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Technical Note

Application of transparent dye-sensitized solar cells to building integrated photovoltaic systems

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A B S T R A C T

Dye-sensitized solar cell (DSSC) is one of the most promising photovoltaic systems for building integration (BIPV). DSSC can be transparent with various degrees of transparency, which makes it suitable for window application in buildings. In this study, we investigate the relationship between the transparency, the efficiency of DSSC and the overall energy efficiency of a building when DSSC is applied as window system. It is shown that while the efficiency of less transparent DSSC is generally higher due to higher short circuit current density (J_{sc}) from the thick electrode, it does not necessarily maximize the overall energy efficiency of a building. This is because lighting conditions of the building varies with the transparency of the window. The optimum condition should be carefully considered with the transparency of window as computationally simulated in terms of energy generation and consumption. We also find that different orientations of window in the building affect the optimum conditions of DSSC.

1. Introduction

The dye-sensitized solar cell (DSSC) is recently attracting tremendous interest as a green and renewable energy conversion device. The DSSC is one of the promising alternatives to inorganic photovoltaic devices as it can generate electricity with low production cost, which is about 1/5 of the production cost for Si based solar cells, and relatively high-efficiency [1–3]. Moreover, a critical advantage of the DSSC over current technologies is its adaptability as fenestration in buildings. The transparent characteristic of DSSC makes it suitable for outdoor applications such as window systems [4]. In a typical DSSC setup, nanocrystalline $TiO_2$is coated on a transparent conducting oxide (TCO), usually, a fluorine doped SnO_2, FTO. Dyes that convert the photon to electricity are absorbed onto the TiO_2 surface. The large surface area of TiO_2 is, therefore, desirable for high photoelectric conversion efficiency. In fact, the optimal amount and the thickness of TiO_2 has been revealed to be affected generally by (i) electron transport property of TiO_2, (ii) recombination rate between electrons on TiO_2 and electrolyte (I_3^-) or dye and (iii) high surface area [5–10]. The efficiency of DSSCs can be maximized when these conditions are appropriately designed. Recent studies on semi-transparent solar cell include thermal and optical performance [11,12], and simulation of total energy consumption in office building [13–15]. However, there is no detailed study on the impact of changes in the photoelectric conversion efficiency varying transmittance of DSSCs on energy performance. For the application of DSSCs in window system, both overall energy efficiency of the building and the photoelectric conversion efficiency of DSSCs should be considered together. As a rule, the transmitted light through a window affects the energy consumption of building from lighting, heating, or cooling of rooms. Therefore, the degree of transparency of DSSCs should be carefully taken into account when evaluating the efficiency of DSSCs as BIPV [16,17].

In this paper, in the first place, series of DSSCs with various transparencies are fabricated by controlling the thickness of TiO_2 photoelectrodes, and the quantitative relationship between the transparency and the efficiency of DSSC is examined. The obtained numerical relationship is later introduced in simulating overall energy efficiency of a building where DSSCs are integrated as window system.

2. Experimental

2.1. Synthesis of anatase TiO_2 nanoparticle

In order to fabricate TiO_2 paste for DSSC, typically titanium tetraisopropoxide (TTIP), acetic acid, water are used for TiO_2 paste.

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