Self-Assembly of CdS Quantum Dot Films with Chiral Optical Properties

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Abstract:

This project investigates the self-assembly of CdS magic-size clusters (MSCs), a type of quantum dot, into hierarchical films with complex structures that mimic biomolecular organization. We focus on developing chiral optical films through thiolation and examining their optical properties [1]. Our experiments involve time-resolved thiolation, aiming to shift the absorption peak from 324 nm to 350 nm over 48 hours. We also study spatial variations in thiolate films, expecting similar spectral shifts. Glass substrates are prepared and coated with CdS solutions, then thiolate and analyzed using circular dichroism spectrometry. Although the predicted peak shift to 350 nm was not fully achieved, the films exhibit novel chiral and linear dichroic properties, alongside intriguing LDLB interactions. These findings indicate potential applications in creating nano-polarized light pixels. The primary tool used in the lab was the JASCO-1500 CD Spectrometer, which was essential in characterizing and analyzing the films.

Summary of Research:

This research aimed to explore the self-assembly of CdS quantum dot films that exhibit chiral optical properties, with a particular focus on how thiolation affects these films' optical characteristics [1]. Thiolation refers to the process of treating quantum dot films with thiol ligands. This treatment alters the optical properties of the films, including a redshift in the absorption spectrum due to changes in the electronic environment of the quantum dots [2]. This study was motivated by the potential applications of quantum dots in advanced technologies, such as nano-polarized light pixels, which require precise control over chiral optical properties. Additionally, the research aimed to investigate the influence of linear dichroism (ld) and linear birefringence (lb) effects on the optical behavior of the films.

Circular Dichroism (CD) is the differential absorption of right- and left-circularly polarized light used to characterize chiral materials. In this study, CD was employed to analyze the chiral optical properties of the films. LD refers to the differential absorption of light polarized in different linear orientations; an effect important in materials with anisotropic optical properties. LB, on the other hand, is the splitting of a light beam into two rays that travel at different speeds due to the material's optical anisotropy. The combination of LD and LB can result in a CD signal because the orientation and birefringence of the material influence how circularly polarized light is absorbed, leading to chiroptical effects.

This research was conducted through a series of experiments designed to observe the effects of thiolation on CdS films, both over time and across different spatial locations, while also examining the impact of LD and LB effects. The primary objective of the time-resolved experiment was to shift the absorption peak of the CdS films from 324 nm to 350 nm over 48 hours and to study the progression of the absorbance and CD of the film to see if there are different stages or intermediate species. To achieve this, CdS films were prepared and then subjected to thiolation over various time intervals. The optical properties of the films, including LD and LB effects, were measured using CD and absorbance spectroscopy.

The spatial experiment aimed to observe the variations in the optical properties of the thiolate films depending on the location of measurement because we have observed that the chiroptical response can be of opposite-handedness and varying magnitudes across a single MSC film. Measurements were taken at three different spots on the thin film before (Figure 3) and after thiolation (Figure 3) to determine how spatial differences influenced the absorption peaks and the LD/LB effects. In the time-resolved experiments, a progressive shift in the absorption peak was observed during the thiolation process, although the expected shift to 350 nm was not fully achieved within the 48-hour timeframe. The films exhibited distinct chiral properties, with notable variations in left-hand and right-hand circularly polarized light, as indicated

