Solar Energy 137 (2016) 129–133

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

Review

A study on electrical performance of N-type bifacial PV modules

Bo Yu [a,*], Dengyuan Song [a], Zhonggang Sun [a], Keming Liu [a], Ying Zhang [a], Dandan Rong [a], Lijun Liu [b,*]

[a] State Key Laboratory for PV Material and Technology, Yingli Group Co., Ltd., Baoding, Hebei 071051, China
[b] Key Laboratory of Thermo-Fluid Science and Engineering, Ministry of Education, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shanxi 710049, China

ARTICLE INFO

Article history:
Received 25 December 2015
Received in revised form 2 August 2016
Accepted 4 August 2016

Keywords:
Bifacial PV modules
Solar cells
Transparent backsheet
N-type

ABSTRACT

Transparent backsheet is adopted to encapsulate PV modules to take the advantages of the potential of N-type monocrystalline bifacial solar cells. The energy output of bifacial modules is significantly higher than that of regular modules for micro inverter and string inverter PV system at different weather conditions. The monthly energy output of a bifacial module is averagely 4.03% higher than that of a regular module for micro inverter PV system after an outdoor test lasting for six months. The monthly energy output of bifacial modules is averagely 3.21% higher than that of the regular modules for string inverter PV system after an outdoor test lasting for one year. This indicates the advantages of the application of transparent backsheet on the N-type c-Si solar cells and shows good potential in application to rooftop and household photovoltaic systems in large scale. Besides, N-type bifacial PV modules with transparent backsheet is especially suitable to those areas with good irradiance and low temperature.

Contents

1. Introduction

N-type monocrystalline silicon solar cell is a high efficiency and low cost photovoltaic technology. It is competitive in commercialization and has a good potential in application. Compared with P-type solar cell, N-type solar cell has higher Isc, Voc and filling factor (FF). The phosphorus-doped back surface field (BSF) enables a symmetrical bifacial grid design. Besides Yingli, other solar modules manufacturers like Sanyo and Bsolar also provide bifacial PV modules (Song and Xiong, 2013). Sanyo's bifacial hetero-junction with intrinsic thin-layer (HIT) solar cell deposits ultra-thin amorphous silicon stack layers on c-Si wafer to form PN junction (Joge et al., 2003), while the bifacial modules by Bsolar utilizes the reflected lights from ground and its overall performance is equivalent to regular modules with efficiency up to 21–24% at solar cell level (Wang et al., 2008).

* Corresponding authors.
E-mail addresses: vincent.yu@yingli.com (B. Yu), ljliu@mail.xjtu.edu.cn (L. Liu).

http://dx.doi.org/10.1016/j.solener.2016.08.011
0038-092X/

2. The structure and advantages of N-type bifacial solar cells

2.1. The structure of N-type bifacial c-Si solar cells

The solar cells in this work use a phosphorus-doped N-type wafer (1–2 Ω cm) as substrate. Compared to the standard P-type (boron-doped) silicon solar cells, N-type silicon solar cells feature two key advantages. First, they do not suffer from light induced degradation (LID) caused by the simultaneous presence of boron and oxygen in the wafers, a phenomenon that in the standard P-type silicon solar cells leads to reduction of the module's electricity output by usually two to three percent within the first few days of installation. Second, N-type silicon wafers are less sensitive to impurities that are usually present in silicon feedstock. Consequently, less efforts are needed to be made to obtain N-type silicon wafers with a high carrier lifetime (Uematsu et al., 2003). The structure of N-type bifacial solar cells is illustrated in Fig. 1.

2.2. The advantage of N-type bifacial PV modules

The efficiency of N-type PV modules can be higher than conventional P-type modules. The majority of metal impurities in N-type silicon are inactive for mobile carriers. The specialized rear passivation enhances the quantum efficiency of infrared light (Hezel, 2003). The N-type PV modules show an extremely low initial degradation. The N-type solar cells also show a higher electricity output in low irradiance condition like in the morning and evening. Compared with P-type modules, the temperature coefficient of N-type modules is lower. Hence a higher energy output can be expected in warm and sunny days. The measurement of N-type modules with 60 N type solar cells during the first week after fabrication found no efficiency degradation due to any interference of B-O complex (Joge et al., 2004).

