Project 1.

Temperature-dependent Carrier Dynamics in Photoexcited Metal-Halide Perovskites

MAX-PLANCK-INSTITUT FÜR POLYMERFORSCHUNG

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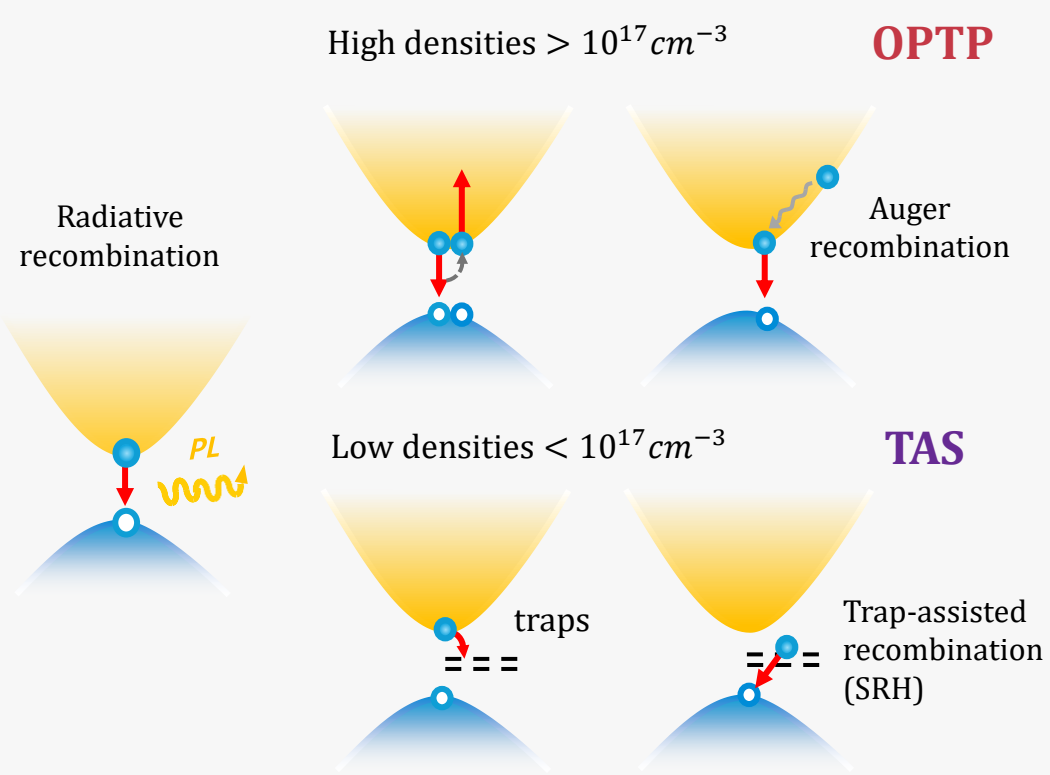
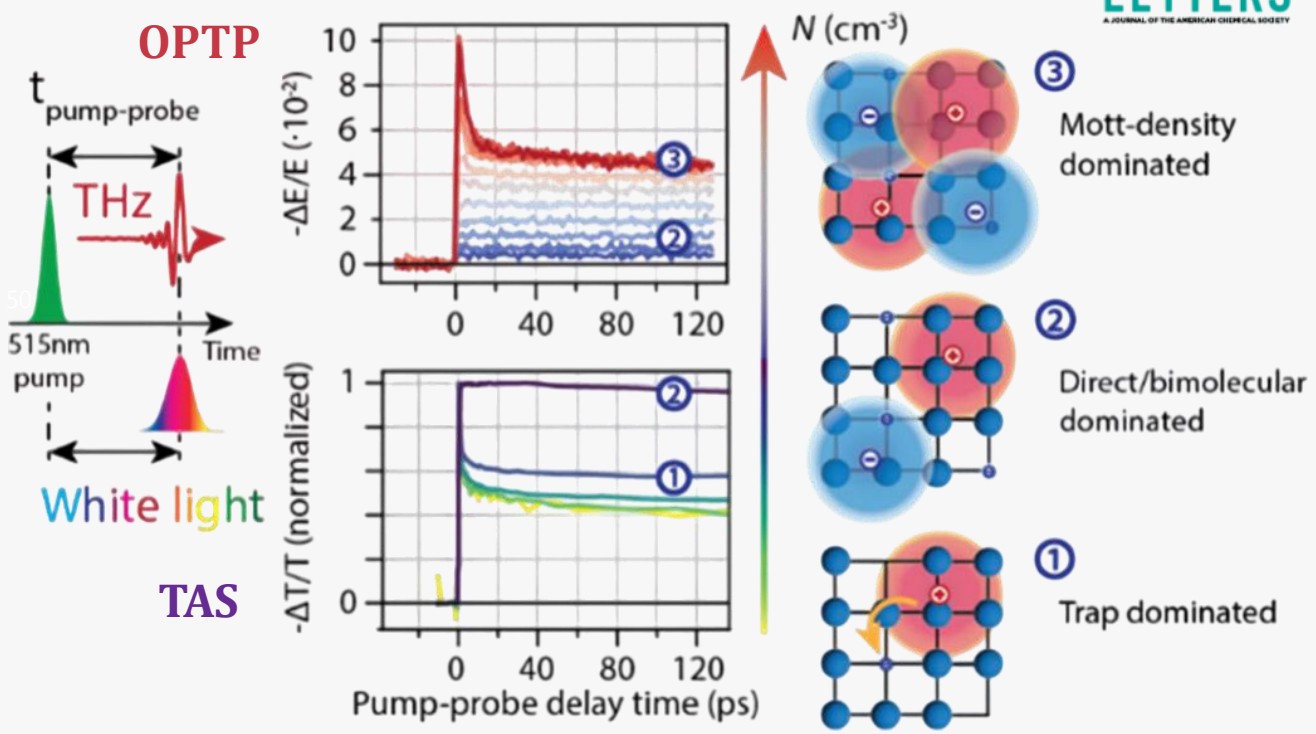
THE JOURNAL OF PHYSICAL CHEMISTRY LETTERS





