Up-conversion of Mid-gap Traps

Ardalan Armin

Centre for Integrative Semiconductor Materials (CISM), Department of Physics, Swansea University Bay Campus, Fabian Way, Swansea SA1 8EN, United Kingdom

Shortwave-infrared (SWIR) photodetectors are crucial for various scientific and industrial applications. Organic photodetectors (OPDs) offer potential advantages like tunable energy gaps and ease of processing, but they have historically suffered from high noise levels compared to inorganic mainstream semiconductors. This noise has primarily been attributed to mid-gap trap states that generate dark saturation current. [1,2] While understanding the origin of these traps remains a challenge,[3] removing them from organic semiconductors is difficult due to their disordered nature.[4] This work introduces a novel "trap-doping" strategy, where a guest organic molecule is incorporated into a bulk heterojunction photodiode to up-convert lower-energy photons into higher-energy charge carriers. [5] This approach extends the spectral response into the SWIR region and significantly improves the specific detectivity and linear dynamic range of the OPD, opening up new avenues for high-performance, low-cost organic photodetector development. Implications of these findings in photovoltaics, especially for indoor applications, will be discussed.

References:

[1] Zarrabi, Nasim, et al. "Charge-generating mid-gap trap states define the thermodynamic limit of organic photovoltaic devices." *Nature communications* 11.1 (2020): 5567.

[2] Sandberg, Oskar J., et al. "Mid-gap trap state-mediated dark current in organic photodiodes." *Nature Photonics* 17.4 (2023): 368-374.

[3] Ma, Xiao, et al. "Origin and Energy of Intra-Gap States in Sensitive Near-Infrared Organic Photodiodes." *Advanced Functional Materials* 33.50 (2023): 2304863.

[4] Smeets, Sander, et al. "Structurally pure and reproducible polymer materials for high-performance organic solar cells." *Chemistry of Materials* 35.19 (2023): 8158-8169.

[5] Zeiske, Stefan, et al. "Enhanced SWIR Light Detection in Organic Semiconductor Photodetectors through Up-Conversion of Mid-Gap Trap States." *Advanced Materials* 36.36 (2024): 2405061.