



山东大学
SHANDONG UNIVERSITY

Sino-Germany Workshop on Printable Photovoltaics

May 21st – 23rd, Erlangen, Germany

Stability of organic optoelectronics: the influence of illumination, thermal and mechanical stress

Xiaoyan Du



Outline

➤ **Photo and thermal stability of organic solar cells**

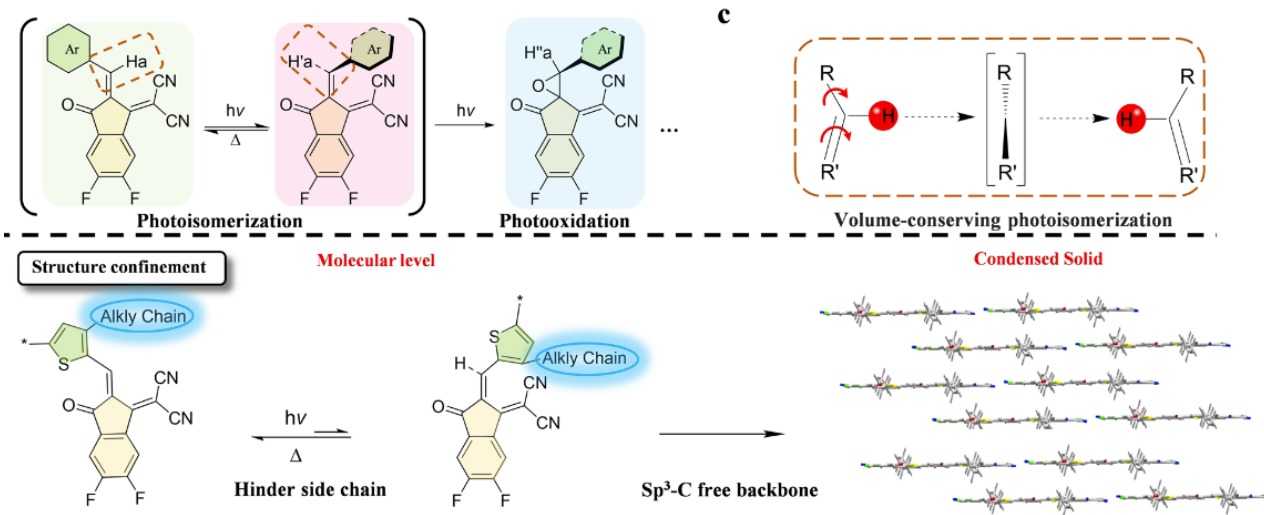
- W. Zhang, X. Du*, Q. Zheng*, X. Hao*, et al., Adv. Funct. Mater., 2023, 2308591.
- K. Zhang, X. Du*, X-T. Hao*, et al, Energy Environ. Sci., 2022, 15, 5261–5273.
- L. Wang, X. Hao*, X. Du*, et al., J. Phys. Chem. Lett. 2022, 13, 11974–11981.
- K. Zhang, X. Du*, X. Hao*, et al., Adv. Energy Mater. 2021, 2103371.
- K. Zhang, X. Du*, X-T. Hao*, et al, Small Methods 2023, 2300397.
- Y. Xu, X. T. Hao*, X. Du*, et al, under review.

➤ **Mechanical stability of NIR self-powered organic photodetectors**

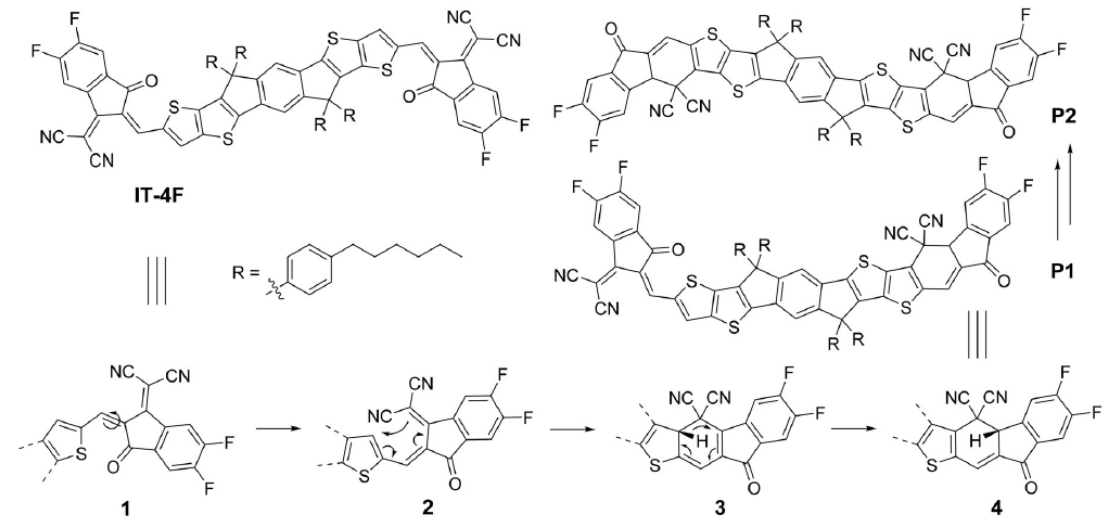
- C. Wang, Z. Meng*, X. Hao*, and X. Du*, et al, Appl. Phys. Lett, 2024, 124 (18).

Photostability of organic solar cells

- The **volume-conserving photo isomerization of exocyclic vinyl groups** is one critical step toward the subsequent photo degradation of a unique series of A–D-A NFAs.
- **Hinder outward-chain** and **planar sp^3 carbon-free** backbones play important roles to enhance the intrinsic photo-stabilities.



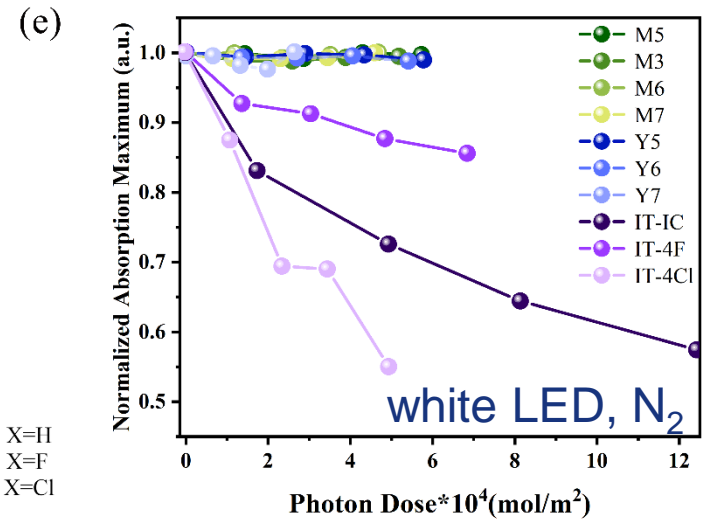
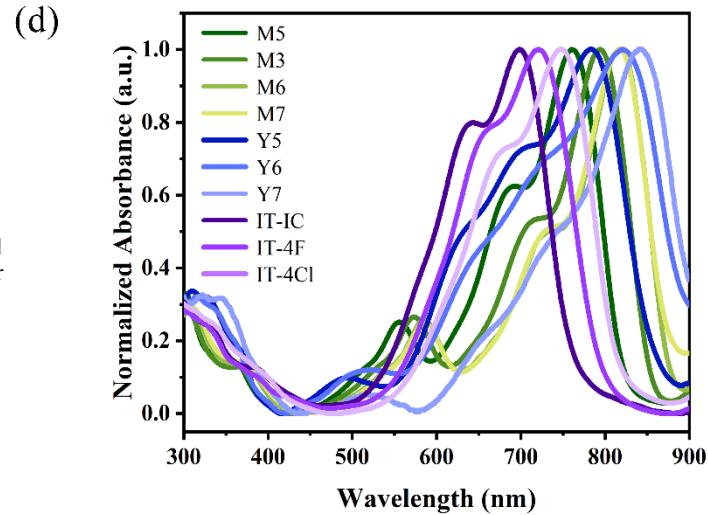
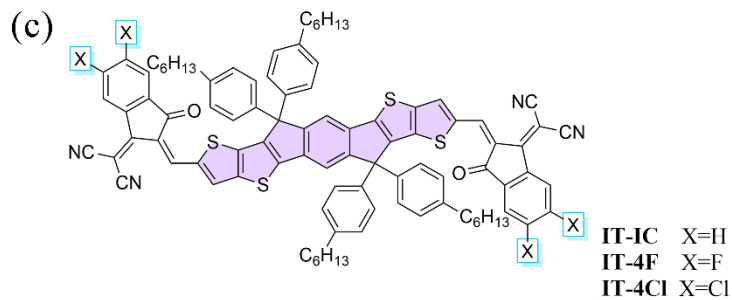
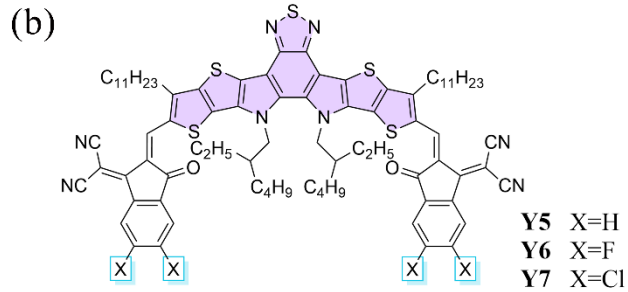
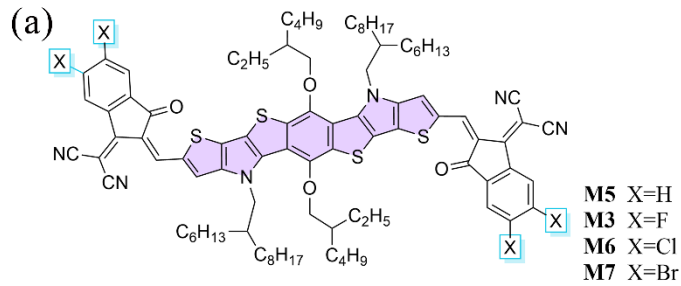
- **Intra-molecular 6-e electrocyclizations** producing fused-ring isomers.
- The reaction proceeds via a triplet state.