- TAS: performed in collaboration with J. Wang, Dalian Institute of Chemical Physics, CAS

Motivation

: recombination pathways in perovskites depend on carrier density and temperature, yet the transitions between trap-, intrinsic bimolecular-, and Mott-dominated regimes are not clearly established.

Outline

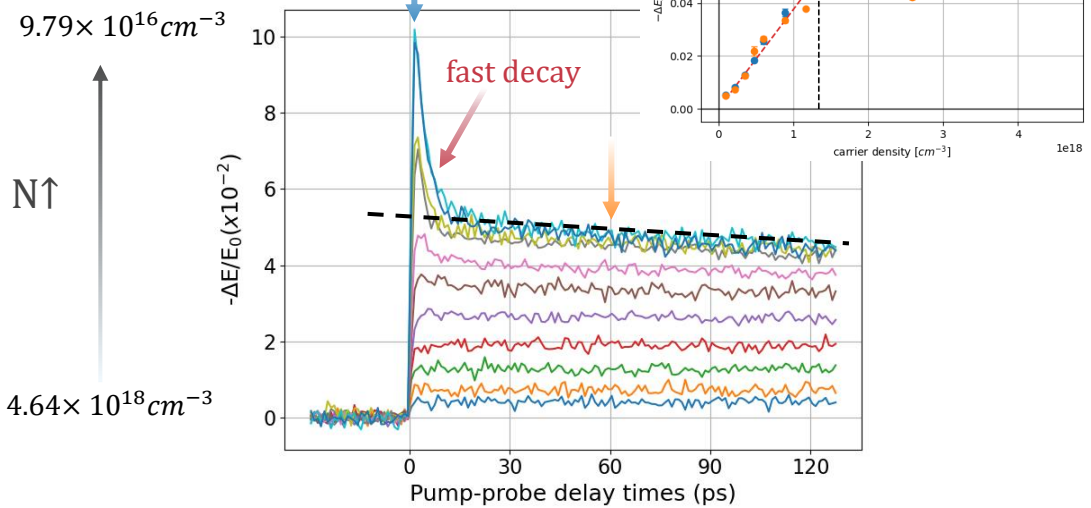
: map density-dependent recombination pathways in photoexcited $MAPbI_3$ by combining **TAS** and **OPTP** spectroscopy to construct an electronic polaron phase diagram.

