

TIME-CONTROLLED SYNTHESIS OF CdTe QUANTUM DOTS FOR TUNABLE PHOTOLUMINESCENCE

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We report the synthesis and time-dependent photoluminescence evolution of colloidal CdTe quantum dots (QDs), demonstrating that reaction duration can be used as an effective lever to tune their emission characteristics. By varying the synthesis time from 3 to 16 minutes, we observed a pronounced red-shift in the fluorescence maxima—spanning from near-UV (~348 nm) to visible-red (~646 nm) when excited at ~200 nm—and a corresponding increase in emission intensity. These trends, consistent with classical quantum confinement theory, suggest larger nanocrystal diameters and improved surface passivation emerge over the course of the reaction. Such behavior is crucial for optoelectronic and bioimaging applications, which often rely on precise emission wavelength control and high photoluminescence quantum yields. While the substantial rise in fluorescence intensity points to enhanced quantum yields, definitive quantification would require comparisons against well-characterized standards. Nonetheless, these findings highlight the relative ease with which CdTe QD emission properties can be modulated by adjusting key synthesis parameters. Future work targeting extended reaction protocols and advanced capping strategies may further refine emission profiles and long-term stability for applications in nano-optoelectronics, sensing, and biomedical imaging.

Keywords: *CdTe quantum dots; Fluorescence; Quantum confinement; Reaction time; Surface passivation; Photoluminescence*

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INTRODUCTION

The study of CdTe quantum dots (QDs) has evolved considerably as researchers strive to understand and harness their unique size-dependent optical properties for diverse applications in bioimaging, optoelectronics, and solar energy conversion. Central to these properties is the quantum confinement effect, which arises when the QD radius approaches or falls below the exciton Bohr radius. Under these conditions, the electronic states become quantized, causing the band gap to widen as QD size decreases, and leading to corresponding shifts in absorption and photoluminescence (PL) spectra. Investigations have consistently shown that smaller QDs exhibit larger band gaps and therefore display blue-shifted emission, whereas larger QDs feature smaller band gaps and red-shifted photoluminescence [1,2,3]. Experimental work has linked these color variations directly to synthesis parameters, particularly reaction time and temperature. For instance, preparing CdTe QDs over extended periods or at higher temperatures results in larger crystallite sizes and a red-shift in both absorption and emission spectra [3,4,5,6]. These findings collectively illustrate how even minor adjustments to the synthesis process can dramatically alter the optical profile of CdTe QDs.

Complementing these experimental efforts, theoretical models like the Brus equation and the effective mass approximation (EMA) have guided interpretations of how QD size correlates with optical band gaps. The Brus equation modifies the standard Schrödinger equation to reflect quantum confinement in semiconductor nanocrystals, successfully reproducing the size-dependent band gap shifts observed in CdTe, CdS, ZnS, and similar materials [7,8]. However, its assumption of an idealized parabolic band structure sometimes conflicts with real systems that display nonparabolicity or multiple crystal phases [9,10]. The EMA provides an alternative perspective, simplifying complex electron-hole interactions by using effective carrier masses; although it is often accurate for relatively large QDs, the approximation may break down when quantum dots are too small, or when detailed surface states and local strain effects come into play [11,12]. These theoretical frameworks remain critical tools for designing experiments that target a specific spectral range—spanning from ultraviolet (~200 nm) to near-infrared (~800 nm)—and for identifying trends in absorption cross-sections and band-edge shifts [8,13].

A key factor in achieving high PL QYs and stable emission under various operating conditions is the deliberate passivation of surface traps, since unpassivated or defect-rich surfaces facilitate non-radiative recombination. Strategies involve either depositing inorganic salts or using chelating agents to seal undercoordinated sites and thereby suppress non-radiative decay [14,15]. In some cases, hybrid approaches incorporate multiple passivating species, which reduces hydroxyl traps, improves QD coupling in device films, and can even enhance solar cell efficiencies by a significant margin [16]. Solvent environments further influence QD stability; binary or ternary solvent systems can offer better dispersibility or more controlled QD growth compared to single-solvent protocols [17,18]. Nonetheless, even the best passivation strategies must account for photochemical degradation, a notable challenge in CdTe QDs. Under prolonged irradiation or certain buffer conditions, thiol ligands can detach, exposing fresh defect sites that precipitate QD aggregation and diminish PL [19,20]. Elevated synthesis temperatures, around 180°C in some protocols, can alleviate some of these

concerns by promoting better crystallinity and stoichiometry [21], yet controlling long-term photo-stability remains a fundamental obstacle. Parallel efforts thus explore cadmium-free alternatives (for example, AgInZnS QDs) to reduce toxicity and circumvent instability issues, though these materials often require distinct capping and passivation chemistries to match CdTe's optical performance [22].

