National Taiwan University
Chemical Engineering

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Optoelectronic Polymer Laboratory

Advanced Polymer and Nanotechnology Laboratory

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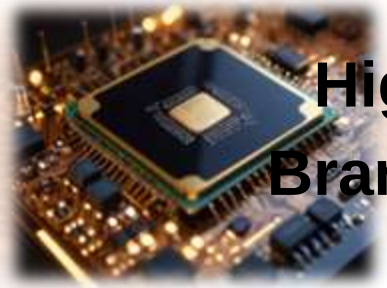
National Taiwan University
國立臺灣大學

Our Research (1/9)

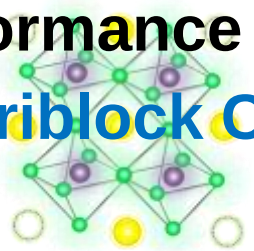
Introduction & Motivation

High Performance Non-Volatile Photomemory Utilizing Branched Triblock Copolymers/Perovskite Quantum Dots



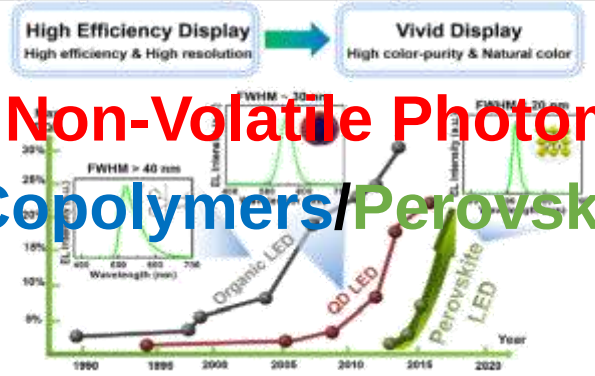
- ✕ Data latency
- ✕ Intralayer consumption
- ✕ Only electric operation

Perovskite (PVSK)

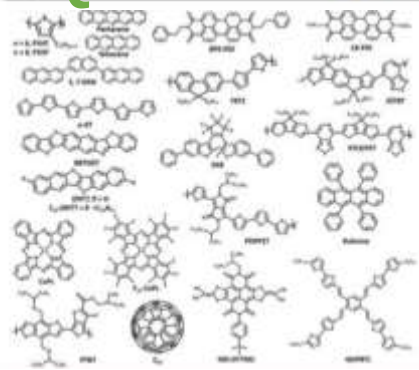


$ABX_3(CsPbX_3)$

- A: Cs^+
- B: Pb^{2+}
- X: Cl^-, Br^-, I^-
- Defect



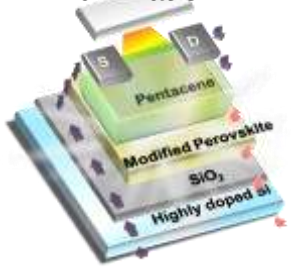
- ✓ High potential
- ✓ High color purity
- ✓ Solution process



- ✓ Flexibility
- ✓ Low cost
- ✓ Processability

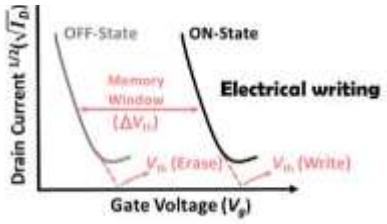
Photomemory

Illumination

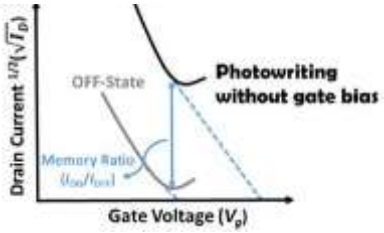


- ✓ Low latency
- ✓ Low energy consumption
- ✓ Arbitrary wavelength

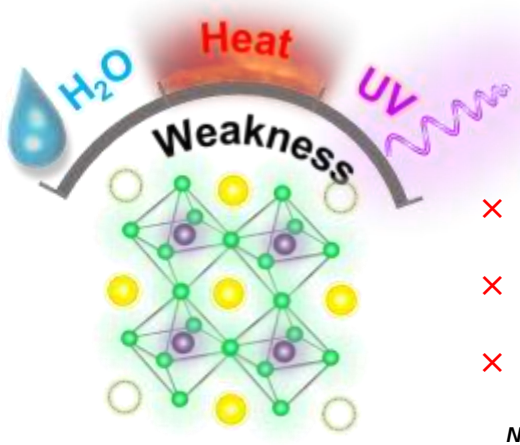
Electric operation



Optical operation



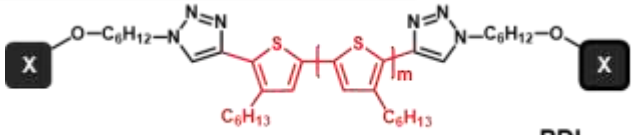
Perovskite



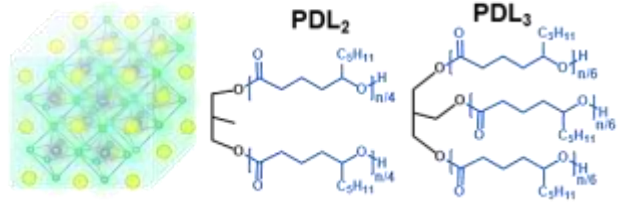
- ✕ Self-aggregation
- ✕ Ion dissociation
- ✕ Solution stability

