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Short Communication

Triphenylvinyl anthracene based emitter for non-doped blue light emitting devices with unusual emission behavior

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ABSTRACT

A novel blue luminogen based on triphenylvinyl anthracene was synthesized. The photophysical, thermal and aggregation induced emission as well as electroluminescent properties were investigated. The luminogen demonstrated typical aggregation caused quenching (ACQ) effect. A non-doped organic light emitting device was fabricated and realized a current efficiency of 3.25 cd/A, an external quantum efficiency of 1.41%, power efficiency of 2.11 m/W and a maximum luminance of 11761.8 cd/m^2 were achieved.

1. Introduction

Blue organic light-emitting devices (OLEDs) have special importance among the OLEDs of different colors (red, green and blue) [1]. Even though phosphorescent OLEDs have realized 100% internal quantum efficiency (IQE) for OLED devices with blue emission, but still phosphorescent OLEDs have significant drawbacks, such as shorter lifetime and high efficiency roll-off at high current density [2]. This is the reason that fluorescence OLED devices are essential and useful for different applications. On the other hand, most of the efficient OLEDs exhibit excellent performance when the emitters are doped into suitable host materials [3]. It creates to a severe phase separation in the dopant and host materials that leads to insufficient energy transfer [4]. Due to these reasons, non-doped OLED devices employing blue fluorescent emitters are still gaining significant attention.

Although several high-performance blue fluorescent luminogens have been synthesized, but most of them emit sky-blue light instead of saturated blue [5]. Also, many blue fluorophores were designed containing electron-withdrawing group for easier electron injection. However, these fluorophores also have deep highest occupied molecular orbital (HOMO) energy level that leads to a large hole−injection barrier at the hole-transporter/emitter interface, thus responsible for high operating voltages and lower efficiencies [6–9].

Design and synthesis of high performance solid-state organic luminogens play a key role in device fabrication because these materials are used in the form of thin film, or in aggregated state in optoelectronic devices [10]. Specially, among the development of OLED devices in the past few years, red- and green materials have demonstrated excellent performances in terms of luminance and external quantum efficiency [11]. However, the development of blue fluorophores is remained to be a challenging task [12]. Although conventional blue emitters, such as fluorene [13], and triphenylamine [14] compounds are highly emissive in dilute solution, but their emission is weakened in the aggregated form.

In this work, we fabricate a blue OLED device based on a novel molecule, *1,2-diphenyl-1,2-bis(4-(10-(1,2,2-triphenylvinyl)anthracen-9-yl)phenyl)ethene* (2TPEA-TPE) based on the integration of

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triphenylvinyl anthracene (TPEA) and tetraphenylethene (TPE) units. Non-doped device based on 2TPEA-TPE have demonstrated a blue emission at 479 nm with an external quantum efficiency (EQE) of 1.5% at low driven voltage (3.5 V) and a small efficiency roll-off.

2. Results and discussion

2.1. Synthesis

Scheme 1 presents the synthetic mechanism of the molecule, which consists of triphenylvinyl anthracene and tetraphenylethene units. As shown in Scheme 1, for the synthesis of this material, two important intermediate compounds, *9-bromo-10-(1,2,2-triphenylvinyl)anthracene* **(5)** and *1,2-diphenyl-1,2-bis(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)ethene* **(6)** were prepared through Suzuki coupling reaction to get the targeted material 2TPEA-TPE in good yield. The compound was characterized by ^{1}H and ^{13}C NMR spectrometry and mass spectrometry.

2.2. Electrochemical properties

The electrochemical behavior of the material was studied by cyclic voltammetry (CV). HOMO energy level of the material was calculated from the equation of onset potential of the first oxidation relative to ferrocene (Fig. S7). HOMO value was determined from the formula of $E_{HOMO} = -([E_{onset}]_{ox} + 4.8)$. The HOMO energy level of 2TPEA-TPE is −5.32 eV. The energy band gap (E_g) of 2TPEA-TPE was found to be 3.00 eV, through the onset of UV–vis absorption spectra. Finally, LUMO energy level of 2TPEA-TPE was found to be −2.32 eV. The results are summarized in Table S1.