In parallel, understanding the balance between radiative and non-radiative recombination pathways is crucial to optimizing QD devices in areas like optoelectronics. Radiative processes yield photon emission that underpins QD fluorescence, whereas non-radiative processes dissipate energy via phonons or defect-assisted transitions, thereby lowering PL QY [23,24]. Intrinsic defects such as cadmium vacancies represent efficient non-radiative centers, and their presence can degrade device performance by several percentage points [25]. In addition, more subtle processes like two-level recombination, where carriers first occupy a metastable intermediate before rapidly transitioning to a stable state, can raise the recombination rate significantly [26]. The external environment, including the dielectric medium and capping ligand coverage, can alter these dynamics by influencing exciton-phonon coupling and trap state energies [27,28].

Because of the inherent complexity of QD materials, researchers often employ a suite of complementary characterization methods. UV-Vis absorption and PL spectroscopy, which reveal excitonic features and relative band-gap changes, are the cornerstone tools [29]. Further methods like Fourier transform infrared (FTIR) spectroscopy or Raman spectroscopy capture vibrational information about ligands, as well as doping-induced changes in the lattice. Likewise, scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy (EDX) or inductively coupled plasma atomic emission spectrometry (ICP-OES) can confirm elemental composition and the ratio of precursors in final QD samples. Using multiple characterization techniques in tandem not only validates size and shape measurements but also helps disentangle the influences of surface functionalization and doping, ensuring that improvements in QD optical output can be reliably traced back to specific synthesis protocols or passivation steps.

Collectively, these studies suggest that continued advances in synthesis, passivation, and theoretical modeling will further expand the practical potential of CdTe QDs. Despite substantial headway in producing highly luminescent and stable QDs, persistent challenges include maintaining uniform quality across large-scale production, preventing photochemical degradation in demanding environments, and reducing the ecological risks posed by cadmium. Future research directions will likely incorporate additional *in situ* techniques for monitoring QD growth, develop refined theoretical tools that incorporate strain and surface complexities, and leverage machine learning algorithms to optimize synthesis in real-time. Such multidisciplinary efforts can substantially raise the performance benchmarks for CdTe QDs in next-generation devices, all while encouraging safer, more cost-effective, and environmentally responsible protocols that secure QDs' position as critical building blocks in modern nanotechnology.

METHODS

All experiments were performed under laboratory conditions that ensured cleanliness, safety, and reproducibility. Prior to any manipulations, all work surfaces and equipment were cleaned with ethanol, and personnel wore laboratory coats and protective gloves throughout. Inert conditions were maintained by purging glassware and reaction vessels with argon gas to remove atmospheric oxygen and moisture. Cadmium acetate dihydrate ($\text{C}_4\text{H}_6\text{CdO}_4 \cdot 2\text{H}_2\text{O}$) and tellurium (99% purity) were gently ground in separate mortar-and-pestle sets to obtain fine powders. Masses of these reagents were measured on an analytical balance, using small squares of aluminum foil to minimize loss of material and ensure accurate weighing. For the tellurium precursor, 24 mg of finely ground tellurium powder was transferred into a sealable glass vial, followed by the addition of 1.5 ml of tri-*n*-octylphosphine (TOP) via syringe. A small magnetic stir bar was placed inside the vial, which was then tightly sealed, purged with argon, and stirred under an inert atmosphere.

