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Well Intended Contact Failures on Interdigitated Back Contact Solar Cells

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Abstract. The interconnection of the cells that make up a solar panel is a simple step, but it is not unimportant. The panels are made up of cells in series, so that a poorly connected cell can spoil the good performance of the entire panel. Back-contact solar cells have polarity connections on the back, making interconnection critical. In this work contact failures are intendedly induced, solar cells are biased at several conditions and electroluminescence measurements are carried out to detect problems. The results show that even at low amperage, connection faults can be identified by simple image processing. As a conclusion, this detection method could be implemented before encapsulating the panels, avoiding efficiency losses.

Keywords: IBC, Interconnection Failures, Electroluminescence

1. Introduction

The interconnection of the cells that make up a solar panel is a simple step, but it is not unimportant. The panels are made up of cells in series, so that a poorly connected cell can spoil the good performance of the entire panel [1], [2], [3], [4]. In first generation solar cell panels, it is necessary to connect the rear side of one cell to the front side of the next cell, as they have each polarity in one surface [5]. In this kind of cells, the front surface metallization generates a grid that covers the whole cell, so that it can easily compensate for the mismatch in the connection of one of the busbars. Some new cell models, such as back-contact cells, have both positive and negative contacts on the rear surface. These cells, indeed, are showing an increase in market share [6]. Experts claim that the global market share of IBC modules could increase from around 2% in 2022 to more than 50% in 2030, pushing solar panels based on both-sided contact-cells out of competition [7]. This type of cells have many advantages [8], but there is no margin for error in the interconnection of the cells when assembling a panel. A mismatch in the connection can lead either to short-circuiting both polarities of the cell, or to part of the cell being practically disconnected, since the back metallization design results being divided into very loosely connected sub-cells. [9].

The aim of this work is to study different connection failures in a Sunpower Maxeon III IBC cell [9] by EL imaging, demonstrating the feasibility of the measurement for early detection of possible failures in PV IBC panels.

2. Sample and measurement equipment

2.1 Cell structure

The cell under study is a Maxeon III IBC cell [10]. This cell has the connections of both polarities in the rear side, and presents three pads for the interconnection of the cells in the module. Figure 1 shows how each of the three pads has a tree-like structure, with the central trunk branching into several branches from which the metal fingers hang. These fingers run through the cell from one side to the other (horizontally in our image), with a single metal finger connecting the pads to each other, which makes the cell practically divided into three sub-cells. A mismatch in the connection between cells can cause a short-circuit between both polarities of the cell or can leave one third of the cell in open circuit. The latter scenario is analysed in this paper, being the short-circuit case outside the scope of this work.

