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Bifacial photovoltaic performance of semitransparent ultrathin $Cu(In,Ga)Se_2$ solar cells with front and rear transparent conducting oxide contacts

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ABSTRACT

We report the bifacial photovoltaic performance of semitransparent ultrathin $Cu(In,Ga)Se_2$ (CIGS) solar cells with Sn-doped In_2O_3 front and F-doped SnO_2 rear contacts prepared using a single-stage co-evaporation process under front- and rear-illumination conditions. The power conversion efficiencies (PCEs) of the solar cells measured at 100 mW/cm^2 increased with increasing ultrathin CIGS absorber thickness (200–400 nm), from 6.89 to 9.75% when front illuminated, and from 4.91 to 6.46% when rear illuminated, while the corresponding average visible transmission values (420–720 nm) gradually decreased from 18.53% to 5.06%. The bifacial photovoltaic performance of semitransparent solar cells with 200-nm- and 300-nm-thick CIGS absorber layers was also investigated under low-light conditions (100–10 mW/cm^2). The PCE of the solar cell with a 300-nm-thick CIGS absorber layer remained almost constant with decreasing light intensity (100–10 mW/cm^2), at ~8% (front illumination) and ~6% (rear illumination), while that of the solar cell with 200-nm-thick layer decreased from 6.84% to 3.43% (front illumination) and from 4.91% to 2.41% (rear illumination). The enhanced bifacial performance of the solar cell with the 300-nm-thick CIGS absorber layer is attributed to high shunt resistance in the solar cell owing to the improved microstructural qualities.

1. Introduction

Innovative and cost-effective renewable energy technologies are required to replace fossil fuels amid growing environmental pollution concerns. Photovoltaics (PV), renewable energy technology, has attracted much attention due to advantages that include high reliability, low operational costs, and non-polluting nature. Over the past few decades, building-integrated photovoltaics (BIPV) has been considered very promising for solar-cell applications in urban environments because it provides practical PV systems that replace existing building exteriors and do not need additional sites [1,2]. Bifacial and semitransparent solar cells can be designed as attractive building exteriors such as windows, façades, and skylights that convert a portion of sunlight into electricity while passing the remainder into the building. They reduce the summer cooling load and enhance visible and physical comfort in a similar manner to typical architectural glass products that transmit around 10% of the visible light and offer soft daylight effects in the 100–2000 lx range [3]. The skin of modern buildings consists of translucent curtain walls and claddings, and thus the importance of semitransparent solar cells is growing. Also, these cells can apply to a variety of urban outdoor-PV applications because of their bifacial characteristics providing opportunities for generating more electrical power in urban sunlight environments with strongly diffused light by absorbing sunlight either at the front or at the rear of the solar devices, or both. Bifacial solar cells also deliver enhanced performance from the Earth's albedo [4]. The power conversion efficiencies (PCEs) and average visible transmissions (AVTs) of bifacial and semitransparent solar cells with broadband absorption depend critically on the application requirements; these two parameters are trade-off related, with PCE approaching zero as AVT approaches 100% [5].

$Cu(In,Ga)Se_2$ (CIGS) is considered to be a good absorber material for high-efficiency thin-film solar cells due to its high absorption coefficient (~10^5/cm) and good durability to light and humidity [6,7]. As the absorber layer is sandwiched between the front and rear transparent conducting oxide contacts, CIGS thin-film solar cells with ultrathin absorbers allow part of the incident visible light to pass through and can be applied to a variety of applications that require bifacial performance and semitransparency in the visible wavelength range [8].

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