Fabrication of Dye-Sensitized Solar Cells

Background

Recently there has been increasing interest in dye-sensitized solar cells (DSCs) as a potential low cost alternative to conventional solar cells. Energy conversion efficiencies greater than 10% were reported. For attaining high efficiencies in DSCs, the dye-sensitized nanocrystalline TiO_2 (nc-TiO_2) film is believed to be the most important constituent element. In fact, a lot of approaches attempting to improve the efficiencies have been reported by modification of the nc-TiO_2 film. For preparation of the nc-TiO_2 film, high quality materials, such as TiO_2 pastes and sensitizer dyes, are recently available commercially. Even with these materials, however, attaining a high efficiency is not an easy task. Thus, it is important to clarify key factors to high efficiencies in detail.

Objectives

The purpose of this study is to investigate requirements for attaining a high energy conversion efficiency in a standard DSC, which employs an N719(cis-bis(isothiocyanato) bis(2,2'-bipyridyl-4,4'-dicarboxylato)-ruthenium(II) bis-tetrabutylammonium)-sensitized single nc-TiO_2 layer.

Principal Results

The nc-TiO_2 film is believed to be the most important constituent element for attaining high efficiencies. However we have demonstrated that efficiencies vary from 4.8% to 8.6% without any changes of the nc-TiO_2 film. The improvements of the short-circuit current, the open-circuit voltage, and the fill factor [*1] are summarized as follows.

1. Short-circuit current (Jsc)

For high Jscs with a maximum internal quantum efficiency [*2] of approximately 100%, it is important to employ an ion-conducting electrolyte prepared from a solvent of very low viscosity, such as acetonitrile. Analyses of the incident photon-to-current conversion efficiency in moderate efficiency DSCs suggested that the dependence of Jsc on the viscosity of the electrolyte stems from its light absorption. It was suggested that a low density of tri-iodide ions in acetonitrile makes the light absorption small in wavelengths of 400-600nm, where the solar spectral irradiance is high. Decrease of the interface area between the electrolyte and the front F-doped transparent conductive glass (FTO) substrate, and light reflection on the bottom surface were also effectual measures for high Jscs. As a result, an internal quantum efficiency of a maximum of approximately 100% is attained as shown in Fig.2, increasing Jscs from $12mA/cm^2$ to $16mA/cm^2$.

2. Open-circuit voltage (Voc)

The cell fabrication atmosphere strongly influences Voc. Specifically, DSCs fabricated in a glovebox filled with a dry Ar gas had significantly low Voc, compared to that of DSCs fabricated in the ambient air.

3. Fill factor (FF)

We have demonstrated that decrease of sheet resistance at the FTO, which accounts for the largest part of the series-internal resistance, is important for attaining high FFs. Shortening current paths at the FTO leads to a high FF of 0.721.

Future Developments

We are developing DSCs with high performance properties in practical use. We will attempt to elucidate the Voc determining mechanisms influenced by the atmosphere because this might have a close relationship with the DSC energy conversion mechanism, details of which are not known.

Main Researcher: Akira Usami, Ph. D.,
Research Scientist, Batteries and Electrochemical Materials Sector, Materials Science Research Laboratory

Reference

A. Usami, 2009, “Fabrication of dye-sensitized solar cells with a high energy conversion efficiency”, CRIEPI Report Q08019 (in Japanese)

＊1：Fill factor is given by Pmax/(Jsc*Voc), where Pmax is the maxmum power.

＊2：Quantum efficiency is conversion efficiency from an incident photon to an externally available electron under the short-circuit conditions. Light reflection at the solar cell surface is neglected in the internal quantum efficiency.