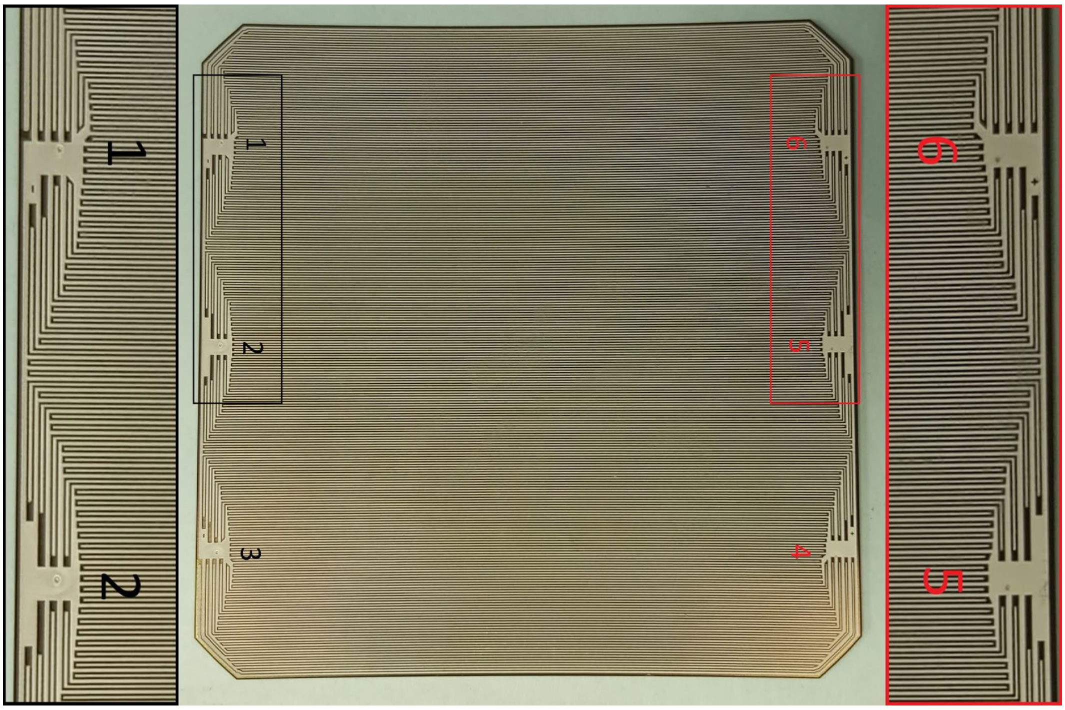

Figure 1. *Rear metallization and polarities in the Maxeon III IBC cell.*

2.2 Measurement prototype

The Institute of Microelectronic Technology (TiM) is a research institute in the Bilbao School of Engineering. It is composed of a group of faculty members and students from the University of the Basque Country (UPV/EHU) and has extensive experience in photovoltaics. Its facilities allow the design and manufacture of measuring equipment, the simulation and manufacture of semiconductor devices and the characterisation of photovoltaic solar cells. Given that its measurement and characterisation equipment is adapted to front contact cells, the first step was to design and manufacture a platform that would allow us to carry out measurements in IBC cells. The aim is to perform EL measurements simulating the situation in which there is a failure in one or more of the contacts of the cell. Figure 2 shows the equipment for measuring luminescent signals, it consists of (1) a multimeter for displaying measurement parameters such as current, voltage or temperature, (2) an electronic load to control the operating point of the solar cell, (3) the CCD camera to capture the luminescent signal and (4) a platform specifically designed to measure back-contact solar cells. The designed platform has all the contacts in the same side and some switches that allow connecting or disconnecting them at will.

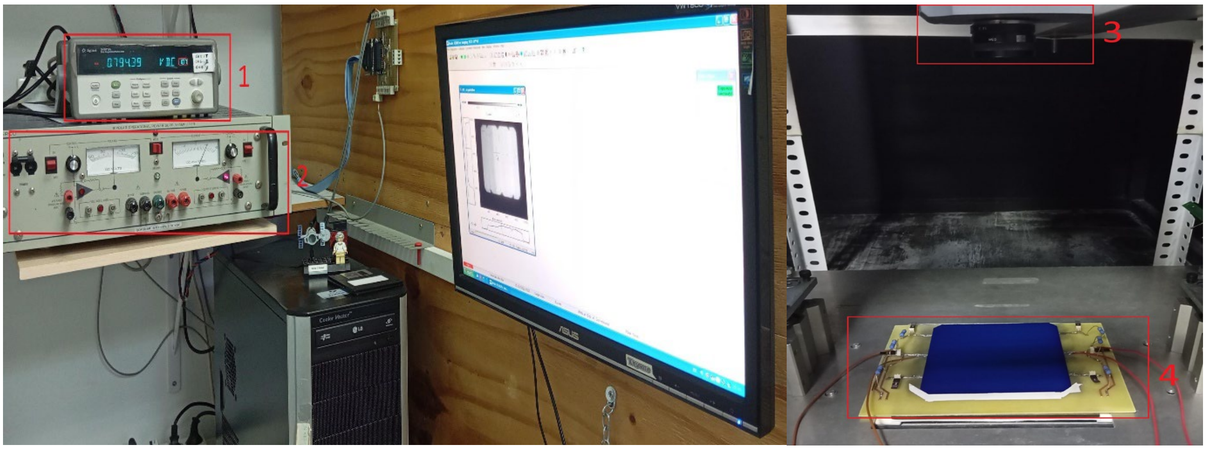

Figure 2. *Equipment for the measurement. Multimeter, electronic load, and computer (LEFT) and CCD camera and homemade platform (RIGHT).*

