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Continuous-Flow Synthesis of CdTe Quantum Dots in Microfluidic System

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MS Physics, November 2020

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AGENDA

NANOSCALE

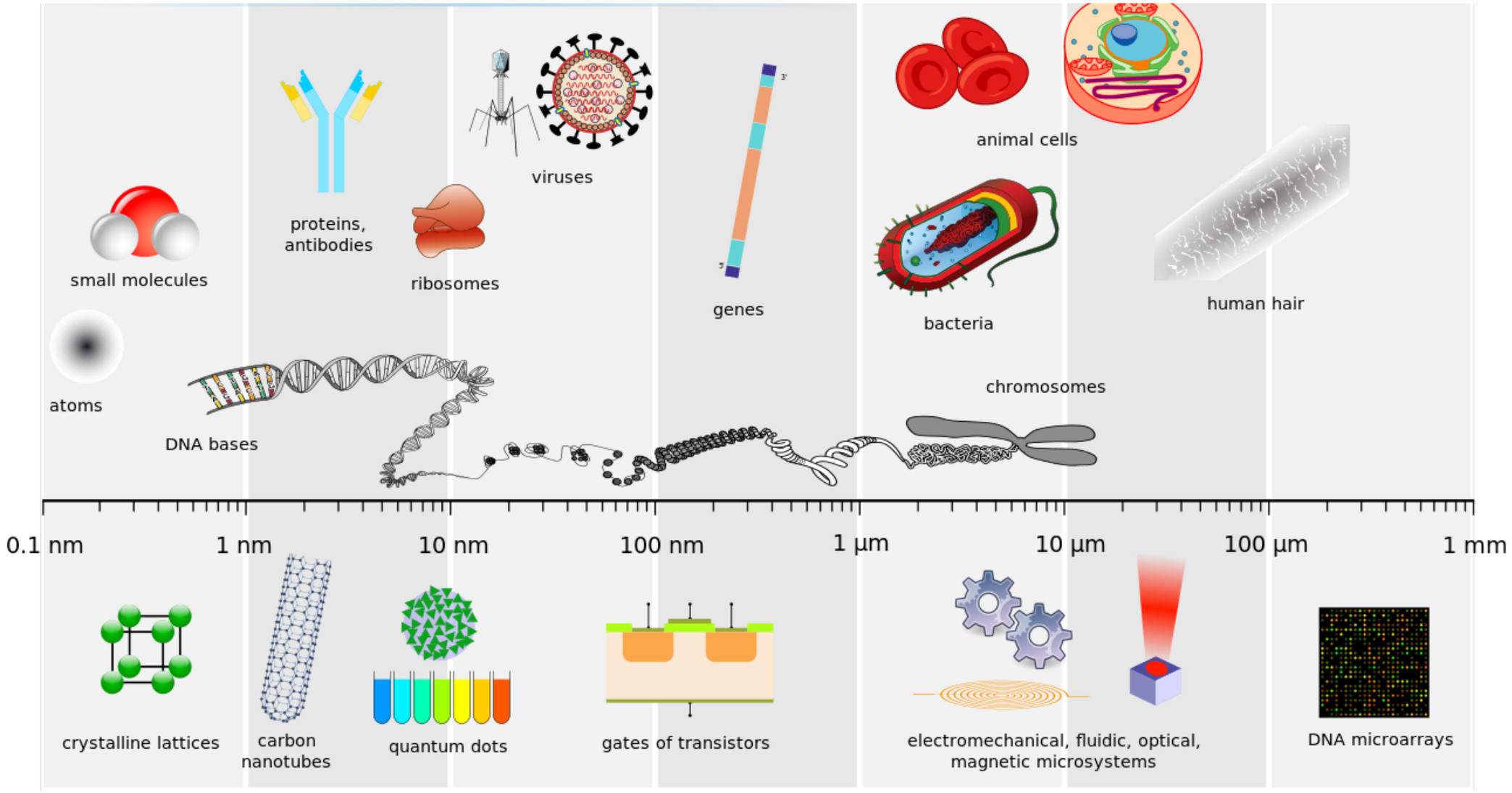
QUANTUM DOTS

MICROFLUIDIC SYSTEM

RESEARCH IDEA

RESULTS

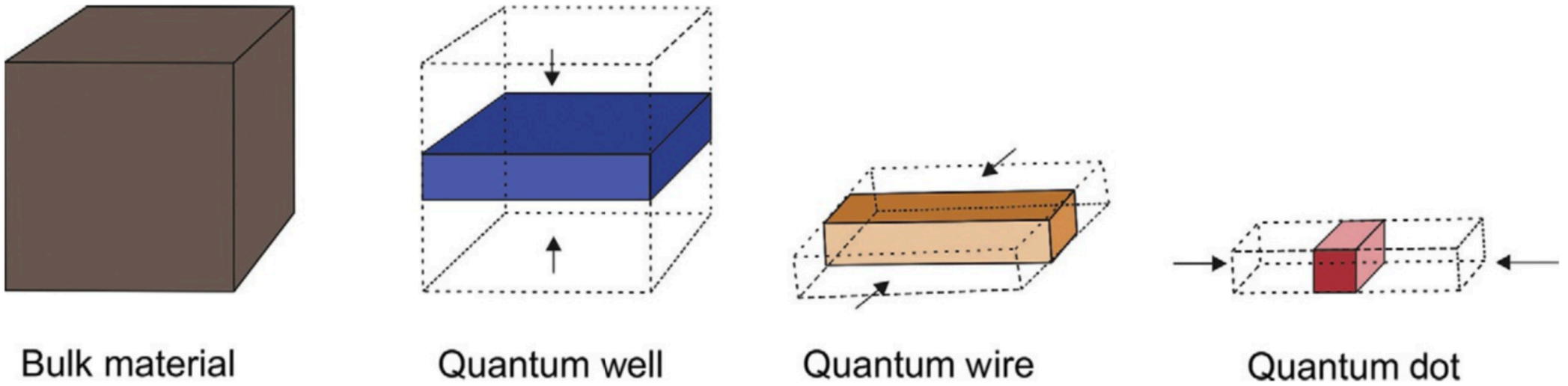
NANOSCALE



https://commons.wikimedia.org/wiki/File:Biological_and_technological_scales_compared-en.svg Credit: Guillaume Paumier, Philip Ronan, NIH, Artur Jan Fijałkowski, Jerome Walker, Michael David Jones, Tyler Heal, Mariana Ruiz, Science Primer (National Center for Biotechnology Information), Liquid_2003, Arne Nordmann & The Tango! Desktop Project Creative Commons Attribution-Share Alike 2.5 Generic license.