DOI: https://doi.org/10.1021/acs.jpclett.5c02164
J.Phys.Chem. Lett.2025,16,9925−9932

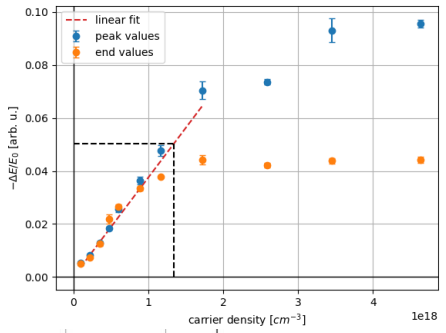
2023.08 – 2024.05 Max-Planck-Institute for Polymer research (*Prof. Mischa Bonn's group*)

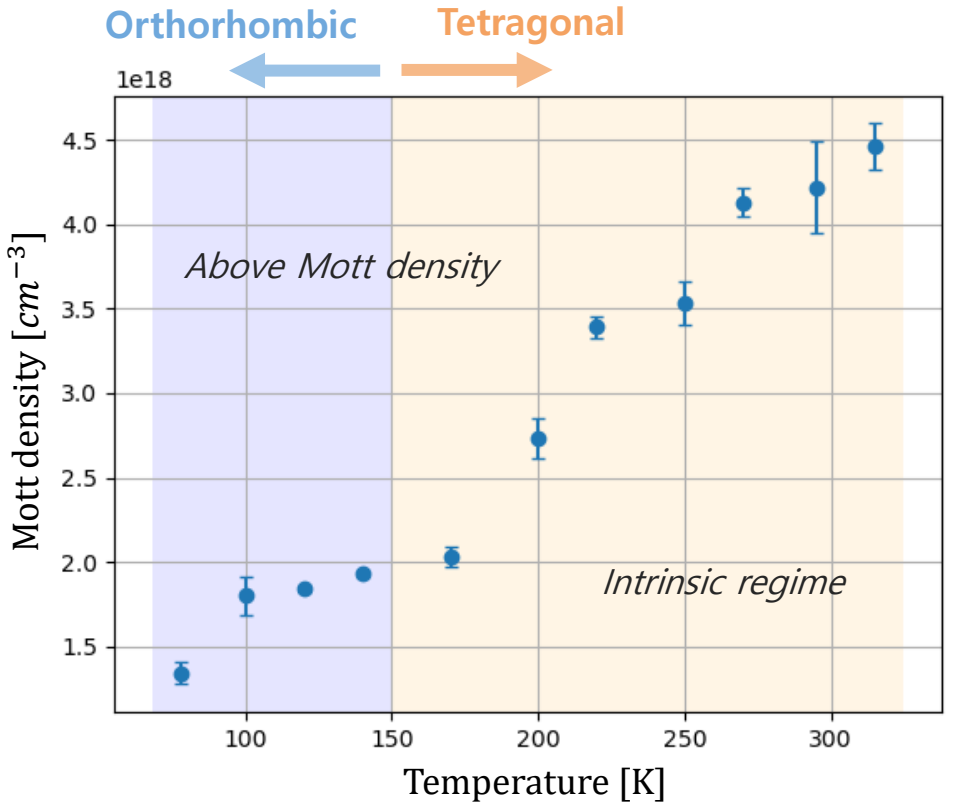
Project 1. Experiment – OPTP analysis & T-dept Mott density

❖ **OPTP** (78 K, varying carrier density)