In a separate setup, 108 mg of cadmium acetate dihydrate was placed into a three-necked flask. Oleic acid (0.5 ml) and 20 ml of octadecene were then added to the same flask, along with a magnetic stir bar. One neck of the flask was equipped with an argon inlet, another contained the temperature probe that interfaced with the magnetic stirring hotplate, and the third was fitted with a sealed syringe port to allow reagent additions. The mixture was heated at 120°C for 1 hour under continuous argon flow, after which both this flask and the vial containing the tellurium–TOP solution were kept stirring on separate magnetic stirrers. After 2 hours, the tellurium–TOP mixture was taken off the stirrer; the three-necked flask containing cadmium acetate dihydrate, oleic acid, and octadecene was then heated under argon until the internal temperature reached 180°C. A 1.5 ml aliquot of the tellurium–TOP solution was withdrawn by syringe and quickly injected into the hot cadmium mixture. After 1 minute, an additional 0.5 ml portion of a cadmium acetate dihydrate/oleic acid/octadecene pre-mix (similarly prepared) was introduced, and its reaction time was carefully recorded. Further additions of 0.5 ml portions were made at 20-minute intervals, with a total of four injections. Once the desired reaction times had elapsed and the targeted synthesis stages were completed, the mixture was allowed to cool to room temperature under an argon blanket.

RESULTS

The fluorescence measurements obtained from the SHIMADZU RF-6000 spectrofluorophotometer for quantum dots synthesized at 3, 7, 9, and 16 minutes reveal clear time-dependent shifts in emission maxima and intensities under different excitation wavelengths, consistent with established quantum confinement phenomena in colloidal semiconductor nanocrystals. Examination of the emission profiles excited at approximately 200 nm indicates that the sample harvested

at 3 minutes exhibits its dominant emission feature near 348 nm with a peak intensity of about 5.88×10^5 arbitrary units, whereas the 7-minute sample shows an emission maximum at around 528 nm, displaying an intensity of roughly 5.08×10^5 . Notably, the 9-minute sample under the same excitation conditions red-shifts further to around 614 nm with an increased maximum intensity of approximately 9.87×10^5 , and by 16 minutes, the emission maximum extends to about 646 nm with a substantially higher peak intensity of around 3.06×10^6 . In parallel, measurements collected with an excitation near 400 nm unveil a similar pattern of progressive red-shifting: from ~410 nm (peak intensity $\sim 1.35 \times 10^6$) at 3 minutes, to ~546 nm ($\sim 3.41 \times 10^6$) at 7 minutes, ~628 nm ($\sim 9.84 \times 10^6$) at 9 minutes, and ~668 nm ($\sim 1.33 \times 10^7$) at 16 minutes (fig.1-fig.4). The consistent displacement of the emission maximum to longer wavelengths (higher nanometer values) over prolonged reaction times confirms that these cadmium tellurides (CdTe) quantum dots undergo size growth or increased crystallinity, aligning with the well-documented notion that larger quantum dots emit at lower energies (longer wavelengths) due to a reduction in the quantum confinement effect.

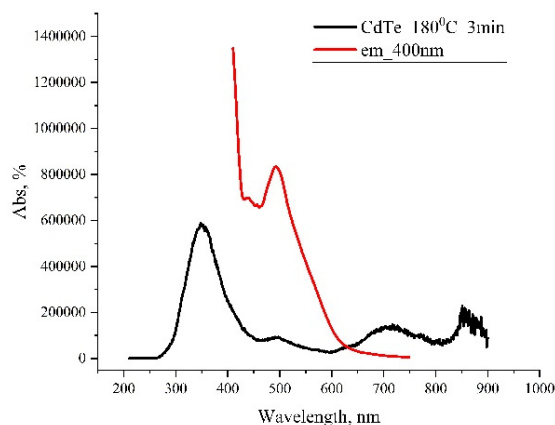


Figure 1. Emission spectra of CdTe QDs (3-minute synthesis) measured at two excitation wavelengths: 200 nm (black) and 400 nm (red). The shorter reaction time yields relatively higher-energy (blue-shifted) emission peaks, indicating smaller nanocrystal diameters