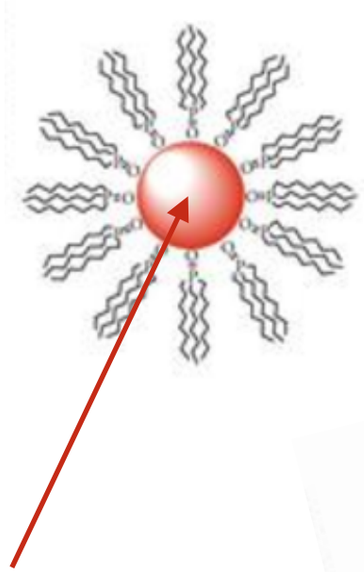
NANOSTRUCTURES

Figure credits: Quantum Nanostructures (QDs): An Overview D. Sumanth Kumar, B. Jai Kumar and H.M. Mahesh
Department of Electronic Science, Thin Films and Solar Cells Laboratory, Bangalore University, Bengaluru, India

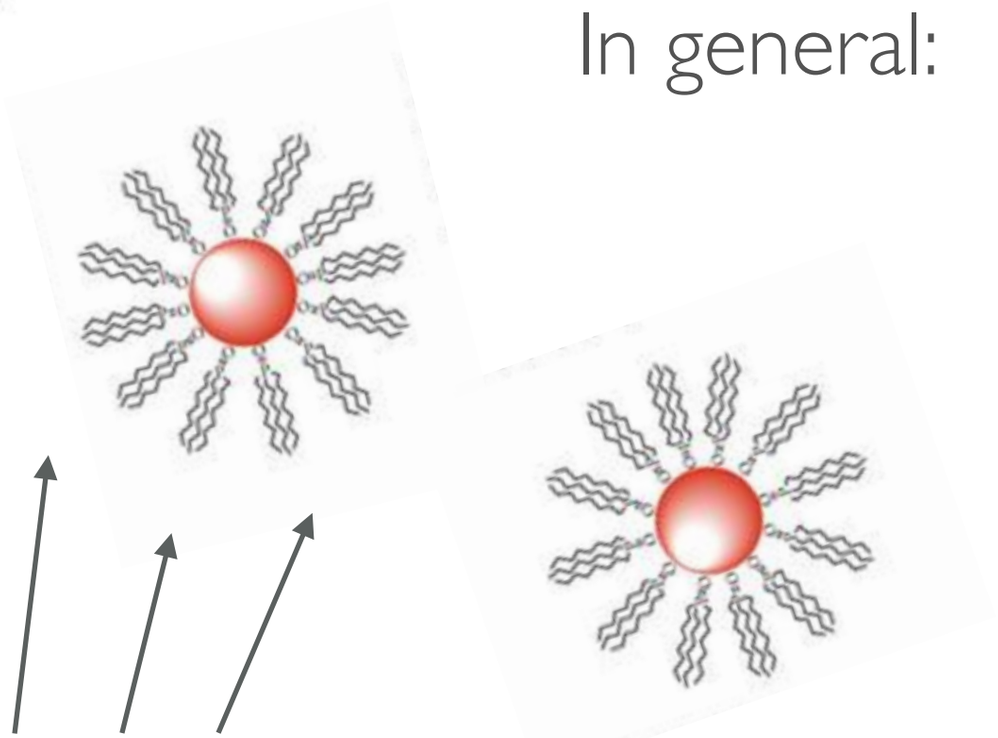


QDs are 0-dimensional structures ⟶ Electrons are confined in three dimensions.

QUANTUM DOTS



INORGANIC CORE



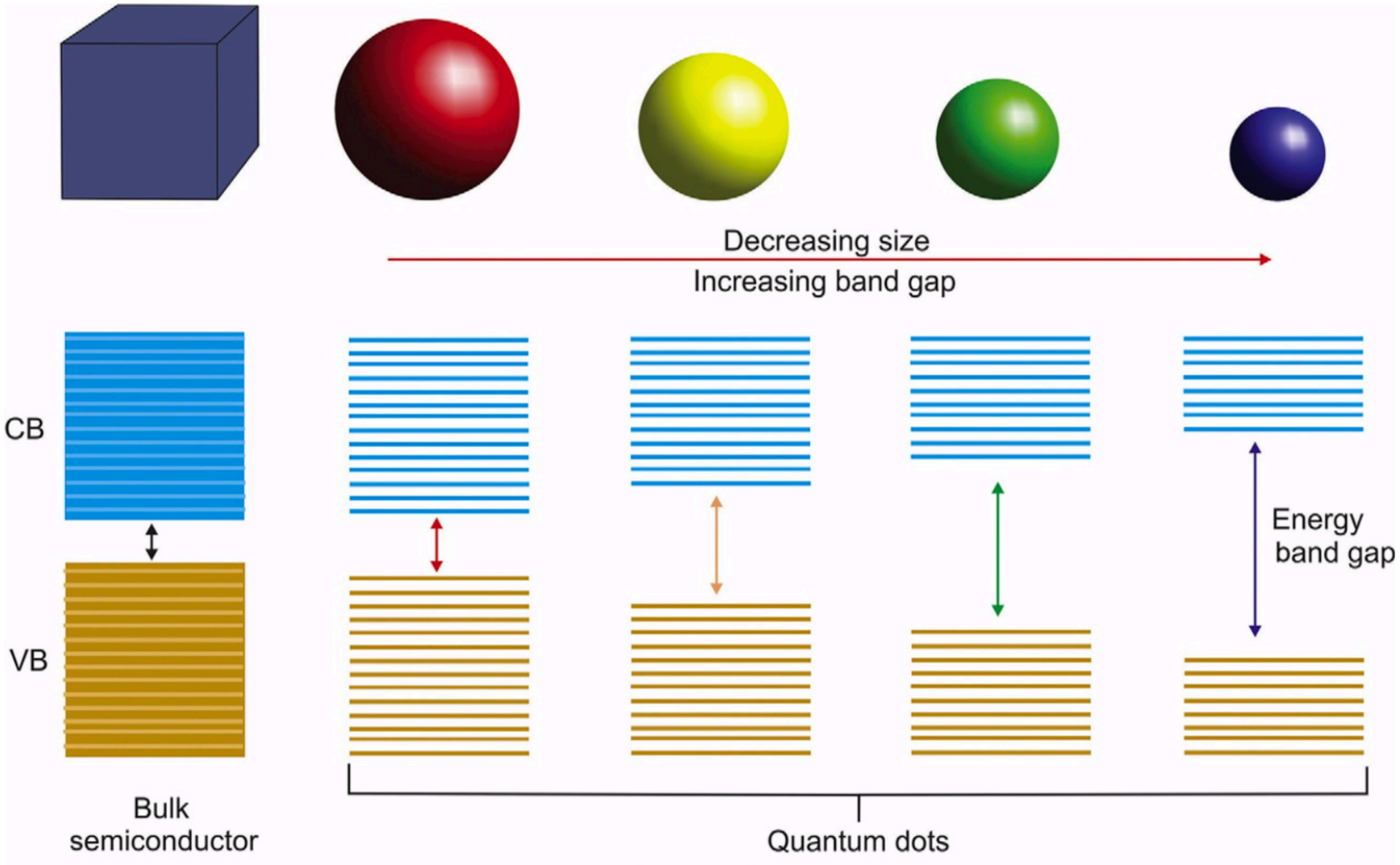
ORGANIC LIGANDS

SIZE: 1 - 20 nm

In general: BOHR RADIUS!

depends on the material

QUANTUM DOTS



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Department of Electronic Science, Thin Films and Solar Cells Laboratory, Bangalore University, Bengaluru, India

QUANTUM DOTS

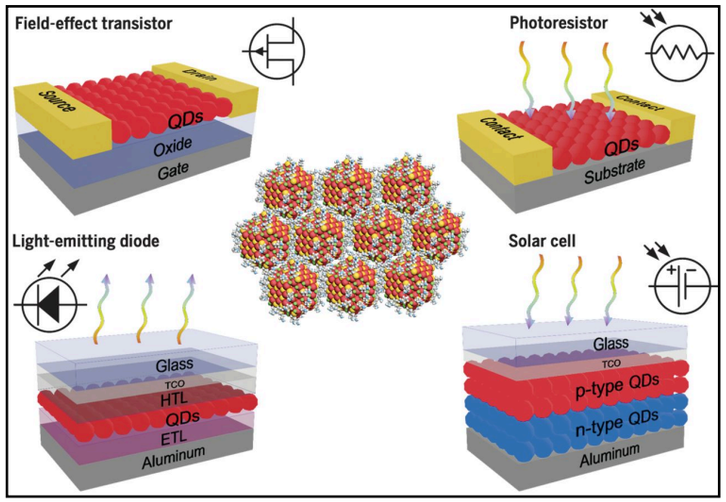
UNUSUAL PROPERTIES:

- high photoluminescence
- narrow emission
- tunable wavelength (from UV to IR)
- photochemical stability

Image credits: https://www.dday.it/redazione/15213/cosa-sono-le-tv-quantum-dots

APPLICATIONS:

- optoelectronic devices
- quantum computing
- displays
- medical imaging



Building devices from colloidal quantum dots By Cherie R. Kagan, Efrat Lifshitz, Edward H. Sargent, Dmitriv. Talapin *SCIENCE*26 AUG 2016

CHARACTERIZATION

- X-Ray Powder Diffraction Analysis → characterization of crystalline materials; determination of unit cell dimensions; measurement of sample purity
- Optical Absorption Spectroscopy → determination of energy band-gap; calculating the size of QDs
- Photoluminescence Spectroscopy → the photoluminescence peak wavelength
- Tunneling Electron Microscopy → 2D images of the nanocrystal; determination of the size and shape
- Scanning Electron Microscopy → 3D images of the nanocrystal; determination of the size and shape; characterization of material structures (SEM/EDX)

MICROFLUIDICS SYSTEM

Image credits: Darwin Microfluidics
from the website https://darwin-microfluidics.com/

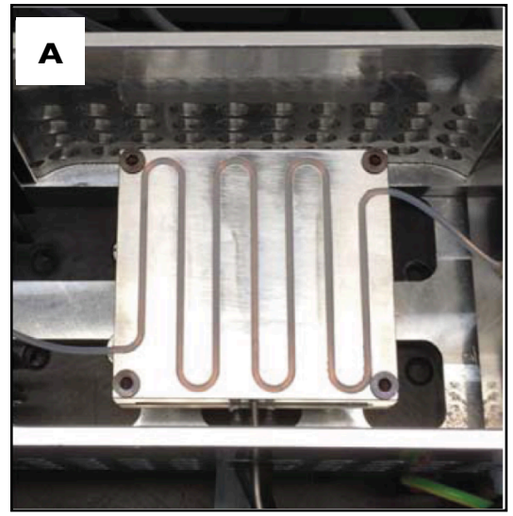
SYRINGE PUMPS

TUBING

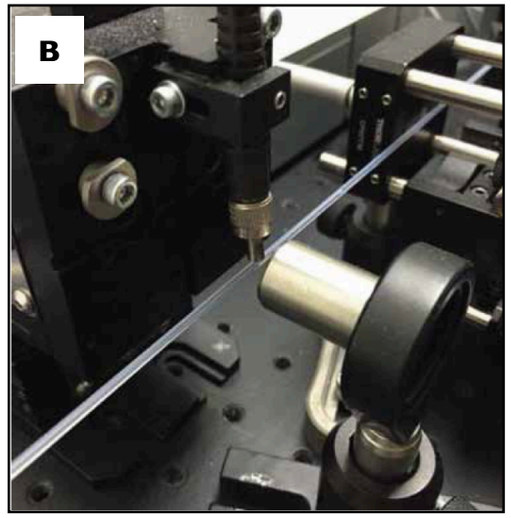
CONNECTIONS

RESERVOIRS

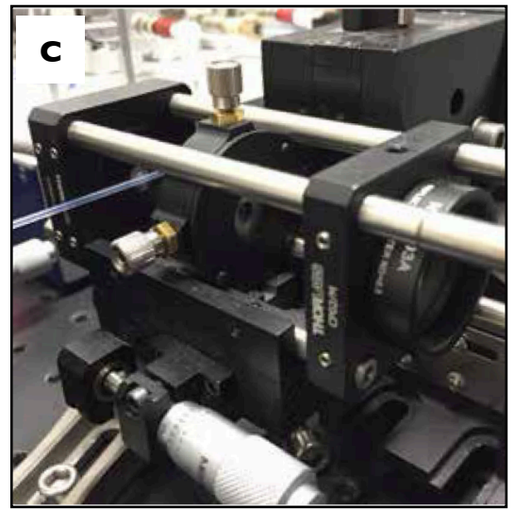
Fig. (a) Image of PTFE tubing embedded into a heated block. (b) Image of an in-line fluorescence detector. (c) Image of an in-line absorption unit. Image credits: Acc. Chem. Res. 2017, 50, 1248−1257



HEATING



DETECTORS



MICROFLUIDICS SYSTEM

PRECISE CONTROL OVER CRUCIAL PARAMETERS:

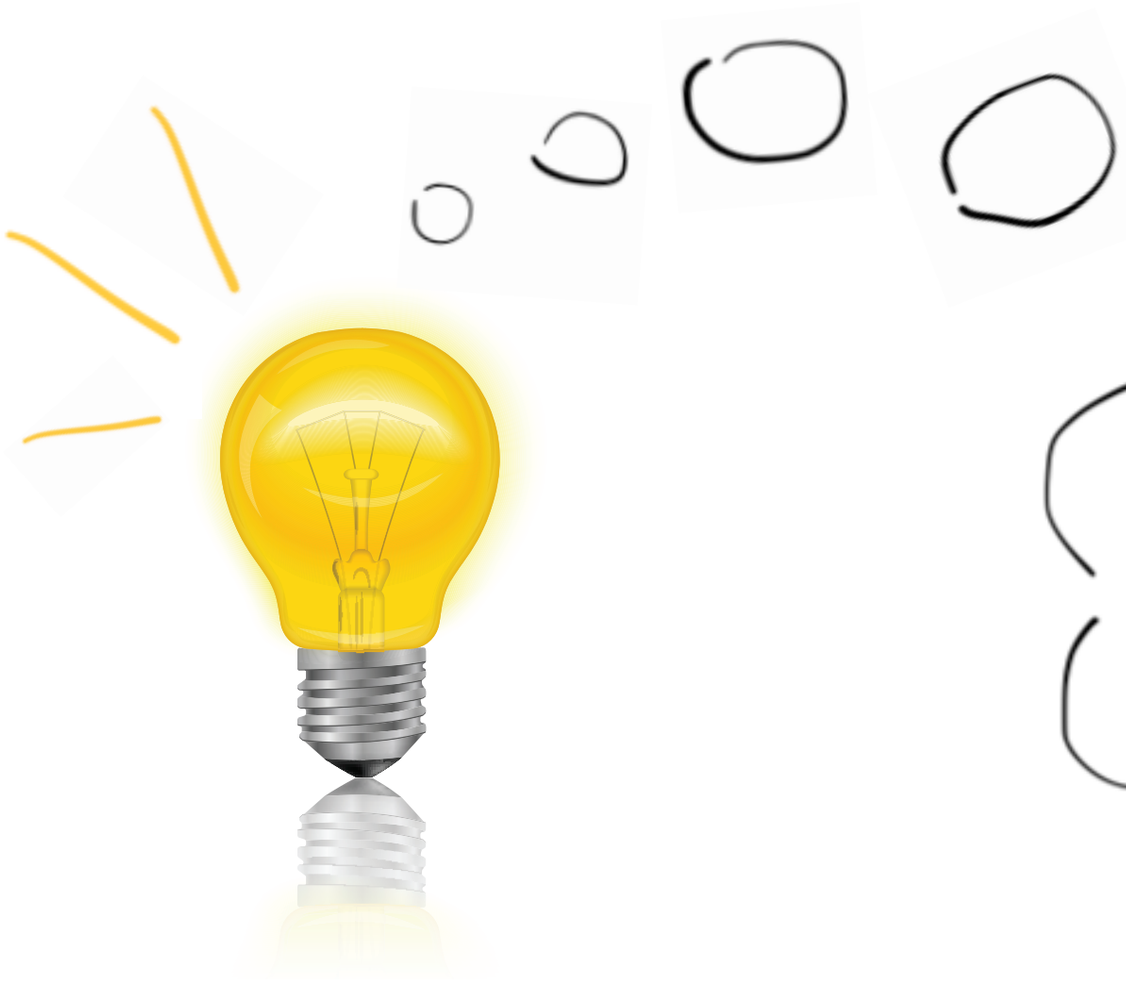
- Temperature
- Flow velocity
- Cross section area
- Reaction time