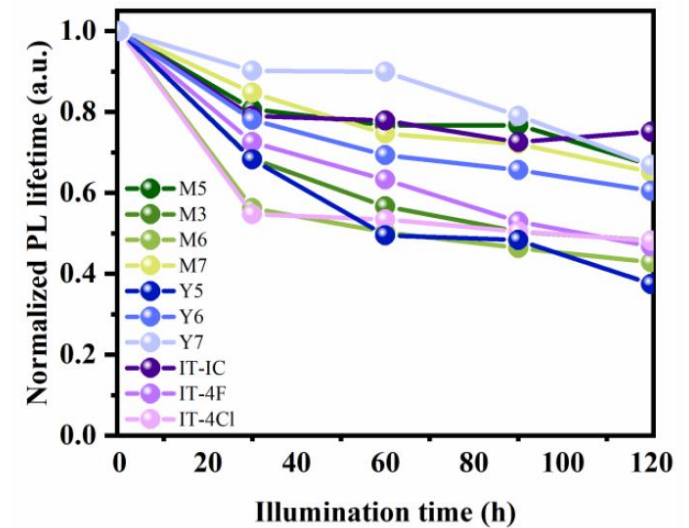
Z.-X. Liu, C.-Z. Li, et. al., Nat. Commun. 2021, 12:3049

Y. Che, D. F. Perepichka, et. al., Angew. Chem. Int. Ed. 2021, 60, 24833 –24837

Photostability of organic solar cells

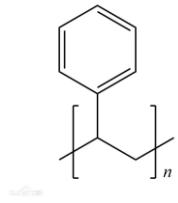


- **M and Y Series:** exceptional molecular level photo-stability
- Decrease of exciton lifetime



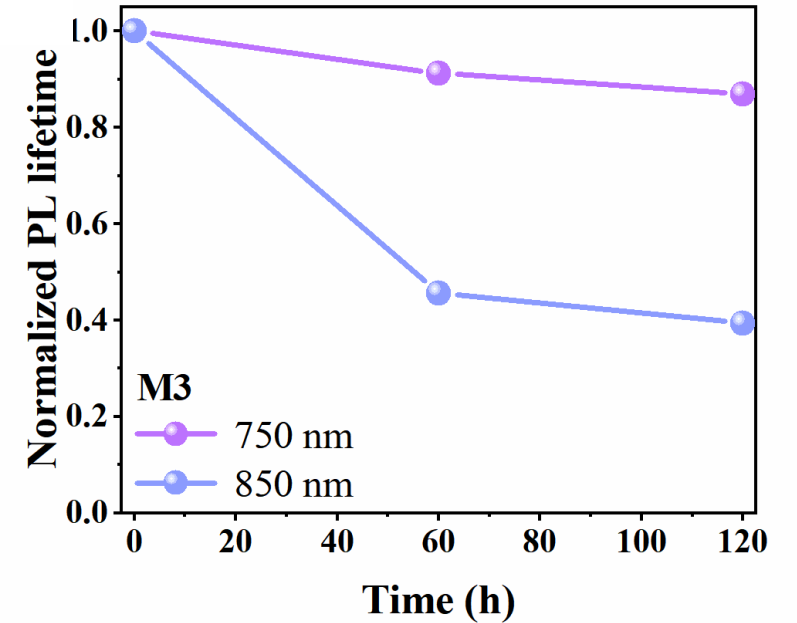
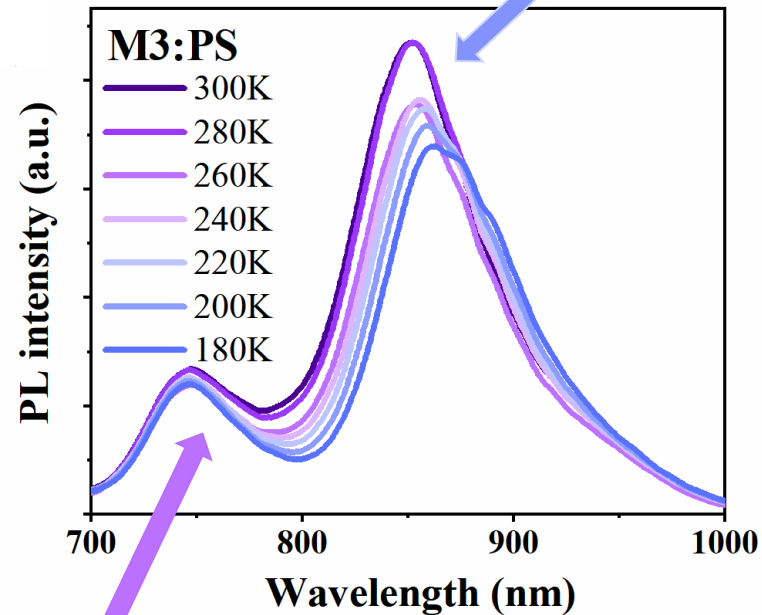
Photostability of organic solar cells

Degradation in transient PL lifetime mainly comes from **inter-molecular excitons**



PS

NFA



intra-molecular excitons

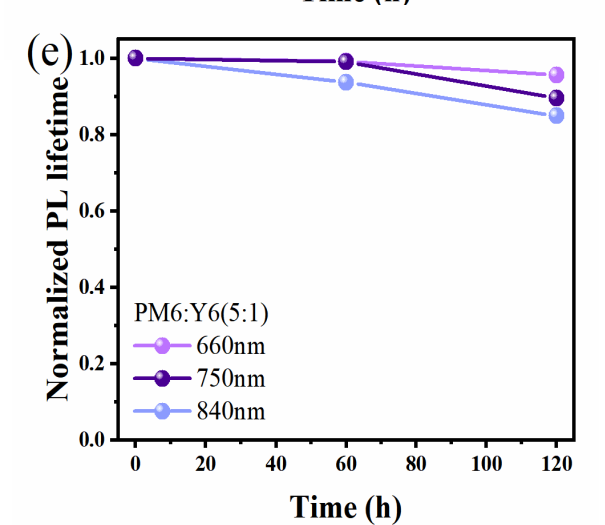
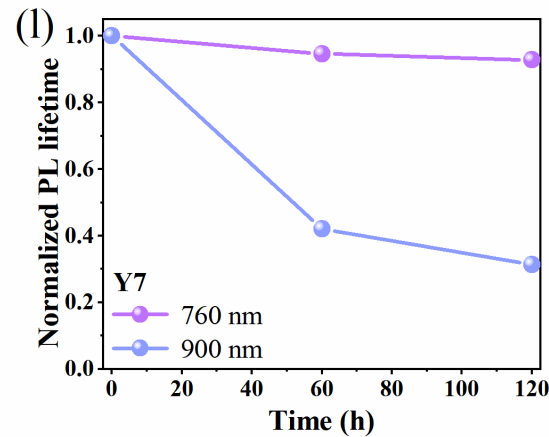
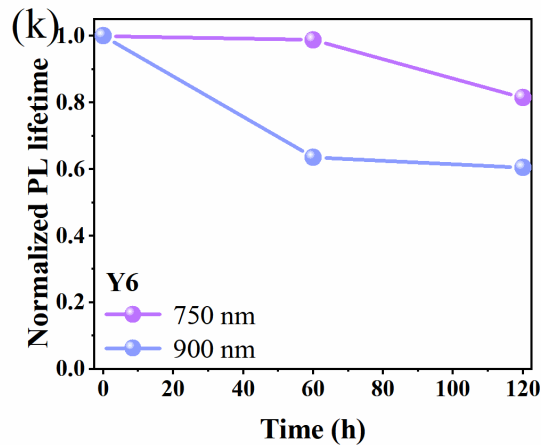
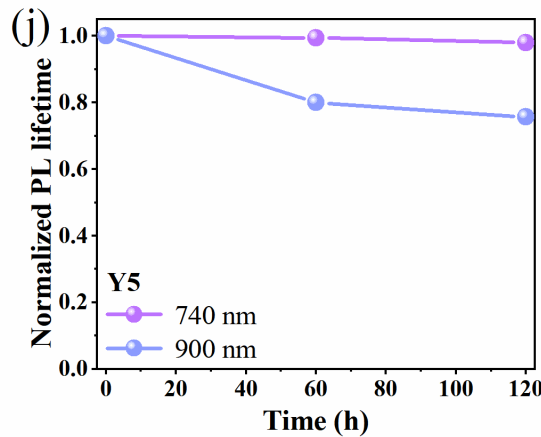
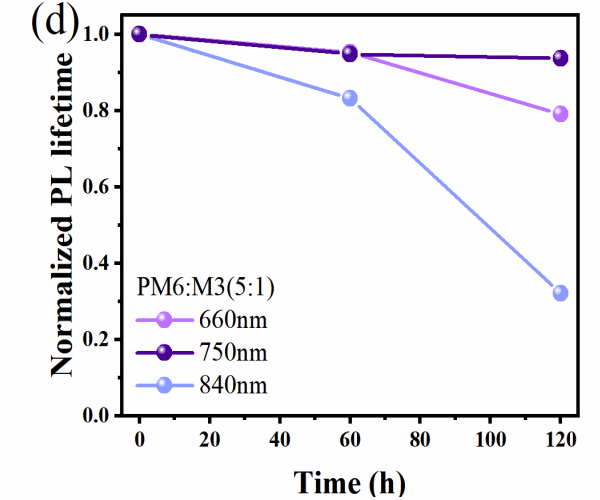
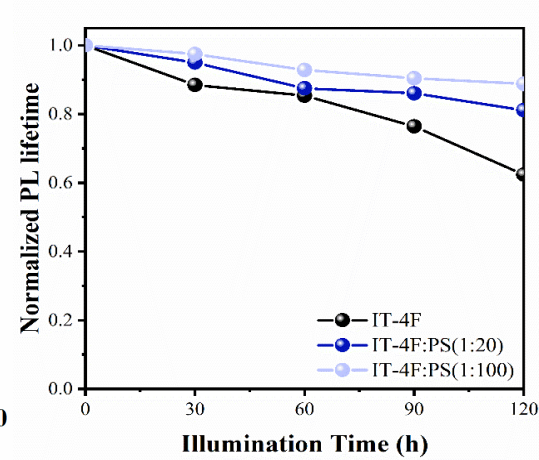
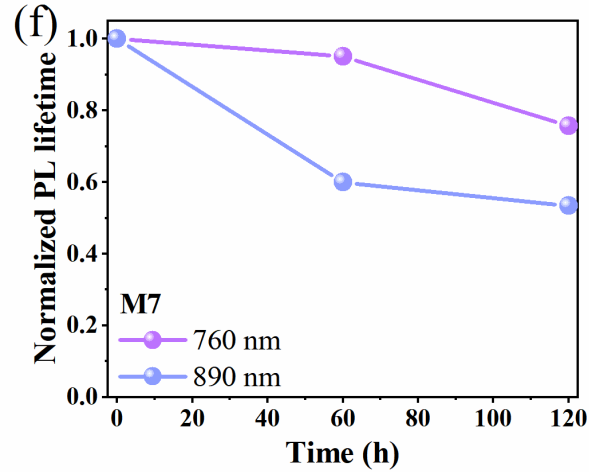
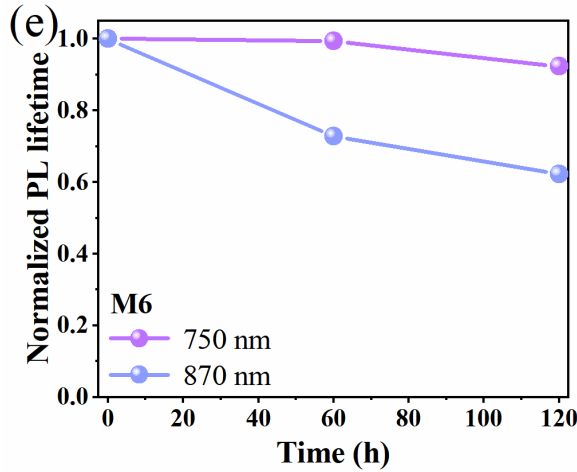
inter-molecular excitons