Conjugated Polymer

Triblock copolymers



PDL

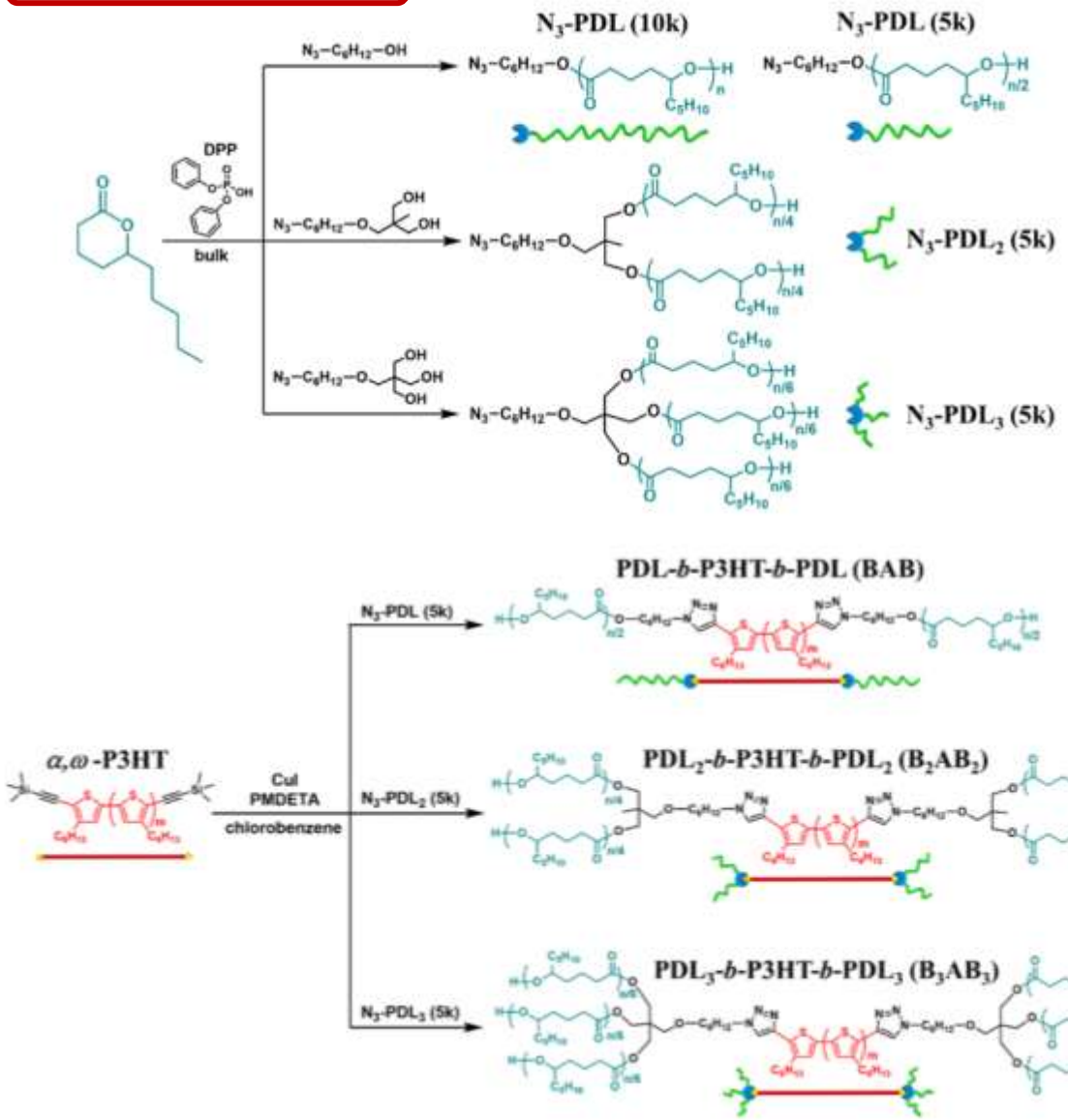


NATURE PHOTONICS , VOL 10, MAY 2016
PNAS, October 18, 2016, vol. 113, no. 42 , 11697
Small Sci. 2022, 2100109
Adv. Funct. Mater. 2019, 1904545

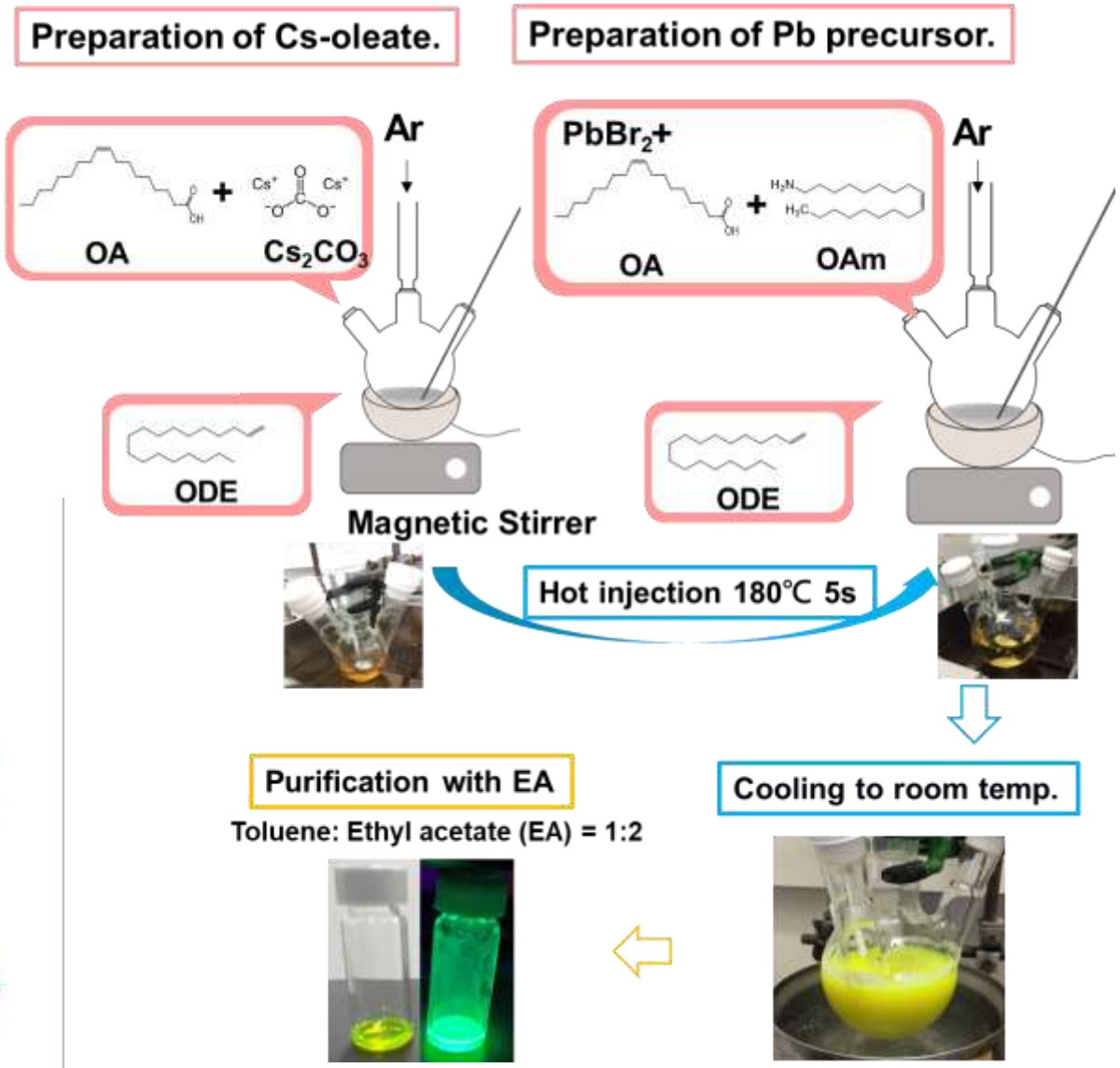
Our Research (2/9)

