



# Synthesis and photophysical properties of tetraphenylethylene derivatives as luminescent downshifting materials for organic photovoltaic applications

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## ARTICLE INFO

### Keywords:

Organic solar cells  
Luminescent dyes  
UV filters  
Luminescent down-shifting  
Intramolecular charge-transfer

## ABSTRACT

Luminescent Down-Shifting (LDS) is an optical approach applied in several photovoltaic (PV) technologies in which high energy solar radiation is converted to a wavelength region where the response of the photovoltaic devices is better. The use of LDS layers on organic photovoltaics (OPV) could serve two purposes: to prevent cell degradation by filtering the incident ultraviolet (UV) radiation and to improve the spectral response of PV cells at short-wavelength. This work reports, the design and synthesis of a series of tetraphenylethylene (TPE) derivatives based on TPE-A or A- $\pi$ -TPE- $\pi$ -A molecular structure featuring various electron-acceptor (A) groups. The photophysical properties of the new LDS compounds were systematically studied in 1,4-dioxane solution and film (Zeonex) by UV-visible absorption and fluorescence spectroscopy, and electrochemical properties studied by cyclic voltammetry. Thermal stability of the new LDS compounds was evaluated by Thermogravimetric analysis (TGA). Theoretical computational studies provided evidence of existence of intramolecular charge-transfer (ICT) between frontier orbitals of donor and acceptor moieties. The good photophysical and thermal properties of the synthesized TPE derivatives, associated with high molar absorption coefficients in UV spectrum and emission maximum in the range of 476–531 nm, make them promising candidates for LDS layers in OPV application.

## 1. Introduction

Luminescent Down-Shifting (LDS) is an optical approach applied in several photovoltaic (PV) technologies to improve the spectral match between solar cells and the distribution of sunlight (AM 1.5 G). The LDS layer consists of a polymer sheet (e.g poly (methyl methacrylate PMMA, ethylene vinyl acetate EVA polymer) with luminescent molecules embedded in it, which can absorb the short wavelength ( $\lambda$ ) photons, where the PV cell responds poorly ( $\lambda < 400$  nm) and re-emit photons in the visible spectrum, where its spectral response is much greater.

The use of LDS layers positioned on top of the PV cell (Scheme 1) could serve two purposes: to prevent cell degradation by filtering the incident ultraviolet (UV) radiation and to improve the spectral response of PV cells at short-wavelength [1]. So far, the majority of studies have focused on the effects of LDS in the external quantum efficiency (EQE) of solar cells [2–5]. Although the stability issue is a major obstacle for the commercialization of the emerging PV technologies, such as organic photovoltaic (OPV) and perovskite (PSC) cells, the potential for

efficiency and stability enhancements via LDS layer on these PV materials and devices were investigated only in a few number of published studies [1,6,7]. It's known that some components of OPV, namely the active layer, are susceptible to photodegradation, due to the combined effect of the UV component of solar radiation and oxygen from the ambient air [8–10]. Kettle et al [1]. and Fernandes et al. [7,11] have reported promising results demonstrating the proof of concept of improvement of both the lifetime and efficiency of OPV cells by applying LDS layers based on a lanthanide-based metal complex [1] or a mixing of two luminescent materials forming multi-dye blends, respectively [7, 11].

Over the years, a large number of luminescent materials, such as organic dyes [7], quantum dots [12,13] and rare-earth ion complexes [14,15] have been investigated for their use as LDS layers. In particular, organic dyes have been highlighted for presenting high absorption coefficient, good Luminescent Quantum Yield (LQY), large Stokes shift i. e, good shift between absorption and emission bands, and good solubility in polymeric matrix [11,16]. However, most of the organic dyes already

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<https://doi.org/10.1016/j.dyepig.2021.109724>

Received 5 March 2021; Received in revised form 21 July 2021; Accepted 14 August 2021

Available online 15 August 2021

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