Research Article

MONOARYLATION OF DIPHENYLDITHIENYLETHENE
BY LIGAND-FREE PALLADIUM CATALYZED C-H ACTIVATION

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Received: May 25, 2021; Revised: June 20, 2021; Accepted: September 01, 2021

ABSTRACT

This work reports on a green and convenient methodology for the arylation of diphenyldithienylethene by direct ligand-free palladium-catalyzed C-H bond functionalization. Based on this approach, a new diphenyldithienylethene-based compound with aryl substituent DTE-3-COOH was successfully synthesized from thiophene via four steps. These compounds were structurally identified by NMR and HR-MS spectral analyses.

Keywords: aggregation-induced emission; diphenyldithienylethene; direct palladium-catalyzed arylation; fluorescence

1. Introduction

Over the past decades, luminescent organic materials have been developed and applied to many research fields including photoelectronic devices, fluorescent sensors, bioimaging trackers, and photoluminescence therapy. In particular, aggregation-induced emissions (AIE) have gained increasing attention on account of their fundamental importance and highly promising potential applications. Many compounds are showing the AIE effects such as tetraarylethenes, multi-substituted alkenylated benzenes, heteroatom-bridged pentacyclic compounds (1,1-disubstituted tetraphenygermole, p-aryltetraphenylphospholes, 1,1-diphenyltetraphenylsiloles, tetrabromothiophene, N-phenyltetraphenylpyrrole, tellurophenes, 1,1-disubstitutedtetraphenylstannoles), and boron diketonates (Mei et al., 2015). Among them, tetraphenylethene has been widely developed due to its facile synthesis and straightforward post-functionalization for multi-purposed applications (Hong et al., 2011). The synthesis of tetraarylethenes was based on titan-assisted McMurry coupling of...
ketones. Normally, this approach gave low yields with many accompanying isomer products. Recently, there have been two efficient methodologies to construct multiarylated ethenes with high yields based either on palladium-catalyzed syn-direct diarylation of arylethynyl N-methyliminodiacetyl boronates (Lin et al., 2019) or palladium-catalyzed consequential multi-Suzuki reaction of di-, tri- and tetraboronated ethenes (Zhang et al., 2020).

Post-mono-functionalized TPEs have applications in various research fields because of their interesting physical properties (Li et al., 2013). For example, 2-formylthienyl-TPE showed bright green color mechanoluminescence upon pressing or grinding under daylight at room temperature (Rananaware et al., 2015). 2-PyrilTPE was observed to quench light emissions in solution by \( \pi-\pi \) stacking of luminophores and to exhibit the AIE characteristics in the condensed phase by the restriction of intramolecular rotation (RIR) (Zhao et al., 2011). TPE carboxylic acid has been studied for its application in photobleaching and bioimaging activity towards bacteria including several species of gram-negative and gram-positive (Shi et al., 2019; Liu et al., 2017). Almost all of the post-mono-functionalized TPEs were synthesized after two steps, which are bromination and the classical palladium catalyzed coupling reactions or the metal halide exchanged reaction (Zhang et al., 2014).

To give a convenient approach for post-mono-functionalisation of diphenyldithienylethenes (DTE) that have dual fluorescent and aggregation induced emission effects, we have studied a synthetic protocol to synthesize monoarylated DTE by a direct ligand-free palladium-catalyzed arylation of DTE with 3-bromobenzaldehyde.

2. Materials and methods

2.1. Instrumentation

NMR spectroscopic data were acquired on a Bruker Avance III at 500 MHz for \(^1\text{H}-\)NMR and 125 MHz for \(^{13}\text{C}-\)NMR. HR–MS spectra were recorded on a Bruker MICROTOF-Q 10,187.

2.2. Material

Reagents and solvents were obtained from commercial suppliers and were used without further purification. Column chromatography was carried out using Merck Kieselgel 60 silica gel (particle size: 32-63 Å). Analytical TLC was performed using Merck precoated silica gel 60 F-254 sheets. All the CH activation reactions were carried out under a nitrogen atmosphere.