Synthesis of Copolymers and Perovskite

Synthesis



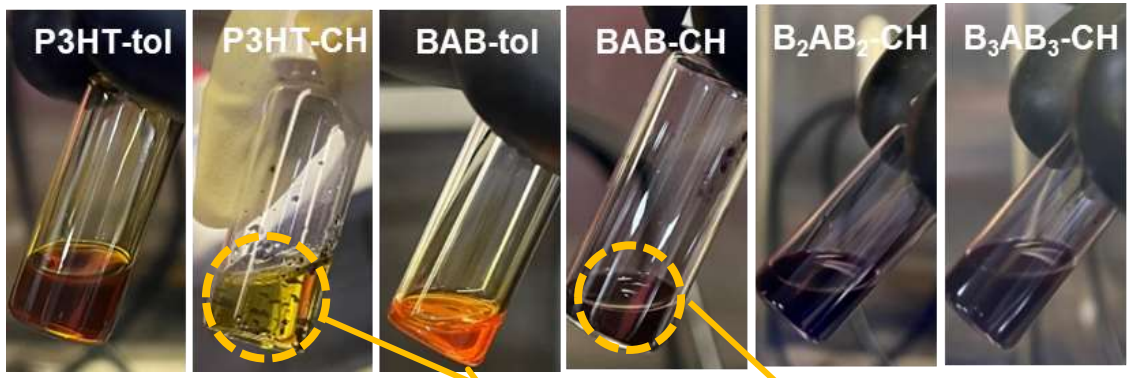
Hot Injection Method



Our Research (3/9)

