Chapter 20
Polymer Solar Cells

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ABSTRACT

Currently, the active materials used for the fabrication of solar cells are mainly inorganic. Materials such as silicon (Si), gallium-arsenide (GaAs), cadmium-telluride (CdTe), and cadmium-indium-selenide (CIS). Nevertheless, the large production cost for the silicon solar cells is one of the major drawback in this field. This chapter is dedicated to a critical presentation of another type of photovoltaics, called polymer, or plastic, solar cell technology. Polymer solar cells have attracted significant attention in the past few years due to their potential of providing environmentally safe, lightweight, flexible, and efficient solar cells.

INTRODUCTION

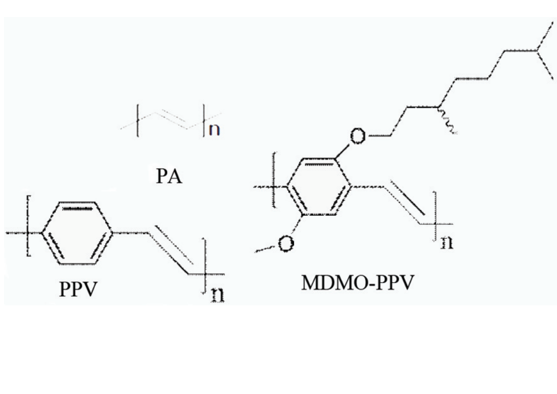
Photovoltaics (PV) is one of the fastest growing of all the renewable energy technologies. Solar cell manufacturing based on the technology of crystalline, silicon devices is growing by approximately 40% per year and this growth rate is increasing nowadays (Jäger-Waldau, 2003). This has been realized mainly by special market implementation programs to encourage a substantial use of the current PV technologies based on silicon. Efforts are now made to diminish the costs of these silicon-based technologies. To ensure a sustainable technology path for PV, efforts to reduce the costs of the current silicon technology need to be balanced with variety in PV technology.

DOI: 10.4018/978-1-4666-4852-4.ch020

The new approach consists in entirely new materials, namely conjugated polymers and molecules. Polymer solar cells are lightweight, flexible, and cheap to make (Chen, Hong, Li, & Yang, 2009; Roncali, 2009; Tremolet de Villers, Tassone, Tolbert, & Schwartz, 2009). Nevertheless, these devices have been too inefficient to compete with silicon solar cells for most applications. Now researchers from a few institutions claim to have made polymer solar cells with record-breaking efficiencies. These cells still are not good enough to compete with silicon, but polymer efficiencies have been increasing at a rate of about 1 percent a year. If this rate increases, plastic solar cells will be competing with silicon within a few years.

Conjugated materials are organics consisting of alternating single and double bonds. Conjugated polymers and molecules have the immense advantage of facile, chemical tailoring to alter their properties, such as the band gap. Conjugated polymers (Figure 1) combine the electronic properties known from the traditional semiconductors and conductors with the ease of processing and mechanical flexibility of plastics. Therefore, this new class of materials has attracted considerable attention owing to its potential of providing environmentally safe, flexible, lightweight, inexpensive electronics. The field of electronics based on conjugated materials started in 1977 when Heeger, MacDiarmid, and Shirakawa discovered that the conductivity of the conjugated polymer polyacetylene (PA, Figure 1) can be increased by seven orders of magnitude upon oxidation with iodine, for which they were awarded the Nobel Prize in Chemistry in 2000 (Heeger, 2001; MacDiarmid, 2001; Shirakawa, 2001; Shirakawa, McDiarmid, Heeger, 2003) This discovery led, subsequently, to the discovery of electroluminescence in a poly(p-phenylene vinylene) (PPV, Figure 1) by Burroughes et al. (1990). The first light-emitting products based on electroluminescence in conjugated polymers have already been emerged on the consumer market by Philips (The Netherlands) in 2002, and light-emitting products based on conjugated molecules have been introduced by the joint venture of Kodak and Sanyo (Japan).

Figure 1. Molecular structures of conjugated polymers: polyacetylene (PA), poly(p-phenylene vinylene) (PPV), and poly(2-methoxy-5-(3,7'-dimethyloctyloxy)-1,4-phenylene vinylene) (MDMO-PPV)



In organic Photovoltaic Devices (PVDs), the energy conversion efficiency up to 3% under illumination of AM 1.5 has now been reached, in devices based on organic small molecule solar cells and in polymer-based systems such as poly(3-hexylthiophene) (P3HT) and poly (2-methoxy, 5-(3',7'-dimethyl-octyloxy))-p-phenylene vinylene) (MDMO-PPV, Figure 1) combined with a fullerene derivative [6,6]-phenyl-C61-butyric acid methyl ester (PCBM, Figure 2) (Brabec, Sariciftci, & Hummelen, 2001; Chen, et al., 2009; Hoppe, et al., 2006; Offermans, Meskers, & Janssen, 2006; Padinger, Rittberger, & Sariciftci, 2003; Roncali, 2009).

Polymer PVDs are thin film cells with a thickness of only a few hundred nanometers (nm), in which a polymer film deposited by solution processing is the active layer. The film is sandwiched between two electrodes with different work functions, one of which is transparent for incident

Figure 2. Molecular structures of [6,6]-phenyl-C61-butyric acid methyl ester and phenyl-C_{71}-butyric-acid-methyl ester, $PCBM_{60}$ and $PCBM_{70}$