2.3. Synthesis

\textit{Di(thiophen-2-yl)methanone 1}: A mixture of 2-thienoic acid (1.2 g, 0.01 mol, 1 eq), thiophene (0.84 g, 0.01 mol, 1 eq), and phosphorus pentoxide (1.6 g, 0.12 mol, 1.2 eq) in anhydrous toluene (10 mL) was refluxed for 2h. Another portion of phosphorus pentoxide (1.6 g, 0.12 mol, 1.2 eq) was added and the mixture was continued to reflux for another 2h. The precipitate was filtered off and the combined filtrates were washed with water (3 x 50 mL), 1M \( \text{aq. NaOH} \) (3 x 50 mL), dried over \( \text{Na}_2\text{SO}_4 \), concentrated \textit{in vacuo} to give a residue
which was chromatographed over silica gel (n-hexane: ethyl acetate (5:1)) to give 1 (970 mg, 50 %) as a white solid. $^1$H-NMR $\delta$H (500 MHz, CDCl$_3$, $\delta$ ppm): $\delta$ 7.91 (2H, dd, $J = 4.0$ Hz, $J = 1.0$ Hz), $\delta$ 7.70 (2H, dd, $J = 5.0$ Hz, $J = 1.0$ Hz), $\delta$ 7.19 (2H, dd, $J = 5.0$ Hz, $J = 4.0$ Hz); $^{13}$C-NMR $\delta$C (125 MHz, CDCl$_3$, $\delta$ ppm): $\delta$ 178.8, 142.9, 133.4, 133.1, 127.9 (Bottalico et al., 2009).

1,1-Bis(thiophen-2-yl)-2,2-dibromoethene 2: 1 (194 mg, 1 mmol, 1.0 eq), CBr$_4$ (662 mg, 2 mmol, 2.0 eq) and PPh$_3$ (1.05 g, 4 mmol, 4.0 eq) were dissolved in dry toluene (8.0 mL). The solution was refluxed for 24h. After filtration, the filtrate was washed with water (3 x 50 mL), dried over Na$_2$SO$_4$ and concentrated in vacuo. Chromatography on silica gel (n-hexane) afforded 2 (150 mg, 43 %) as a red oil. $^1$H-NMR $\delta$H (500 MHz, CDCl$_3$, $\delta$ ppm): $\delta$ 7.39 (2H, dd, $J = 5.0$ Hz, $J = 1.0$ Hz), $\delta$ 7.10 (2H, dd, $J = 4.0$ Hz, $J = 1.0$ Hz), $\delta$ 7.00 (2H, dd, $J = 5.0$ Hz, $J = 4.0$ Hz) (Chang et al., 2016).

1,1-Bis(thiophen-2-yl)-2,2-diphenylethenene 3: A mixture of 2 (70 mg, 0.2 mmol, 1.0 eq), PPh$_3$ (26 mg, 0.1 mmol, 0.5 eq), Na$_2$CO$_3$ (106 mg, 1.0 mmol, 5.0 eq), Pd(OAc)$_2$ (5 mg, 0.022 mmol, 0.1 eq) and phenylboronic acid (122 mg, 1.0 mmol, 5.0 eq) in dioxane : H$_2$O 4:1 (v:v) (10 mL) was refluxed overnight. After the completion of the reaction, the precipitate was filtered and the filtrate was washed with water (3 x 50 mL). The organic layer was dried over Na$_2$SO$_4$ and concentrated in vacuo. The residue was purified by column chromatography on silica gel (n-hexane) to yield 3 (38 mg, 55 %) as a white solid. $^1$H-NMR $\delta$H (500 MHz, CDCl$_3$, $\delta$ ppm): $\delta$ 7.19-7.13 (12H, m), 6.80 (2H, $dd$, $J = 5.0$ Hz, $J = 4.0$ Hz), 6.76 (2H, $dd$, $J = 4.0$ Hz, $J = 1.0$ Hz) (Wang et al. 2018); $^{13}$C-NMR $\delta$C (125 MHz, CDCl$_3$, $\delta$ ppm): $\delta$ 145.6, 143.2, 142.3, 130.6, 129.7, 128.0, 127.0, 126.6, 126.3, 126.1.

3-(5-(2,2-Diphenyl-1-(thiophen-2-yl)vinyl)thiophen-2-yl)benzaldehyde DTE-3-CHO: A suspension of 3 (69 mg, 0.2 mmol, 1.0 eq), Pd(OAc)$_2$ (1.0 mg, 0.006 mmol, 0.03 eq), KOAc (58 mg, 0.6 mmol, 3.0 eq) and 3-bromobenzaldehyde (3.0 eq) in DMAc (5.0 mL) was stirred at 120 °C for 16h. All the insolubles were filtered and the combined filtrates were washed with water (3 x 30 mL), dried over Na$_2$SO$_4$, and the solvent was evaporated in vacuo to give a crude residue which was purified by column chromatography on silica gel (n-hexane:ethyl acetate 9:1, v/v) to give the pure monoarylated product DTE-3-CHO (44 mg, 49%) as a yellow solid. $^1$H-NMR $\delta$H (500 MHz, CDCl$_3$, $\delta$ 10.00 (s, 1H), 7.96 (t, $J = 2.0$ Hz, 1H), 7.74 – 7.69 (m, 2H), 7.48 (t, $J = 7.5$ Hz, 1H), 7.22 – 7.14 (m, 11H), 7.11 (d, $J = 4.0$ Hz, 1H), 6.87 – 6.81 (m, 2H), 6.73 (d, $J = 4.0$ Hz, 1H). $^{13}$C-NMR $\delta$C (125 MHz, CDCl$_3$) $\delta$ 192.0, 145.2, 143.1, 143.0, 142.9, 142.8, 136.9, 131.1, 130.9, 130.6, 130.6, 129.9, 129.5, 128.4, 128.2, 128.0, 127.3, 127.1, 126.6, 126.4, 126.3, 123.3. HR-ESI-MS: calcd [C$_{29}$H$_{21}$OS]$^+$ ([M+H]$^+$) = 449.1034, found = 449.1012.