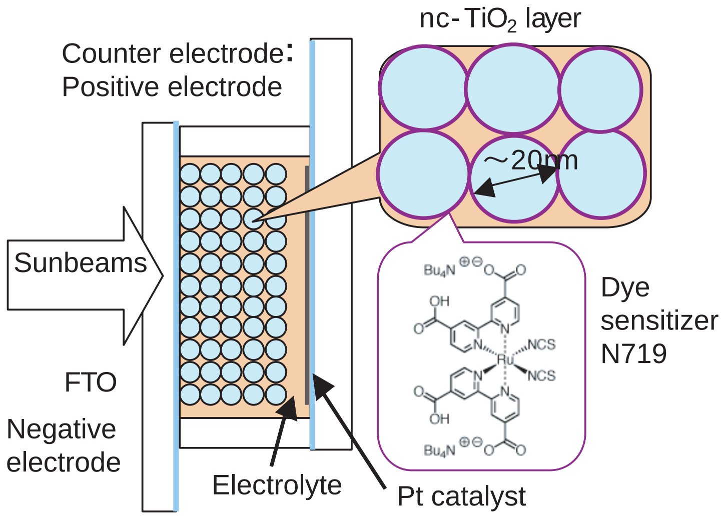
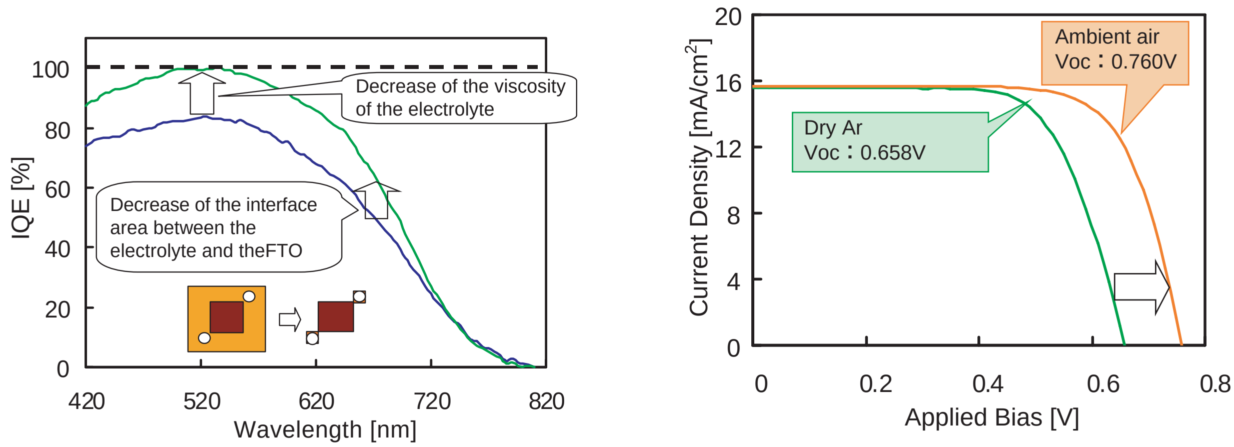


Fig.1 A schematic image of the dye-sensitized solar cells



(a) Short-circuit current density

(b) Open-circuit voltage

Fig.2 Improvement of the short-circuit current density and the open-circuit voltage

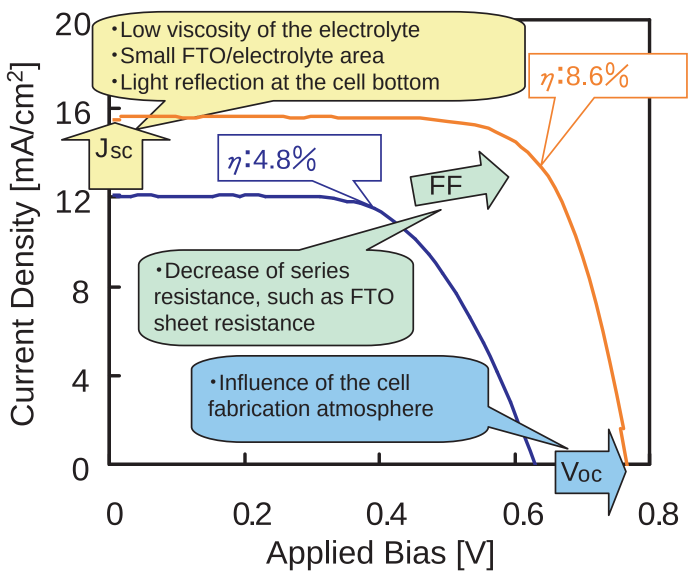


Fig.3 Summary of the improvements of the cell efficiency η

7