75	517	525	20.39	2.36
90	456	528	16.37	2.34

PH=12				
Reaction Time (min)	*Wavelength (nm)*	*Intensity of peak (a.u)*	*Emission intensity (a.u)*	*Energy gap (eV)*
0	465	473	71.92	2.62
5	473	481	82.97	2.57
10	481	490	89.95	2.53
15	490	500	98.89	2.48
20	497	506	106.08	2.45
30	502	510	109.68	2.43
45	509	516	115.07	2.40
60	514	523	118.67	2.37
75	519	530	124.06	2.33
90	523	534	127.66	2.32

Conclusion

A difference in absorbance and PL intensities of peaks at pH 10.5 and 11.5 was observed during the reaction period. The growth rate of the NPs (nucleation) was irregular when the pH was decreased. Optical examinations showed that the best growth rate of NPs happened when the pH was 12. The decrease in PL intensity can also be attributed to the presence of precursors of Cd^{+2} ions in the reaction solution (non-reactive), which act as surface defects that capture electrons, thus decreasing the intensity of the PL.

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