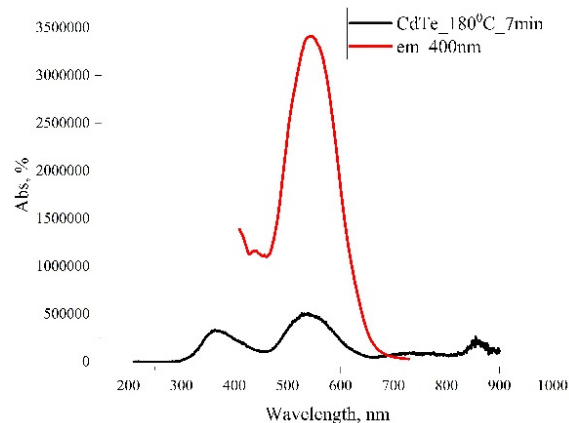


Figure 2. Emission spectra of CdTe QDs (7-minute synthesis) recorded at 200 nm excitation (black) and 400 nm excitation (red). Compared with the 3-minute sample, the emission peaks have shifted to longer wavelengths, reflecting increased particle size.

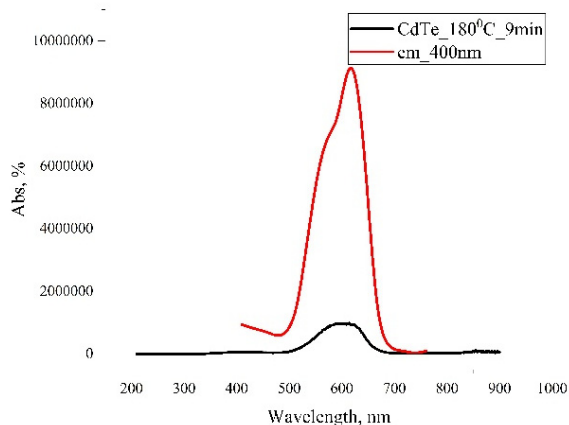


Figure 3. Emission spectra of CdTe QDs (9-minute synthesis), with excitation at 200 nm (black) and 400 nm (red). The pronounced red-shift and higher intensity suggest further growth of the nanocrystals and improved surface passivation.

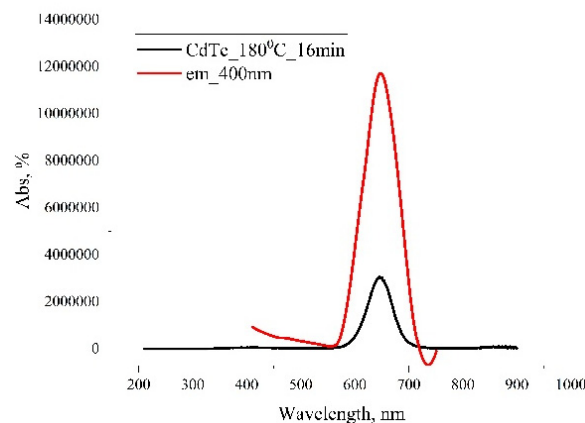


Figure 4. Emission spectra of CdTe QDs (16-minute synthesis) at 200 nm (black) and 400 nm (red) excitations. The most prominent red-shift and highest emission intensity of all samples underscore the largest average nanocrystal size reached within the studied reaction times.

Such marked red-shifts in fluorescence, coupled with the intensification of emission over time, are characteristic of colloidal quantum dot systems and can be understood in the context of exciton confinement: early in synthesis, smaller nanocrystals possess wider band gaps and thus fluoresce at higher energies. As reaction duration increases, dots grow and coalesce into larger crystalline domains, narrowing their band gap and shifting their emission toward the red region. This process is widely described in prior studies of CdTe and related systems, where an evolution from blue-green to orange-red emission is commonly reported and is frequently harnessed to tune optical properties for various applications. The progressive increase in emission intensity is similarly indicative of improved crystallinity or more efficient passivation of surface trap states, both of which can elevate the probability of radiative recombination. Although distinguishing between improvements in surface chemistry and pure particle growth requires complementary analytical methods (such

as transmission electron microscopy or X-ray diffraction), the growing intensities here are strongly suggestive of quantum dot surfaces becoming better stabilized or less defect-prone over time.