The *I-V* curves from both sides of N-type solar cells with N type wafer of 200 μm thickness and 2 Ω cm resistivity are illustrated in Fig. 2.

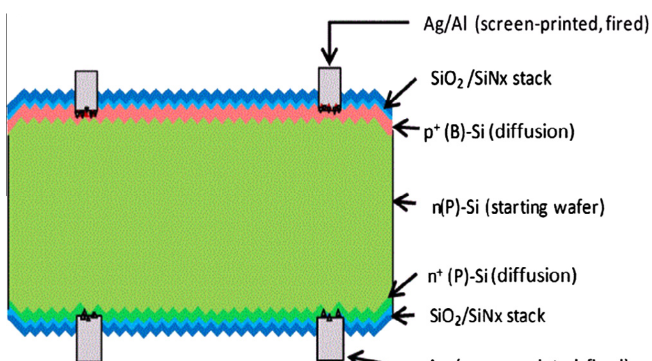

Fig. 1. A cross section of a N-type bifacial solar cell.

3. Bifacial PV modules

3.1. Properties of bifacial PV modules

Bifacial modules with transparent backsheet which is light transmittance above 80% with excellent transparency. Regular modules with a white reflective backsheet which is light transmittance nearly zero. Bifacial modules and regular modules are used the same material including bifacial cells, EVA, and tempered glass except backsheet. Transparent backsheet was developed under the impetus of the emerging building integrated photovoltaics (BIPV) and bifacial solar cells. The advantage of this material is its low density and transparency. Expensive polyvinyl Butyral (PVB) is used as encapsulating materials in the application of BIPV (Sánchez-friera et al., 2007). Cheaper materials like ethylene vinyl acetate (EVA) and polyolefin are used in other applications. For bifacial solar cells, the IR lights are susceptible to the reflection from the ground, and are accepted from the rear side of the solar cells and the electricity output is therefore enhanced (Robles-Ocampo et al., 2007). Several research institutes indicated that an improvement up to 30% can be expected (Kreinin et al., 2010). Besides, conventional laminating machines suffice to process transparent backsheet and it's not necessary to purchase excess equipments like autoclaves.

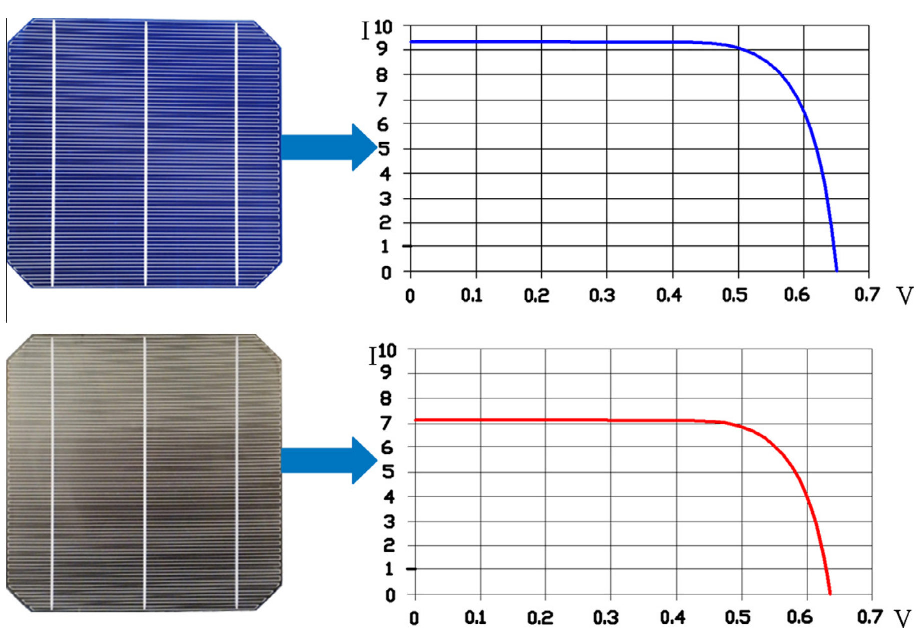

Fig. 2. *I-V* characteristic of N-type solar cells (156 × 156) from the front and rear sides (front efficiency 18–20%, rear efficiency 13–16%).