Photostability of organic solar cells

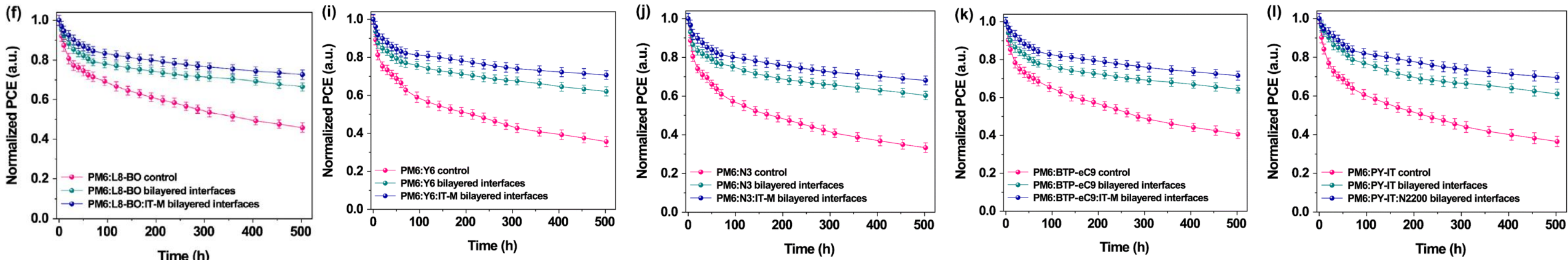
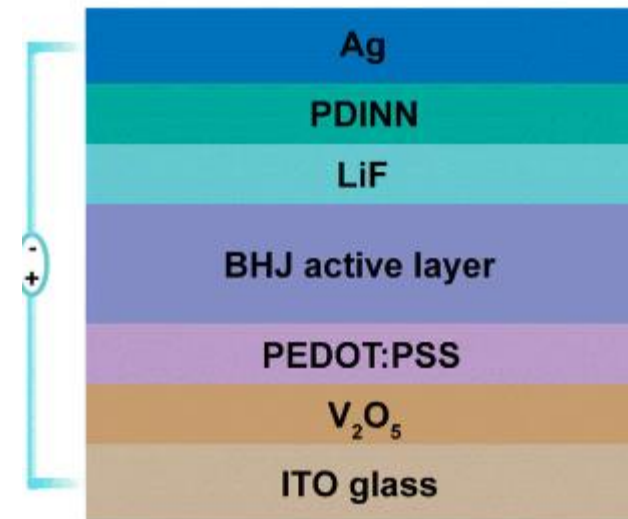
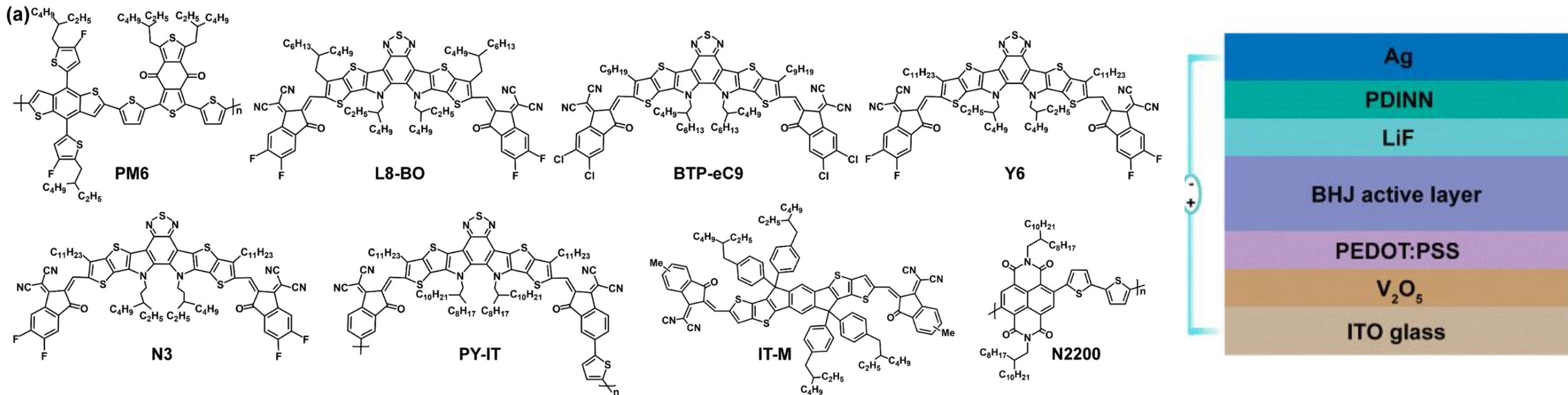
Fast quenching of the excitons is essential for photo stability.