BENEFITS:

- Efficient mixing
- High heat and mass transfer
- High surface-to-volume ratio
- Temperature control
- Continuous production
- Low reagents consumptions

IDEAL FOR LARGE-SCALE SYNTHESIS

RESEARCH



THE IDEA

Magnetic Quantum Dots

Fe_3O_4 / CdTe

synthesized in
microfluidics system

CdTe QDs

MY PROJECT

Optimize the synthesis of CdTe quantum dots by Microfluidics System

SYNTHESIS

CdTe QDs synthesis recipe

<u>In a flask A:</u>

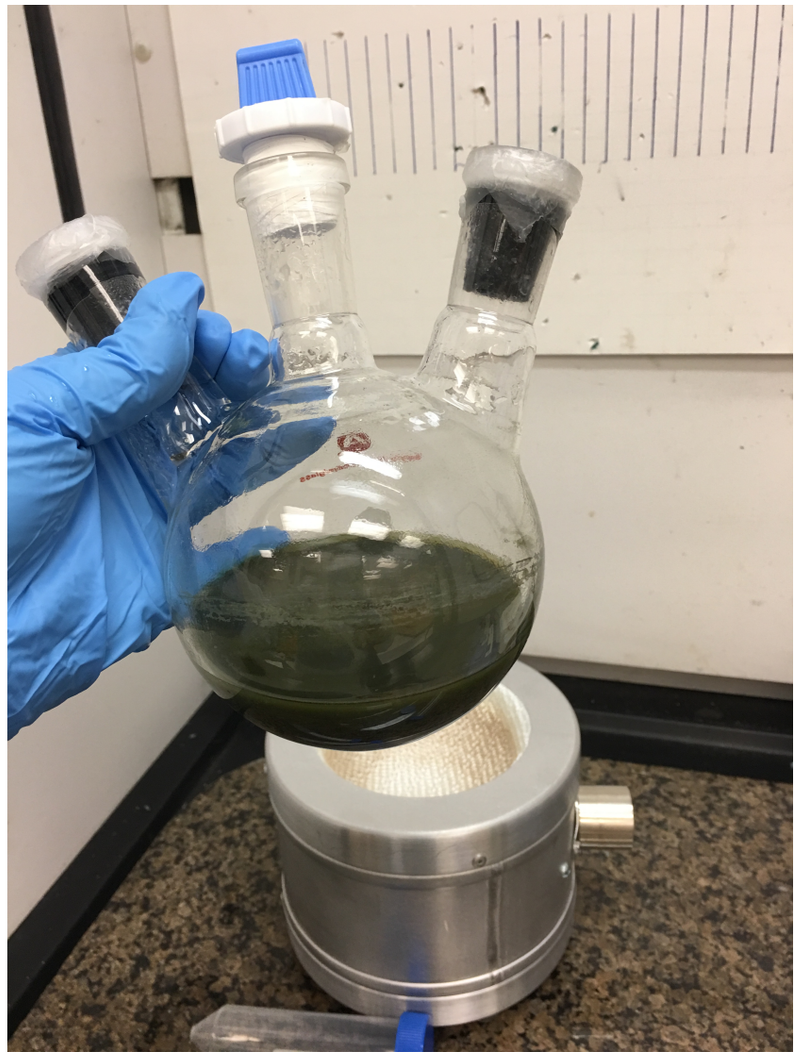
0.475 g of $CdCl_2 \cdot 2.5\ H_20$ (n=2,09 mmol) dissolve in 100 ml of deionized water, stir for 10 minutes. When solution is clear add 0.3mL of TGA. Add NH4OH in small portions to maintain pH around 11.

<u>In a flask B:</u>

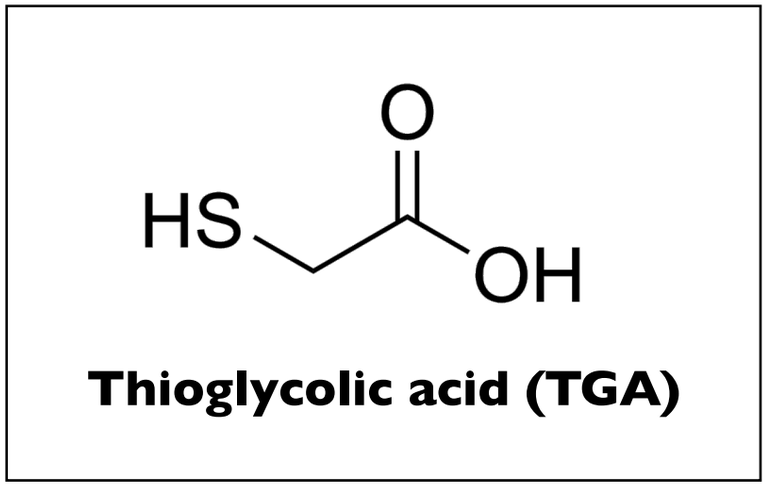
0.667 g of TeO_2 (n=4.18 mmol) dissolve in small amount of 1M NaOH solution (10.05mL) and fill it with water to 100 ml.

Mixture in a flask A heat to 80°C and add Te precursor. Substantially heat the mixture to 110°C and keep it in that temperature for 30 minutes.