Self-assembly of Copolymers

Solvent selectivity

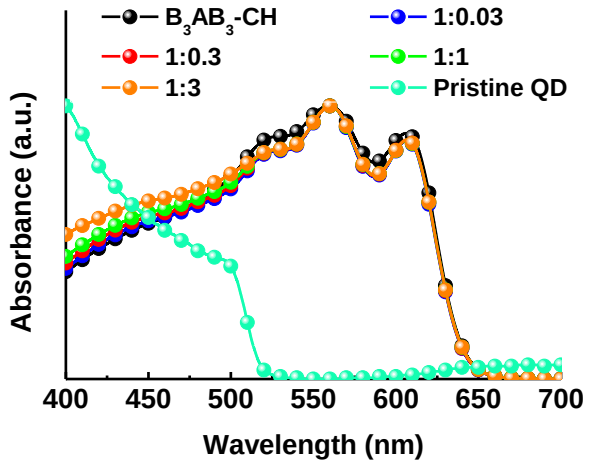


Tol = Toluene
CH = Cyclohexane

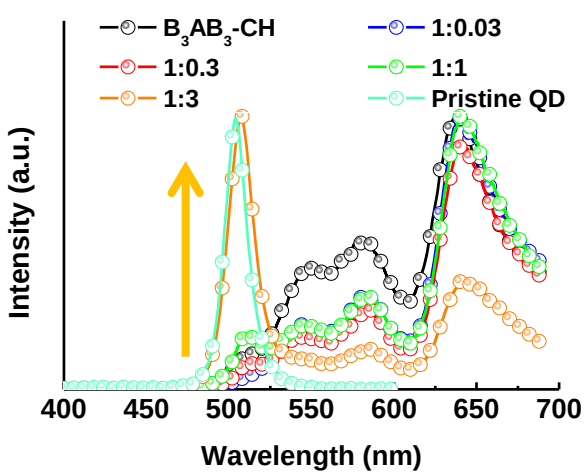
Insoluble at room temperature

Phase separation

Optimizing QD ratio

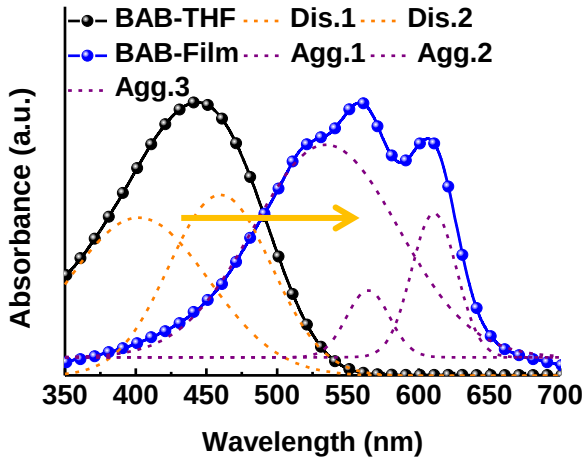


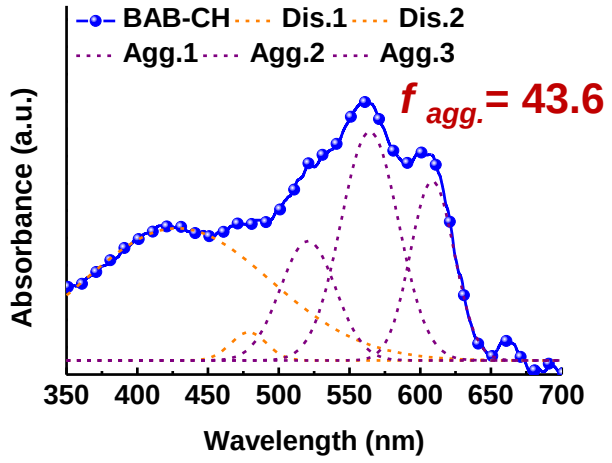
PL

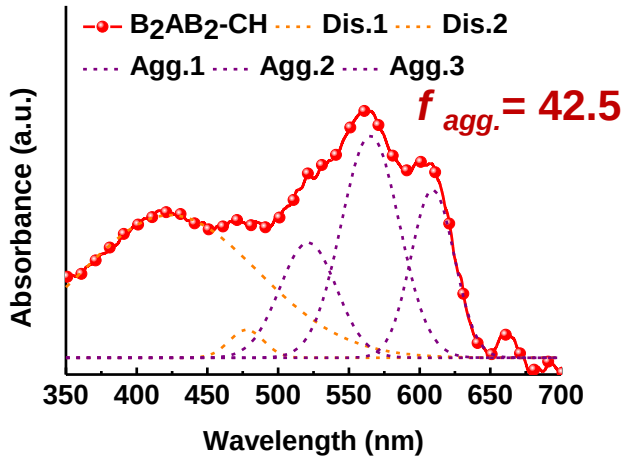


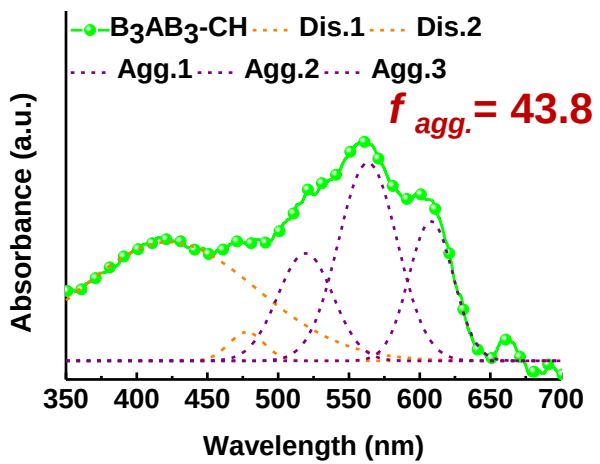
Fraction of aggregation

$$f_{aggregation} = \frac{\frac{A_{aggregate}}{F}}{A_{disorser} + \frac{A_{aggregate}}{F}}$$