General trend in other 6 NFAs

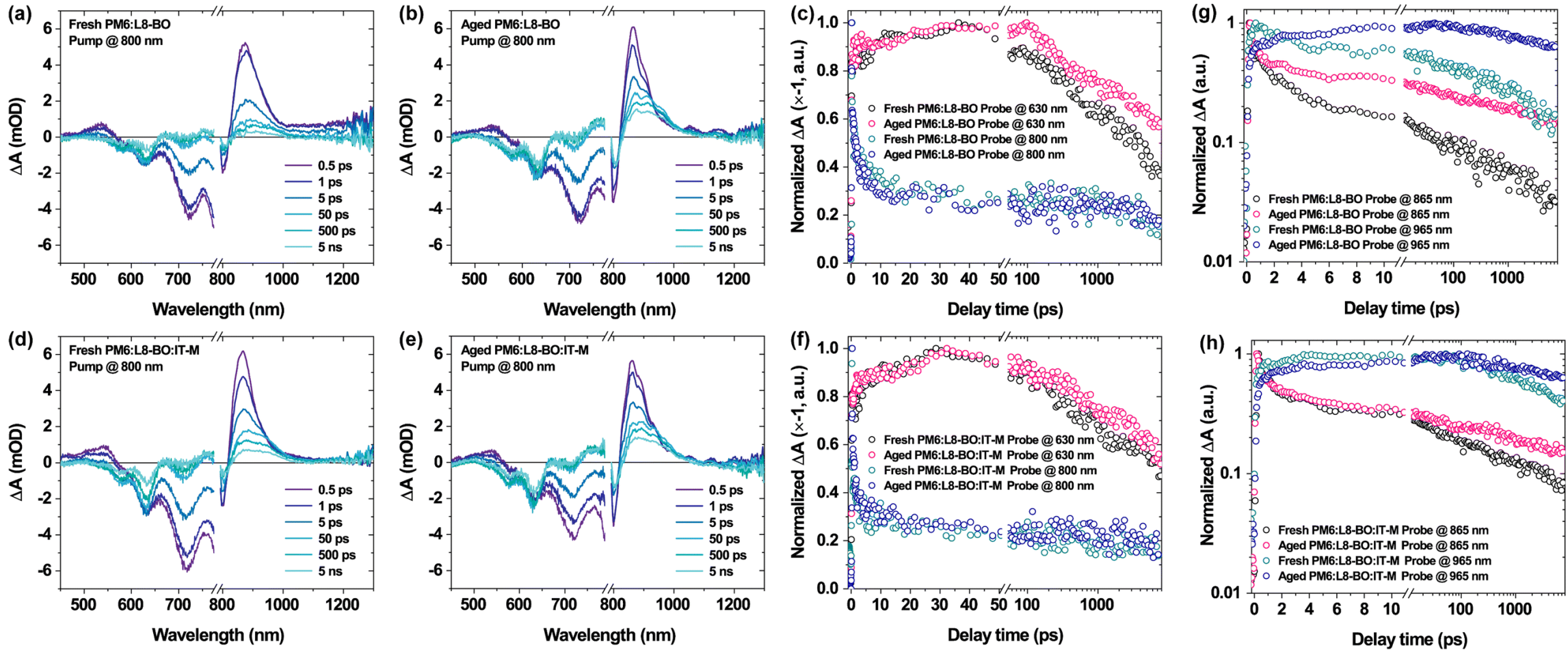
Relevant in donor:
acceptor blends



Photostability of organic solar cells

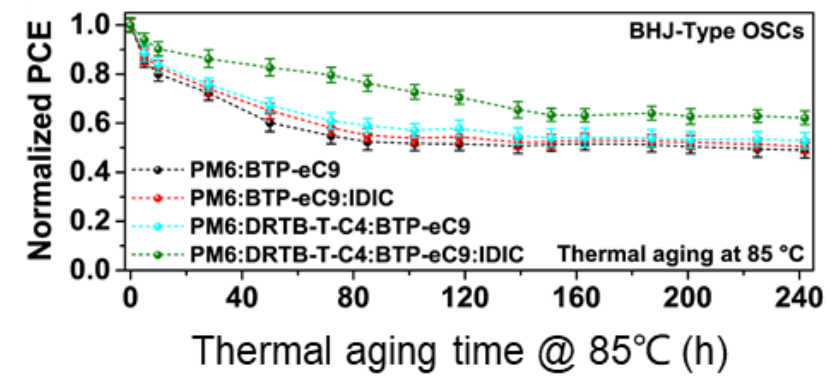
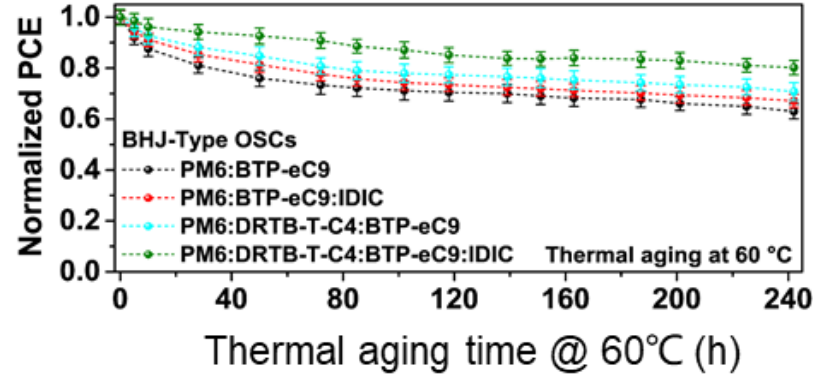
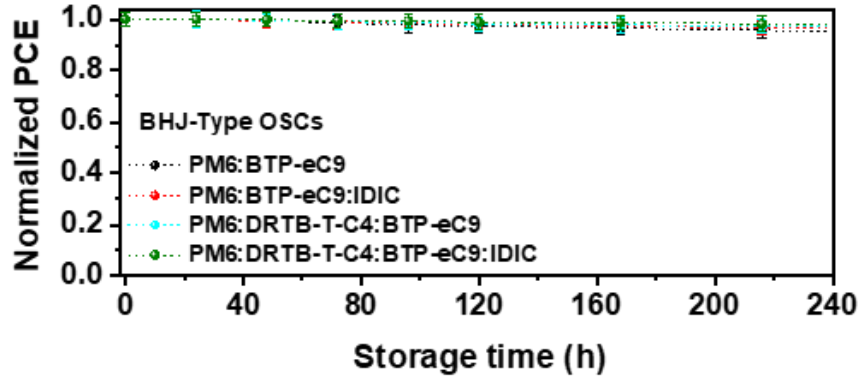
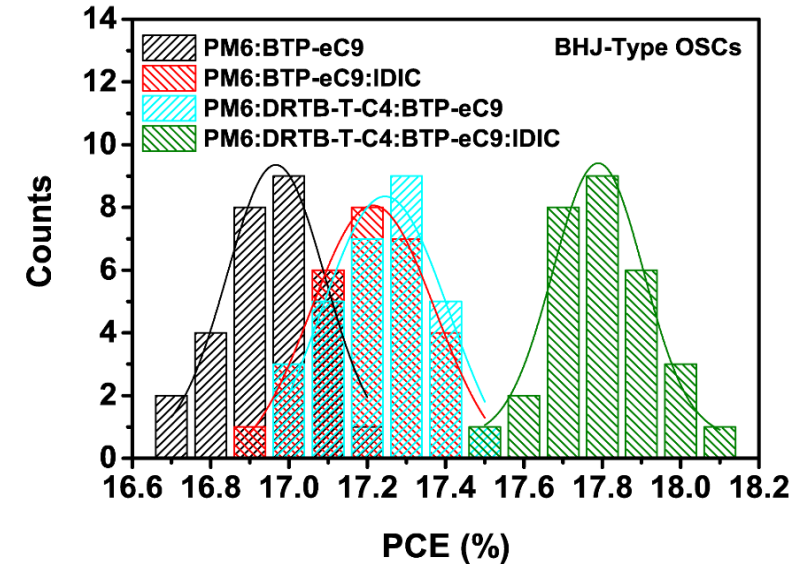
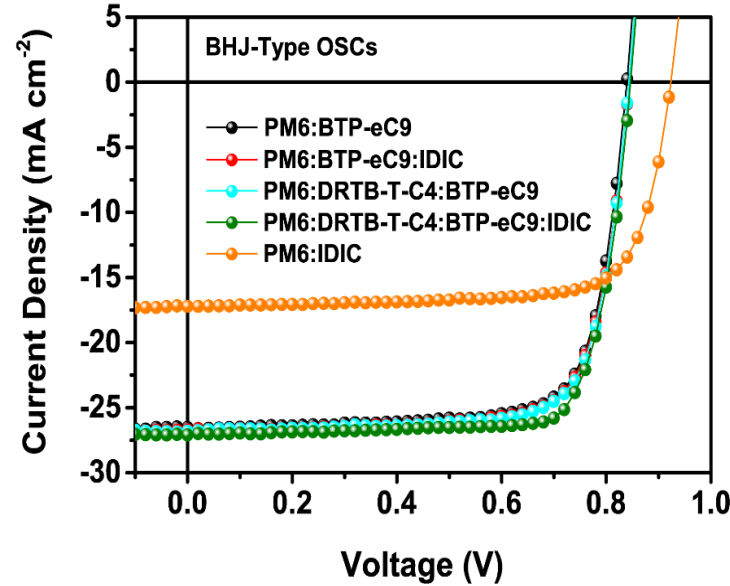
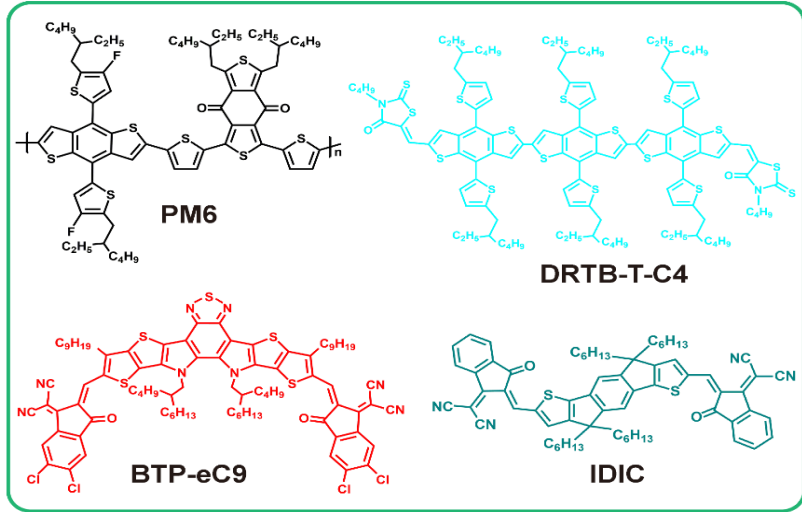


Photostability of organic solar cells



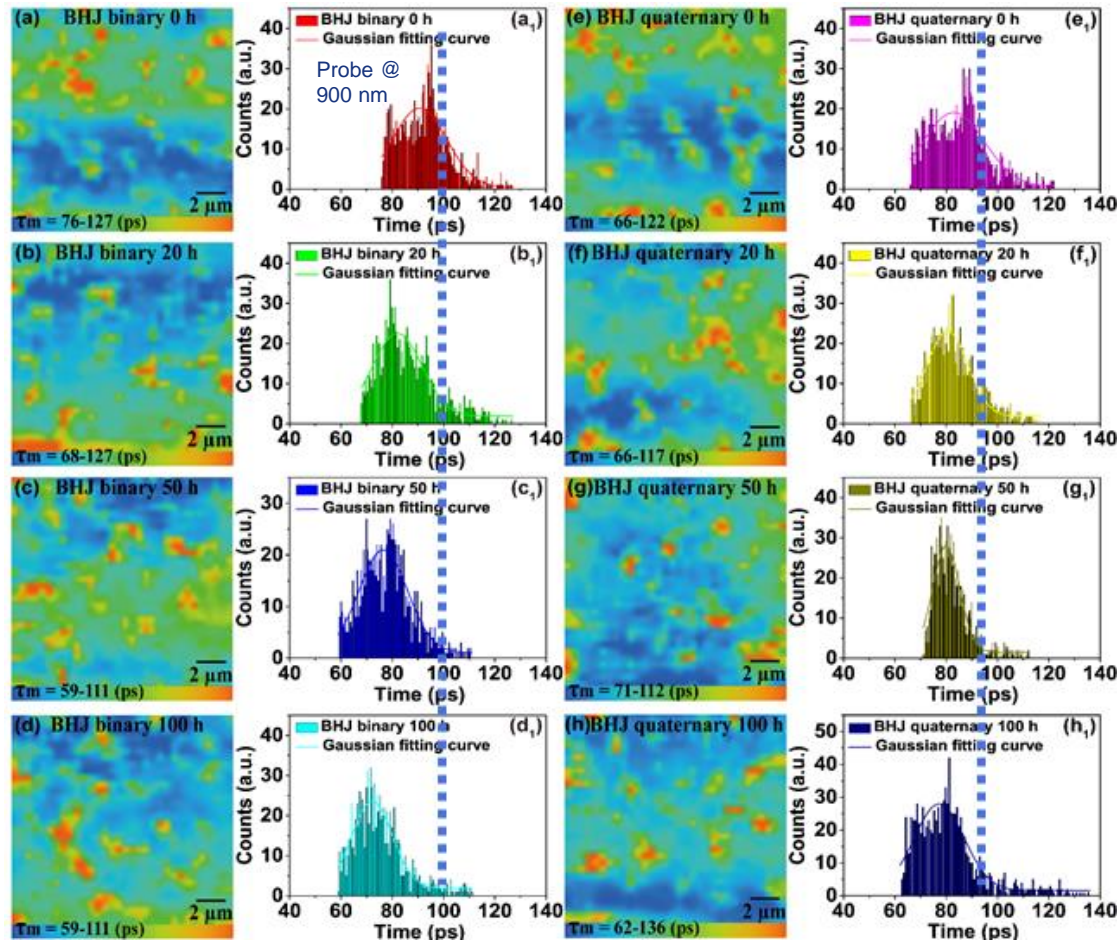
Thermal stability of organic solar cells

