



Contents lists available at ScienceDirect

Journal of Photochemistry and Photobiology A: Chemistry

journal homepage: www.elsevier.com/locate/jphotochem

Near-infrared absorption bacteriochlorophyll derivatives as biomaterial electron donor for organic solar cells



Shengnan Duan^a, Guo Chen^b, Mengzhen Li^a, Gang Chen^a, Xiao-Feng Wang^{a,*}, Hitoshi Tamiaki^c, Shin-ichi Sasaki^{c,d}

^a Key Laboratory of Physics and Technology for Advanced Batteries (Ministry of Education), College of Physics, Jilin University, Changchun 130012, PR China

^b Key Laboratory of Advanced Display and System Applications (Ministry of Education), Shanghai University, Shanghai 200072, PR China

^c Graduate School of Life Sciences, Ritsumeikan University, Kusatsu, Shiga 525-8577, Japan

^d Nagahama Institute of Bio-Science and Technology, Nagahama, Shiga 526-0829, Japan

ARTICLE INFO

Article history:

Received 2 June 2017

Received in revised form 5 July 2017

Accepted 15 July 2017

Available online 17 July 2017

Keywords:

Organic solar cells

Biomaterials

Bacteriochlorophyll aggregate

Photosynthesis

Planar-heterojunction

ABSTRACT

In this paper, we investigate two bacteriochlorophyll (BChl) derivatives, namely methyl (pyro) bacteriopheophorbide *a* [BChl-(2)1], with excellent absorption in near-infrared regions as donor materials for organic solar cells (OSCs). In the meantime, we prepare two methyl (pyro)pheophorbide *a* [Chl-(2)1] as reference to make a comparison. Compared to the small red-shifts of absorption bands of Chls-1/2 after forming the thin film through spin coating of the homogeneous solution, the absorption spectra of BChls-1/2 exhibited larger red-shifts from the absorption peak at 750 nm in the solution to the absorption peak at 860 nm after forming the solid film. This significant absorption shift is attributed to the formation of *J*-type aggregates by intermolecular π - π stacking among the BChl-1/2 molecules. What's more the absorbed sunlight of the BChls-1/2 aggregates at the near-infrared (NIR) region can be transferred into photocurrent which can be proved from the EQE indicating the energy and electron transferring between BChl aggregates are efficient. The optimized power conversion efficiency (PCE) value of 1.43% under standard AM1.5 mW/cm² sunlight was achieved with the BChl-1: C₇₀ planar-heterojunction (PHJ) cells.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Organic solar cells (OSCs) have shown the potential to be the next generation of photovoltaic devices since they have many advantages including flexible, light weight, low cost and easy to manufacture [1–4]. In general, broadening the absorption range to near-infrared (NIR) wavelength in solar energy can enhance the generation of photocurrent [5,6]. Organic small molecule such as porphyrin are widely used in dye-sensitized solar cells [7–10]. Bacteriochlorophylls (BChls) which are analogues of porphyrin are capable of harvesting sunlight and transferring the excited energy in natural photosynthetic processes [11–13]. Another advantage of

using BChl molecules as the donor materials of OSCs is that the molecular structure of the BChls is tunable through replacing the molecular peripheral substituents thus we can design and synthesize the suitable molecules with a proper energy level, an excellent charge transport capacity, a high solubility and so on [14–16].

The BChl and chlorophyll (Chl) molecules used in the present investigation are cyclic tetrapyrroles [17,18]. Such (B)Chls can readily self-assemble into *J*-type of aggregation and in general the formation of *J*-type aggregates can enlarge the carrier mobility and charge transportation ability [19–22].

In this work, we employed two BChls, methyl bacteriopheo-

Abbreviations: AFM, atomic force microscopy; (B)Chl, (bacterio)chlorophyll; BChl-1, methyl pyrobacteriopheophorbide *a*; BChl-2, methyl bacteriopheophorbide *a*; BCP, bathocuproine; Chl-1, methyl pyropheophorbide *a*; Chl-2, methyl pheophorbide *a*; CV, cyclic voltammogram; D/A, donor and acceptor; ΔE_{LUMO} , energy gap of LUMO between donor and acceptor material; ΔE_{DA} , the energy gap between donor's HOMO and acceptor's LUMO; FF, fill factor; HOMO, highest occupied molecular orbital; ITO, indium tin oxide; IPCE, monochromatic incident photon-to-electron conversion efficiency; J_{sc} , short-circuit current; LUMO, lowest unoccupied molecular orbital; OSC, organic solar cell; PCE, power conversion efficiency; PHJ, planar-heterojunction; PL, photoluminescence; RMS, root-mean-square; UPS, ultraviolet photoelectron spectroscopy; V_{oc} , open-circuit voltage.

* Corresponding author.