In some quantum dot experiments, fluorescence quantum yields can be approximated from relative integrated emission areas when measured against a reference fluorophore or when an absolute photoluminescence quantum yield setup is available. Given the data presented here, which comprise only emission intensities as a function of wavelength for the as-prepared quantum dots, it is not feasible to derive absolute quantum yields without additional information on the instrument's geometry, the incident photon flux, and either a well-characterized standard sample or integrating sphere measurements. The substantial increases in fluorescence intensity do suggest that quantum yields might be improving with longer synthesis times, but any numerical yield determination requires calibration against known standards under matched conditions. Literature on CdTe quantum dots generally indicates that proper surface passivation through thiol ligands and prolonged reflux can heighten quantum yields significantly, often from less than 10% to well over 50%, depending on the reaction environment, capping agents, and post-synthetic treatments. In the current context, the dramatic rise in raw fluorescence signal from 3 to 16 minutes is qualitatively aligned with such improvements, though exact quantification would demand additional experimental calibrations.

From a mechanistic standpoint, the correlation between reaction duration and progressive red-shifting is consistent with a diffusional growth model, wherein initial nuclei form during the early stages of reaction and subsequently ripen into larger nanocrystals. This ripening often follows an Ostwald-type process, with smaller, less stable crystallites dissolving and redepositing onto larger, more energetically favored particles. The net effect is a broadening of size distribution and an overall shift of the average crystal size toward larger diameters, translating to the observed movement of emission to the red. Parallel improvements in the structural order or surface coverage by capping ligands can ameliorate nonradiative decay pathways. Numerous studies of CdTe quantum dots synthesized in aqueous media under thiol stabilization attest to this dynamic, reinforcing that reaction control—whether by time, temperature, or reagent concentrations—offers a direct handle over emitted color and quantum yield.

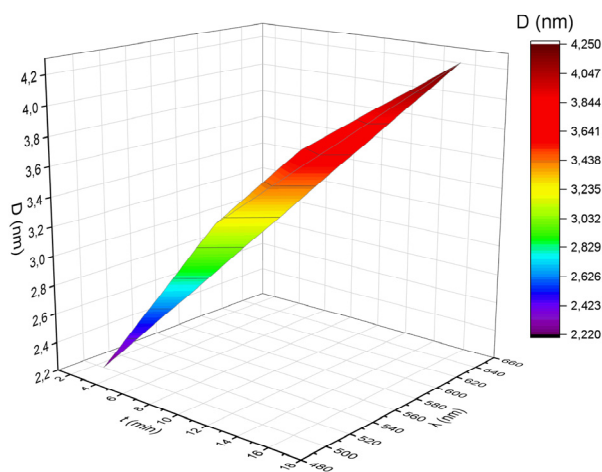


Figure 5. Three-dimensional plot illustrating how the estimated CdTe quantum dot diameter ($\langle D \rangle$, in nm) depends on synthesis time (t , in minutes) and emission wavelength (λ , in nm). Warmer (red) regions correspond to larger particle sizes, corroborating the progressive red-shift observed in Figures 1–4.

In light of these findings, the results strongly encourage further optimization of reaction duration as a straightforward lever to tailor the optical properties of CdTe quantum dots. Specifically, a 16-minute synthesis delivers the highest emission intensity and the greatest red-shift among the tested conditions, which could be especially advantageous for applications requiring long-wavelength emission with robust brightness, such as near-infrared bioimaging. The novelty and relevance of these observations reside in verifying that within a relatively short interval, one can systematically modulate fluorescence behavior to align with various technological demands—be it sensing, labeling, or incorporation into light-emitting diodes. Such tunability underscores the broader utility of quantum dots across nanoelectronics, photonics, and biomedical imaging. As future work, quantitative comparisons of quantum yield could be introduced by employing established reference fluorophores or absolute yield measurement protocols, thereby enabling a more precise link between particle size, crystallinity, and photoluminescence efficiency. The demonstrated capacity to alter emission maxima by nearly 300 nm over a quarter-hour reaction window highlights the potent versatility of solution-processed CdTe nanocrystals, substantiating their place at the forefront of ongoing research in functional nanomaterials.

CONCLUSIONS

This study confirms the strong influence of synthesis time on the optical characteristics of colloidal CdTe quantum dots, showing a systematic red-shift and enhanced fluorescence intensity as reaction duration increases. By comparing emission spectra at different time points (3, 7, 9, and 16 minutes) and excitation wavelengths (~200 nm and ~400 nm), we demonstrate that prolonged reaction times yield larger nanocrystals with narrower band gaps, as expected from

established quantum confinement principles. Concurrently, the increasing emission intensities across samples point to improved crystallinity or more efficient passivation of surface trap states over time. These observations emphasize the utility of relatively simple synthesis modifications—such as adjusting reaction duration—to finely tune the photoluminescence of CdTe QDs for diverse technological applications, from bioimaging to optoelectronics.

