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INTRODUCTION

Water-soluble cadmium telluride quantum dots (CdTe QDs) are utilized in various optoelectronic and biological applications due to their tunable size and optical properties. CdTe QD cores obtained from an aqueous synthesis route produces QDs with excellent water solubility, biological compatibility, and stability. However, aqueous synthesis using the traditional reflux method requires long reaction times that can generate many surface defects, resulting in a low quantum yield. Microwave irradiation methods can be used instead of the traditional reflux methods to rapidly synthesize high quality CdTe QDs. Microwave synthesis uses cheap precursor materials, has fast reaction times, does not require an inert atmosphere, and is environmentally friendly. In our study, CdTe QDs were synthesized by combining cadmium chloride and tellurium dioxide in the presence of 3-mercaptopropionic acid (MPA) in Millipore water. MPA was used as both a capping ligand and a reducing agent of tellurium dioxide. Reaction time, temperature, pH and the molar ratio of MPA stabilizer to Cd²⁺ were found to affect QD particle size and emission quantum yield. As expected, coating the CdTe QDs with CdS and ZnS shells induced significant red shifts in the absorption and emission maxima and increased the QD emission quantum yield. In the near future, experiments will be conducted to assess the toxicity of CdTe, CdTe/CdS, CdTe/ZnS, and CdTe/CdS/ZnS QDs which are prepared using our microwave-based technique in comparison to the same QDs when prepared using traditional synthesis routes in aqueous solutions and organic solvents, against bacteria and aquatic organisms which are ubiquitous in the environment.

OBJECTIVE

- ❖ Aim to develop a simple synthesis for CdTe QD cores and the addition of CdS and ZnS shells using only microwave irradiation
- ❖ ZnS present to decrease the toxicity of cadmium and increase quantum yield
- ❖ CdS shell is necessary since it acts as a transition shell due to the large lattice mismatch between CdTe and ZnS

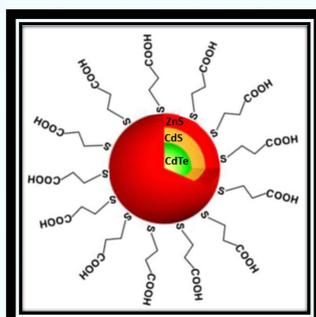


Figure 1. MPA capped CdTe/CdS/ZnS QD.

QD CORE SYNTHESIS

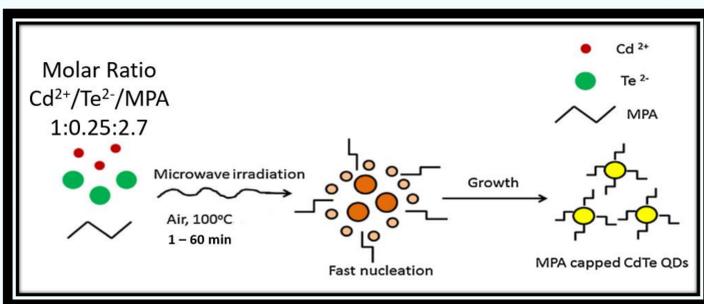


Figure 2. Schematic representing the synthesis of CdTe QDs via microwave irradiation.

A solution of cadmium chloride and MPA is brought to a pH of 10.0 with 1 M NaOH before the addition of tellurium dioxide in open air conditions. The solution is placed in a microwave reactor at 100°C for varying reaction times to produce MPA capped CdTe QDs.

SHELL ADDITION SYNTHESIS

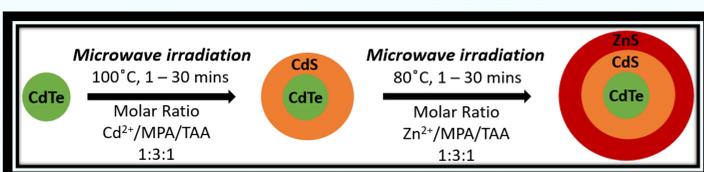


Figure 3. Schematic representing the CdS and ZnS shell addition synthesis via microwave irradiation.

For the CdS shell addition, a solution of cadmium chloride and MPA is brought to a pH of 8.5 with 0.5 M NaOH before the addition of thioacetic acid (TAA) and CdTe QD core solution. The solution is placed in a microwave reactor at 100°C for varying reaction times to produce MPA capped CdTe/CdS QDs. For the ZnS shell addition, a solution of zinc chloride and MPA is brought to a pH of 8.5 with 0.5 M NaOH before the addition of thioacetic acid (TAA) and CdTe/CdS QD solution. The solution is placed in a microwave reactor at 80°C for varying reaction times to produce MPA capped CdTe/CdS/ZnS QDs.

