Extended Abstracts of the 2016 International Conference on Solid State Devices and Materials, Tsukuba, 2016, pp867-868

PS-10-02

Control of crystalline nesting structure of vacuum deposited organic photovoltaic cells by co-evapotrant induced crystallization method

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Abstract

Organic photovoltaic cells (OPVs) with crystalline nesting structure, often called as ideal structure, of donor:acceptor blend is fabricated and generation/collection ability of photocurrent is examined depending on the width/thickness of the nesting structure. Fine control of crystallinity and phase-separation structure is realized by co-evaporant induced crystallization method. For the photovoltaic materials, phthalocyanine:fullerene blends are adopted as commonly used combination for vacuum deposited small molecule OPVs.

1. Introduction

Recently, organic photovoltaic cells (OPVs) are widely researched in the world, as one of the next generation solar cell candidates. In OPVs, photocurrent is generated by the separation of holes and electrons from excitons at the interface of p-type (donor) and n-type (acceptor) semiconductors. Because the diffusion length of exciton is limited to several tens of nanometers, blend film of donor and acceptor ─bulk-heterojunction structure─ is the mainstream of OPV structure to maximize the area of the donor-acceptor interface.

Fabrication method of this blend film is roughly classified in two methods: solution method and vacuum deposition method. Most of high efficiency OPVs, especially, almost all of over 10% single cell OPVs reported so far, are solution processed polymer cells that are composed of polymer donors and small molecule fullerene derivative acceptors. On the contrast, most of high efficiency vacuum deposited OPVs are tandem cells, because of low carrier transfer ability at large film thickness: typically more than 100 nm.

To crystallize thick vacuum deposited blends, we have developed "co-evaporant induced crystallization method" [1, 2]. This method utilizes liquid, such as polydimethil siloxane (PDMS), as the co-evaporant during vacuum deposition of donor:acceptor materials and enables fine control of crystallization and film growth, which can drastically overcome the controllability limit of conventional vacuum deposition.

Although high efficiency OPVs by this method has not been realized so far, here, we demonstrate the interesting phenomena that occur when blend structure of vacuum deposited OPVs are precisely controlled, showing the examples of typical combinations for vacuum deposited small molecule organic semiconductors, phthalocyanines and fullerenes.

2. Thickness/width control of $H_2Pc:C_{60}$ nesting structure

First, we examined fabrication method of nesting structure. The nesting structure, which is sometimes called ideal structure of OPVs (Fig. 1). For this examination, we used metal-free-phthalocyanine (H_2Pc) and fullerene (C_{60}) as the photovoltaic materials for this structure. Then, photovoltaic properties of fabricated devices were electrically measured and their actual structures were observed by optical microscopy and scanning electron microscopy.

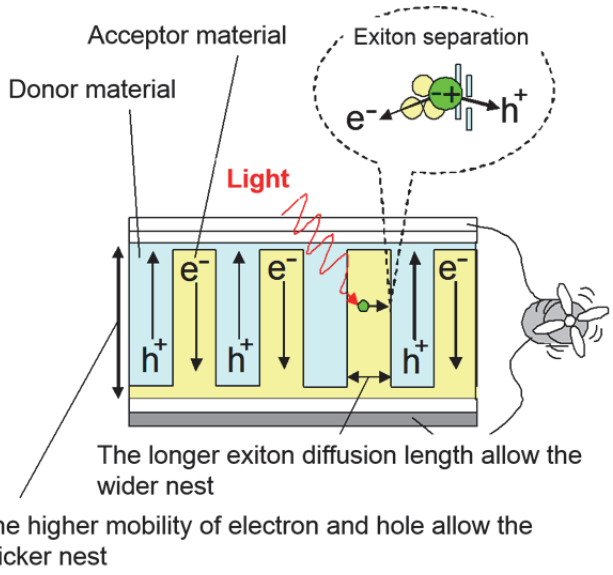

Fig. 1 nesting structure of donor:acceptor.

Unique nature of co-evaporant induced crystallization method enabled fine control of nesting structure width. When the evaporation speed of PDMS becomes faster, the width of the nesting structure becomes larger. Resultantly, photocurrent clearly changed depending on the width of nesting structure. Especially, when the width of nesting structure was maximized lower than the resolution of optical microscope (around 300 nm), short circuit current density showed maximum value. Figure 2 shows result of photocurrent depending on the width of the nesting structure. The mechanism of this photocurrent change is considered as commented in Fig.2 and the detail will be discussed in the presentation.

3. Conclusions

Crystalline nesting structure, often called as ideal structure, of donor:acceptor blend is fabricated by utilizing co-evapotrant induced crystallization method. The gene-ra-tion/collection ability of photocurrent is examined de-pending on the width/thickness of the nesting structure and resultant photocurrent showed clear dependence on the width of the nesting structure.

Acknowledgements

This study was carried out with the assistance of JST advanced low carbon technology research and development program (ALCA).

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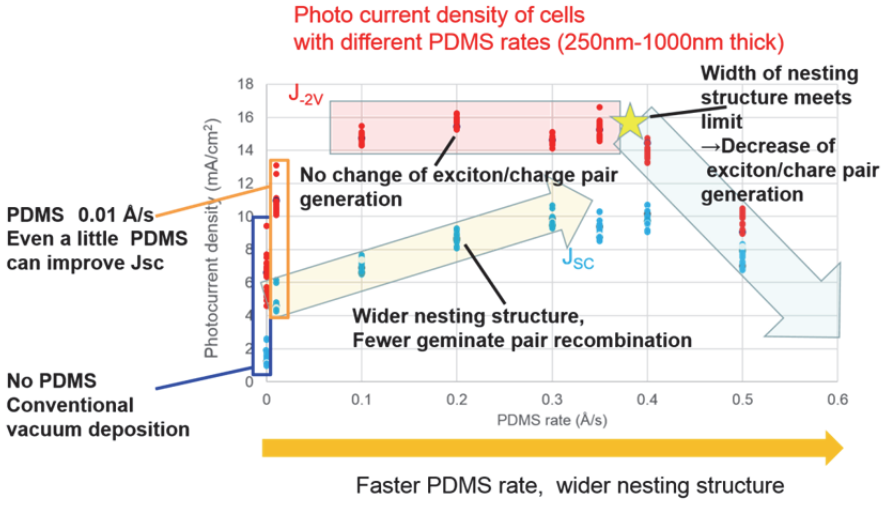

Fig. 2 Short circuit current density of photovoltaic cells with various width/thickness.