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Design and fabrication of diffusive solar cell window

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A R T I C L E I N F O

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A B S T R A C T

A diffusive solar cell window was designed and fabricated with uniformly distributed nanocomposite particles in a light diffusive plate that was sandwiched between two glass layers. The entire composite construction transfers light radiation to solar cells at the edge of the windows. It is based on a new combination of existing technologies because of it uses mature, mass-produced components - solar cells - as well as nanocomposite particles that are embedded inside the light-guide plate. They are integrated using an inexpensive and widely used method for making building windows. The result is an inexpensive, strong, stable, view quality-preserving solar energy-harvesting window that has no close competition. The diffusive solar cell window does not suffer from aging, and products that are made using diffusive solar cell window technology will be new entries to the solar power generation window market.

1. Introduction

Building-integrated photovoltaics (BIPV) have received increasing attention in recent years as awareness of energy conservation and environmental protection has increased. They will continue to appeal only if the benefits of their use justify their overall cost. BIPV technology combines the design and fabrication of various solar energy-related materials and common building construction materials in a functional system that can effectively be integrated into modern architecture. Solar material can be embedded directly into the fabric of a building in the forms of solar windows, walls and roofing tiles. The priority concern is to reduce running costs and carbon emissions.

Various types of power generator on windows have been developed as applications of BIPV technology. For example, a translucent amorphous silicon (a-Si) solar cell, called a see-through a-Si solar cell, has been developed. It has many microscopic holes over its effective area to transmit light and it generates electric power. The see-through a-Si solar cell has been mounted on the sunroof of car to drive its ventilation system or to charge its battery [1]. Dye-sensitized solar cells (DSCs) are suitable for building-integrated photovoltaics with 5% energy conversion efficiency. Semi-transparent DSCs can be produced in many colors (determine by the dye used) and perform stably at high temperature, opening up an avenue to the development of power-producing windows [2,3]. The Kyosemi Corporation developed the so-called Sphelar solar cells [4]. These are solidified drops of silicon that can be molded into any shape and placed on a curved dome, which sunlight can hit from any angle. They can also be embedded in glass to produce transparent solar cell windows [5]. Konarka developed a transparent solar cell, which has the potential to be used in electricity-generating windows. Prototypes of such windows are composed of a solar cell between two panes of glass. Although they can be integrated into typical windows, some current-collecting grids can be clearly be seen in these systems. Transparency is an important issue in the development of a commercially viable solar-powered glass window. A semi-transparent plastic solar cell can be fabricated in a single step using an electronic glue-based lamination process with interface modification [6]. The fluorescent planar concentrator was developed for converting solar energy into electrical and thermal energy. Direct and diffuse radiation can be collected and concentrated using a stack of transparent sheets of material that are doped with fluorescent dyes. The advantages of such a system include its variable transparency, which enables it to be used in many hybrid applications [7–9]. A dye-based organic solar concentrator that can be integrated into building materials was also recently developed. A thin film of dye molecules are deposited on glass and absorb sunlight, which is trapped and transported in the glass by total internal reflection until it is captured by solar cells that are mounted on the edges of the glass [10].

The solar cells of contemporary BIPV windows stand directly in the way of the light that passes through the glass [11,12]. The view is unfortunately obstructed by the out-look circuitry or current-

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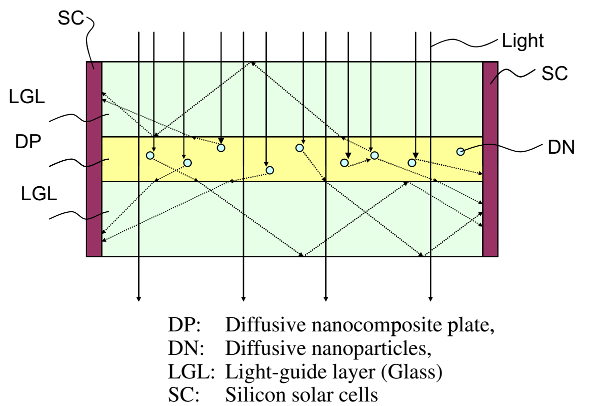

Fig. 1. Schematic view of light guided to solar cells by a light diffusive layer and light-guide layer.

collecting conductor grids or patterns. To satisfy the design goal, a technical solution to the problem of generating solar power without obstructing view through the window glass must be found; ideal BIPV windows should be made with the basic requirement that neither the lighting of the room or the view must be sacrificed. In this work, a diffusive solar cell window is designed and fabricated with uniformly distributed diffusive nanoparticles in a nanocomposite plate that is sandwiched between two glass layers. The entire composite construction transfers light radiation onto solar cells at the edge of the window. No solar cell stands in the way and the particles are transparent; the view is therefore preserved.