Figure 3 shows in detail the prototype specifically designed and manufactured to measure back-contact solar cells. This platform consists of 6 pads in accordance with the 6 pads of the solar cell shown in figure 1, 0.22 ohm resistors to equalize the current in the 3 sub-cells and jumpers that allow disconnecting the 6 pads at will. The IBC solar cell will be placed on the platform (LEFT) and the platform has also holes for the vacuum to hold the sample and make a good connection (RIGHT).

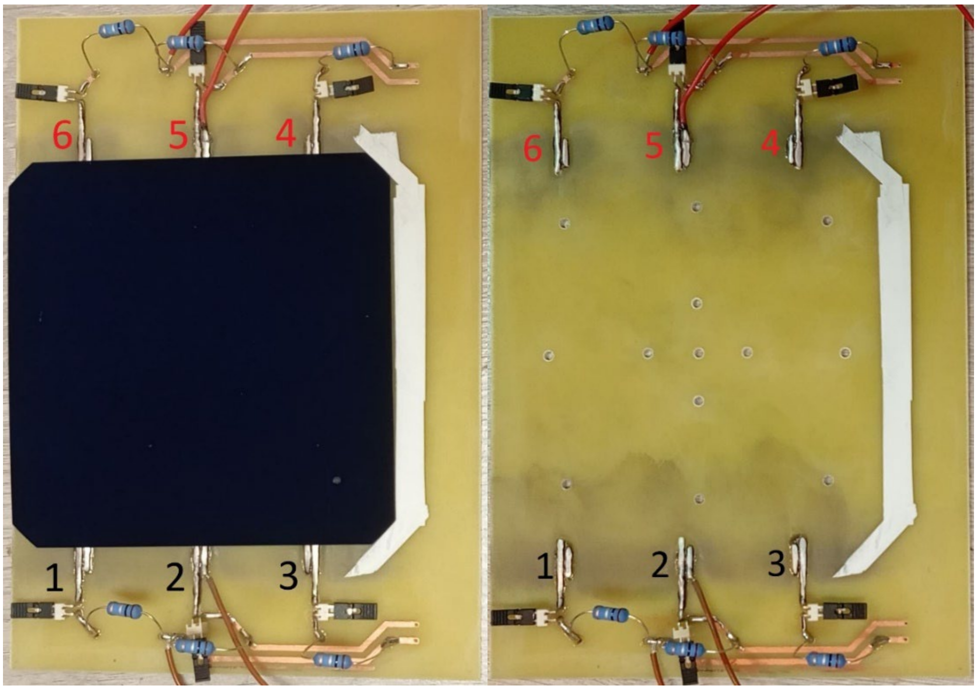

Figure 3. *Connection prototype with a cell (LEFT) and showing the holes for the vacuum to hold the sample and make a good connection (RIGHT).*

3. Measurements

3.1 Image acquisition

EL images have been acquired using a CCD camera. The camera used was the Ikon-M PV Inspector from Andor, Oxford Instruments, with 1024x1024 pixels. The platform were the circuit with the cell were placed was at room temperature and the acquisition time was 0.5 seconds. The measurements were taken for different current values (1, 2, 4 and 6 amperes) and with intentionally disconnected pads, simulating a soldering defect. The following table summarizes the different measurements performed. The nomenclature used is the following: ***current_voltage_disconnected pad(s)***. The voltage refers to the value measured between pads 2 and 5 (see figure 1).