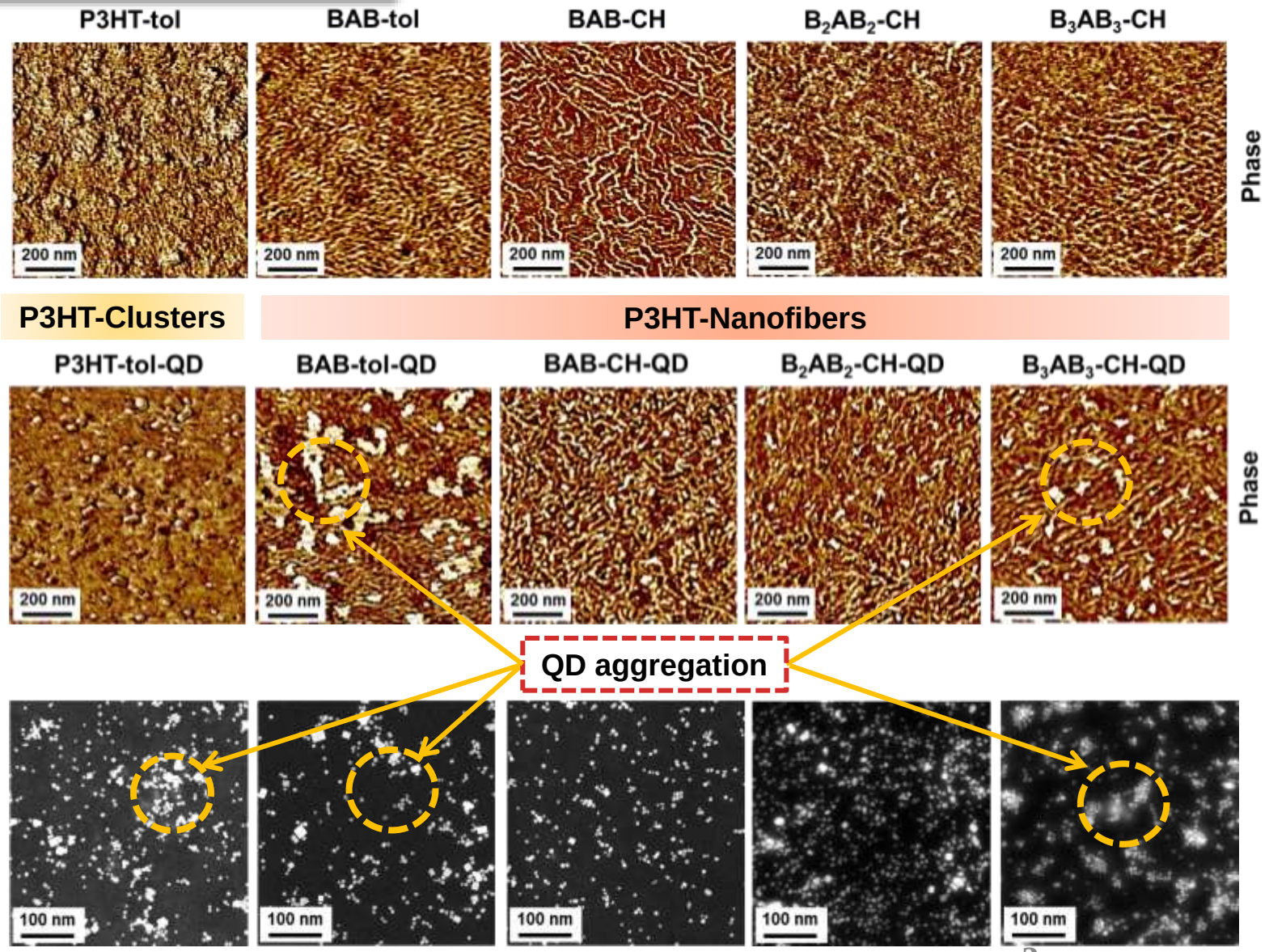


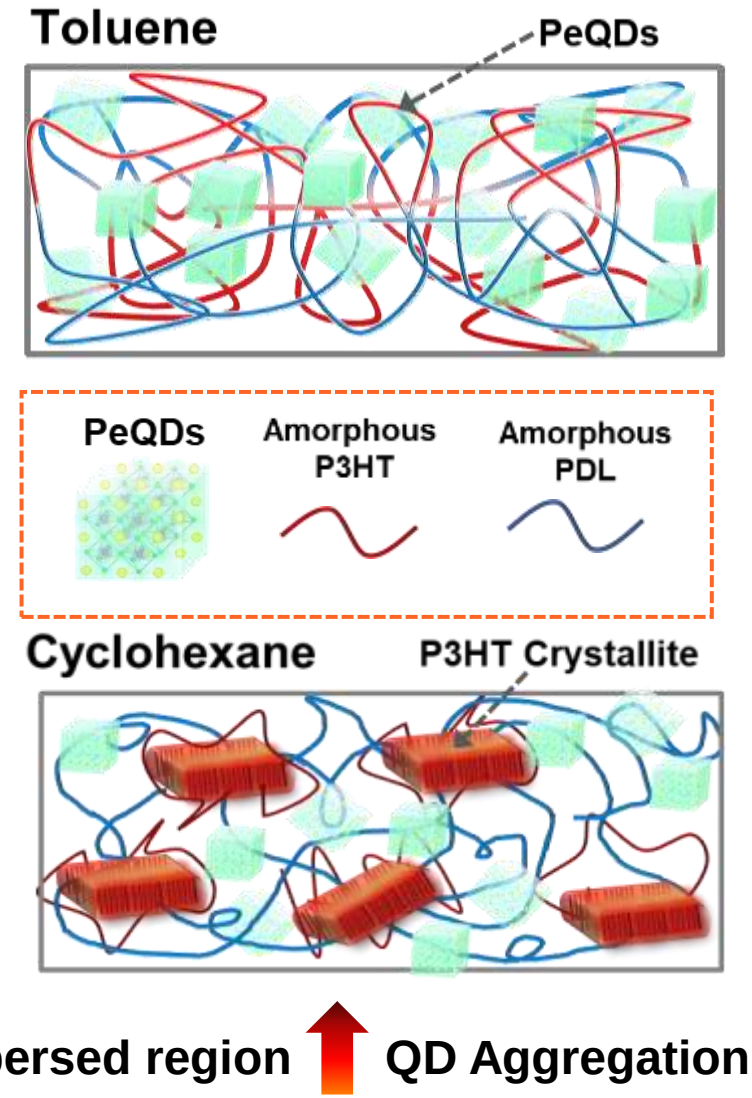


C. Scharsich et al., J. Polym. Sci. B Polym. Phys. 50 (2012) 442-453

Our Research (4/9)

Morphology and QD distribution

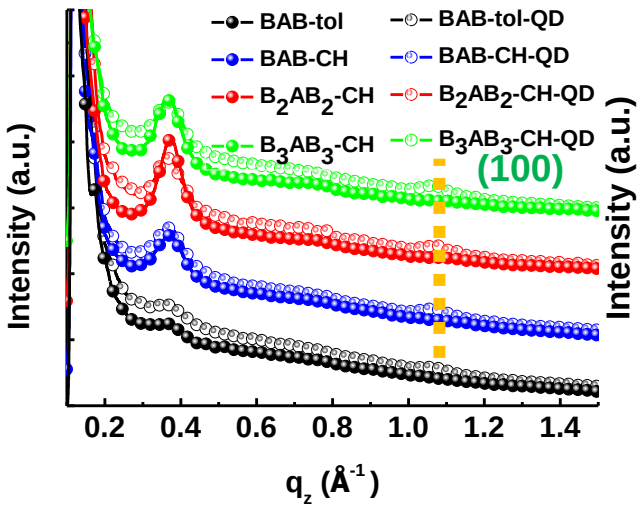




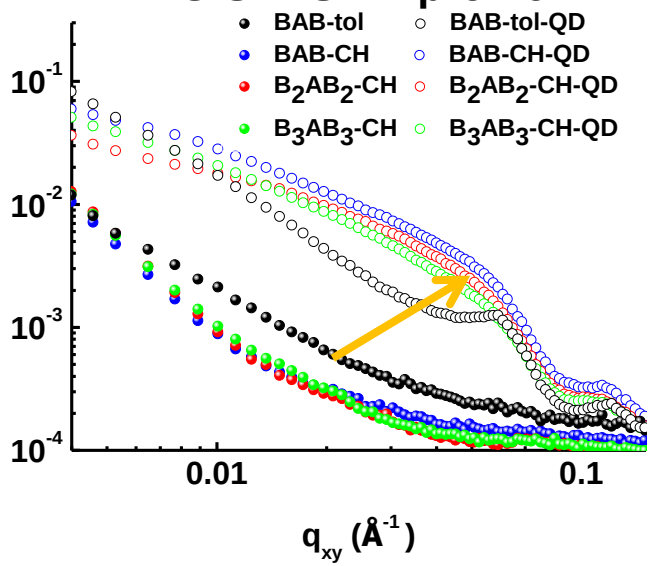
Our Research (5/9)

