

Effect of Silver Nanoparticles on Photoelectric Conversion Efficiencies of P3HT/PCBM Organic Solar Cells

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1. Introduction

Solar cells are attractive devices in various fields as a clean energy source. Organic thin film solar cells are expected as one of the next generation solar cells that possess many advantageous properties, such as light weight, low cost, fabrication at low temperature, and mechanical flexibility. Many researches have been reported in order to achieve the higher power conversion efficiency of those organic thin film solar cells.

On the other hand, noble metal nanoparticles, such as gold and silver, are irradiated by visible light, the localized enhanced electric field originating in surface plasmon resonance is generated around the nanoparticle surface. Since excitation of a photoactive molecule is possible for this electric field like light, it is expected to be able to contribute to the improvement of power conversion efficiency of photoelectric transducer and solar cell [1-8].

Moreover, the inverted-type organic thin film solar cell which designs to reverse the direction through which the electron of a typical organic thin film solar cell flows has high stability in order to use Au electrode for the back electrode [9-10].

From the above background, in this research, silver nanoparticles were incorporated in the inverted-type organic thin film solar cells, and examination is repeated for the purpose of clarifying the effect on the photoelectric conversion properties of the organic thin film solar cells by plasmonic noble metal nanoparticles.

2. Experimental Procedures

Silver nanoparticles were prepared according to the previous report [11]. The silver nanoparticle colloidal solution was obtained by adding the trisodium citrate which is a reducing agent and functions also as a protection layer of a nanoparticle, while heating at reflux silver nitrate solution. After condensing silver nanoparticle colloidal solution using a centrifuge, it was mixed with a PEDOT:PSS aqueous dispersion solution acting as the hole-transportation layer of the organic thin film solar cell.

The precursor solution of TiO_x thin film acting as the electron-transporting layer of the organic thin film solar cell was prepared by the mixture ratio of titanium (IV) isopropoxide, 2-methoxyethanol, and ethanolamine.

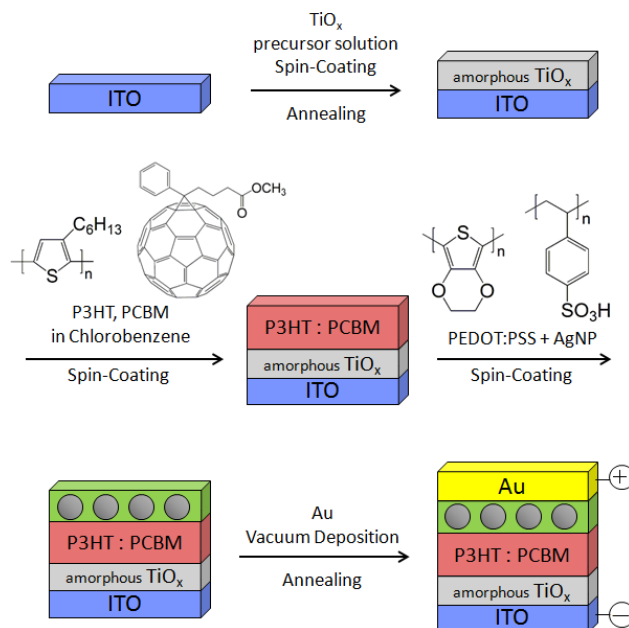


Fig. 1 Fabrication route of silver nanoparticle incorporated inverted-type organic solar cells.

The preparation route for inverted-type organic thin film solar cells incorporating Ag nanoparticle is summarized in Fig. 1. First, the precursor solution of TiO_x was spin-coated on ITO, being accompanied by hydrolysis in an ambient atmosphere and by heat treatment. Thereafter, a chlorobenzene solution containing P3HT and PCBM was spin-coated onto the ITO/ TiO_x substrate; further, a PEDOT:PSS aqueous dispersion solution incorporating Ag nanoparticles was spin-coated onto its blend film. Finally, an Au metal as the back electrode was vacuum-deposited on the PEDOT:PSS solid film. The device was heated for an annealing treatment. For comparison, the control devices were also fabricated under the same experimental procedures with those of Ag nanoparticles.

