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A Study on the Development of Polymer Photovoltaic Devices

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ABSTRACT:-

Polymer photovoltaics offer great technological potential as a renewable, alternative source of electrical energy. The potential advantages of an all-polymer hetero-junction solar cell include: low cost (large scale production using the existing polymer processing technology), large area (plastic thin films can be produced with macroscopic dimensions), flexibility (the mechanical properties of polymers). The materials used are hydrocarbon-based non-toxic molecules, and the production of these thin film solar cells is done at room temperature without any dangerous exhausts. Since the band gap of polymeric semiconductors can be manipulated, it is possible to tune the colour of the solar cells, which in return is uniquely important for architecture.

INTRODUCTION :

Polymer-based photovoltaic cells are thin-film devices fabricated in the metal-insulator. The absorbing and charge separating bulk-hetero junction layer with a thickness of approximately 100 nm is sandwiched between two charge selective electrodes; a transparent bi-layer electrode comprising poly(3,4-ethylenedioxylenethiophene): polystyrene sulfonic acid (PEDOT:PSS) on indium tin oxide (ITO) glass for collecting the holes and a lower-work-function metal (here, Al) for collecting the electrons. The work-function difference between the two electrodes provides a built-in potential that breaks the symmetry, thereby providing a driving force for the photo-generated electrons and holes toward their respective electrodes.

Photovoltaic (PV) devices based on thin films made from conjugated polymers and [6,6]-phenyl C61-butyric acid-methyl ester (PCBM) have been extensively investigated due to the advantages they offer: easy solution process-ability and positive potential applicability. There are great positive aspect of polymer based PV devices, such as allowing the realization of large area devices, lowering the low-cost processes due to solution spin casting, and allowing the creation of a flexible device with soft polymer properties. Moreover, a roll-to-roll process enabling fabrication of ITO-free polymer solar cells on flexible substrates has been realized from the inverted device geometry. When the PV devices are composed of an electron donor and acceptor in a bi-layer active structure, the device operated well even though the performance showed low efficiency of 1% of the level achieved in early 1985. In the mechanisms of bi-layer based PV devices, due to the short exciton diffusion length (typically 1_10 nm scale), most of the created charge carriers may be recombined or trapped in the active layer before the charge separation and transportation to each electrode. Therefore, the bulk-hetero junction (BHJ) concept which has an organized efficient interpenetrating donor–acceptor structure, has been introduced to overcome this low charge carrier mobility and recombination, resulting in an increase of the photocurrent density of polymer based PV devices.

PV devices with bi-layer active films showed low power conversion efficiency because most of the charge generation and separation was carried out only at the interface between the two layers with different electron and hole affinities. However, since the separated electrons and holes can be easily transported to each electrode with a lower possibility of electron and hole recombination, a bi-layer device could be more effective compared to the BHJ as far as the charge transporting ability is concerned. Generally, it is difficult to fabricate a solution processable well-organized bi-layer device with P3HT and PCBM because the pre-coated P3HT bottom layer can be destroyed or dissolved when the PCBM top layer from the organic solvent is spin-coated.

Therefore, the printing transfer technique or the thermal evaporation method was adapted to fabricate the different P3HT/PCBM compositional bi-layer in the active layer. Recently, our group reported on solution processed polymer based PV devices with concentration graded bi-layers with P3HT from chloro-benzene (CB)/PCBM from dichloromethane (DCM) solvent. It was found that a bi-layer P3HT/PCBM device can be successfully prepared because the DCM solvent did not destroy the P3HT bottom layer. To give an overview of the BHJ research area, the P3HT/PCBM ratio controlled BHJ device has been widely studied because it enhances the device performance. For example, the Dyakonov group reported that the fill factor of BHJ polymer based PV devices is strongly dependant on the PCBM loading, because optimizing the composition plays an important role in active film morphology.

The field of organic electronic devices, such as light emitting diodes, field-effect transistors, sensors, lasers and photovoltaic devices is rapidly expanding due to the promise of inexpensive material and device fabrication accompanied by the wide variety of functionality of organic materials. The most important functionality is the large polarizability of the extended π -conjugated electron systems of organic compounds, among which p-conjugated semiconducting polymers are one of the prominent materials.

REVIEW LITERATURE:

Polymer photo-voltaics have attracted a great deal of attention in recent years because they offer a way of producing inexpensive electricity from the sun due to the inherent low cost of polymer processing. Still, after a decade of research, the device efficiency of polymer photo-voltaics lags significantly behind that of the inorganics.

This has hampered the introduction of the technology into the marketplace – the presumed goal of the research efforts. Bell Laboratories developed the first solar cell in 1965. It was based on silicon and was about as efficient as the best of today's organic cells – 6% (Chapin, Fuller et al. 1964). Today's triple-junction inorganic cells boast efficiencies of 35.2% in the lab using solar concentrators, and 19.2% in thin film copper indium gallium diselenide. The standard modules found on most rooftops are made of cheaper amorphous silicon with more modest efficiencies around 15%.

Since 1980, solar energy production has grown by about 20-25% each year, reaching 427 mega-watt production capacity in 2002 (Scott and Malliaras 1999), accounting for less than 0.1% of the world's energy production. Cost remains the major challenge to more widespread use of photo-voltaics. Without subsidies, the cost per kW-hr from photo-voltaics is 25 cents, compared to ~10 cents for fossil fuels.