Synthesis of CdTe

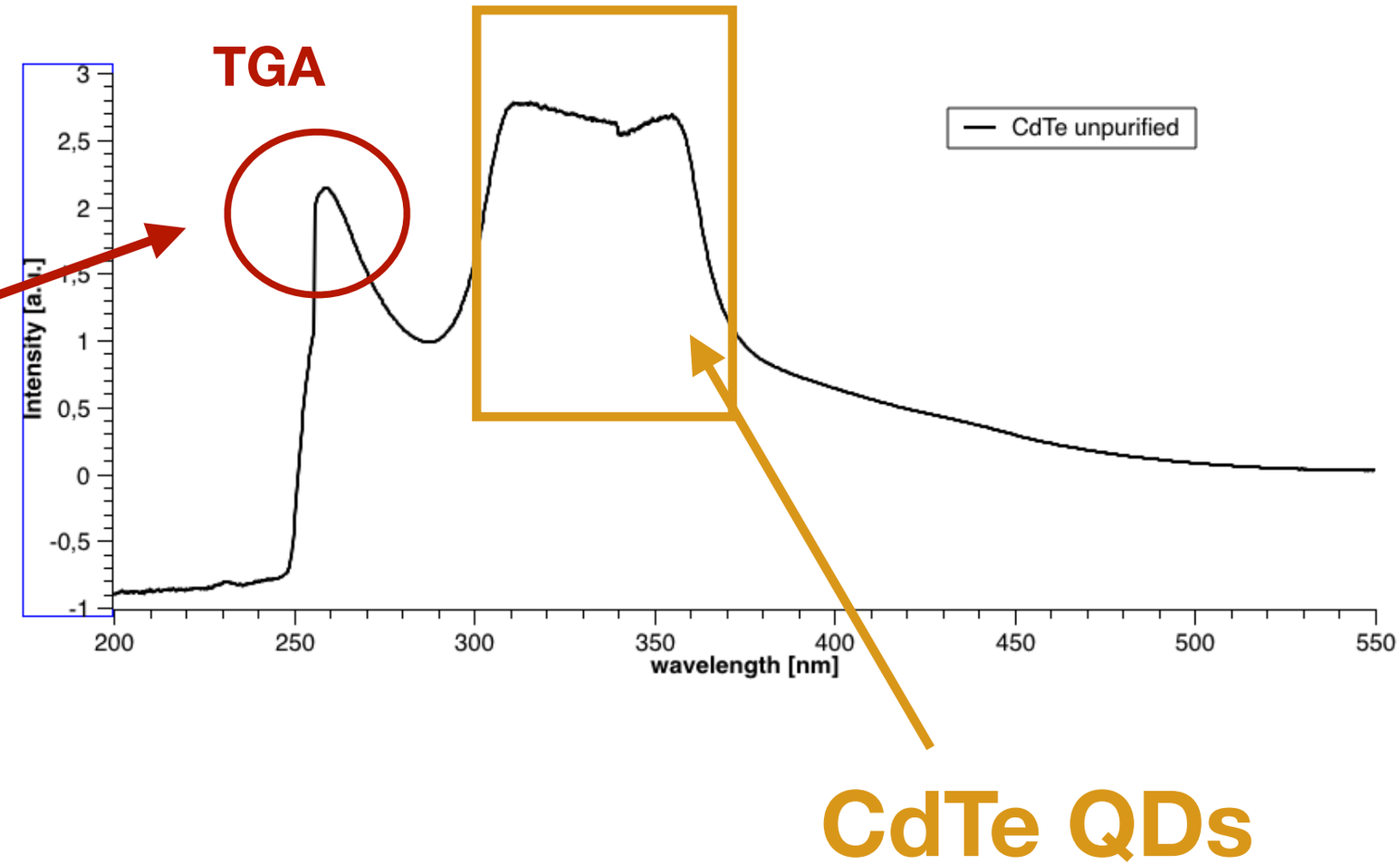


CLASSICAL SYNTHESIS



Thioglycolic acid (TGA)

FIG. 1. UV-Vis absorption spectra for free TGA in water. The intense absorption peaks at 250 and 185 nm (a) were assigned to the S_1 and S_2 transitions, respectively. In the same spectrum, an additional absorption transition in the visible region was resolved (b) and indicates that excitation via a single 400 nm photon can occur.



CLASSICAL SYNTHESIS

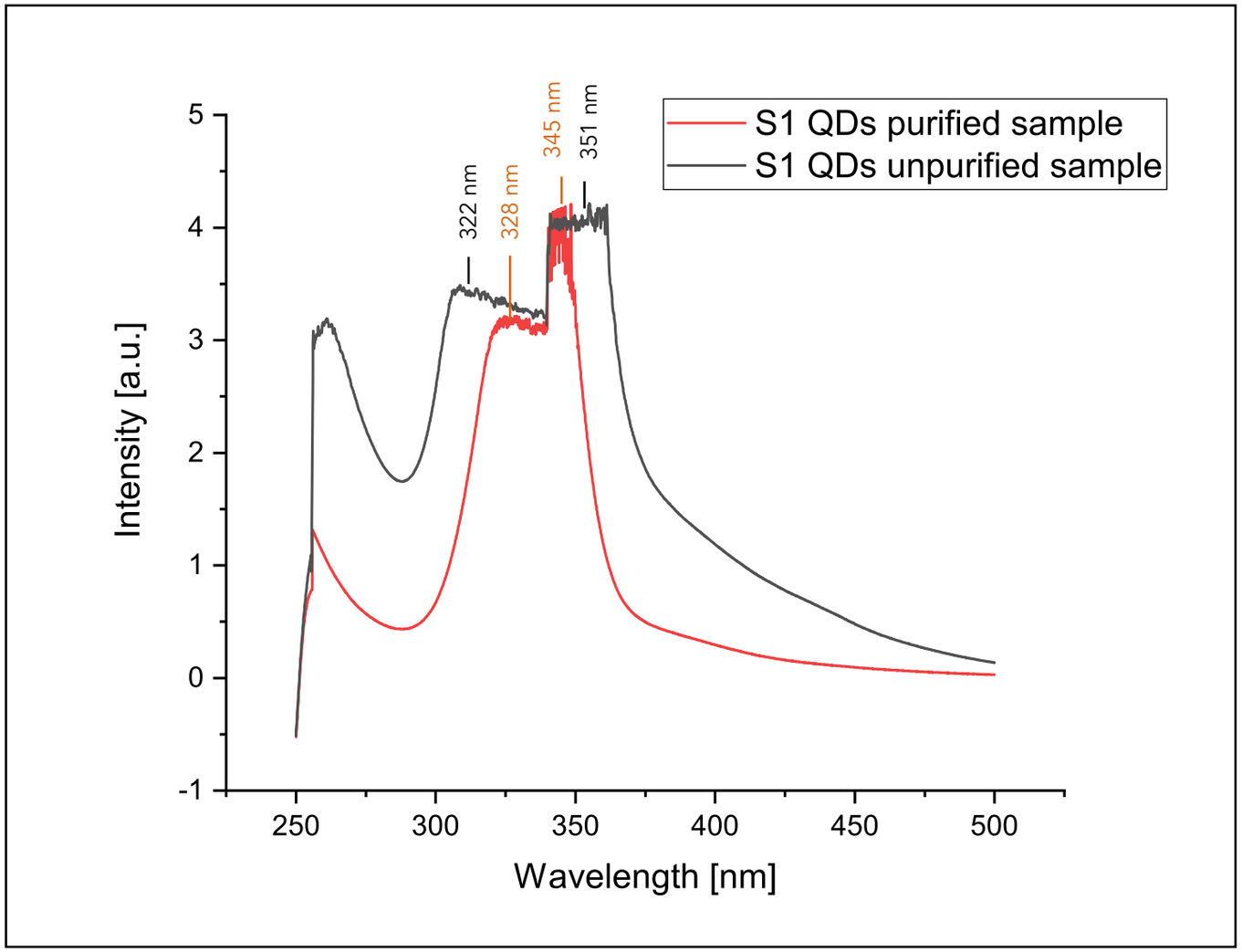


Figure 1. UV-Vis Absorption Spectroscopy measurement of purified and unpurified CdTe quantum dots obtained by classical synthesis.