Nonetheless, while the significant rise in fluorescence suggests improved quantum yields, accurately determining absolute values would require further experiments with standard references or integrating-sphere measurements. Characterization methods such as transmission electron microscopy or X-ray diffraction could also provide direct confirmation of size evolution and crystallinity. Future work might investigate additional passivation agents and explore more precise temperature controls to further stabilize the QDs and minimize non-radiative losses. Broader adoption of these refined protocols could ultimately expand the range of wavelengths accessible to CdTe QDs and enhance their operational stability, fueling continued research and development in next-generation nano-optoelectronic and biophotonic devices.

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REFERENCES

- [1] P. Pooja, M. Rana, and P. Chowdhury, "Influence of size and shape on optical and electronic properties of CdTe quantum dots in aqueous environment," In IEEE International Conference on Photonics, **2136**, 040006 (2019). <https://doi.org/10.1063/1.5120920>
- [2] S. Sadjadi, F. Asgari, N. Farhadyar, and N. Molahasani, "Study of quantum size effects and optical characteristics in colloidal cd1-xsnxte quantum dots," Int. J. Nano Dimens. **5**(1), 57-61 (2014). https://www.sid.ir/EN/VEWSSID/J_pdf/1010420140108.pdf
- [3] E. Groeneveld, C. Delerue, G. Allan, Y.-M. Niquet, and C. de M. Donegá, "Size dependence of the exciton transitions in colloidal CdTe quantum dots," Journal of Physical Chemistry C, **116**(43), 23160–23167 (2012). <https://doi.org/10.1021/JP3080942>
- [4] S. Kiprotich, M.O. Onani, and F.B. Dejene, "High luminescent L-cysteine capped CdTe quantum dots prepared at different reaction times," Physica B: Condensed Matter, **535**, 202-210 (2018). <https://doi.org/10.1016/J.PHYSB.2017.07.037>
- [5] S. Kiprotich, F.B. Dejene, J. Ungula, and M.O. Onani, "The influence of reaction times on structural, optical and luminescence properties of cadmium telluride nanoparticles prepared by wet-chemical process," Physica B: Condensed Matter, **480**, 125-130 (2016). <https://doi.org/10.1016/J.PHYSB.2015.08.062>
- [6] J.S. Kamal, A. Omari, K.V. Hoecke, Q. Zhao, A. Vantomme, F. Vanhaecke, R. Capek, and Z. Hens, "Size-dependent optical properties of zinc blende cadmium telluride quantum dots," J. Phys. Chem. C, **116**(8), 5049–5054 (2012). <https://doi.org/10.1021/JP212281M>
- [7] A.A. Issa, and T.A. Hamoudi, "Theoretical studies of the optical properties of ZnS, ZnO and CdS nanoparticle using the Brus equation," Tikrit Journal of Pure Science, **27**(3), 15–18 (2022). <https://doi.org/10.25130/tjps.v27i3.55>
- [8] A. Kafel, and S.N.T. Al-Rashid, "Study using the Brus equation to examine how quantum confinement energy affects the optical characteristics of cadmium sulfide and zinc selenide," International Journal of Nanoscience, **22**(04), 2350034 (2023). <https://doi.org/10.1142/S0219581X23500345>
- [9] S.T. Harry, and M.A. Adekanmbi, "Ground state confinement energy of quantum dots and the Brus equation: A mathematical approach," Current Perspective to Physical Science Research, **8**, 146-155 (2024). <https://doi.org/10.9734/bpi/cppsr/v8/7943e>