Mott density



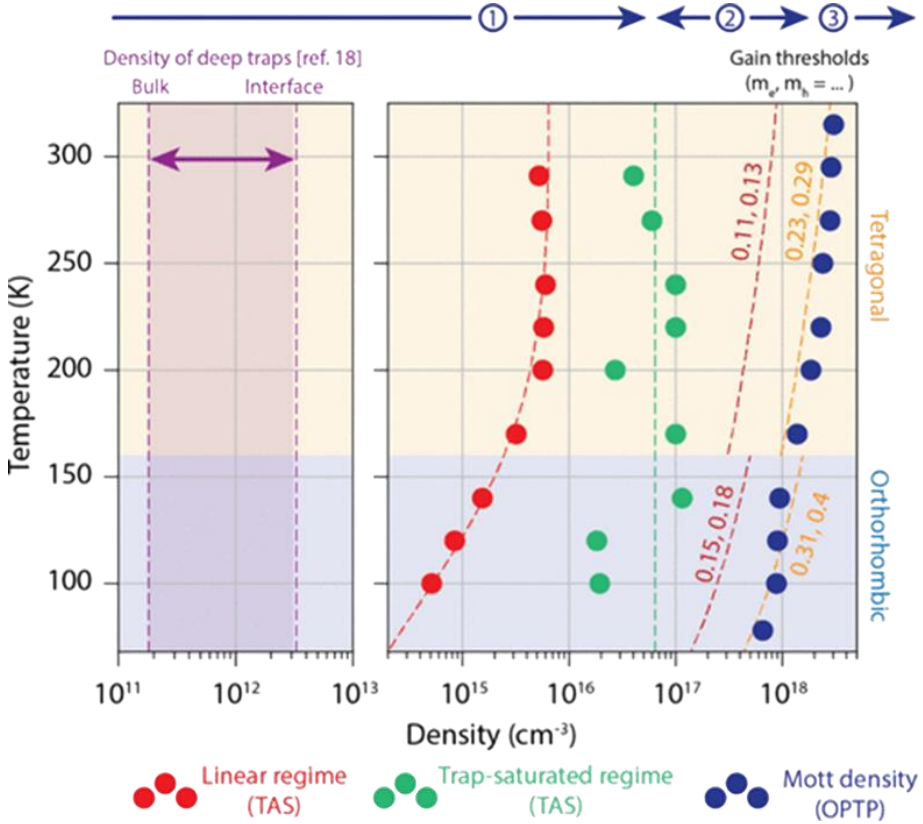


Key Results

- **Quantified the temperature-dependent Mott density** (N_{mott}) from OPTP measurements across 78–315 K.
- **Observed rapid carrier decay** above N_{mott}, consistent with polaron–polaron overlap.
- **Identified a density-dependent transition** from intrinsic bimolecular recombination to ultrafast many-body decay.

DOI: https://doi.org/10.1021/acs.jpclett.5c02164
J.Phys.Chem. Lett.2025,16,9925−9932

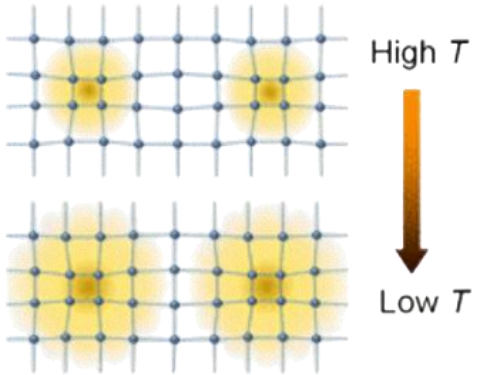
Project 1. Results – Polaron Phase Diagram



Polaron phase diagram

- **Low densities**
  : ps–scale trapping → ns – μs trap-assisted recombination dominates.
- **Above Mott density**
  : polaron overlap + Auger recombination → ultrafast decay. (fs – tens ps)

OPTP-derived N_{mott} + TAS regimes map the **full density–temperature landscape**.



Temperature effect
: higher lattice vibrations reduce the polaron radius
→ requiring higher N_{mott} for overlap.

Heng Zhang et al. ACS Energy Lett. 2023, 8, 420–428.