Table 1. *EL measurements obtained at 0.5 s with the CCD camera.*

All pads connected	1 pad disconnected	2 pads disconnected
1A_760mV	1A_762mV_pad1 1A_706mV_pad2 1A_738mV_pad3 1A_731mV_pad4 1A_702mV_pad5 1A_715mV_pad6	1A_769mV_pad1&6 1A_709mV_pad2&5 1A_860mV_pad3&4
2A_828mV	2A_781mV_pad1 2A_724mV_pad2 2A_789mV_pad3 2A_758mV_pad4 2A_736mV_pad5 2A_770mV_pad6	2A_787mV_pad1&6 2A_709mV_pad2&5 2A_763mV_pad3&4
4A_838mV	4A_794mV_pad1 4A_754mV_pad2 4A_796mV_pad3 4A_796mV_pad4 4A_755mV_pad5 4A_789mV_pad6	4A_814mV_pad1&6 4A_726mV_pad2&5 4A_804mV_pad3&4
6A_809mV	6A_747mV_pad1 6A_777mV_pad2 6A_756mV_pad3 6A_759mV_pad4 6A_777mV_pad5 6A_769mV_pad6	6A_833mV_pad1&6 6A_738mV_pad2&5 6A_837mV_pad3&4

The following image shows an example of the acquired EL images. The position of the cell is the same as in the figure showing the prototype (figure 3). It can be seen that when all the pads are connected we can differentiate the three sub-cells, indicating there is still some resistance mismatch in the contacts of our prototype. The sub-cell on the left appears brighter when all the pads are connected, so we are going to show the results obtained when the pads of the right sub-cell are disconnected, as they seem to have a poorer connection already. These are pads 3 and 4. Although we only show these results, we remind you that all raw images are available for anyone who wants to consult them.

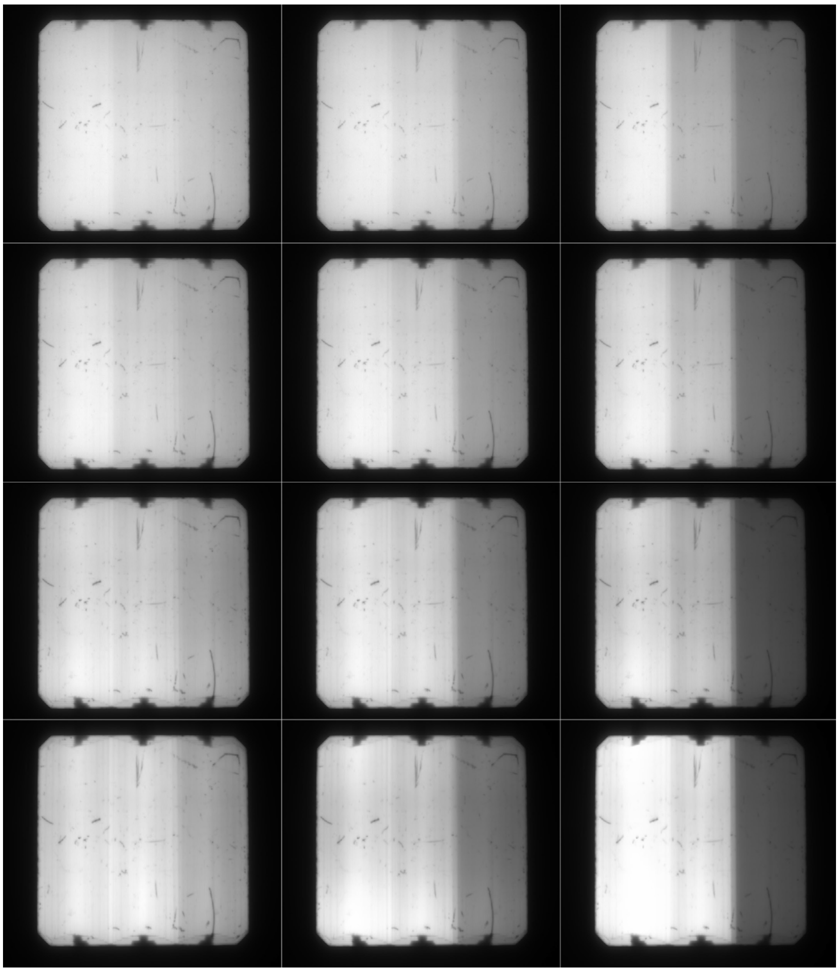

Figure 4. *EL images from top to bottom: 1, 2, 4 and 6 amperes. Left images have all the pads connected, centre images have pad 3 disconnected and right images have pads 3 and 4 disconnected.*

3.2 Image processing

As discussed in a previous section, the cell under study is composed of three sub-cells connected by a single thin line (see figure 1). When all the pads are connected, the cell should radiate homogeneously. When one pad is disconnected, the corresponding cell third will be fed by the mentioned thin line, but this line will be able to handle only a low current.