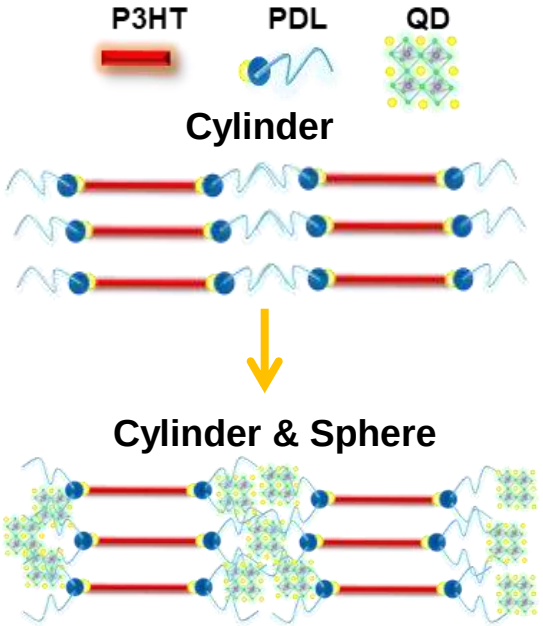
GIWAXS and SAXS for Crystallites

GIWAXS 1D profile



GISAXS 1D profile





Parameter

D = Domain size
Xc= peak center of GIWAXS

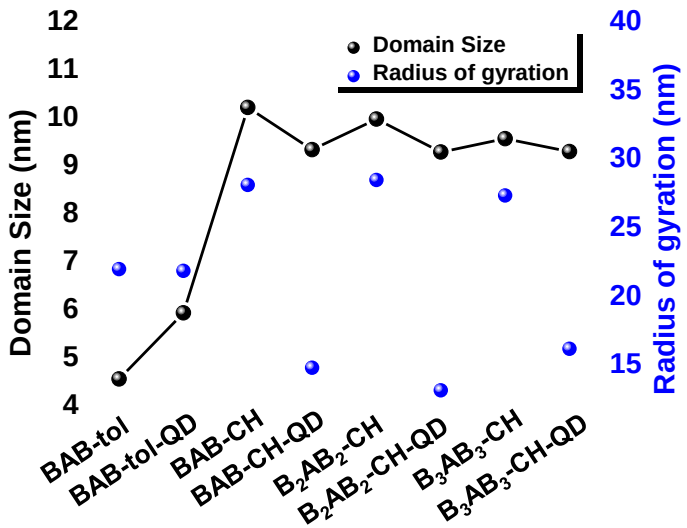
$K = 0.9$ $\lambda = 0.102164$ nm

R_g = Radius of Gyration

$$Domain\ size = \frac{K\lambda}{FWHM \times \cos\theta}$$

$$q = \frac{2\pi}{d} = \frac{4\pi \sin\theta}{\lambda}$$

Guinier Plot: $\ln(I(q)) = \ln(I_0) - \frac{R_q^2}{3} \times q^2$

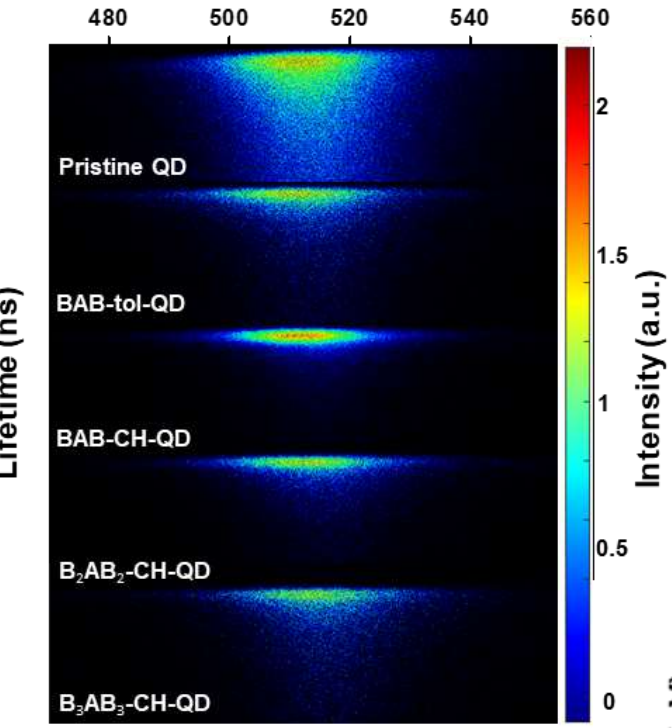


	D (nm)	Xc (q,A^{-1})	d-spacing (A)	Rg
BAB-CH	10.28	0.368	17.1	28.15
BAB-CH-QD	9.42 ↓	0.366	17.2	14.82 ↓
B_2AB_2-CH	9.99	0.369	17.0	28.52
B_2AB_2-CH-QD	9.30 ↓	0.367	17.1	13.17 ↓
B_3AB_3-CH	9.62	0.372	16.9	27.39
B_3AB_3-CH-QD	9.31 ↓	0.366	17.2	16.20 ↓
BAB-tol	4.57	0.356	17.7	21.89
BAB-tol-QD	5.95	0.363	17.3	22.01

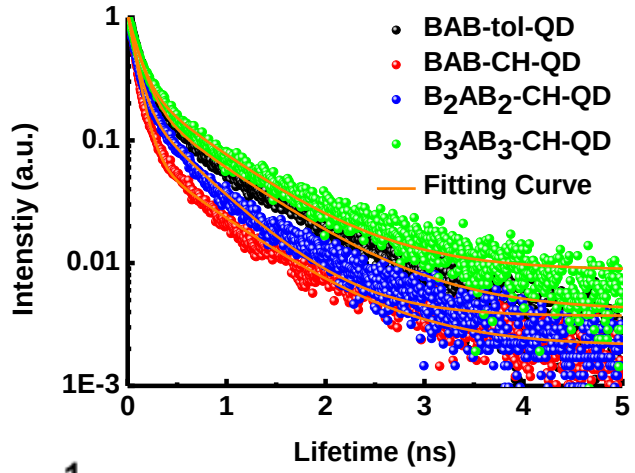
Our Research (6/9)

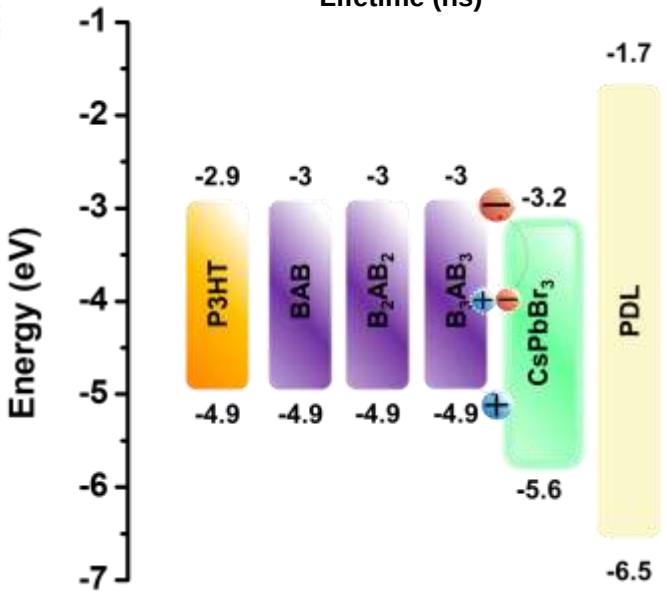
Time-resolved PL and Charge Transfer Efficiency