E-mail address: xf_wang@jlu.edu.cn (X.-F. Wang).

phorbide *a* (BChl-1), and methyl pyrobacteriopheophorbide *a* (BChl-2) as an electron donor and two Chls, methyl pheophorbide *a* (Chl-1), methyl pyropheophorbide *a* (Chl-2) as references. These semi-synthesized (B)Chls were employed in conjunction with fullerene C₇₀ as an electron acceptor in planar-heterojunction (PHJ) cells. The PHJ solar cells based on BChl-1 exhibit the power conversion efficiency (PCE) of 1.43% under AM1.5 solar illumination (100 mW/cm²) at room temperature. Since the devices were fabricated with BChl-1/2 aggregates absorbing the NIR light energy and can eventually transform the NIR light into photocurrent, they are inexpensive and less pollutive to the environment compared with other systems using fully synthesized chemicals.

2. Experimental section

2.1. Materials

BChls-1/2 and Chls-1/2 are semi-synthesized as reported before [23–25]. Both the indium-tin oxide (ITO), MoO₃, C₇₀, bathocuproine (BCP), and Al were commercially available.

2.2. Device fabrication

PHJ solar cells were fabricated with the following structures: indium tin oxide (ITO)/MoO₃ (5 nm)/(B)Chls (10 nm)/C₇₀ (40 nm)/BCP (8 nm)/Al (100 nm). The ITO substrates were pre-cleaned with detergent, deionized water, acetone and isopropyl alcohol in an ultrasonic bath for 20 min in sequence and then exposed in ultraviolet-ozone for 15 min. Then the substrates were transferred into high-vacuum chamber where a 5 nm thick MoO₃ layer were thermally deposited on the ITO substrates. After that, the (B)Chls in chloroform (10 mg/mL) were spin-coated on the MoO₃ modified ITO substrate to reach a 10-nm thickness film. Then C₇₀, BCP, and Al were sequentially thermally deposited in high vacuum.

2.3. Material characterization

UV/Vis/NIR absorption spectra of (B)Chls on the solid film and in a tetrahydrofuran (THF) solution were recorded by a Shimadzu UV-3100 spectrophotometer. The cyclic voltammograms (CVs) of (B)Chls dispersed in dichloromethane were recorded by a VSP

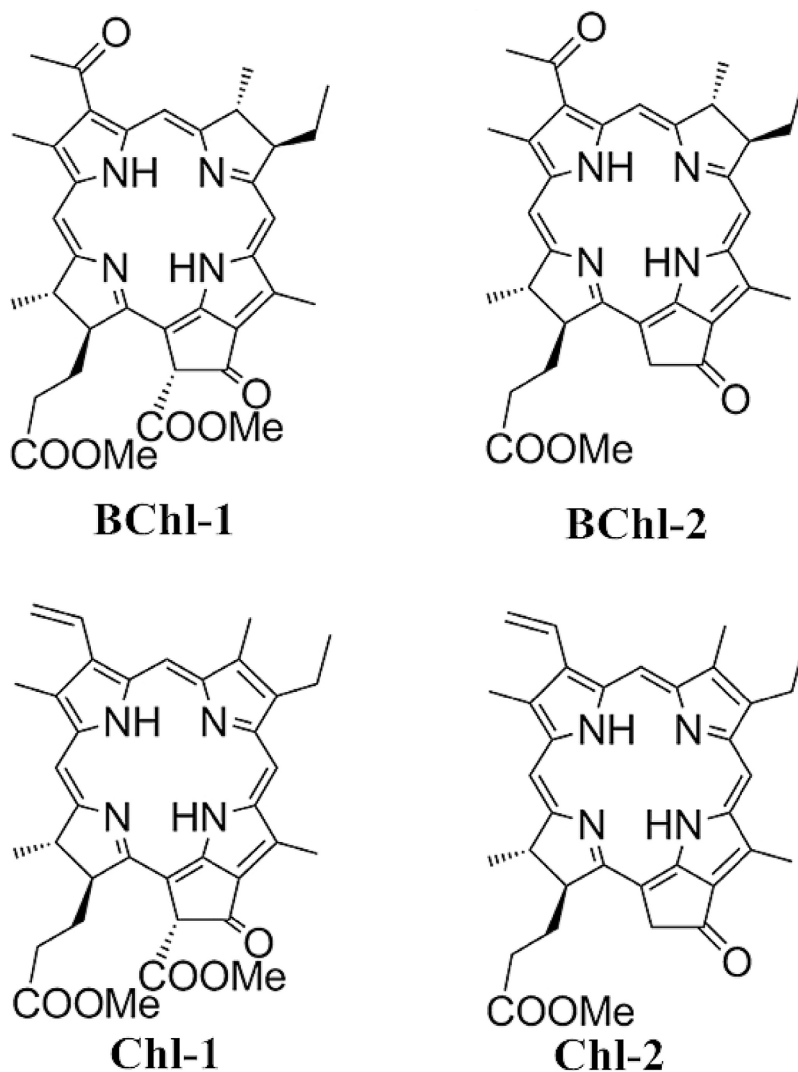


Fig. 1. The molecular structures of (B)Chls-1/2 as donor materials.

Download English Version:

<https://daneshyari.com/en/article/4753866>

Download Persian Version:

<https://daneshyari.com/article/4753866>

[Daneshyari.com](https://daneshyari.com)