QD CORE CHARACTERIZATION

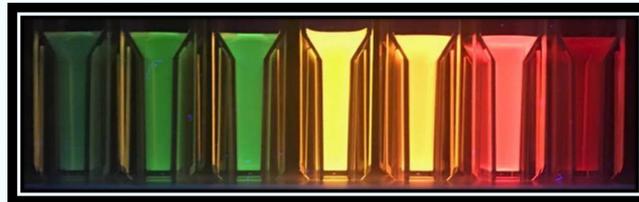


Figure 4. Fluorescence photograph of CdTe QD cores with growth times of (from left to right) 1 minute, 5 minutes, 10 minutes, 20 minutes, 30 minutes, 45 minutes, and 60 minutes.

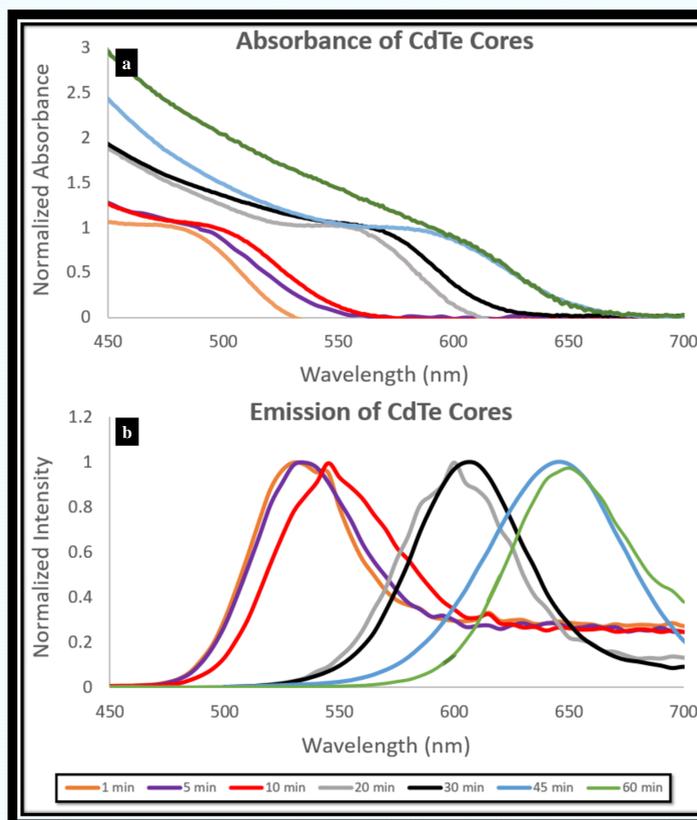


Figure 5. (a) Absorption spectra of CdTe QD cores at different reaction times; (b) Fluorescence emission spectra (λ_{ex} = 375 nm) of CdTe QD cores under UV irradiation.

Core Growth Time (min)	λ_{abs}	Diameter (nm)	Concentration (M)	λ_{em}	FWHM
1	470	1.27	7.15E-06	531	58
5	477	1.57	1.57E-06	534	62
10	488	1.98	2.38E-06	546	67
20	546	3.20	6.95E-07	600	59
30	560	3.34	1.17E-06	607	60
45	577	3.48	8.84E-07	645	56
60	590	3.58	3.86E-07	647	67

Table 1. Absorbance peak, emission peak, QD diameter, QD concentration, and full width at half maximum (FWHM) values of different growth times.