2.3. Thermal properties

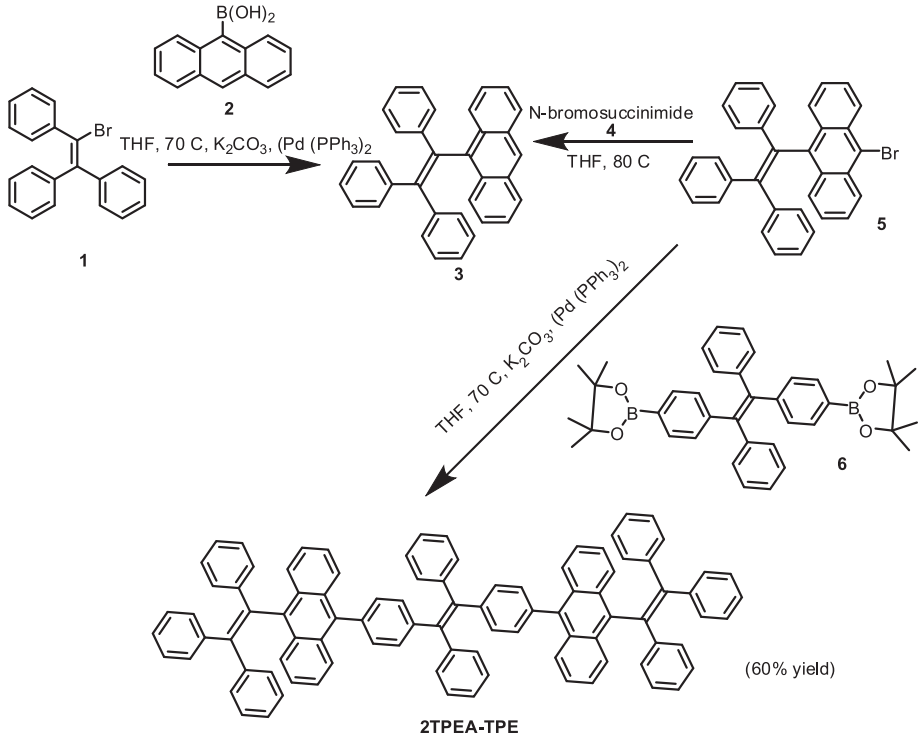
The thermal properties of 2TPEA-TPE were investigated through (thermogravimetric analysis) TGA under nitrogen atmosphere and their thermal data are summarized in Table S1. The TGA measurement shows that this derivative possesses high thermal stability of more than 400 °C. Weight loss of 5% (T_d) was realized at 425 °C, indicating the high thermal stability of this fluorophore. The glass transition temperature (T_g) of 2TPEA-TPE was found to be 128.48 °C. Such high values of T_d and T_g reveal the high stability of this material.

2.4. Theoretical calculations

To explore the electronic structure of the compound, the ground-state geometries and the frontier molecular orbital energy levels were calculated using density functional theory (DFT) in Gaussian 03 program at the B3LYP/6-31G (d) level. In 2TPEA-TPE, the HOMO level is distributed on the anthracene moiety of TPEA unit (Fig. S8), whereas LUMO level is also totally localized on the anthracene moiety of TPEA unit (Fig. S8). The HOMO and LUMO energy level of 2TPEA-TPE were calculated to be −4.99 and −1.68 eV, (Table S1) respectively. Theoretically calculated band gap is found to be 3.31 eV for 2TPEA-TPE (Table S1).

2.5. Absorption and photoluminescence properties

2TPEA-TPE derivative exhibited good solubility in common organic solvents like tetrahydrofuran (THF), dichloromethane, chloroform, etc., but was insoluble in water and methanol. Absorption and photoluminescence (PL) spectrum of the material is shown in Figs. S9 and S10, and the photophysical parameters are summarized in Table S1. The absorption spectra of 2TPEA-TPE exhibited two peaks, one at 386 nm and other at 407 nm. 2TPEA-TPE also exhibited blue emission at 479 nm with a little red shift as compared to absorption spectra. From the onset of absorptions, the optical band gaps (E_g) of 2TPEA-TPE was estimated to be 3.00 eV respectively.



Scheme 1. Synthetic mechanism of 2TPEA-TPE.