- [10] J.-L. Liu, "Mathematical modeling of semiconductor quantum dots based on the nonparabolic effective-mass approximation," Nanoscale Systems: Mathematical Modeling, Theory and Applications, **1**, 58-79 (2012).
- [11] H. Yeo, J. Lee, M.E. Khan, H. Kim, D.Y. Jeon, and Y.-H. Kim, "First-principles-derived effective mass approximation for the improved description of quantum nanostructures," J. Phys. Mater. **3**, 034012 (2020). <https://doi.org/10.1088/2515-7639/AB9B61>
- [12] N.B. Abdallah, C. Jourdana, and P. Pietra, "An effective mass model for the simulation of ultra-scaled confined devices," Mathematical Models and Methods in Applied Sciences, **22**(12), 1250039 (2012). <https://doi.org/10.1142/S021820251250039X>
- [13] A. Gusev, O. Chuluunbaatar, S.I. Vinitsky, K.G. Dvoyan, E.M. Kazaryan, H.A. Sarkisyan, V.L. Derbov, et al., "Adiabatic description of nonspherical quantum dot models," Physics of Atomic Nuclei, **75**, 1210–1226 (2012). <https://doi.org/10.1134/S1063778812100079>
- [14] D. Qin, X. Guo, B. Chen, and Z. Rong, "Surface passivated CdTe nanocrystalline film and surface passivation treatment method and application thereof," (2019). U.S. Pat. No. 6,906,339.
- [15] D. Mandal, D. Mandal, N.V. Dambhare, N.V. Dambhare, A.K. Rath, and A.K. Rath, "Reduction of hydroxyl traps and improved coupling for efficient and stable quantum dot solar cells," ACS Applied Materials & Interfaces, **13**(39), 46549–46557 (2021). <https://doi.org/10.1021/ACSAMI.1C11214>
- [16] Q. Zhang, H. Huang, J. Wang, M. Wang, S. Qu, Z. Lan, T. Jiang, et al., "A universal ternary solvent system of surface passivator enables perovskite solar cells with efficiency exceeding 26%," Advanced Materials, **36**(50), 2410390 (2024). <https://doi.org/10.1002/adma.202410390>
- [17] L.T.A. da Rosa, I.F.S. Aversa, E. Raphael, A.S. Polo, A. Duarte, M.A. Schiavon, and L.S. Virtuoso, "Improving photoluminescence quantum yield of CdTe quantum dots using a binary solvent (water + glycerin) in the one-pot approach synthesis," Journal of the Brazilian Chemical Society, **32**(4), 860-868 (2021). <https://doi.org/10.21577/0103-5053.20200237>
- [18] T. Dudka, S.V. Kershaw, S. Lin, J. Schneider, and A.L. Rogach, "Enhancement of the fluorescence quantum yield of thiol-stabilized CdTe quantum dots through surface passivation with sodium chloride and bicarbonate," Zeitschrift für Physikalische Chemie, **232**(9-11), 1399-1412 (2018). <https://doi.org/10.1515/ZPCH-2018-1130>
- [19] J. Ma, J.-Y. Chen, Y. Zhang, P.-N. Wang, J. Guo, W. Yang, and C. Wang, "Photochemical instability of thiol-capped CdTe quantum dots in aqueous solution and living cells: Process and mechanism," Journal of Physical Chemistry B, **111**(41), 12012-12016 (2007). <https://doi.org/10.1021/JP073351+>
- [20] A.S. Tsipotan, M.A. Gerasimova, A.S. Aleksandrovsky, S.M. Zharkov, S.M. Zharkov, and V.V. Slabko, "Effect of visible and UV irradiation on the aggregation stability of CdTe quantum dots," Journal of Nanoparticle Research, **18**, 324 (2016). <https://doi.org/10.1007/S11051-016-3638-0>

