Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp1107-1108

Fullerene separation by sublimation and its influence on the performance of organic photovoltaic cells

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Abstract

Sublimation purification of C_{70} from mixed fullerene and effect of C_{60} impurity on the performance of organic photovoltaic cells that contain C_{70} as acceptor material were investigated.

1. Introduction

Organic photovoltaic cells are one of organic electronic devices together with organic light emitting devices and organic thin film transistors, in which organic semiconductors are used as the main material. It is inexpensive, lightweight and flexible as compared with the conventional silicon solar cell, and is expected as one of the next generation solar cells. C_{70} has a wide absorption wavelength in visible light and is suitable as an acceptor material for organic photovoltaic cells. However, in order to produce a solar cell using C_{70}, high cost is a problem due to the low content of C_{70} to the mixed fullerene raw material and the large number of separation steps therefrom. Moreover, when incorporating C_{70} into a solar cell, the influence of its purity on solar cell characteristics has not been clarified. Therefore, the aim of this research is to find an efficient purification method of C_{70} by sublimation and to clarify the influence of C_{70} purity on solar cell characteristics.

2. Experiments

The sublimation purification was carried out using mixed fullerene containing 70% of C_{60}, 20% of C_{70} and 10% of other higher fullerenes as a raw material. The purified C_{70} samples were dissolved into toluene. Their purities were analyzed using their absorption spectrum (see Fig. 1). Using C_{70} with five kinds of purity as an acceptor material, solar cells as shown in Fig.2 were fabricated. To realize solar cell operation with donor:acceptor thickness over 100 nm, co-evaporant induced crystallization method [1,2] was utilized. The thickness of the C_{70}:ZnPc blend layer was changed from 40 nm to 1000 nm. Then, J–V curves were obtained with a custom-designed probe box and solar cell measurement software under one sun illumination from a solar simulator. IPCE (incident photon to current efficiency spectra, i.e., spectra of conversion efficiency from photon to electron at each wavelength) were also measured with the same system under illumination of monochromatic light from a monochromator.

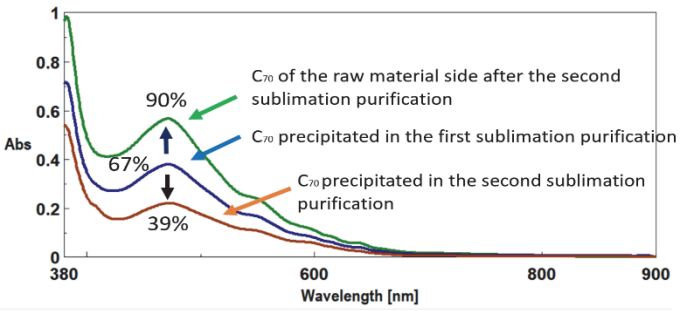

Fig. 1 Absorption spectrum of C_{70} after sublimation purification.

3. Results and discussion

As a result of the first sublimation purification, C_{70} with a purity of 67% was successfully precipitated from the mixed fullerene. However, unexpectedly in the second purification, the purity of C_{70} precipitated decreased to 39%. On the other hand, it was found that purity of C_{70} was improved up to 90% by removing C_{60} from C_{70} on the raw material side as this purification was continued (Fig. 1).

As above, the sublimation purification from C_{70}-rich fullerene mixture was found to improve the purity of C_{70} remaining on the raw material side. To obtain higher purity of C_{70}, 99% of C_{70} purchased was purified by this method. For solar cell fabrication, totally five kinds of C_{70} were prepared, 90% C_{70} precipitated by sublimation purification from mixed fullerene, 99% C_{70} purchased, C_{70} on the precipitation side sublimated from 99% C_{70}, C_{70} on the raw material side from the same sublimation, and, 90% C_{70} adjusted by mixing high-purity C_{70} and C_{60} to confirm the effect of C_{60} as an impurity.

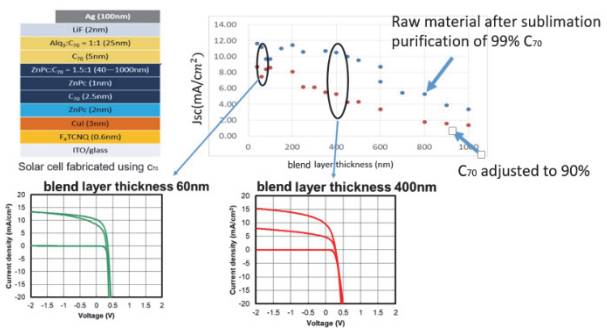

Fig. 2 Solar cell structure and plots of Jsc, with J-V curve of solar

cells (donor:acceptor thickness of 60nm and 400nm)

The solar cells fabricated using these five C_{70} were compared. *J*sc of typical two solar cells are shown in Fig.2. As a result of comparison, no clear difference was observed in the cells where the film thickness of the blend layer was thin, but in the thick cells, a large difference was caused depending on the purity of C_{70}. The cause was analyzed from the change of photoelectric conversion characteristics and diode characteristics due to the film thickness change of the blend layers.

As a result, it was found that the IPCE spectra of the solar cell were largely changed. As shown in Fig. 3, when the film thickness of the blend layer was increased, the IPCE at 620 nm decreased in both purities of C_{70}, whereas this wavelength is the absorption peak of zinc phthalocyanine. These phenomena indicate that inactive region of the blend layer increased. Compared to 90% C_{70}, purified C_{70} retained active region until around 400 nm thickness of the blend layer. This indicates that the film thickness of the effective photoelectric conversion layer varies depending on the extraction distance of electrons to cathode. On the other hand, there was no clear difference in diode characteristics, indicating that there was no significant effect of the purity on the formation of the donor acceptor (pn) junction interface. Therefore, it was revealed that the difference in purity of C_{70} mainly influences the extraction distance of electrons, and as a result, determines the film thickness that can be produced without deteriorating the solar cell performance.

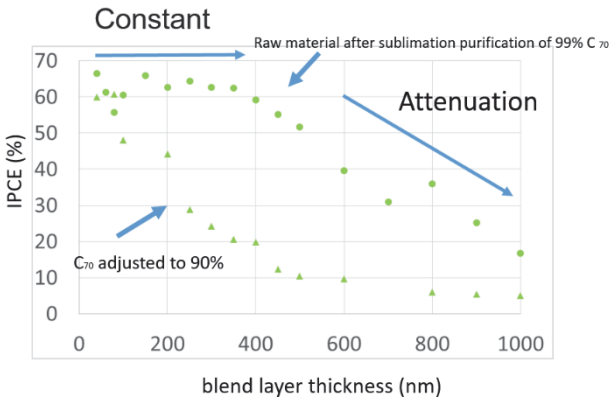

Fig. 3 thickness dependence of IPCE at 620nm

4. Conclusions

From sublimation purification and analysis by spectral measurement, we succeeded in finding an effective sublimation purification method for C70. Then, organic photovoltaic cells were fabricated using the purified C70 as an acceptor. The relationship between the purity of C70 and the solar cell characteristics was clarified. Specifically, we found a correlation between the purity of C70 and the film thickness of the effective photoelectric conversion layer, the extraction distance of electrons becomes narrower as the purity of C70 gets worse, and the large performance difference occurs when the film thickness of the blend layer becomes thicker.

References

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