CdTe QDs obtained in classical synthesis

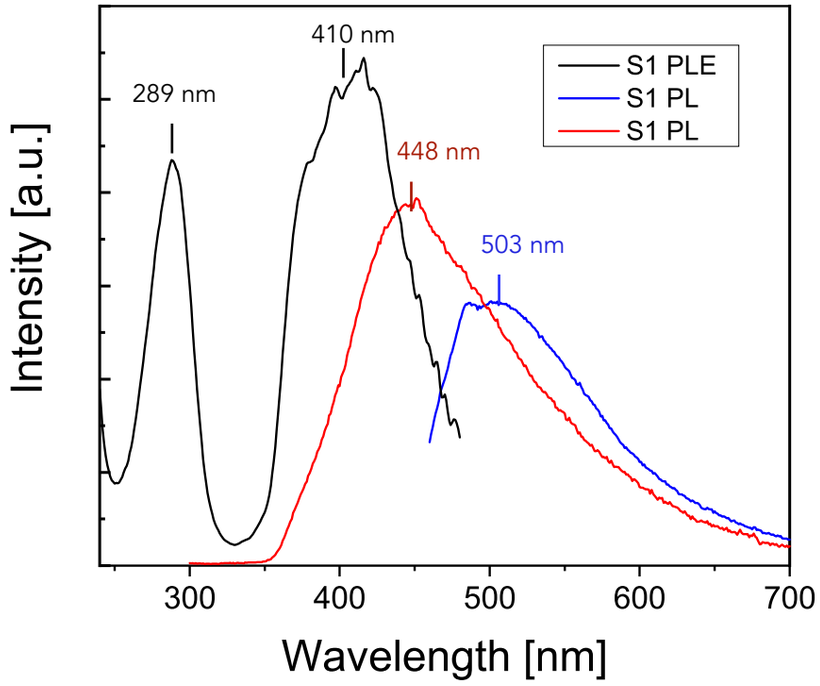


Figure 1. Photoluminescence Spectroscopy measurement of CdTe quantum dots obtained by classical synthesis.

PURIFICATION PROCESS

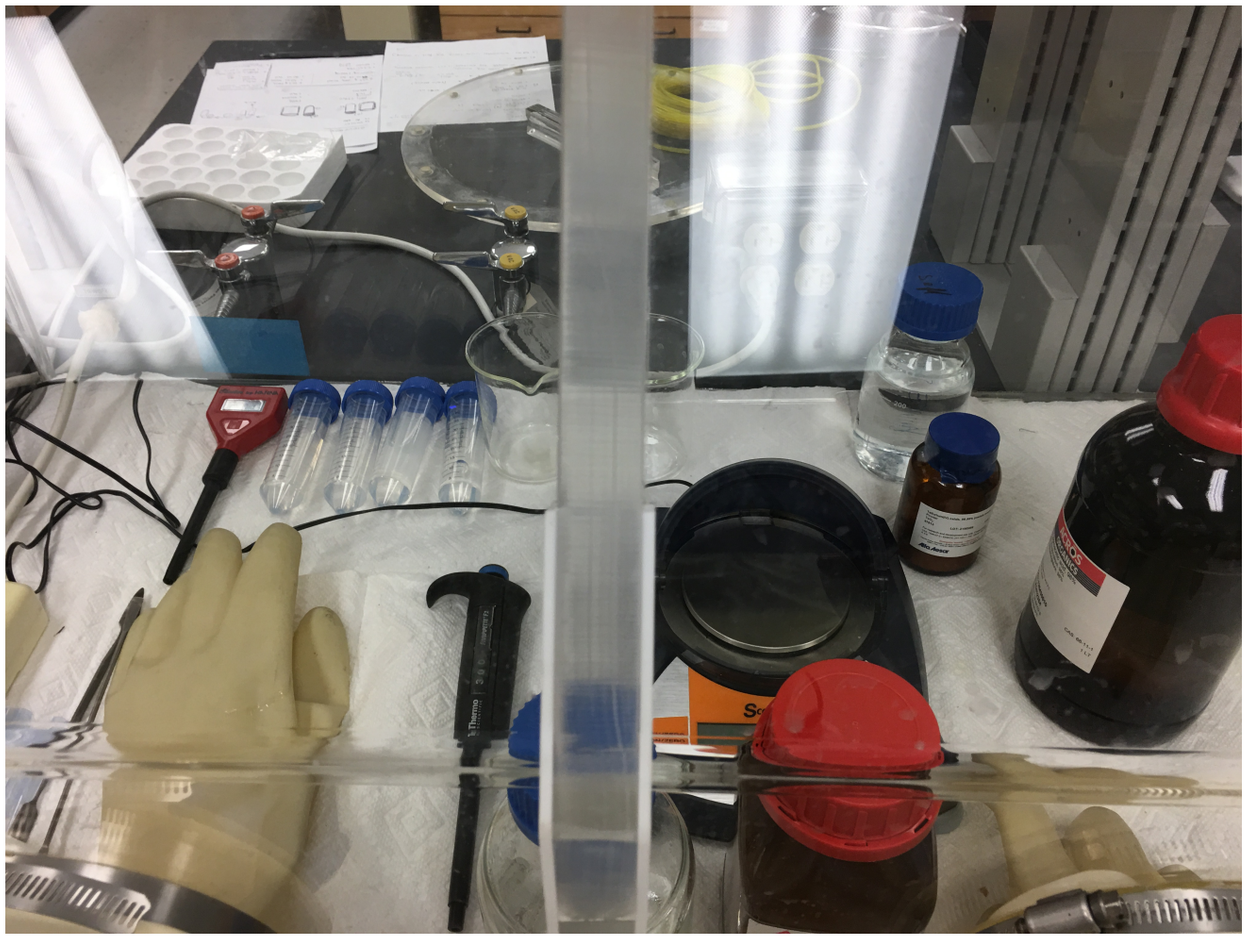
Why the purification process is important?

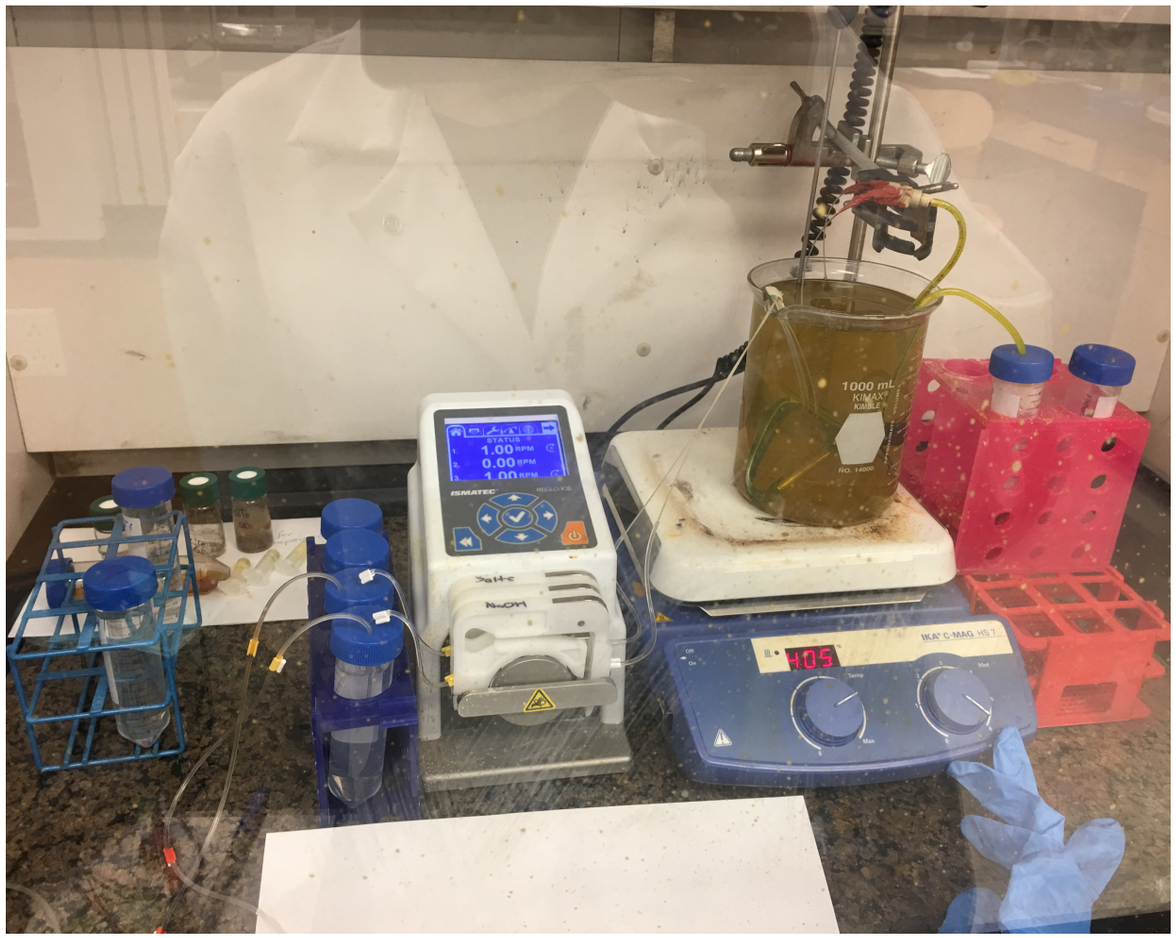
- ☞ stability
- ☞ physicochemical measurements
- ☞ further applications