DOI: https://doi.org/10.1021/acs.jpclett.5c02164
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Project 2. THz Photoconductivity Modelling in Lead-Halide Perovskites

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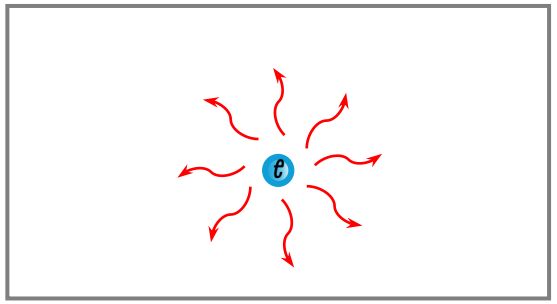
MPK

❖ Models for THz Conductivity

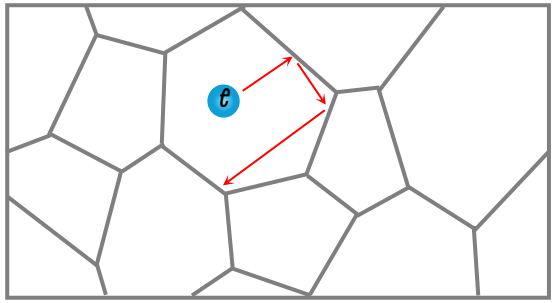
Drude

: no localization (free-carrier response).



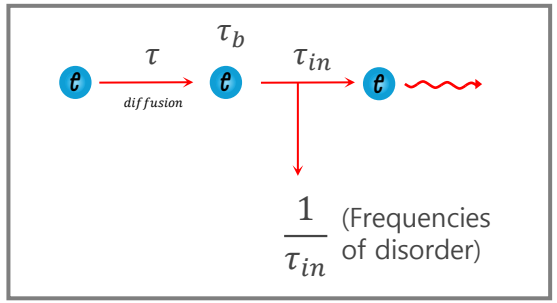
Drude-Smith (DS)

: static disorder + backscattering



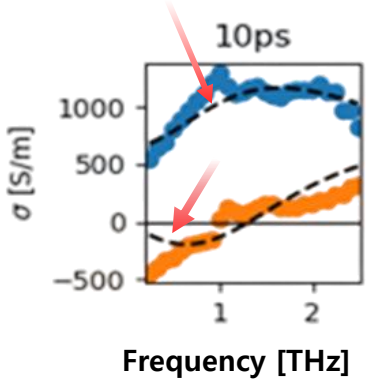
Drude-Anderson (DA)

: dynamic disorder + electron–phonon coupling.

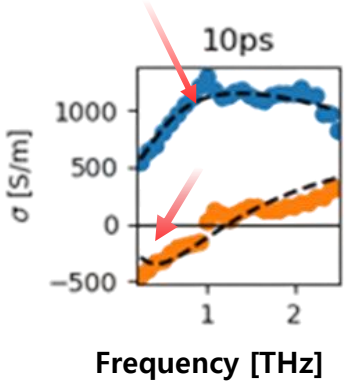


❖ THz Photoconductivity spectra of $FAPbI_3$

DS model fit



DA model fit



- DS model misses low-frequencies σ.
- DA model captures sub-THz roll-off and localization effects.

Motivation

: to clarify how static and dynamic disorder shape early-time carrier localization.

Key Results

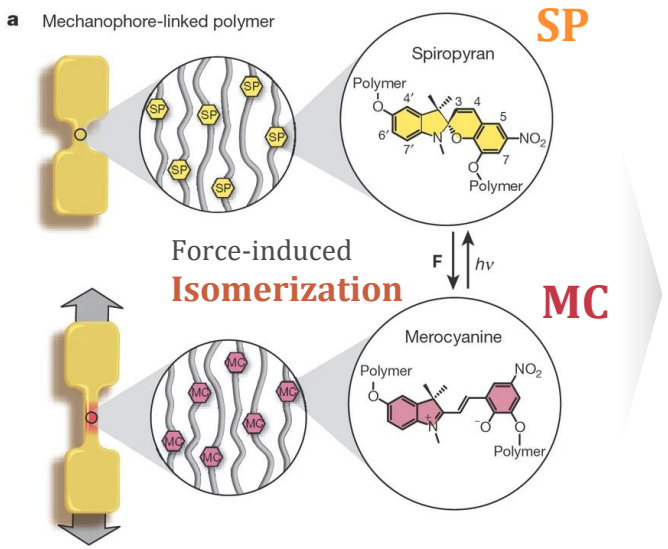
DA model fits the data best

→ Captures dynamic disorder–induced localization.