Quaternary blends to suppress thermal-induced degradation

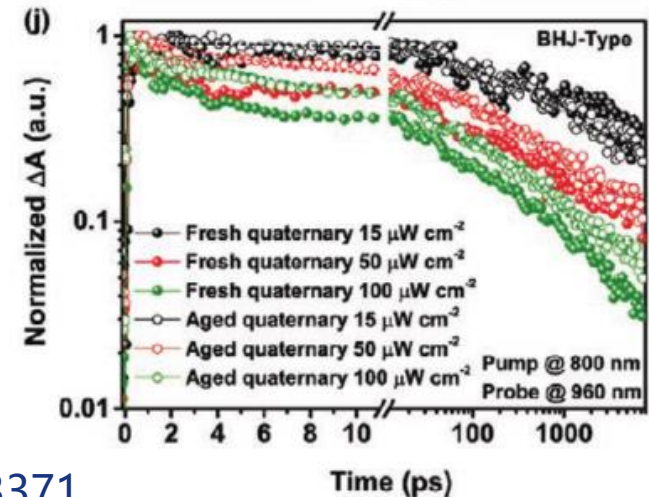
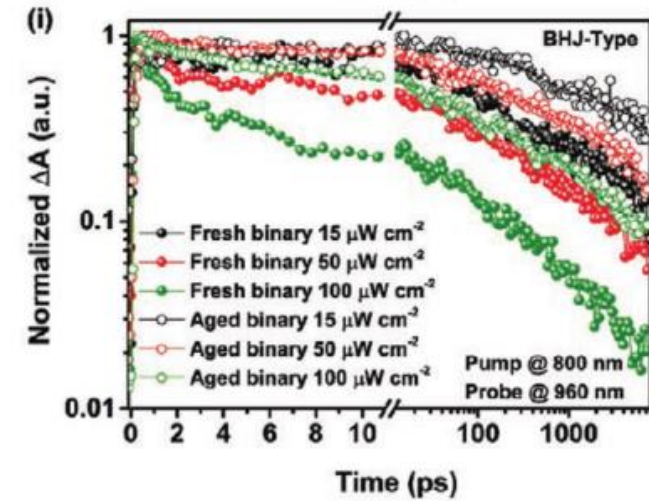


Thermal stability of organic solar cells

Visualizing thermal induced aging in active layer with 2D TRPL

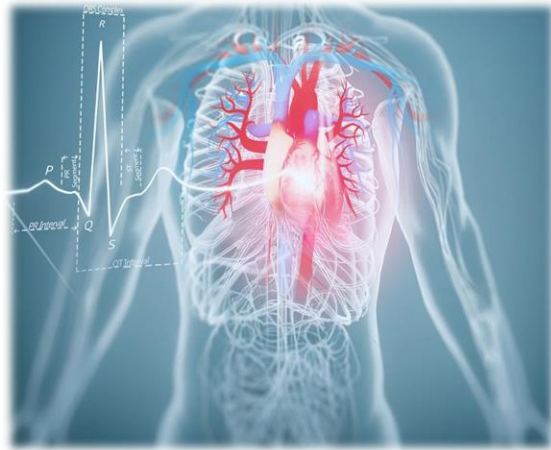


Stabilizing dynamics of charged species with quaternary blends



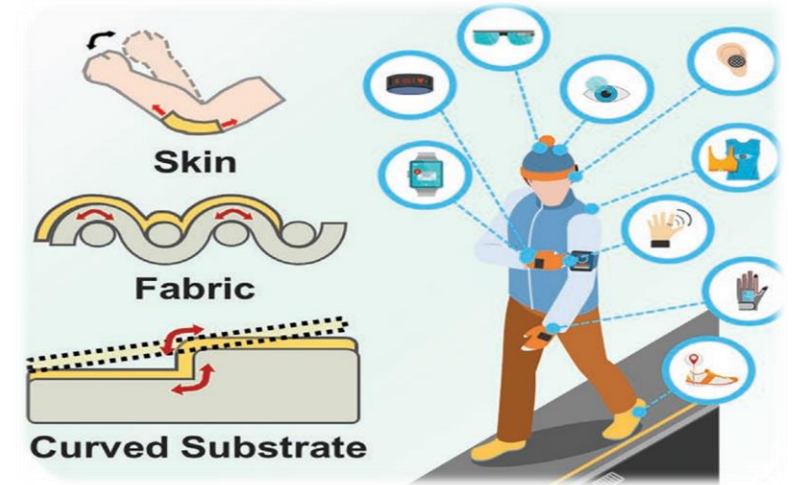
K. Zhang, X. Du*, X-T. Hao*, et al, Adv. Energy Mater. 2021, 2103371
 K. Zhang, X. Du*, X-T. Hao*, et al, Small Methods 2023, 2300397

Mechanical stability of NIR self-powered organic photodetectors



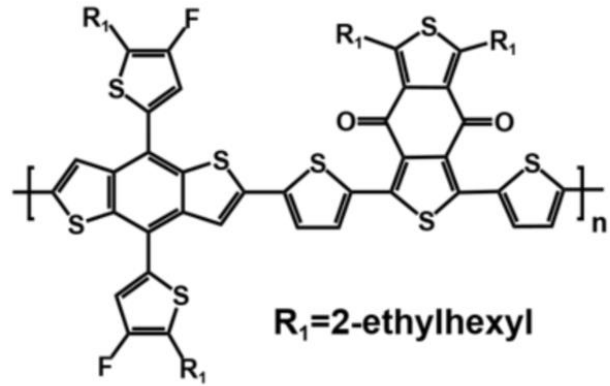
- wearable
- non-invasive
- comfortable
- long-term continuous monitor

