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Luminescent layers based on rare earth elements for thin-film flexible solar cells applications

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ABSTRACT

Flexible inorganic solar cells are nowadays produced commercially on polymer and metal foils. Many technological enhancements are used to increase their conversion efficiency. In this paper authors focused on down conversion of ultraviolet and short wavelength visible light for improvement of amorphous silicon cells' quantum efficiency. Towards this goal, rare-earth elements were applied as active particles in flexible polymer down converting layer. For practical experiments, screen-printing method, as the cheap, reliable and industrially-ready technology was used. Various materials composition as well as different layer thicknesses and morphology were tested in order to obtain optimal luminescent effect.

1. Introduction

The conventional single-junction solar cells have limited photoconversion efficiency. The theoretical maximum efficiency of silicon solar cell with energy bandgap of Eg = 1.1 eV is 31% [1–3]. This limitation is caused inter alia by the spectral losses as the result of the mismatch between the emission spectrum and solar cell's spectral response [1–3].

Down-shifting is one of the approaches to improve the efficiency of photovoltaic cells. In this concept the luminescent layer is applied on the front side of solar cell. This layer is to absorb UV radiation of the solar spectrum and re-emit it in the visible light wave range [3,4], because this radiation is better matched to the solar cell absorption spectrum [1–5]. Thus it is expected that the down-shifting layer can significantly increase the efficiency of solar cells [5,6].

The material used as down-shifting layer should be characterized by the high luminescent quantum efficiency (LQE), high absorption coefficient, good separation of emission and absorption bands, good photostability and low cost. It is also important that the absorption and emission band match to the region of solar cell characteristics, where the external quantum efficiency (EQE) is low (for absorption) or high (for emission) [2]. There are some groups of luminescent materials used as down-shifting layers, such as: ZnO [3,7–10], organic dye [2,11–14], quantum dots [2,11,15] and rare earth elements

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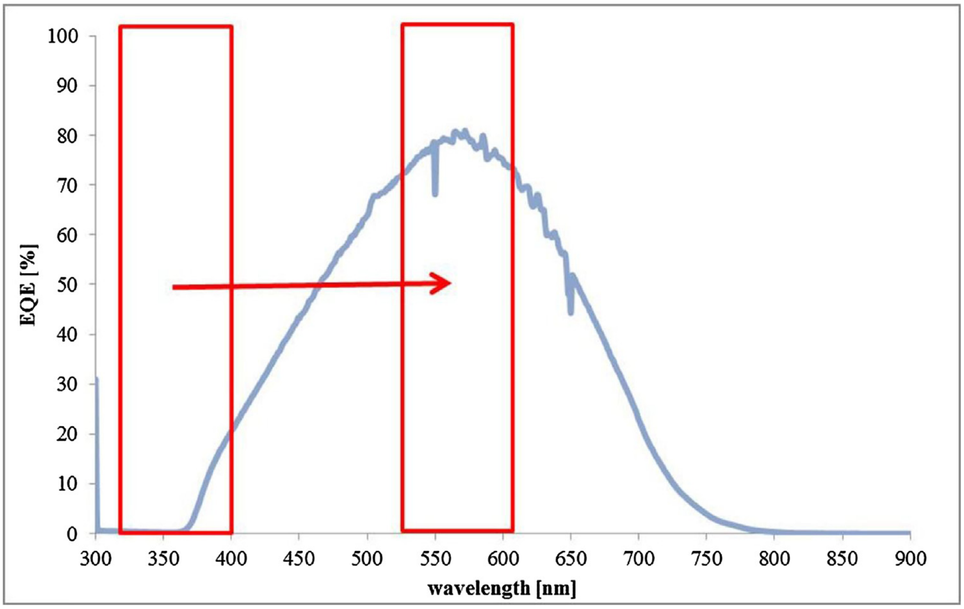

Fig. 1. The EQE of sample solar cell made of amorphous silicon by PowerFilm Solar Cell series MP3-37.

[2,6,16–19]. This paper is focused on the last group of these materials. They are characterized by a high LQE2 and can also exhibit phosphorescence properties [20–22].

The aim of this research is to improve the efficiency of thin-film solar cells. This will affect various solar cells types differently according to their conversion properties. Analysing the EQE characteristics of amorphous silicon cells (Fig. 1), it can be noticed that the profit from the application of down-shifting layer could potentially be significant, since EQE values in the UV region are below 10%.

Current work focuses on the improvement of the efficiency of standard commercial solar cell MP3-37, made of amorphous silicon by PowerFilm, using low cost luminescent layer.

2. Materials and methods

In the experiments a set of pigments: $Sr_4Al_{14}O_{25}$: Eu, Dy and $SrAl_2O_4$: Eu, Dy was used. These materials are characterized by excellent stability and interesting luminescent properties [23,24]. They absorb ultraviolet radiation and emit light in the visible range. The spectral characteristics of excitation and emission of pigments given by Nemoto Lumi-materials CO., LTD. is shown in Fig. 2.

Applied layers were deposited by screen-printing method. The process was made using 130 mesh polyester net, with square pattern of 16 cm^2. The layers were applied on PET film with the thickness of 128.5 μm and the average optical transmittance 88% for the range of wavelength from 300 nm to 800 nm and with a base of colourless dye Polyplast PY383 by FUJIFILM Sericol. The layers were applied in the various variants: with two different pigments, for a single, double and triple layer thickness and with a different concentration of a pigment (10%, 30% and 50%). Double and triple layers were superimposed on each other after the previous drying.

3. Results and discussion

Applied layers were analysed in order their possible application in photovoltaic cells. It is important that the optical transmittance should be as high as possible especially in the wavelength which is not converted by the layer. Therefore, at first the layers were tested according to the optical transmittance for different thicknesses and various pigment concentrations.

The results of optical transmittance measurements are summarized in Fig. 3. Optical transmittance was analysed for several selected thicknesses and concentrations. It was observed that for single layer the optical transmittance for 10% concentration of pigment is about 80%. Unfortunately, lower concentration implicates lower emission of applied layer, and hence, energy gain may not be sufficient to compensate the loss of about 20% of the sun radiation. Optical transmittance for 50% concentration of pigment for all three different thicknesses is rather poor and does not exceed 30% regardless of all thickness. That leads to a conclusion that these layers are too thick to be used in photovoltaic applications.

The characteristics of absorption and emission is extremely important for a successful application of the pigments in down shifting layers. That is why the excitation and emission spectres were analysed for the studied samples. Fig. 4 shows