TRPL 2D profile



TRPL 1D profile





Non-radiative recombination

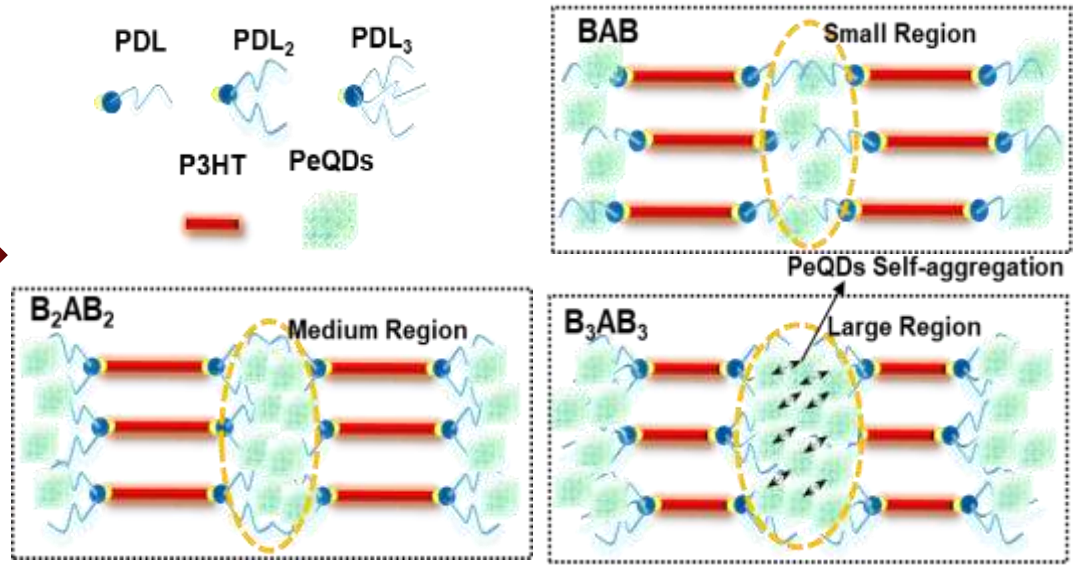
$$CTE = \frac{\tau_{QD} - \tau_{copolymers\&QD}}{\tau_{QD}} \times 100\%$$

Range: 475~540 nm

	A_1	τ_1	A_2	τ_2	τ_{avg} (ns)	CTE (%)
Pristine QD	0.55	0.25	0.45	1.57	1.36	
BAB-tol-QD	0.81	0.12	0.19	0.75	0.50	63.58
BAB-CH-QD	0.93 ↑	0.08	0.07	0.73	0.33 ↓	75.64 ↑
B_2AB_2-CH-QD	0.83	0.08	0.17	0.55	0.35	74.32
B_3AB_3-CH-QD	0.76	0.11	0.24	0.71	0.52	61.96

$$F(t) = \sum_{i=1}^{n} A_i e^{-\frac{t}{\tau_i}} \quad \text{(n=2)}$$

$$\tau_{avg} = \frac{\sum_{i=1}^{n} A_i \tau_i^2}{\sum_{i=1}^{n} A_i \tau_i} \quad \text{(n=2)}$$

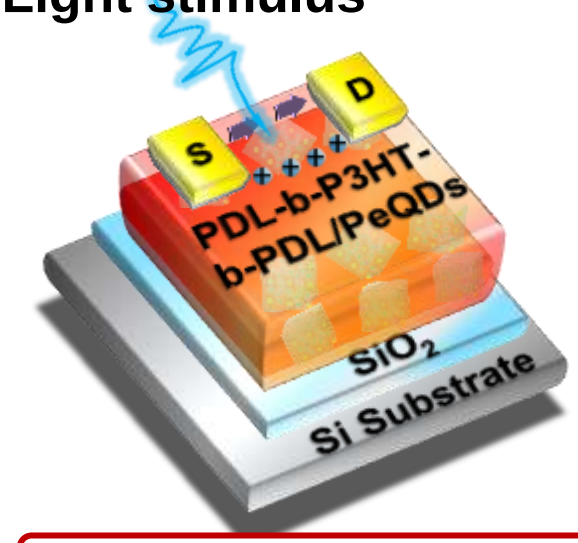


Self-aggregation of PeQDs decreases CTE.

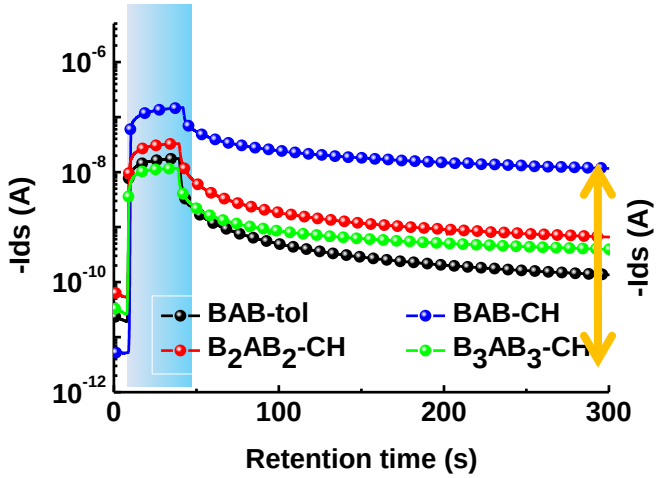
Our Research (7/9)