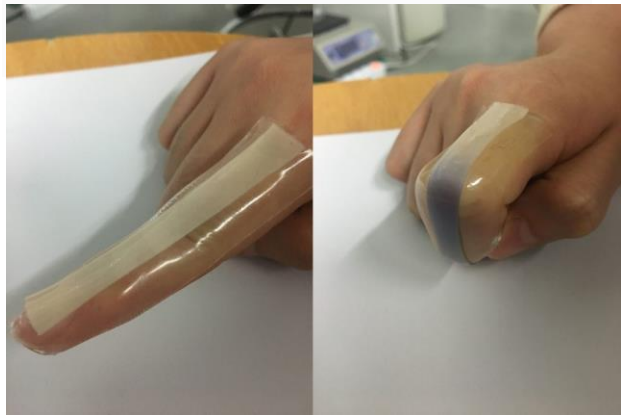
→ Provides more reliable transport parameters (mobility, τ_b, τ_in).

Project 3. Spiropyran Mechanophore for Stimuli-Responsive Polymer Matrices

(Synthesis, Characterization, and Monomer Optimization)



DA Davis *et al. Nature.* **2009**, 459, 68-72.



Jonghwa Park et al. Adv. Mater. **2019**, 1808148.

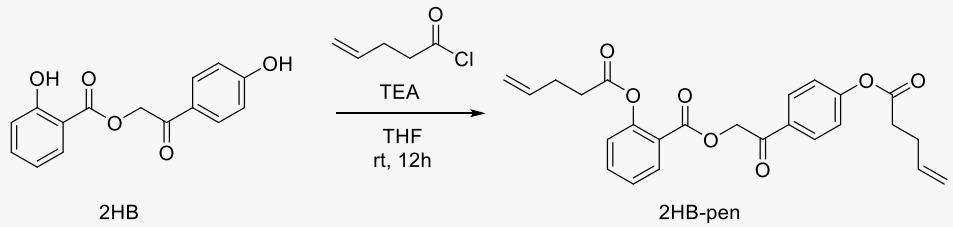
Outlines

- Synthesized a spiropyran (SP) crosslinker with reversible mechano-/photochromic response.
- Application: mechanochromic polymers for damage monitoring.

Achievement

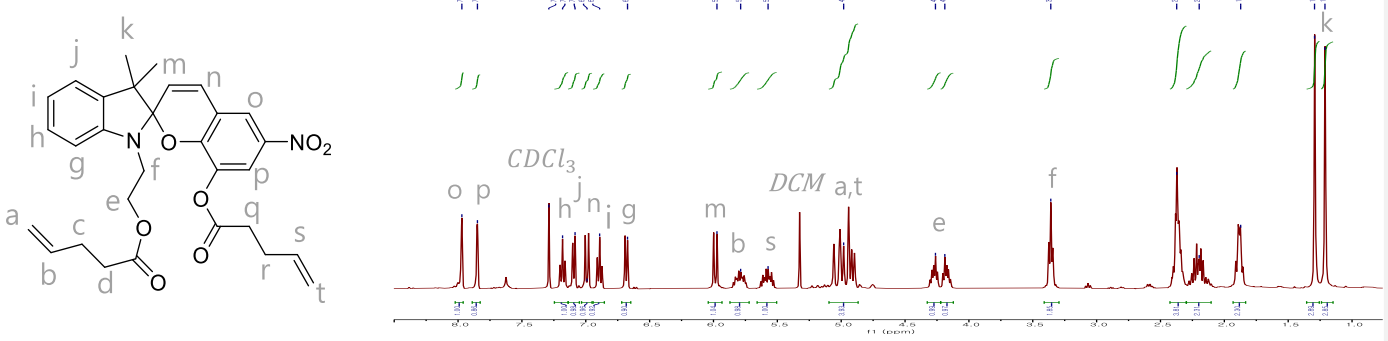
- Motivation : low yield hindered reliable monomer preparation → leading me to identify the main cause using TLC and NMR.