Wearable electronics

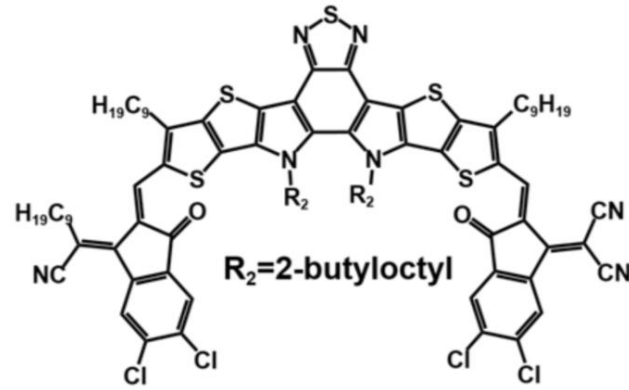


➔ **NIR sensitivity & low power consumption & stretch-ability**

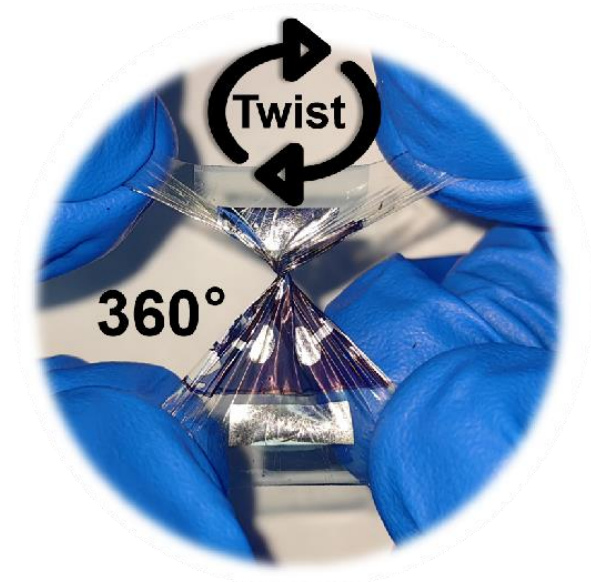
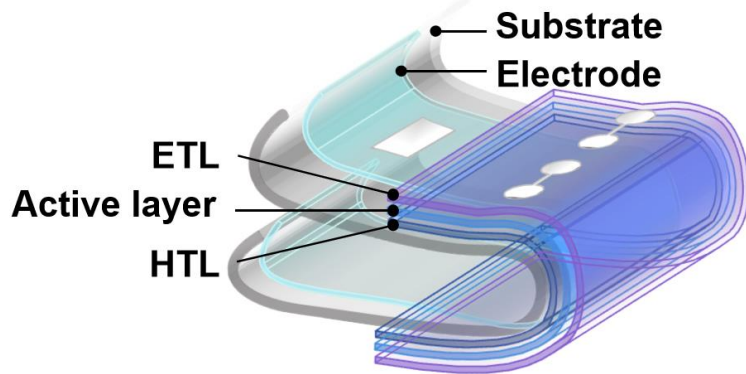
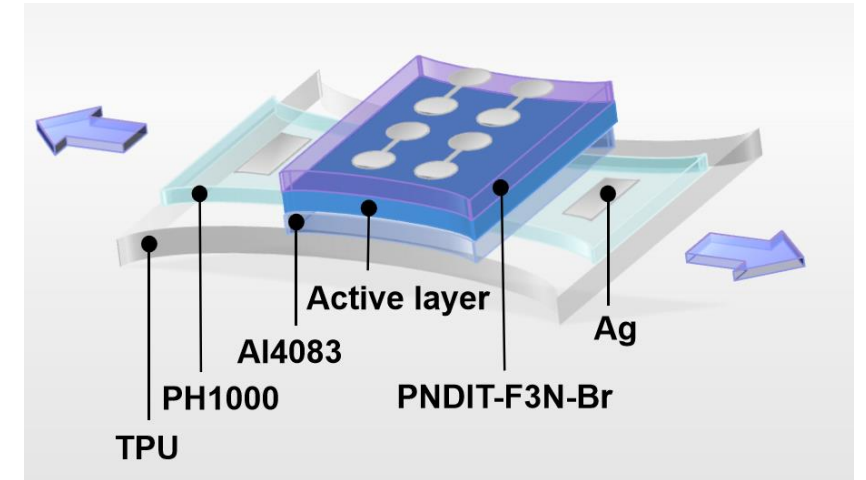
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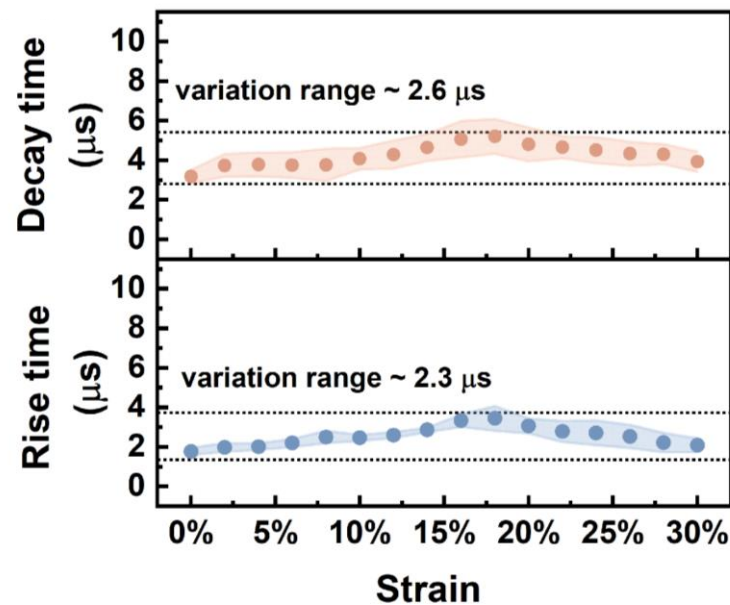
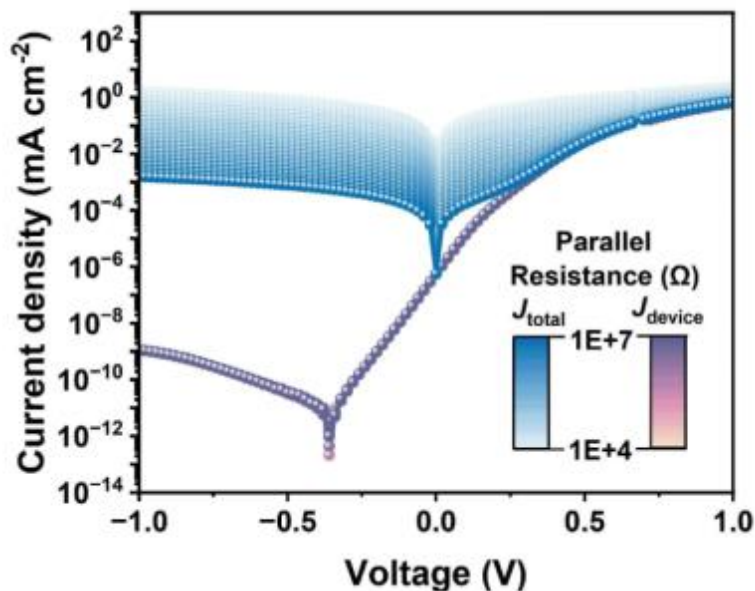
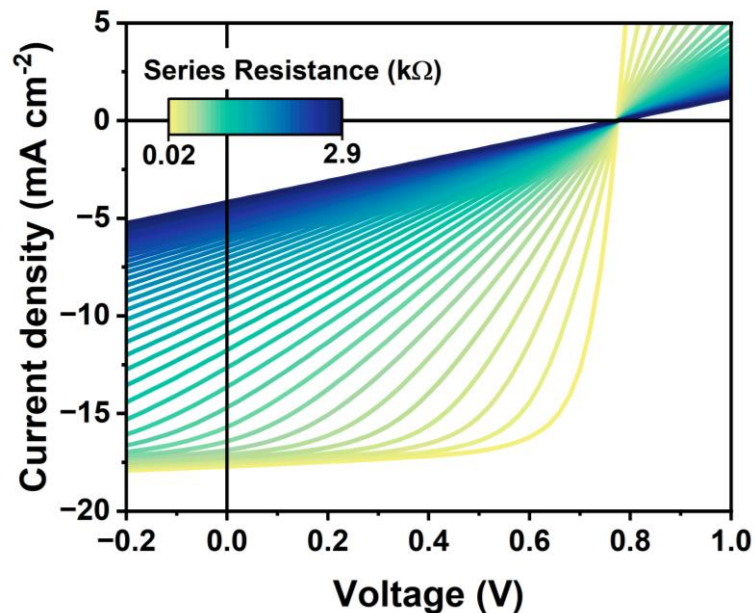
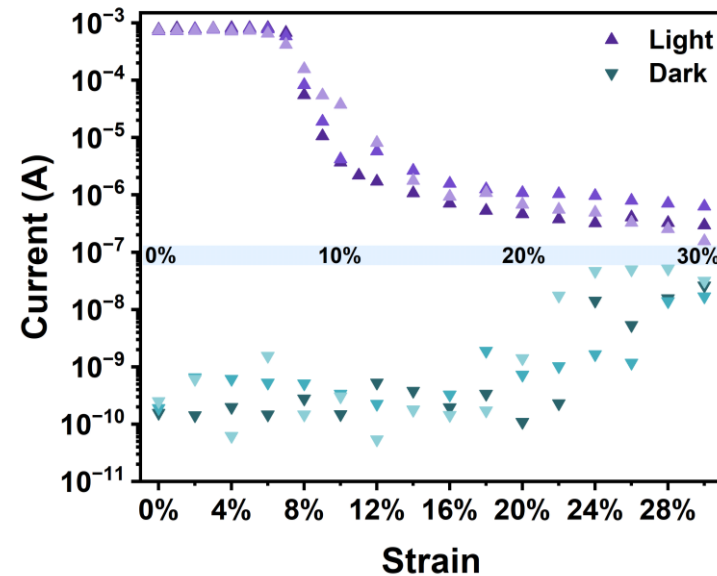
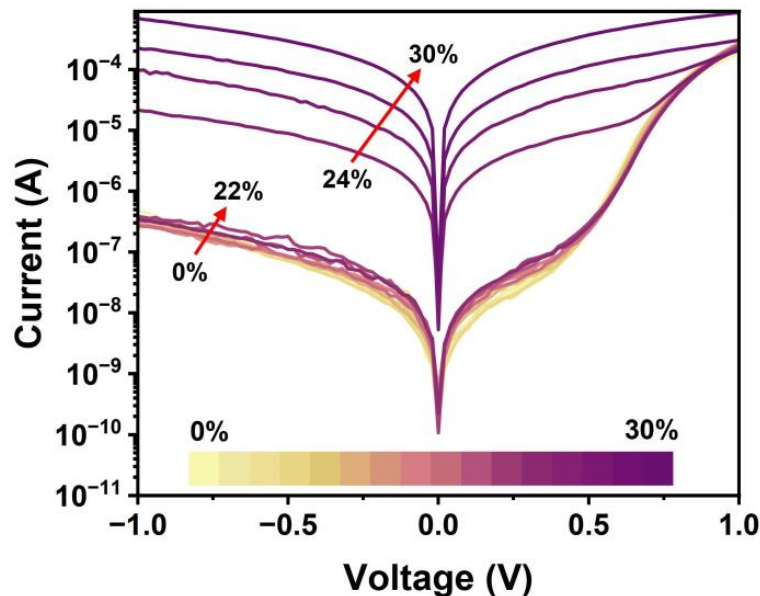
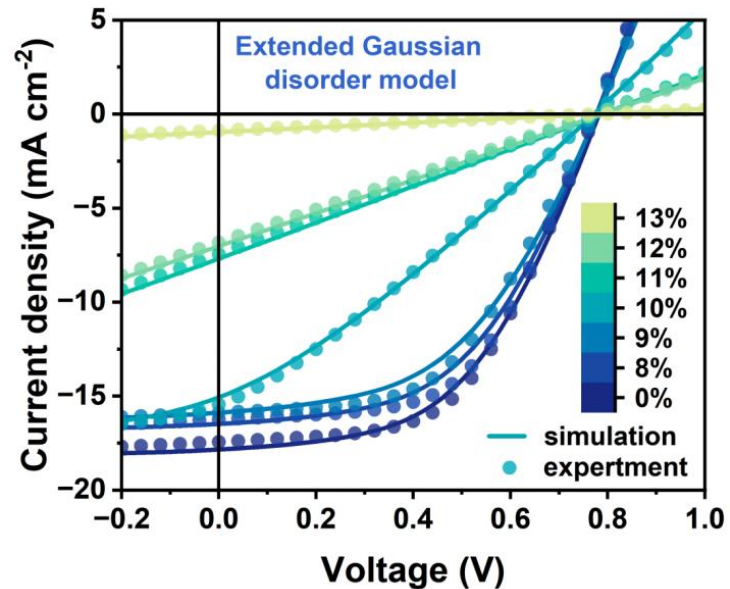
PM6



