

OPTICAL AND TERAHERTZ SPECTROSCOPY OF CdSe/ZnS QUANTUM DOTS

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Due to the unique properties of semiconductor quantum dots arising from the confined nature of their electronic states, they have potential applications in many fields, from biological imaging to photovoltaic cells. In this work, we made a polymer film with CdSe/ZnS core/shell quantum dots and characterized their electronic and vibrational properties by optical and terahertz (THz) spectroscopy. THz spectroscopy is also of interest due to the technology gap in the THz region and the ability to measure phase shifts using time delay. With linear THz spectroscopy, we could observe possible carrier transitions of electronic states as well as acoustic phonon excitations in the quantum dots. We measured temperature-dependent photoluminescence from the quantum dots in a polymer film, from 7 K to 300 K, and with excitation by a 532 nm laser. With increasing temperature, the emission peak photon energy decreased, the linewidth increased, and the photoluminescence intensity generally decreased. We then compared the shift of the peak emission wavelength and the change of the full width at half maximum (FWHM) of the emission curve with a previous study [1]. The results were comparatively similar, with discrepancies potentially due to the size of the quantum dots as well as the differences in the film matrix. We further performed linear THz spectroscopy of the film at various temperatures and analyzed the phase shift and amplitude change results. To observe any acoustic phonon effects, we plan to complete a reference experiment using only the polymer film without quantum dots and compare the results. To observe ultrafast dynamics of optically excited carriers, we also plan to perform THz spectroscopy with optical pump on the quantum dots.

[1] D. Valerini, A. Cretí, M. Lomascolo, L. Manna, R. Cingolani, and M. Anni, *Phys. Rev. B* **71**, 235409 (2005)

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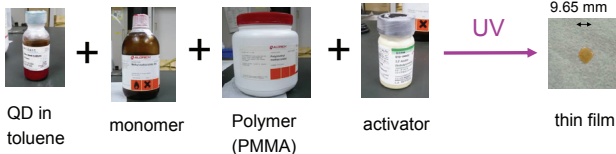
Abstract

Due to the unique properties of semiconductor quantum dots arising from the confined nature of their electronic states, they have potential applications in many fields, from biological imaging to photovoltaic cells. In this work, we made a polymer film with CdSe/ZnS core/shell quantum dots and characterized their electronic and vibrational properties by optical and terahertz (THz) spectroscopy.

Introduction

- Quantum dots (QDs) have discrete energy levels, with their electron-hole pairs confined in 3 dimensions
- Energy gap dependent on size of QD
- With temperature dependent photoluminescence (PL) spectroscopy, we could observe changes in photon emission energy, emission intensity, and phonon coupling behavior with varying temperature
- Using linear THz spectroscopy, we could observe possible carrier transitions and acoustic phonon behavior in QDs without excitation

Sample Preparation



Process:

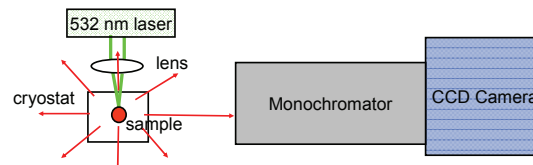
- UV radiation turns activator into radical that breaks bonds within polymer and monomer so they bind to form matrix
- Solution spread on SiO₂ glass to form thin film

Why thin film?

- Low temperature and single QD measurements possible
- QDs as active devices in materials

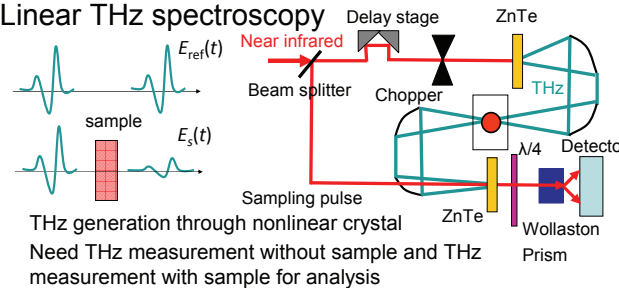
Set-Up

Temperature dependent photoluminescence



- Excitation with 532 nm continuous laser

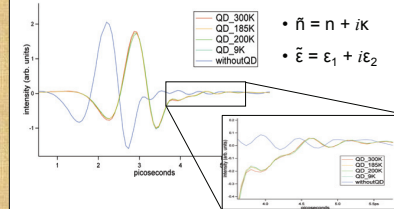
Linear THz spectroscopy



- THz generation through nonlinear crystal
- Need THz measurement without sample and THz measurement with sample for analysis

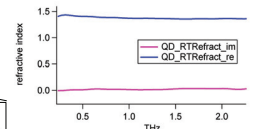
Results Cont.

Linear THz with varying temperature

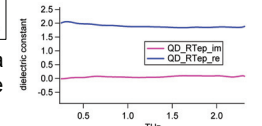


- $\tilde{n} = n + ik$
- $\tilde{\epsilon} = \epsilon_1 + i\epsilon_2$

Refractive Index Values



Dielectric Constant Values



- By comparing Fourier transformed data with and without sample, we can derive real and imaginary parts of \tilde{n} and $\tilde{\epsilon}$

Conclusions

PL Spectroscopy

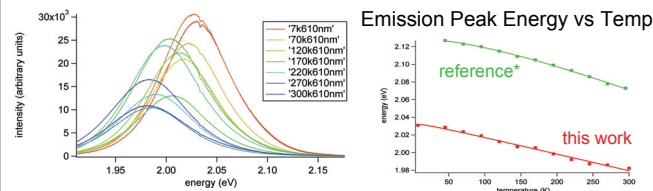
- Atomic separation, phonon coupling, and nonradiative emission account for emission curve changes with temperature
- Differences from previous study potentially due to size differences of QDs and differences in film matrix

THz Spectroscopy

- No change with varying temperature
- Constant n and k show either no electronic/vibrational oscillation in measured region, or QD concentration too small to have effect

Results

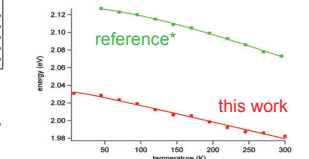
Temperature Dependent PL spectroscopy



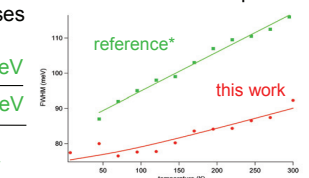
- From 7K to 300K, curve broadens, peak energy and intensity decreases

Energy gap (0K)	2.03 eV	2.13 eV
LO phonon coupling	7 meV	21 meV
Inhomogeneous broadening	75.13 meV	85.5 meV

Emission Peak Energy vs Temp



FWHM vs Temp



Future and Related Work

- Broad band THz spectroscopy
- Temperature dependent optical pump THz probe spectroscopy
 - Lower decay rate at lower temperatures

Acknowledgements

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