The price of silicon photo-voltaics has decreased dramatically since 1976, when amorphous silicon solar cells were developed. The drop in price is due in part to aggressive R&D beginning with the fuel crisis of the 1970's, as well as economies of scale: for each doubling of production capacity, the price of solar panels drops about twenty percent.

Because of the high material costs of silicon, however, the achievable price reductions from further increases in production volume are reaching a plateau. Silicon and other inorganics require high temperature and vacuum conditions required for their production (such as molecular beam epitaxy and chemical vapor deposition), which form fundamental barriers to lowering costs of photo-voltaics. Thus photo-voltaics remain too expensive to compete efficiently with fossil fuels on a strict dollar-per-watt basis. When the cost for a typical photovoltaic panel is spread out over its 20-year lifetime and divided by the approximate amount of power it is expected to produce over that time in a sunny location, it costs about 25 cents per kW-hr higher, on average, than current consumer costs of 10-25 cents per kw-hr for utility generated electricity in California. In fact, it takes an estimated 10 years of use to recoup the energy invested in the manufacture of today's photo-voltaics.

Another interesting class of functional materials is fullerenes. After two decades from the initial discovery of buckminsterfullerene by Kroto et al. in 1985, these materials are being developed to various applications as antioxidants, biopharmaceuticals and active and passive additives for the polymer industry. The science and technology of plastic solar cells which will be reviewed here lies on the frontier of the above mentioned two important classes of functional materials, and shows an example how interdisciplinary research fields can merge together towards the developments of future technologies.

RESEARCH METHODOLOGY :

Devices are prepared on glass substrates pre-patterned with transparent ITO. Because ITO has a variable work function, it is rarely used as the lone bottom electrode. Either PEDOT or TiO_2 is used for the transparent material deposited on top of the ITO substrate, resulting in opposite polarity devices due to differential work-function steps. A transparent semiconductor, TiO2 acts as an electron-transporter and hole-blocker due to its extremely low-lying HOMO. When light is incident on TiO_2, it becomes relatively conducting so that the quasi Fermi-level of the photo-doped TiO_2 appears to play an important role in determining the open circuit voltage.

PEDOT-PSS from Bayer is a metallic polymer poly-ethelyne dioxythiophene (PEDOT) doped with poly-styrenesulfonate (PSS) that acts as an oxygen barrier and planarizing layer. It has a substantially larger work function (~5.1 eV) than ITO (~4.8 eV), thus acting as a hole-acceptor. Both TiO_2 and PEDOT-PSS have been shown to improve device performance over bare ITO (Carter, Angelopoulos et al. 1997; Arias, Granstrom et al. 1999).

Current-density vs. voltage curves were measured using a 2400 Keithley source meter. Since all photovoltaics are photodiodes (though not necessarily viceversa), photovoltaics show rectifying behavior in the dark, with a turn-on voltage roughly equivalent to the band-gap (where the barrier to injection is overcome).

There is currently broad interest in the charge generation and transport properties of conjugated polymers, due to their potential for flexible electronics with an incredibly broad range of applications. They have the electronic properties of a semiconductor, but the mechanical flexibility and ease of production of plastics. Because they can be liquid processed at room temperature using simple deposition techniques such as ink-jet printing and screen printing (Shaheen, Radspinner et al. 2001), their materials costs are lower than traditional semiconductors, and they can be deposited over large areas and/or on plastic substrates. In one day a typical sheet-feed printing machine can process the same area of material as a typical Si wafer production plant can process in one year (Brabec 2004). In addition, the band gap of these materials can, to a certain degree, be tuned by tampering with their chemical structure. In practice, however, it remains difficult to design a polymer with the desired spectroscopic, electronic, and chargetransport properties.

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CONCLUSION:

For photovoltaic devices fabricated from several blends of MDMO-PPV as donor material and different fullerene derivatives (C60, PCBM mono and multi-adducts) as acceptor materials, the highest open circuit voltage and short circuit currents were obtained with a 1:3 (weight/weight) blend of MDMO-PPV and PCBM mono adduct. Although it is shown that the PCBM multi adduct, which achieved the best film quality, shows the lowest short circuit current.

It has also been demonstrated that upscaling of plastic solar cells is possible without decreasing the short circuit current or the open circuit voltage. Using the doctor blade technique solar cells of 10x15 cm^2 with an active area of 2x50 cm^2 were fabricated with efficiencies directly comparable to 6x6 cm^4 cells with an active area of 4x4 cm^2.

The prospects for organic, plastic photovoltaic devices are improving as they get closer to market applications every day. This steady development is based on the optimization of the device physics:

- Optimization of the choice of metallic electrodes to achieve good ohmic contacts on both sides for the collection of oppositely charged photo carriers.
- Optimization of the choice of the donor/acceptor pair (the energy levels of the HOMO/LUMO influence the VOC).
- Optimization of the band gap and absorption profiles of the semiconducting polymer for efficient harvesting of the solar spectrum.
- Optimization of the network morphology of the phase separated composite material to maximize the mobility of the charge carriers within the different components of the bulk heterojunction.

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