Exciton blocking layers in organic photovoltaic devices

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Publication date:
2018

Document version
Final published version

Citation for published version (APA):

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EXCITON BLOCKING LAYERS IN ORGANIC PHOTOVOLTAIC DEVICES

1. NPD as exciton blocking layer [1]
   - NPD is an internal organic semiconductor with a large HOMO-LUMO gap of 5.4 eV.
   - It is often used as hole-injection layer as well as the light-emitting layer in OLEDs.
   - High LUMO (2.5 eV) of NPD compared to LUMO of PPV (1.5 eV) helps blocking excitons from generating in PPV/NPD interface.

2. P3 as exciton blocking layer [2]
   - Prototype (P3) has LUMO at 3.5 eV and HOMO at 7.0 eV hence a good candidate as EBL in OPVs.
   - Upon silver Ag cathode evaporation on top of P3 layer, new P3-Ag complex is formed.
   - The P3-Ag complex facilitates efficient electron transport and outer charge in OPV devices.
   - However, in inverted OPV configuration, P3-Ag complex is absent — making the thickness of P3 layer crucial.
   - The optimum P3 layer thickness hence is different for standard (180 nm) and inverted OPVs (150 nm).

3. P3T-TTPA as exciton blocking layer [3]
   - A small molecule based on P3T-TTPA moieties, composed of three electron-acceptor (TTPA) cores with two electron-rich triphenylamine (TPA) cores, was synthesized in a yellow powder using a Suzuki cross-coupling reaction.
   - The presence of TPA moieties provide on anodized silver ITO with efficient light transport properties.
   - The P3T-TTPA core presents leads to a slightly extended absorption, energy matching with the HOMO of P3 layer in OPV.
   - High LUMO of 3.2 eV (LUMO of TTPA at 3.5 eV) allows P3T-TTPA to be used as EBL in PPV-based OPVs.
   - P3T-TTPA films were prepared using chlorobenzene to form an interfacial EBL between Ag and PPV layers.

**Stability measurements of Inverted vs. Standard OPVs with P3 as exciton blocking / electron transport layer**

- Current-Voltage characteristics of fresh and degraded OPVs.
- Properties of OPVs were monitored over 1,000 hours in environmental chamber.
- The test conditions were as follows:
  - Humidity: 50% ± 5%.
  - Relative humidity: 50% ± 5%.
- The OPVs, after 1,000 hours, showed no significant degradation.

**Physical properties of OPVs**

- Bandgap: 1.5 eV.
- HOMO level: 5.0 eV.
- LUMO level: 2.5 eV.
- Phenomenon: phenol.

**Conclusion**

- Exciton blocking layers (EBLs) reflect off-tracks excitons both in the active layer and thus prevent exciton recombination and quenching.
- Reflective excitons improve charge separation yields at the P3-Ag complex interface in OPVs.
- Exciton blocking efficiency of EBLs are primarily due to their high-lying LUMO and/or lowlying HOMO compared to LUMO of donor and HOMO of acceptor, respectively.

[1] Forth et al., Small, 2010, 6, 2262