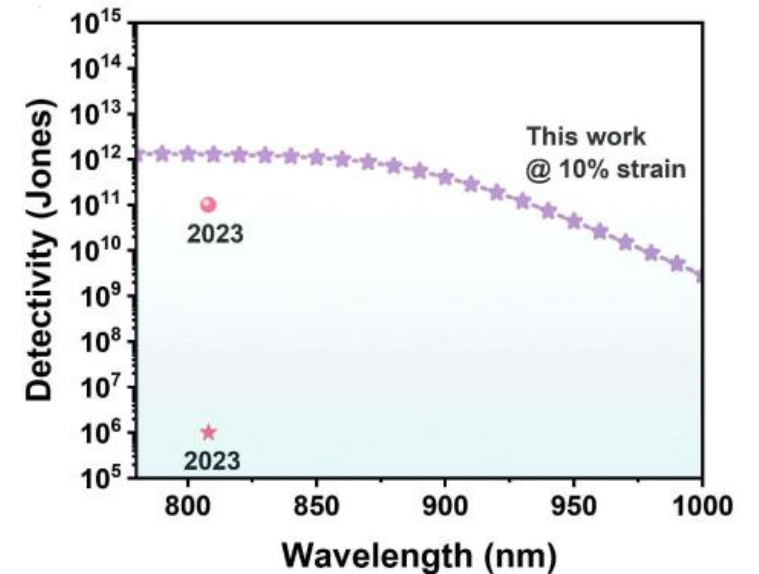
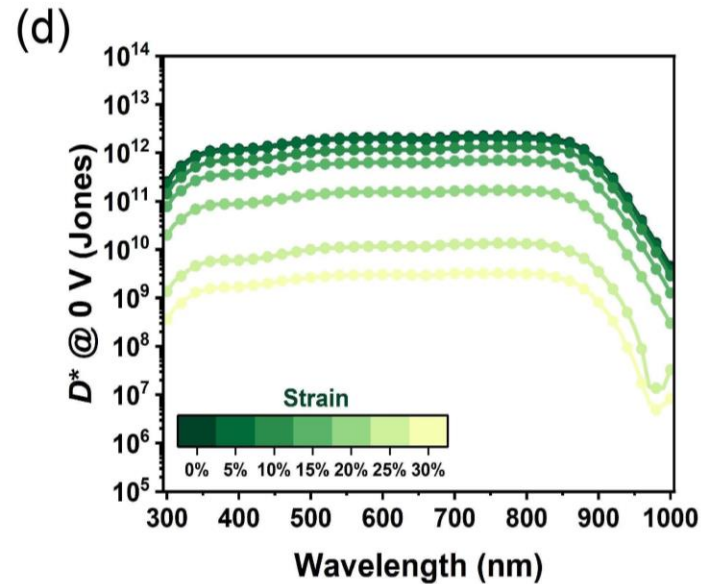
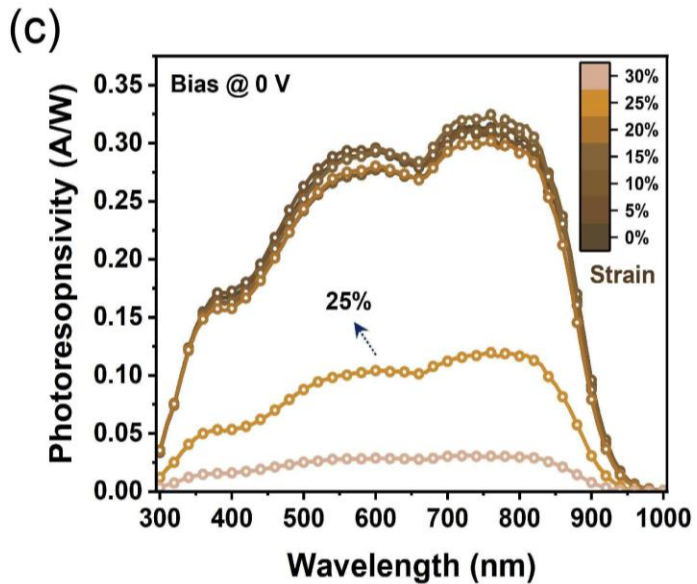
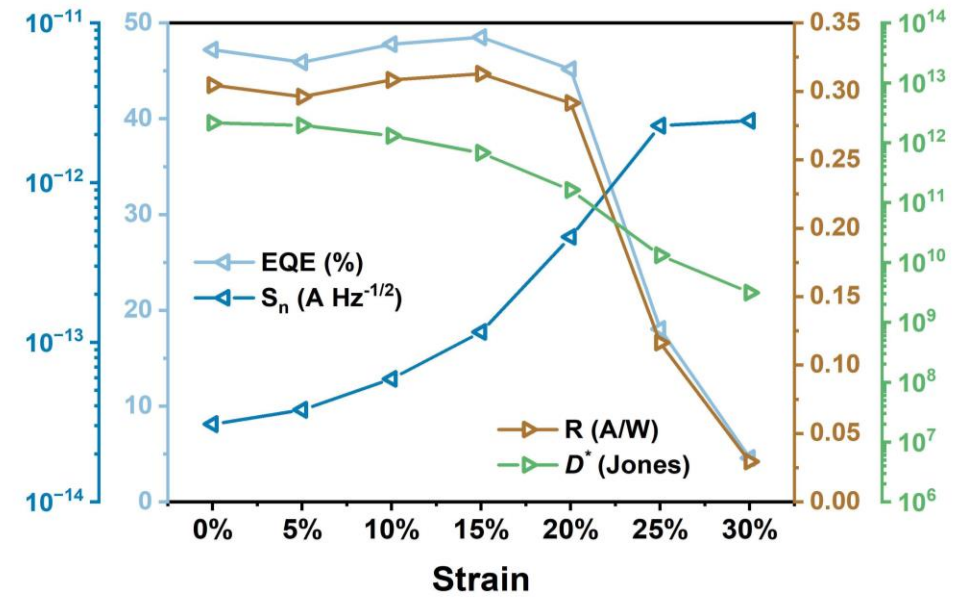
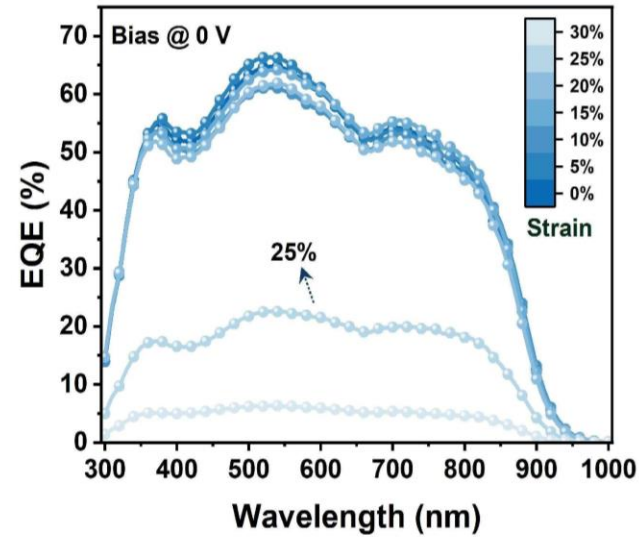
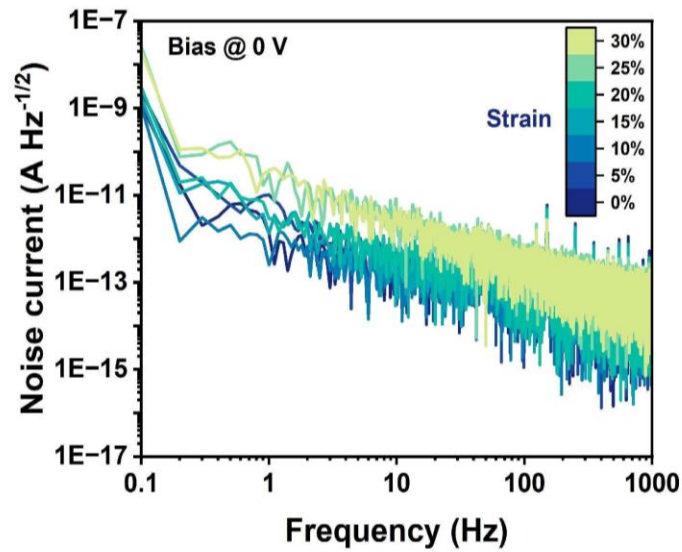
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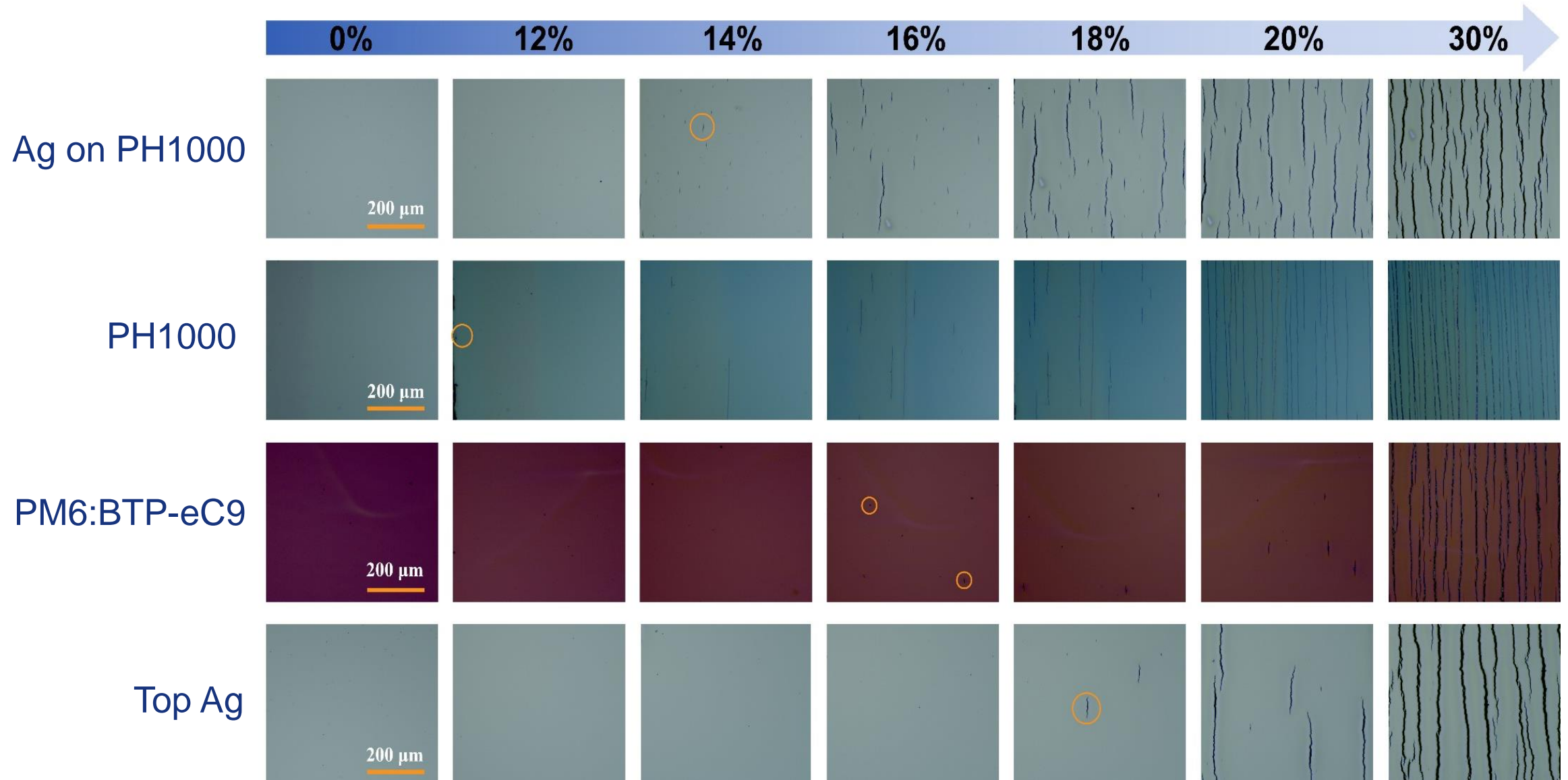
Mechanical stability of NIR self-powered organic photodetectors