Purification process:

- High concentration of the QDs solution
- Precipitate with acetone
- Centrifuge the sample

MICROFLUIDICS SYNTHESIS





MICROFLUIDICS SYNTHESIS

CdTe QDs obtained in microfluidics

Synthesis number	Tube length	Flow rate
S3	80 cm	10 rpm
S4	200 cm	10 rpm
S5	720 cm	5 rpm

- Peek tube deepen in oil bath
- Peek tube diameter d= 0.064 cm
- Temperature 110°C
- Argon flow

MICROFLUIDICS SYNTHESIS

CdTe QDs obtained in microfluidics

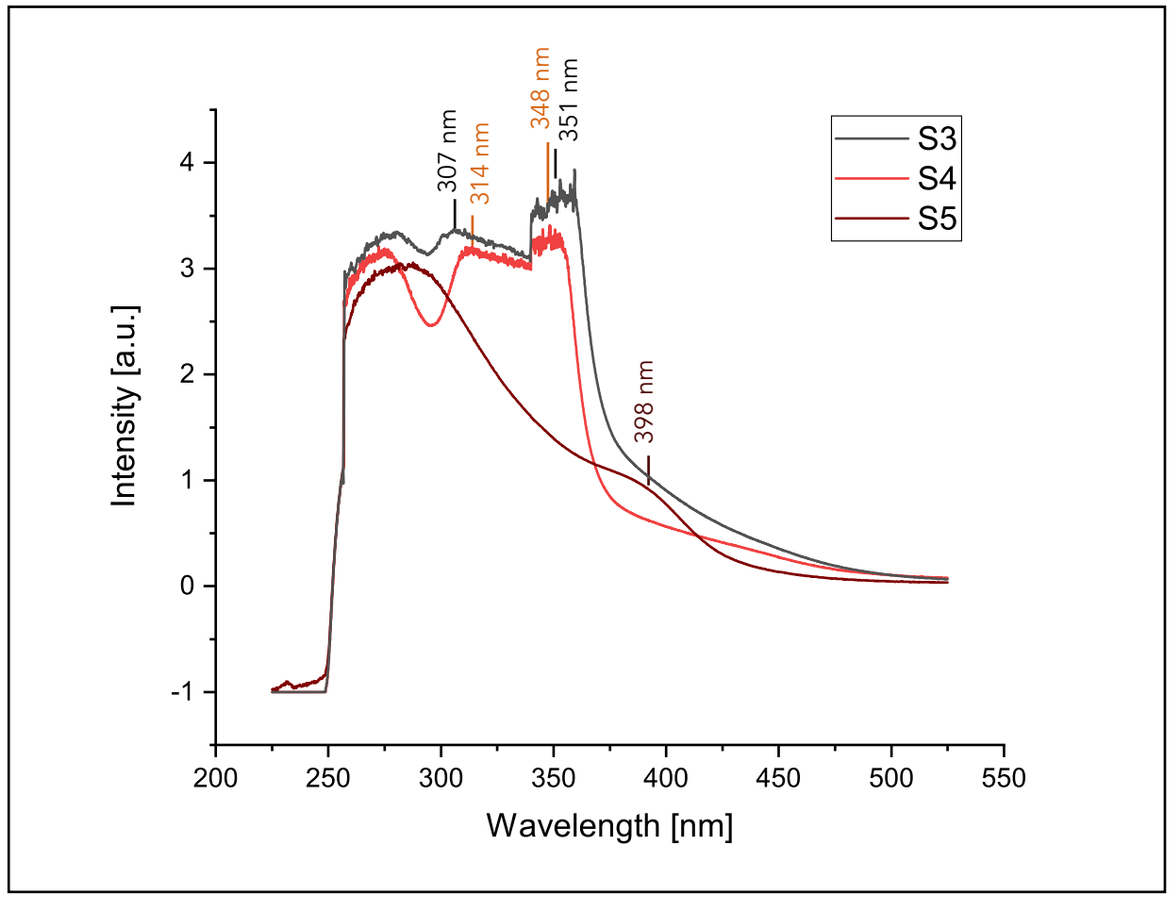


Figure 1. UV-Vis Absorption Spectroscopy measurement CdTe quantum dots synthesized in microfluidics system.