* Acylation step for photodegradable monomer synthesis



- Resolved insufficient chromatographic separation by developing an efficient eluent system, increasing the yield from **22%** → **43%**

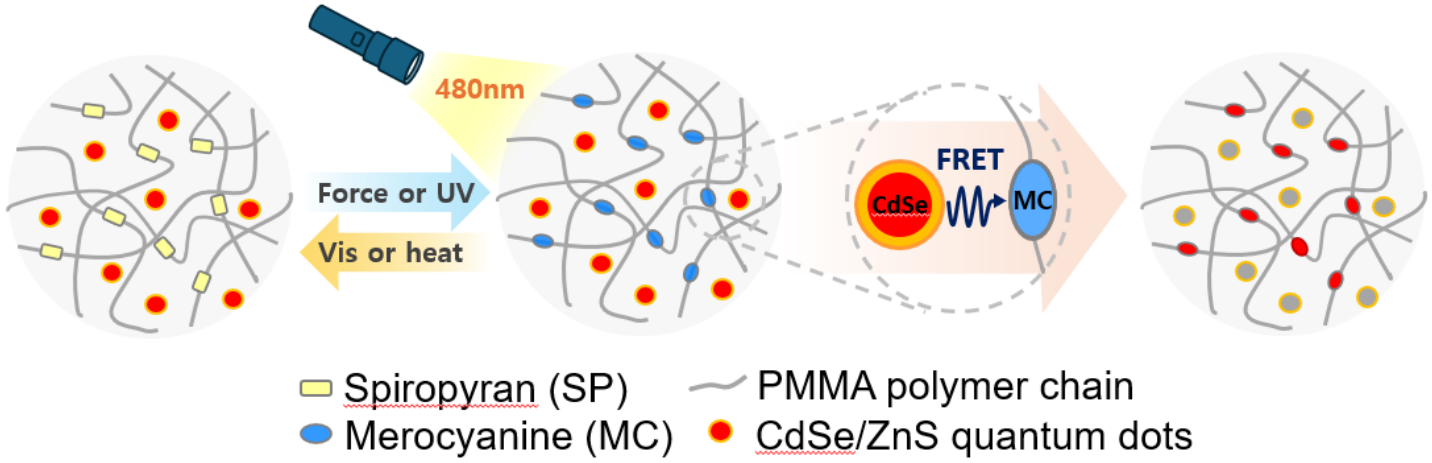
^{1}H NMR (400 MHz, $CDCl_3$)



2023.03 – 2023.06 Korean Institute of Science and Technology (KIST), supervised by Dr. Tae Ann Kim

Project 4. Super-Resolution Mechano-imaging of SP–QD polymer Matrices via FRET.

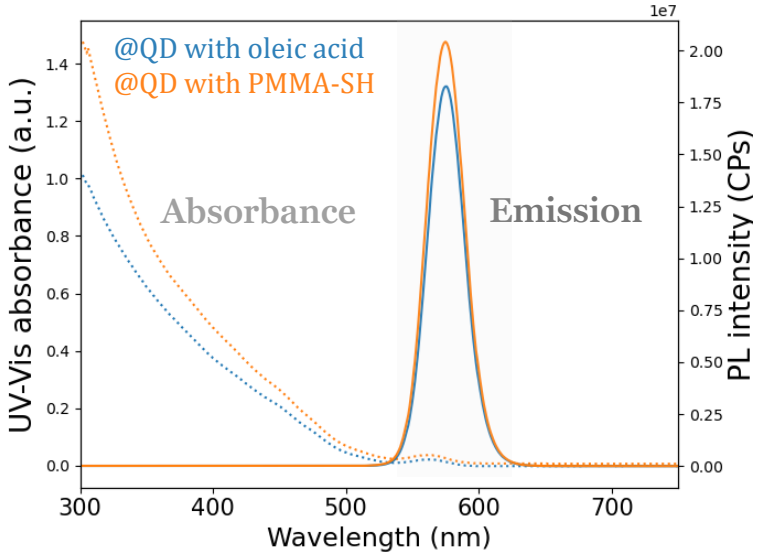
Poster available here: [SP–QD FRET Poster (Google Drive)]



