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PV module current gains due to structured backsheets

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Abstract

We evaluate the optical performance of PV modules with respect to an increase in short circuit current density. Our evaluation is based on the combination of ray tracing simulations and measurements on test modules with four types of backsheets: Two of them are structured, the third is white and diffusively reflecting and the fourth reflects no light. Under normal incidence, structured backsheets reflect incoming light at an angle that causes total internal reflection at the glass/air interface, which guides the light to the solar cell surface. Three different irradiance conditions are studied: a) standard testing conditions (STC) with light incident perpendicular to the module surface, b) variation in the angle of incidence and c) light source with mean annual distribution of angles of incidence. Using the measured refractive index data in ray tracing simulations we find a short circuit current density (J_{sc}) gain of up to 0.9 mA/cm² (2.3%) for monofacial cells and a structured backsheet, when compared to a white backsheet with diffuse reflection. For bifacial cells we calculate an even larger J_{sc} increase of 1.4 mA/cm² (3.6%). The J_{sc} increase is larger for bifacial cells, since some light is transmitted through the cells and thus more light interacts with the backsheet. Our optical loss analysis reveals the best performance in STC for edge-aligned Ag grooves. This structure reduces absorption losses from 1.8 mA/cm² to 0.3 mA/cm² and reflection losses from 0.7 mA/cm² to 0 mA/cm². This trend also holds under various angles of incidence as confirmed consistently by J_{sc} measurements and ray racing simulations. Simulations using an annual light source emitting a mean annual distribution of angles of incidence reveal grooves in both orientations edge alignment and east-west alignment achieve similar current gains of up to 1.5% for mono- and of 2.5% for bifacial cells compared to modules with white back sheets. This indicates that for modules with light guiding structures such as these backsheets optimization for STC differs from optimization for annul yield.

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1. Introduction

We aim at increasing PV module efficiency by implementing light guiding structures to harvest light hitting the inactive areas of PV modules. Commonly used diffusely reflecting white backsheets typically guide half of the light hitting inactive areas onto the cells [1]. In contrast, metal coated structures can guide nearly 75% of this light onto the cell thereby increasing module efficiencies and power output [2][3][4] under standard testing conditions (STC) by around 1%. We analyze PV modules with entire backsheets comprising of triangular shaped metallic groove structures for monofacial cells and for bifacial cells.

2. Ray tracing model

Figure 1 depicts the triangular cross-section that is the basis for the grooves of the backsheet structure investigated in this study. We investigate two different alignments of many of those metal groove structures for the use as backsheet reflector:

- The grooves being aligned parallel to the cells' edges in each cell gap (Fig. 1, left), which we call "edge-aligned".
- The same grooves oriented parallel to two edges and orthogonal the two others (Fig. 1, right), which we call "east-west-aligned", because the grooves are meant be aligned in east-west direction.

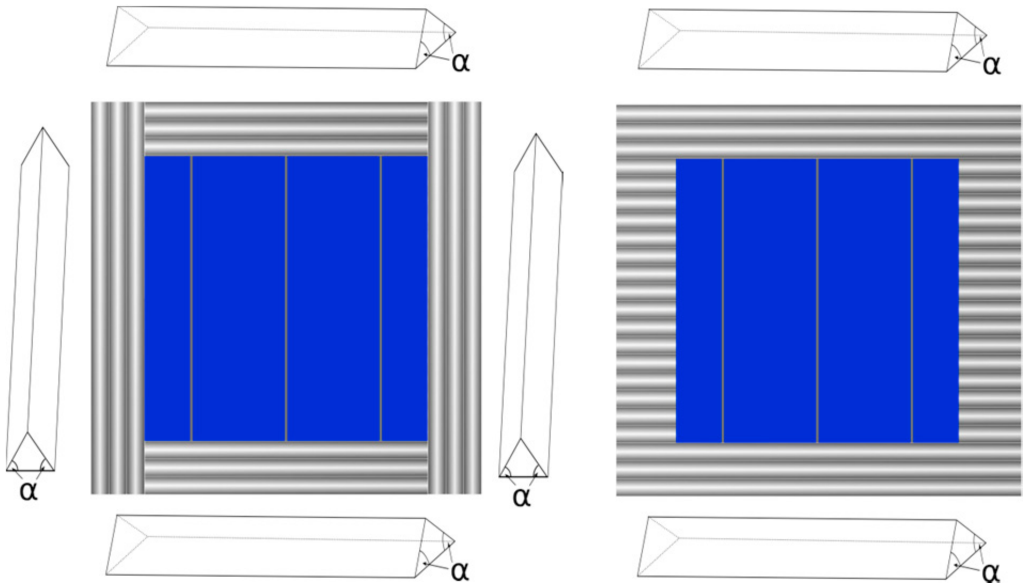

Fig. 1. Alignment of the structured backsheets with triangular grooves. Left: Grooves being aligned parallel to the four cell edges in each cell gap. Right the same grooves oriented parallel to the fingers, which we call "east-west-aligned".

We use the ray tracing framework DAIDALOS [5] to evaluate the optical performance of structured backsheets for PV modules. DAIDALOS models the glass cover, encapsulation, cell metallization and interconnects, cell texture, dielectric layers, local contacts as well as the various backsheet structures all as 3D geometries [6] with spectrally resolved optical constants.

Table 1 lists the geometrical features of the module and the optical constants of all materials (data are available