Memory Device Performance

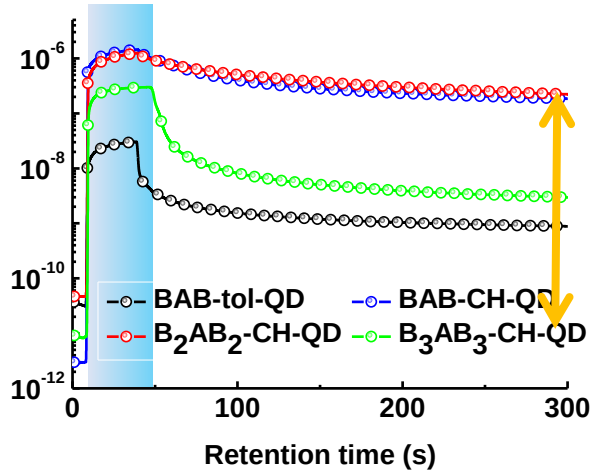
Light stimulus



Without QD



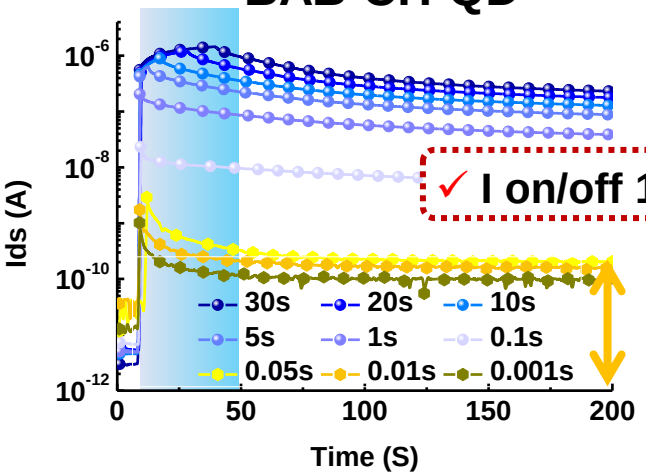
With QD



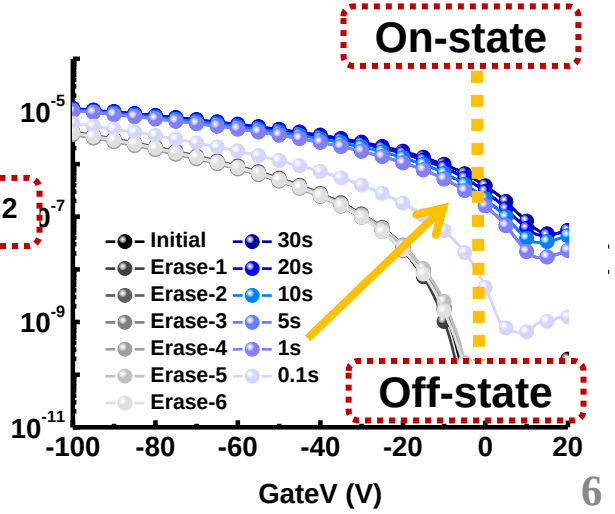
- ✓ The larger domain size of P3HT crystallites reveals better electron trapping.

Transient Photocurrent

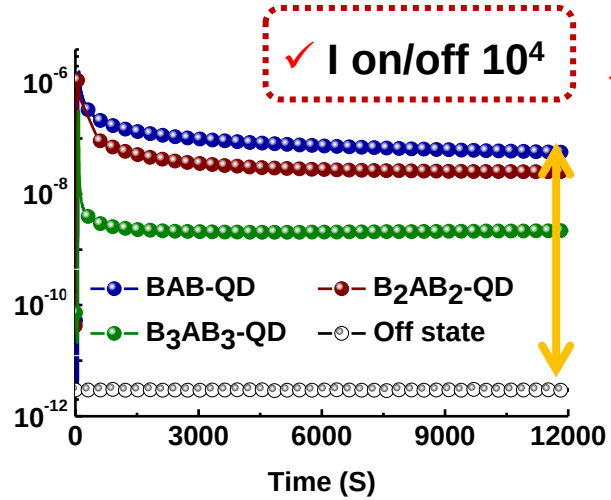
BAB-CH-QD



Transfer Curve

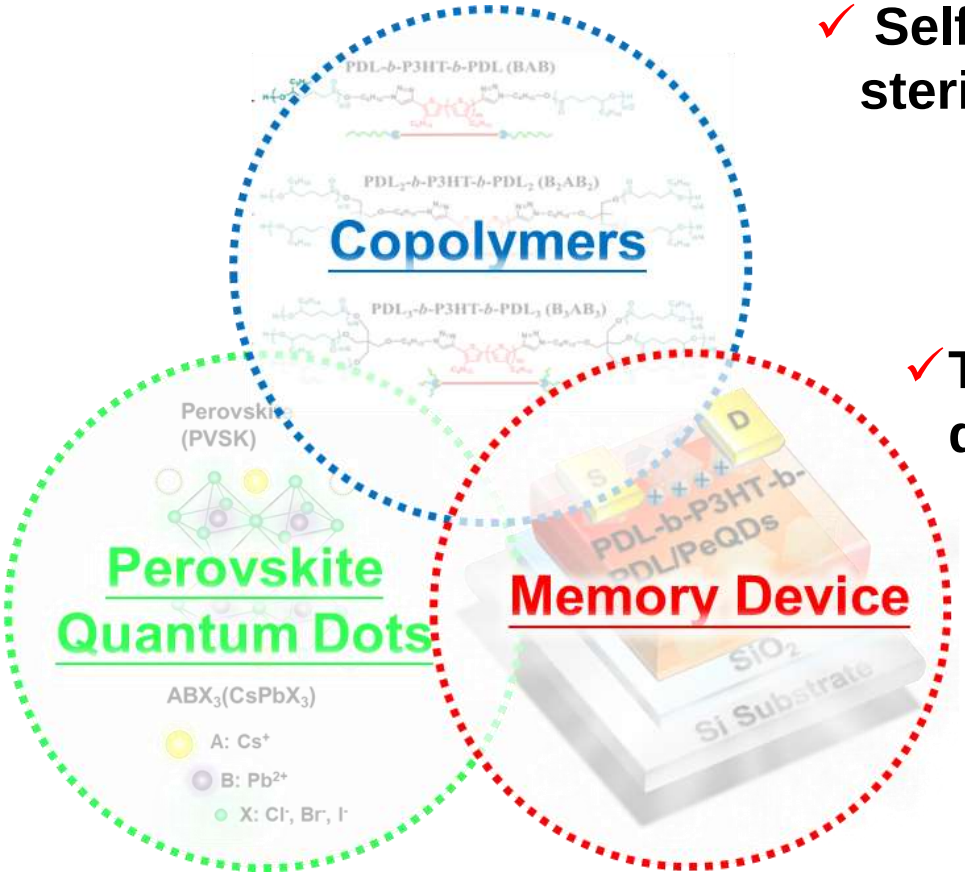


Retention 10^4 s



- ✓ The better distribution of QD in copolymers presents better photo-sensitivity.
- ✓ The closer distance between QD and copolymers crystallites presents better electron trapping.

Conclusion



✓ **Self-aggregation of PeQDs is improved by an appropriate steric hindrance and self-assembly of triblock copolymers.**

✓ **The good distribution of PeQDs and larger P3HT crystallite domain size present higher photosensitivity.**

✓ **A superior charge transfer efficiency (75.6%) is demonstrated by optimizing the interfaces of QD and P3HT crystallites.**

Our Research (9/9)

Acknowledgments

Optoelectronic Polymer Laboratory

National Taiwan University

Advanced Polymer and Nanotechnology Laboratory

National Taipei University of Technology

THANKS FOR ATTENTION

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National Science and Technology Council

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