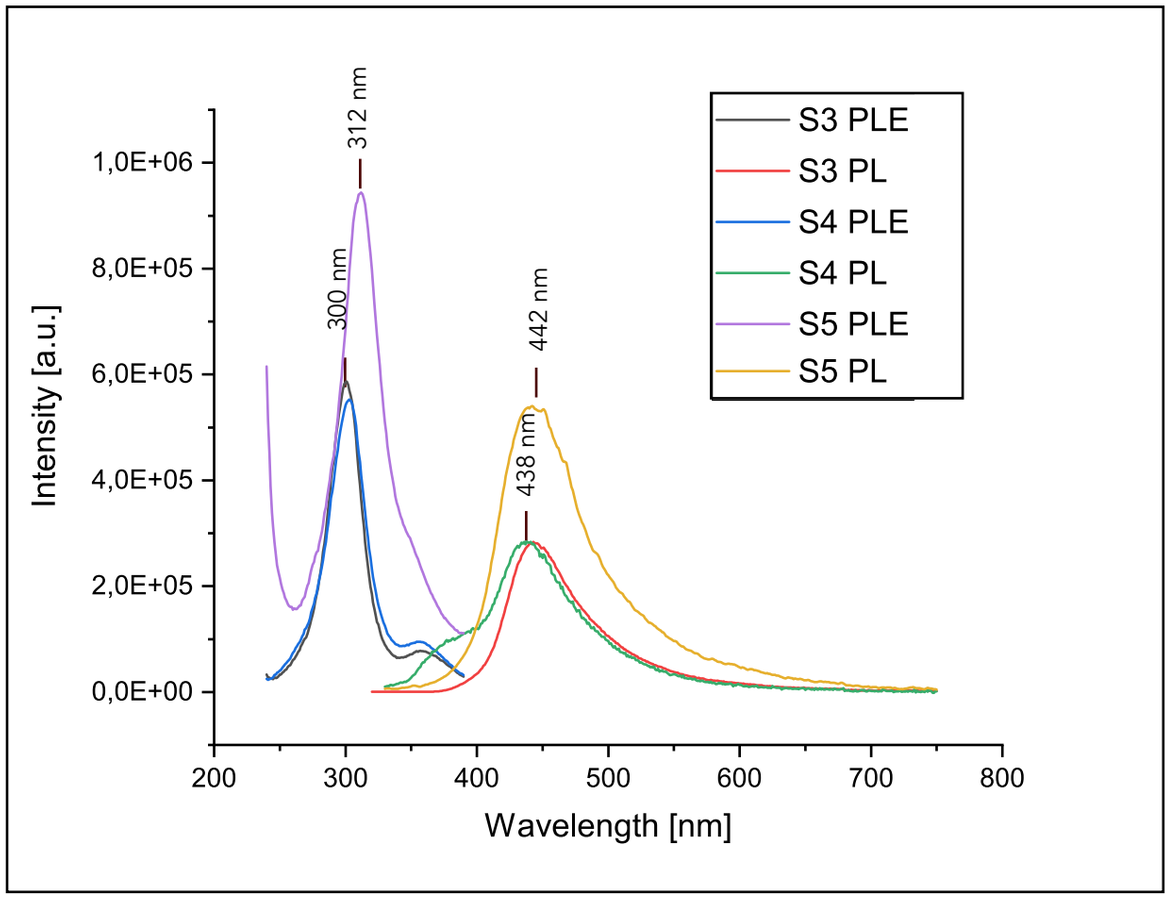
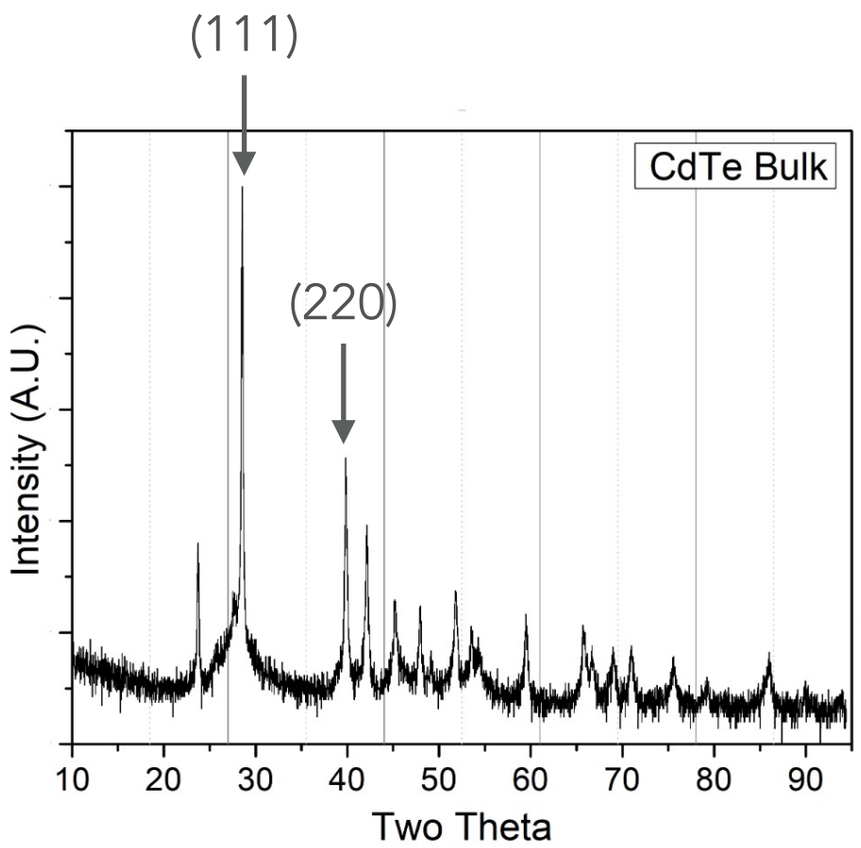
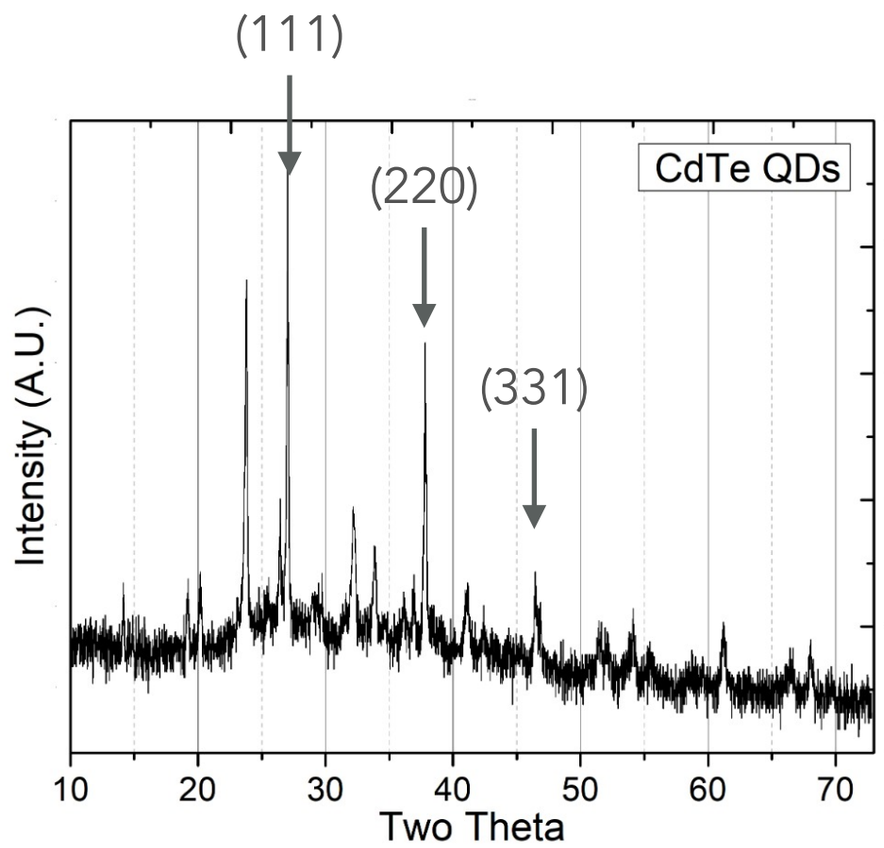


Figure 2. UV-Vis Photoluminescence Spectroscopy measurement CdTe quantum dots synthesized in microfluidics system.

CdTe QDs

X-RAY POWDER DIFFRACTION





PLANS FOR THE FUTURE

- Further work on purification of QDs samples
- Full characterization of CdTe QDs physicochemical properties
  - SEM and TEM imaging
  - XRD
  - Absorption and Emission Spectroscopy
- Increase the efficiency of the QDs synthesis by microfluidics
- Synthesis of Magnetic Quantum Dots
- Encapsulating QDs for biocompatibility

LITERATURE

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Thank You!

THANK YOU
FOR THE ATTENTION!

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Department of Physics