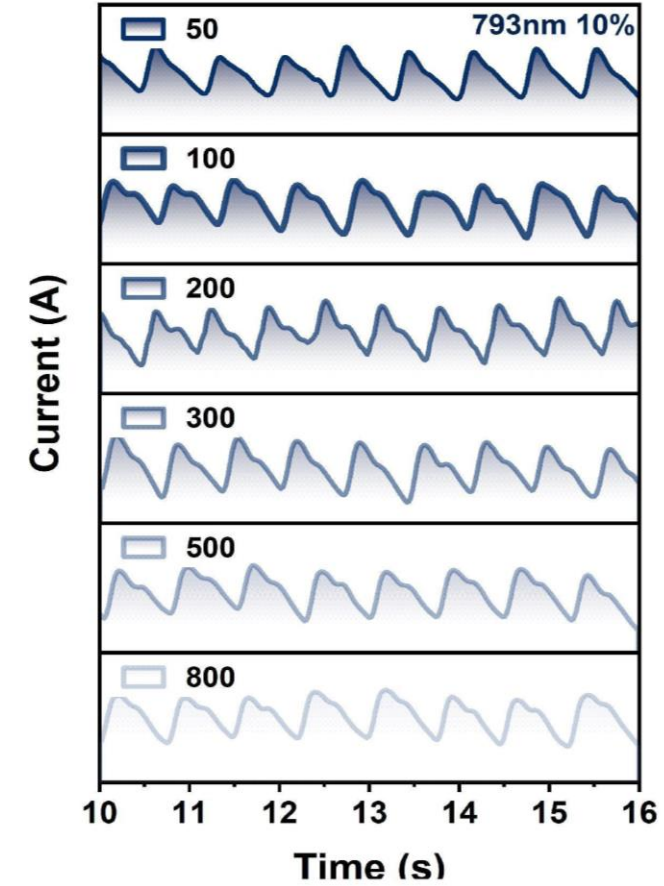
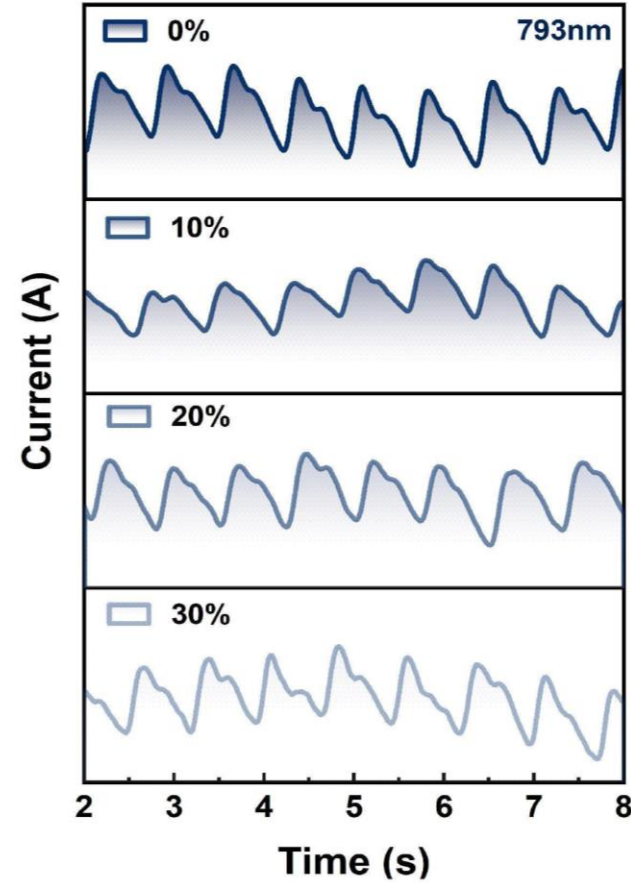
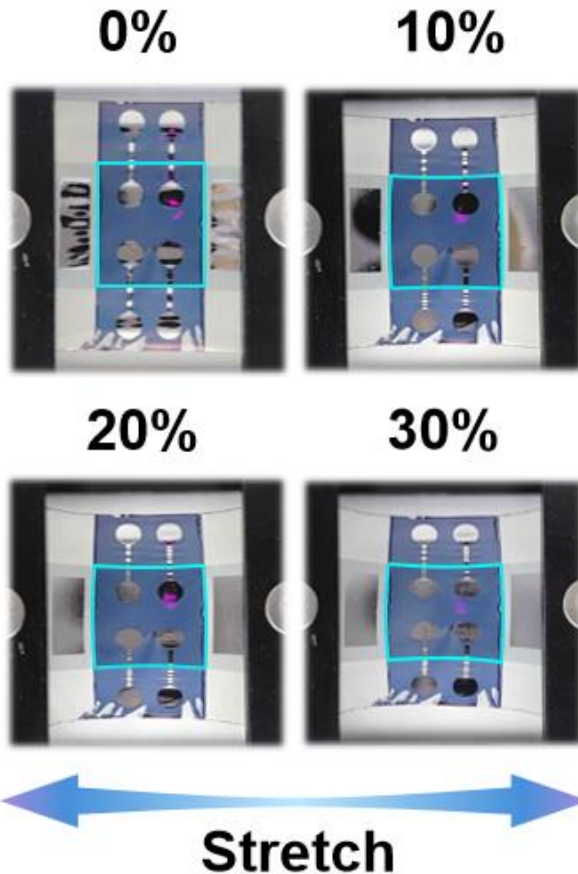
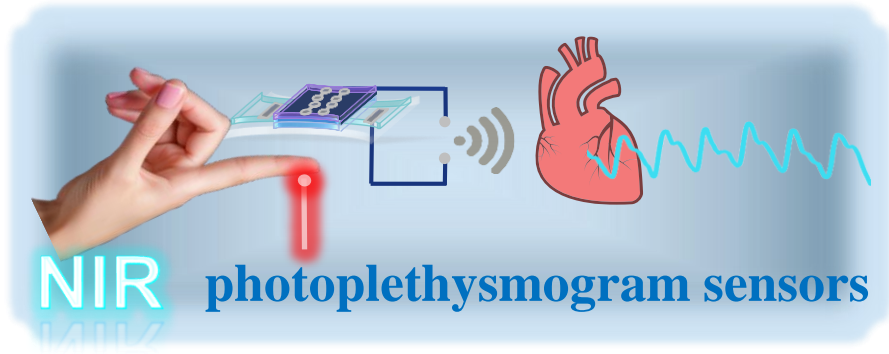
Mechanical stability of NIR self-powered organic photodetectors



Mechanical stability of NIR self-powered organic photodetectors



Mechanical stability of NIR self-powered organic photodetectors



Summary and outlook

- **For photo and thermal stability of OSCs:**
 - Stabilizing inter-molecular interactions for suppressing degradation in exciton lifetime
 - Visualizing ternary and quaternary strategy in stabilizing the excited state dynamics
- **For mechanical stability of NIR self-powered OPDs**
 - Detectivity $> 1 \times 10^{12}$ Jones in the NIR region at 10% tensile strain and μs response time
 - Organic photoplethysmogram heart rate sensor under 30% strain

Acknowledgement

Excited state dynamics

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Yujie Xu

Master students

Min Li

Linghua Wang

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Mengfei Xiao

Kaixing Wang

Wenjun Lu

Organic electronics team 2023



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**Thank you for your
attention!**