Current density-voltage ($J - V$) characteristics of the organic photoelectric conversion devices were measured by potentiogalvanostat under illumination at 100 mW cm^{-2} (AM 1.5) using solar simulator. Light was irradiated from ITO side.

3. Results and Discussion

Average particle size of the obtained Ag nanoparticles was approximately 50-100 nm, and it became clear to have the optical absorption based on localized surface plasmon resonance. The absorption spectrum of PEDOT:PSS thin film incorporating Ag nanoparticle is shown in Fig. 2.

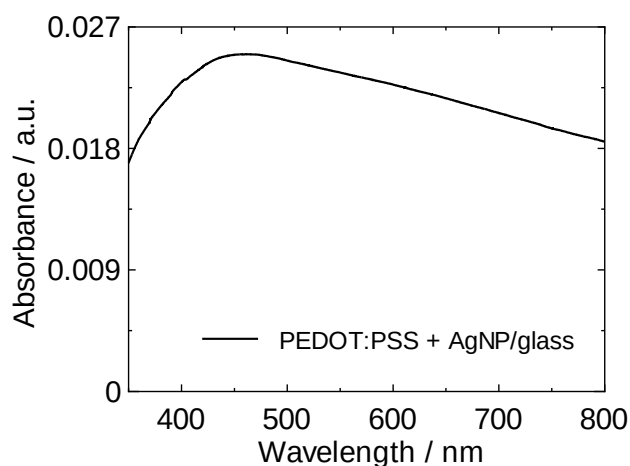


Fig. 2 Absorption spectrum of AgNP incorporated in PEDOT:PSS film.

The absorption peak resulting from the localized surface plasmon resonance of Ag nanoparticle is observed near 450 nm. Since the absorption band was broad, aggregation of the nanoparticle was suggested, however the absorption band based on the localized surface plasmon resonance of Ag nanoparticle is maintained in a PEDOT:PSS layer.

Fig. 3 shows the J - V curves of the inverted-type organic thin film solar cells with and without Ag nanoparticles.

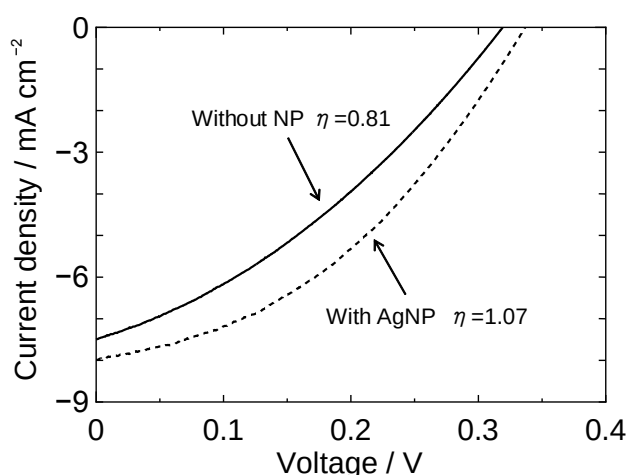


Fig. 3 J - V characteristics of solar cells with and without Ag nanoparticles.

As compared with the control device without Ag nanoparticle, it was observed that power conversion efficiency of the organic thin film solar cell with Ag nanoparticle is enhanced. As a factor of this enhancement, the localized enhanced electric field and light scattering by Ag nanoparticle can be considered.

4. Conclusions

We have demonstrated that the fabrication and evaluation of the inverted-type organic thin film solar cells incorporating Ag nanoparticles in a PEDOT:PSS layer. Although Ag nanoparticles were incorporated into the PEDOT:PSS layer, it was shown that the absorption band based on the localized surface plasmon resonance of Ag nanoparticles is maintained. As compared with the control device without Ag nanoparticles, it was observed that power conversion efficiency of the organic thin film solar cell with Ag nanoparticle is enhanced. Investigation of effect on each characteristic by changing the amount of addition of Ag nanoparticles is now in progress.

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