2. Experimental

Various amounts of commercial diffusive nanoparticles (ITC-30) were mixed with pristine polycarbonate resin. A diffusive nanocomposite plate was prepared by typical injection-compression molding at temperatures of 270–390 °C. No modification of the molding machinery or molding process was necessary. The diffusive nanoparticles were mixed directly with polymer pellets in the compounding stage, significantly simplifying the process for preparing nanocomposite materials. The polycarbonate nanocomposite plates were cut into various dimensions according to the various sizes of the window modules. Silicon solar cells with an efficiency of 16% were purchased from Motech Industrial Inc. They were directly mounted on four edges of the nanocomposite plate using traditional silicone adhesive. The polycarbonate light diffusive plate with embedded, uniformly distributed diffusive nanoparticles is then sandwiched between the two layers of the glass plate. Fig. 1 schematic depicts the diffusive solar cell window. Each interface between the polycarbonate diffusive plate and its stacked top and bottom glass plates traps lights inside the layered sandwich structure, and the highly reflective nanoparticles scatter the light sideways toward the solar cells that are positioned at the edge of the sandwiched window glass structure, as shown in Fig. 1. The proportion of light that is converted by the diffusive solar cell window can be set to meet the requirements of a product by simply adjusting a characteristic, such as the size or the concentration of the nanoparticles that are embedded in the PC plate. The crystal phase of the diffusive nanoparticles was determined by powder X-ray diffraction with Cu Kα radiation (Philips PW-1700). The morphology of commercial diffusive nanoparticles was observed under a scanning electron microscope (SEM, JEOL-5400). The transmission haze of the nanocomposite plate was measured using a haze meter (Nippon NDH-2000). The efficiency of the diffusive

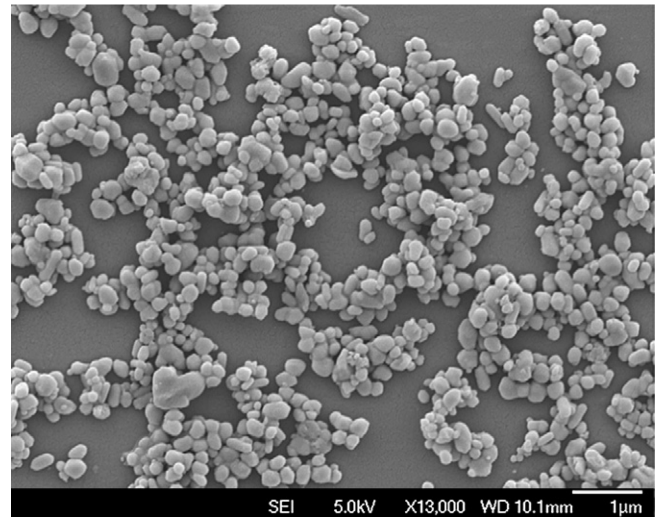

Fig. 3. Scanning electron micrograph of diffusive nanoparticles.

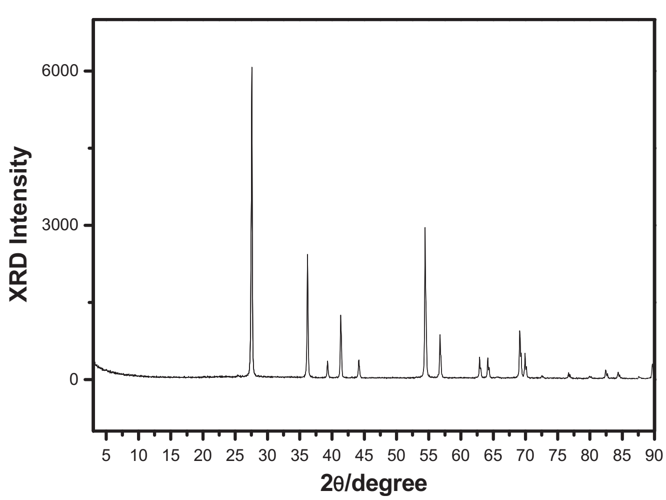

Fig. 2. XRD pattern of the light diffusive nanoparticles.

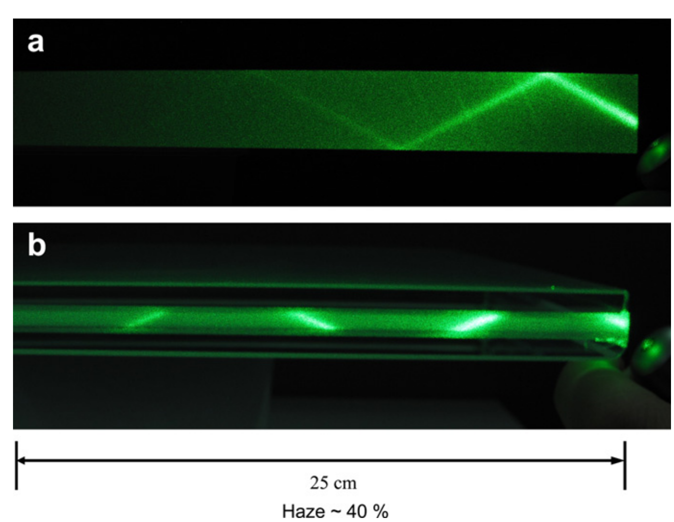

Fig. 4. The cross-sectional view of light path transmitted in (a) single diffusive plate and (b) diffusive plate with sandwiched glass structure (Haze ~40%).