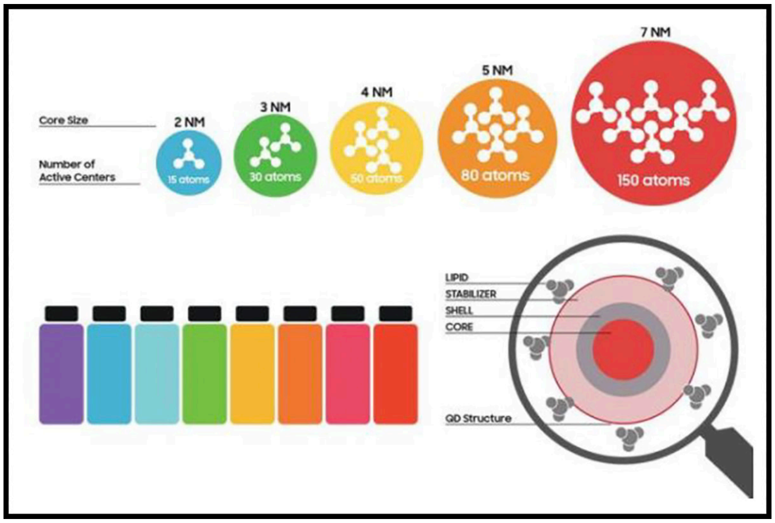

Figure 1: Quantum dots & Products/Technology -QD-OLED. Samsung Display. (n.d.). https://www.samsungdisplay.com/eng/tech/quantum-dot.jsp

Figure 2: Films made of glass substrates and tape.

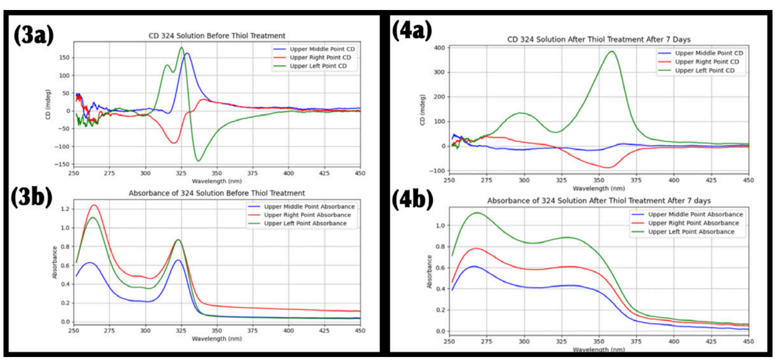

Figure 3, left: a, CD for 3 different positions on an MSC film before treatment. b, Absorbance for 3 different positions on an MSC film before treatment. Figure 4, right: a, CD for 3 different positions on an MSC film after treatment. b, Absorbance for 3 different positions on an MSC film after treatment.

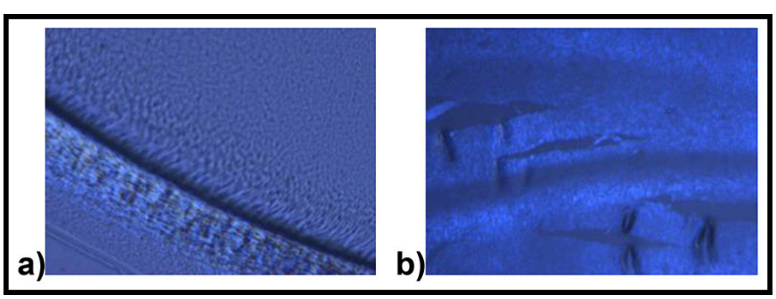

Figure 5: a, MSC film under a microscope before treatment. b, MSC film under a microscope after treatment.

by the CD spectra. Furthermore, the LD and LB effects were prominent, demonstrating how the orientation of the films influenced the absorption of polarized light and the splitting of light beams traveling through the material.

The spatial experiments revealed that the absorption peaks varied depending on the specific location measured on the film (Figure 4), confirming that the effects of thiolation were not uniform across the entire mo. The spatial differences also highlighted variations in LD and LB effects across the film. The thiolation process induced significant changes in the chiral properties of the CdS films, though the desired peak shift to 350 nm was not fully realized. The observed LD and LB effects further contributed to understanding how film orientation and thiolation influence the optical properties of quantum dot films. These results suggest that thiolation has the potential to fine-tune the optical properties of quantum dot films and the structure of the film (Figure 5), particularly in enhancing their chiral and polarized light responses. Future research could explore longer thiolation times, alternative thiol ligands, and manipulating LD/LB effects to achieve more pronounced shifts in optical properties.

This study successfully demonstrated the potential of thiolation to modify the optical properties of CdS quantum dot films, particularly in enhancing their chiral characteristics and LD/LB effects. While the specific goal of shifting the absorption peak to 350 nm was not met, the findings provide valuable insights into quantum dots' self-assembly, optical behavior, and polarization effects.

References:

[1] Chem. Commun., 2017, 53, 2866-2869.

[2] Nano Lett. 2022, 22, 1778-1785.