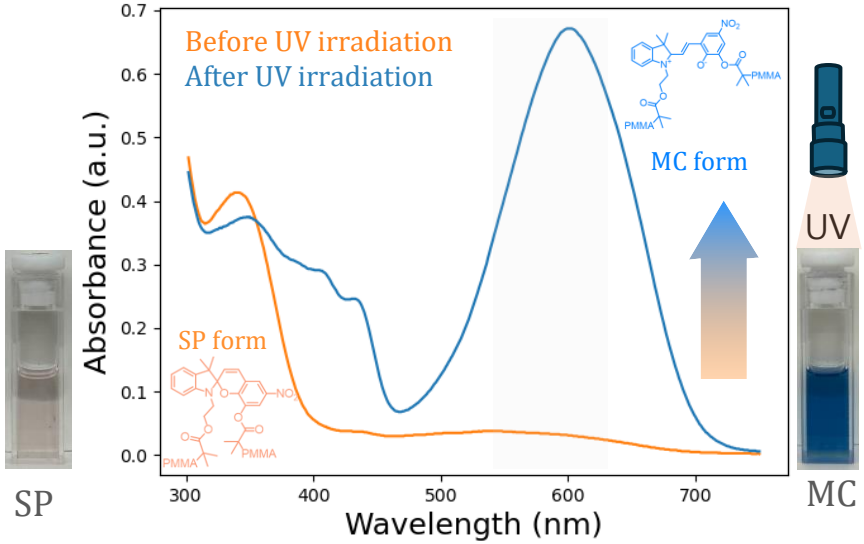
Outlines

- Motivation: Spectral overlap between QD emission and merocyanine absorption enables QD→MC FRET for mechano-responsive imaging.
- Synthesized SP–PMMA and PMMA–SH polymer ligands, followed by QD ligand exchange to improve dispersion & FRET compatibility.

❖ UV-Vis absorption & PL @QDs-polymer

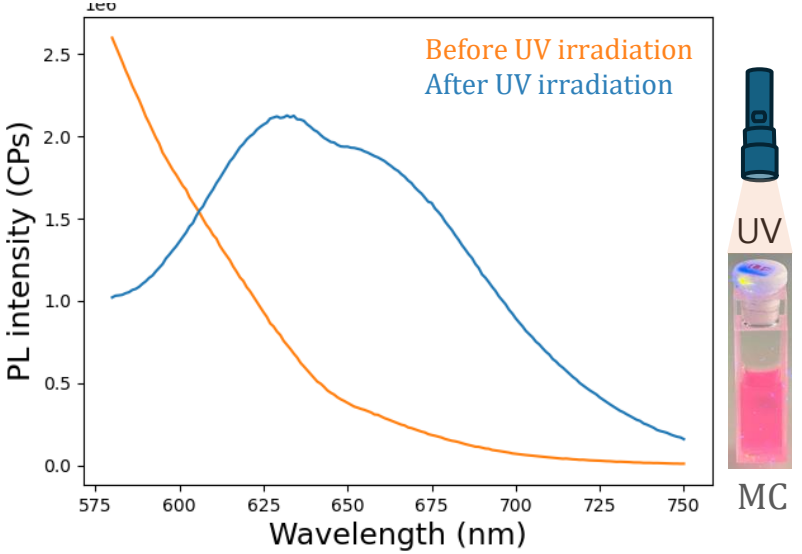


❖ UV-Vis absorption @SP-PMMA



* MC form - strong absorption in VIS region

❖ PL spectra @SP-PMMA



* MC form - strong fluorescence under UV

2024.06 – 2024.08 Adolphe Merkle Institute (AMI), supervised by Prof. Jessica Clough

Thank you for your attention.

Jungmin Park

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