3. Results and discussion

1561
Diphenyldithienylethene was synthesized by two methodologies. First, dissymmetric 1,1-diphenyl-2,2-(hetero-)arylethene was synthesized by Suzuki and/or Stille coupling reaction of corresponding gem-dibromoethene and boronic or stannyl (hetero-)aryl (Zhang et al., 2014). One year later, diphenyldithienylethene was synthesized by desulfurization of thiiranes (Młostoń et al., 2016). This method was known as ‘two-fold extrusion reaction’ and needed further two steps for synthesis of starting materials including diaryldiazomethane and dithienyl thioacetones or dithienyl diazomethane and diaryl thioacetones. In our strategy, we have modified the synthesis of diphenyldithienylethene by reversing both reactants via gem-dibromo dithienylethene and phenylboronic acids. Gem-dibromodithienylethene was synthesized after two steps as described in Scheme 1. The Suzuki reaction was employed for the construction of tetrasubstituted ethene 3 which was isolated in 55% yield. The post-monoarylation of diphenyldithienylethene 3 by direct palladium catalyzed reaction was conducted at C2-atom of thiophene ring. The new compound DTE-3-CHO-1 was synthesized with moderate yields (49%). The structures of DTE-3-CHO-1 were confirmed by NMR and HR-MS spectroscopies.

![Scheme 1. Synthetic strategy for DTE-3-CHO-1](image)

4. Conclusions
We reported herein a new synthetic pathway for the preparation of diphenyldithienylethene. The direct palladium catalyzed C-H bond functionalization provided a convenient approach for the regioselective monoraylation of diphenyldithienylethene. The structure of the obtained compound was confirmed by NMR and HR-MS spectral data. This method can be easily applied to prepare arylated diphenyldithienylethene with interesting photophysical properties. In addition, the fluorescence and the aggregation induced emission of this compound have shown promising results which will be published soon in due course.
Conflict of Interest: Authors have no conflict of interest to declare.

Acknowledgment: This research was funded by the Ministry of Education and Training under a grant number B2018-SPS-22.

REFERENCES


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**MONO ARYL HÓA DIPHENYLDITHIENYLETHENE THÔNG QUA PHÂN ÜNG HOẠT HÓA TRỰC TIẾP LIÊN KẾT C-H SỬ DỤNG XÚC TÁC PALLADIUM KHÔNG LIGAND**

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Ngày nhận bài: 25-5-2021; ngày nhận bài sửa: 20-6-2021; ngày duyệt đăng: 01-9-2021

**TÓM TÁT**

Bài báo trình bày một phương pháp hiệu quả để thực hiện aryl hóa diphenyldithienylethene thông qua phân ứng hoạt hóa trực tiếp liên kết C-H sử dụng xúc tác palladium không ligand. Họp chất diphenyldithienylethene **DTE-3-CHO-1** được tổng hợp từ thiophene qua bón giai đoạn. Giải đoạn chia khoa của quá trình tổng hợp **DTE-3-CHO-1** là phân ứng hoạt hóa trực tiếp liên kết C-H được thực hiện giữa diphenyldithienylethene 3 và 3-bromobenzaldehyde sử dụng xúc tác Pd(OAc)₂ base KOAc trong dung môi DMAc tại 120 ℃ trong 16h. **DTE-3-CHO-1** thu được với hiệu suất 49%. Họp chất **DTE-3-CHO-1** tổng hợp được hóa hện là một hợp chất có các tính chất quang li hấp dẫn. Cấu trúc của diphenyldithienylethene **DTE-3-CHO-1** cũng như các hợp chất trung gian trong quá trình tổng hợp được xác định dựa vào phổ NMR và HR-MS. Họp chất **DTE-3-CHO-1** là một hợp chất mới.

*Từ khóa*: aggregation-induced emission; diphenyldithienylethene; phân ứng aryl hóa trực tiếp xúc tác palladium; fluorescence