- [21] A. Ospanova, Y. Koshkinbayev, A. Kainarbay, T. Alibay, R.K. Daurenbekova, A. Akhmetova, A. Vinokurov, *et al.*, “Investigation of the influence of structure, stoichiometry, and synthesis temperature on the optical properties of CdTe nanoplatelets,” *Nanomaterials*, **14**(22), 1814 (2024). <https://doi.org/10.3390/nano14221814>
- [22] L. Wang, H. Zhang, C. Lu, and L. Zhao, “Ligand exchange on the surface of cadmium telluride quantum dots with fluorosurfactant-capped gold nanoparticles: Synthesis, characterization and toxicity evaluation,” *Journal of Colloid and Interface Science*, **413**, 140–146 (2014). <https://doi.org/10.1016/J.JCIS.2013.09.034>
- [23] T. Kümmell, S.V. Zaitsev, A. Gust, C. Kruse, D. Hommel, and G. Bacher, “Radiative recombination in photoexcited quantum dots up to room temperature: The role of fine-structure effects,” *Physical Review B*, **81**, 241306(R) (2010). <https://doi.org/10.1103/PHYSREVB.81.241306>
- [24] C.H. Wang, T.T. Chen, Y.-F. Chen, M.-L. Ho, C.-W. Lai, and P.-T. Chou, “Recombination dynamics in CdTe/CdSe type-II quantum dots,” *Nanotechnology*, **19**, 115702 (2008). <https://doi.org/10.1088/0957-4484/19/11/115702>
- [25] S.R. Kavanagh, A. Walsh, and D.O. Scanlon, *Rapid recombination by cadmium vacancies in CdTe*, (Zenodo, 2021). <https://doi.org/10.5281/zenodo.4541602>
- [26] J. Yang, L. Shi, L.-W. Wang, and S.-H. Wei, “Non-radiative carrier recombination enhanced by two-level process: A first-principles study,” *Scientific Reports*, **6**, 21712 (2016). <https://doi.org/10.1038/SREP21712>
- [27] M. Califano, “Origins of photoluminescence decay kinetics in CdTe colloidal quantum dots,” *ACS Nano*, **9**(3), 2960–2967 (2015). <https://doi.org/10.1021/NN5070327>
- [28] B. Omogo, J. Aldana, and C.D. Heyes, “Radiative and non-radiative lifetime engineering of quantum dots in multiple solvents by surface atom stoichiometry and ligands,” *Journal of Physical Chemistry C*, **117**(5), 2317–2327 (2013). <https://doi.org/10.1021/JP309368Q>
- [29] M.A. Ruiz-Robles, F. Solis-Pomar, G.T. Aguilar, M.M. Mijares, R.G. Arteaga, O.M. Armenteros, C.D. Gutiérrez-Lazos, *et al.*, “Physico-chemical properties of CdTe/Glutathione quantum dots obtained by microwave irradiation for use in monoclonal antibody and biomarker testing,” *Nanomaterials*, **14**(8), 684 (2024). <https://doi.org/10.3390/nano14080684>

КЕРОВАНИЙ У ЧАСІ СИНТЕЗ КВАНТОВИХ ТОЧОК CdTe ДЛЯ РЕГУЛЬОВАНОЇ ФОТОЛЮМІНЕСЦЕНЦІЇ

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Ми повідомляємо про синтез і залежну від часу еволюцію фотолюмінесценції колоїдних квантових точок (КТ) CdTe, демонструючи, що тривалість реакції можна використовувати як ефективний важіль для налаштування їхніх характеристик випромінювання. Змінюючи час синтезу від 3 до 16 хвилин, ми спостерігали виражене червоне зміщення максимумів флуоресценції – від ближнього УФ (~348 нм) до видимого червоного (~646 нм) при збудженні при ~200 нм – і відповідне збільшення інтенсивності випромінювання. Ці тенденції, що відповідають класичній теорії квантового обмеження, припускають, що в ході реакції з’являються більші діаметри нанокристалів і покращена пасивація поверхні. Така поведінка має вирішальне значення для оптоелектронних і біовізуалізаційних програм, які часто покладаються на точний контроль довжини хвилі випромінювання та високі квантові виходи фотолюмінесценції. Хоча значне підвищення інтенсивності флуоресценції вказує на підвищені квантові виходи, остаточне кількісне визначення вимагатиме порівняння з добре охарактеризованими стандартами. Тим не менш, ці висновки підкреслюють відносну легкість, з якою властивості випромінювання КТ CdTe можна модулювати шляхом регулювання ключових параметрів синтезу. Майбутня робота, спрямована на розширені протоколи реакції та передові стратегії обмеження, може ще більше вдосконалити профілі викидів і довгострокову стабільність для застосувань у нанооптоелектроніці, зондуванні та біомедичних зображеннях.

Ключові слова: квантові точки CdTe; флуоресценція; квантове обмеження; час реакції; пасивація поверхні; фотолюмінесценція