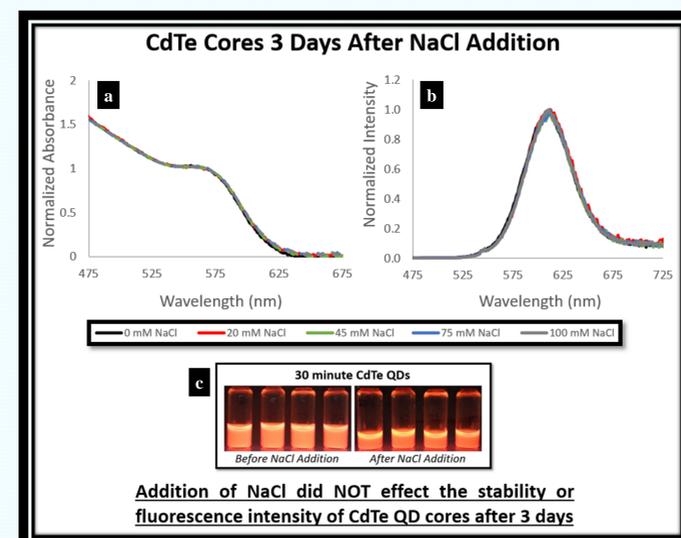


Figure 6. (a) Absorption spectra of 30 minute CdTe QD cores 3 days after NaCl addition; (b) Emission spectra of 30 minute CdTe QD cores under UV (λ_{ex} = 375 nm) irradiation 3 days after NaCl addition; (c) Fluorescence photographs of 30 minute QD cores before and after the addition of NaCl in varying concentration (from left to right: 20 mM, 45 mM, 75 mM, 100 mM).

RESULTS OF SHELL ADDITION

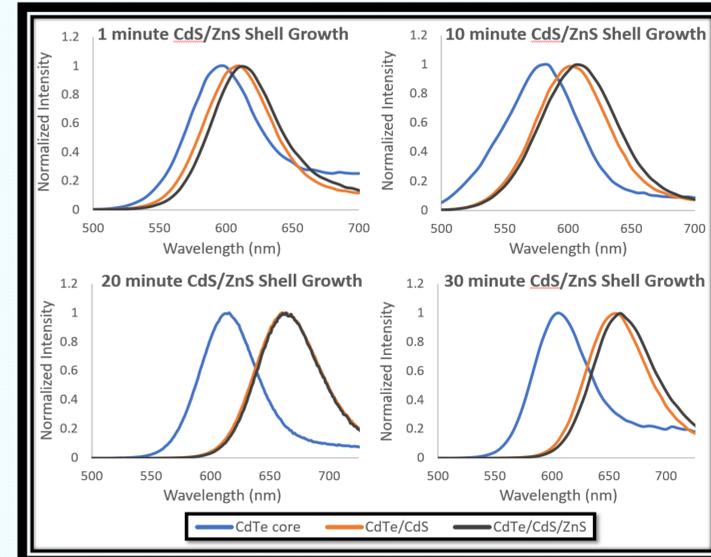


Figure 7. Fluorescence emission spectra of CdTe, CdTe/CdS, and CdTe/CdS/ZnS QDs under UV irradiation (375 nm).



Figure 8. Fluorescence photographs of (from left to right) CdTe, CdTe/CdS, and CdTe/CdS/ZnS QDs for CdS/ZnS shell growth times of (a) 1 minute, (b) 10 minutes, (c) 20 minutes, and (d) 30 minutes.

Quantum Yield (%) After Shell Addition

Shell Growth Time (min)	CdTe core	CdTe/CdS	CdTe/CdS/ZnS
1	5.06	21.75	20.77
10	7.45	8.84	19.52
20	7.31	23.12	50.63
30	6.16	37.72	41.88

Table 2. Quantum Yield (%) data for CdTe, CdTe/CdS, and CdTe/CdS/ZnS QDs with CdTe core growth time of 20 minutes and CdS/ZnS shell growth times of 1 minute, 10 minutes, 20 minutes, and 30 minutes.

FUTURE WORK

- ❖ Assess the toxicity against bacteria and aquatic organisms of CdTe, CdTe/CdS, CdTe/ZnS, and CdTe/CdS/ZnS QDs prepared using the microwave based technique in comparison to QDs produced through the traditional organic and aqueous synthesis routes
- ❖ Experiments to determine the chemical and photo stability of CdTe, CdTe/CdS, and CdTe/CdS/ZnS QDs of varying shell sizes in the presence of phosphide and salt buffers
- ❖ Perform a ligand exchange to replace 3-mercaptopropionic acid (MPA) with a bidentate ligand to measure the effects of increasing ligand bonding affinity on QD emission quantum yield

CONCLUSION

- ❖ Aqueous synthesis of CdTe QDs via microwave irradiation is simple, fast, and cheap in comparison to the typical reflux methods
- ❖ Increasing the reaction time results in red shifts in the absorption and emission maxima, indicating growth of QDs during heating treatment
- ❖ Coating the CdTe QDs with CdS and ZnS shells causes a significant red shift in the absorption and emission maxima and increases the QD emission quantum yield
- ❖ The emission quantum yield and emission peak widths obtained for CdTe/CdS/ZnS quantum dots are superior to any other quantum dots of this composition, particularly in aqueous solution. Yet, future studies will aim to lower the emission peak width of the quantum dots further

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