Available online at www.sciencedirect.com

SCIENCE DIRECT

Solar Energy Materials & Solar Cells 90 (2006) 133–141

Solar Energy Materials & Solar Cells

www.elsevier.com/locate/solmat

A polymer photodiode using vapour-phase polymerized PEDOT as an anode

Shimelis Admassie[a,b], Fengling Zhang[a,b,*], A.G. Manoj[a,b], Mattias Svensson[c], Mats R. Andersson[c,b], Olle Inganäs[a,b]

[a]*Biomolecular and Organic Electronics, IFM, Linköping University, S-581 83 Linköping, Sweden*
[b]*Center of Organic Electronics, Linköping University, S-581 83 Linköping, Sweden*
[c]*Materials and Surface Chemistry/Polymer Technology, Chalmers University of Technology, SE-412 96 Göteborg, Sweden*

Received 29 January 2005; received in revised form 22 February 2005; accepted 23 February 2005
Available online 12 April 2005

Abstract

We report the photovoltaic properties of devices made using a highly conducting polymer electrode, from vapour-phase polymerized poly (3,4-ethylenedioxy) thiophene (VPP PEDOT) on glass substrate as an anode and a polyfluorene copolymer poly[2,7-(9,9-dioctyl-fluorene)-alt-5,5-(4′,7′-di-2thienyl-2′,1′3′-benzothiadiazole)] (APFO-3) mixed with [6,6]-phenyl-C_{61}-butyric acid methylester (PCBM) in the ratio of 1:4 as the active layer. The device performance was compared with that of devices made with PEDOT-PSS on glass substrates. The surfaces of VPP PEDOT were imaged using atomic force microscopy (AFM).

Keywords: Polymers solar cells; Vapour-phase polymerized poly (3,4-ethylenedioxy) thiophene; Polymer electrode

*Corresponding author. Biomolecular and Organic Electronics, IFM, Linköping University, S-581 83 Linköping, Sweden. Tel.: +46 13 28 1257; fax: +46 13 28 8969.
E-mail address: fenzh@ifm.liu.se (F. Zhang).

0927-0248/$ - see front matter
doi:10.1016/j.solmat.2005.02.005

1. Introduction

Conjugated polymers with heterocyclic structures like polypyrrole, polythiophene, polyaniline, polyphenylenes, and poly(*p*-phenylene vinylene)s have attracted a great deal of attention because of their great potential of application in a number of electronic devices like displays, smart windows, sensors, capacitors, batteries, and photovoltaic devices [1,2]. Among the various organic conducting polymers, poly (3,4-ethylenedioxy) thiophene is one of the most widely studied conducting polymer because of its unique properties like high electrical conductivity, almost transparent thin film in the oxidized state and excellent stability at ambient and elevated temperatures [3].

For large-area electronics, it is desirable to use flexible transparent and conducting electrodes. For photovoltaic energy conversion devices, the large active area is a necessity to compensate for the lower energy conversion efficiencies still found in these systems. Deposition of the transparent electrode material should preferably be done by reel-to-reel methods, such as web coating. Also, the difficulties of using transparent oxides on flexible supports during reel-to-reel processing are considerable, arguing the use of flexible metallic polymer conductors. The commercially available polyelectrolyte complex PEDOT-PSS can be easily spin coated resulting in a highly transparent and conducting (0.05–10 S/cm) polymer film. To use this polymer as an anode material in flexible polymeric devices, higher values of conductivities are needed. Electrochemical polymerization is widely used to get high conductivity. However, the method is restricted to depositing the polymer only on conducting substrates. For applications of such materials in large-area electronics, deposition must be done over very large areas, and it is preferable if the deposition methods exclude electropolymerization.

Very recently, several groups are working to improve the conductivity of PEDOT using different approaches. Jönsson et al. significantly improved the conductivity of the commercially available PEDOT-PSS up to 48 S/cm for a film thickness of about 110 nm by mixing the polymer solution with sorbitol as a secondary dopant [4]. Similar works using blending with polyethylene oxide [5] or using other secondary dopants like dimethyl sulfoxide, *N*,*N*′-dimethyl formamide, tetrahydrofuran and 2,2′-thiodiethanol also significantly improved the conductivity of PEDOT-PSS in thin films up to 98 S/cm and optical transmission of 84% [6,7].

PEDOT-PSS modified by glycerol treatment has been reported as anode material for polymer light emitting diodes [8]. Earlier, we reported polymeric photovoltaic cells using polymer anodes made of PEDOT-PSS and PEDOT-PSS modified with sorbitol treatment on a glass substrate, which demonstrated the possibility of using flexible polymer anodes in plastic solar cells [9].

Others have used the chemical oxidative polymerization of PEDOT from its monomer (3,4-ethylenedioxythiophene) by optimizing the ratio of the monomer, the oxidant (iron(III)*p*-toluenesulfonate ($Fe(OTS)_3$), and a weak base (imidazole) [10–12]. With this method, conductivity as high as 750 S/cm and 81% transparency have been reported. Further enhancement of the conductivity up to 900 S/cm and 82% transparency has been achieved by using methanol-substituted EDOT [13].