The raw EL images are sufficient to detect a connection failure at simple eye inspection. However, minimal image processing of these images can provide the input to an automated detection of this type of failure in a similar way to other proposals [11], [12]. Figure 5 shows some El images and their corresponding horizontal profile. The step in the luminescent emission that indicates some failure in the connection of that part of the cell is detectable even at only 1 ampere. Images have been processed using ImageJ software [13].

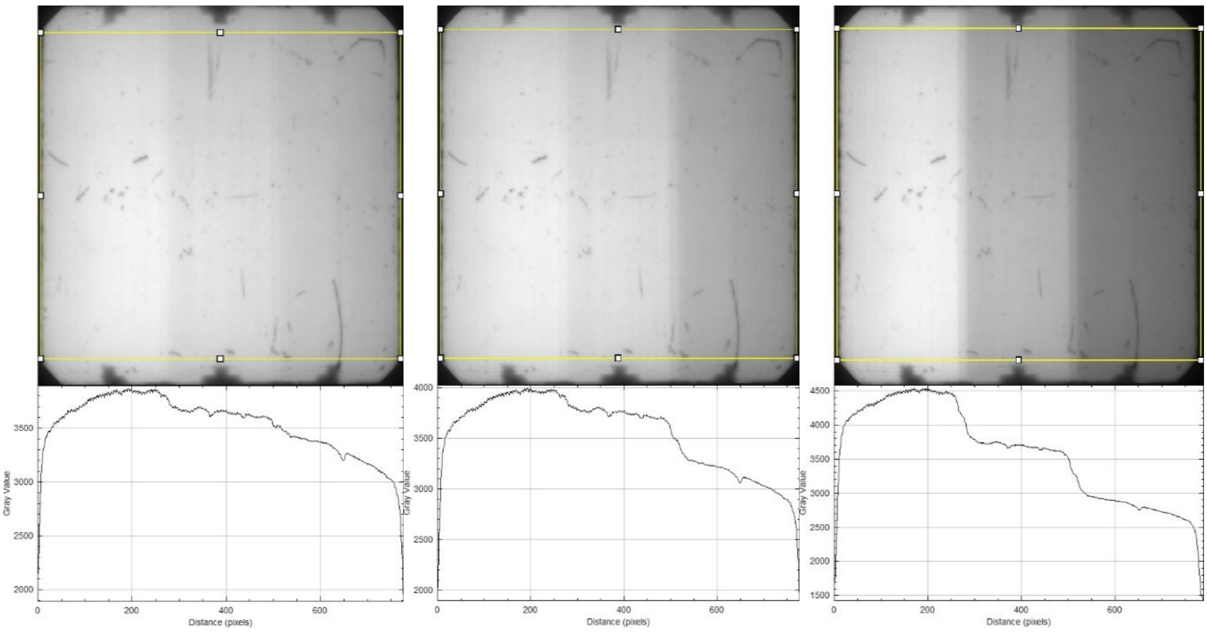

Figure 5. *EL images at 1ampere and their corresponding horizontal profile plots, with all the pads connected (LEFT), with pad 3 disconnected (CENTRE) and with pads 3 and 4 disconnected (RIGHT).*

3.3 Normal cell working conditions

Although only 1 ampere and 0.5 seconds are enough to detect a connection failure in the cells, it must be taken into account that 1 ampere is a current value far from the normal working conditions of this type of cell. According to the manufacturer's data [14] these cells have an I_{MP} close to 6 amperes, exceeding this value at the short-circuit point. The following images show how in the event of a connection failure, current values close to 6 amperes will demand an overload of the adjacent sub-cells.

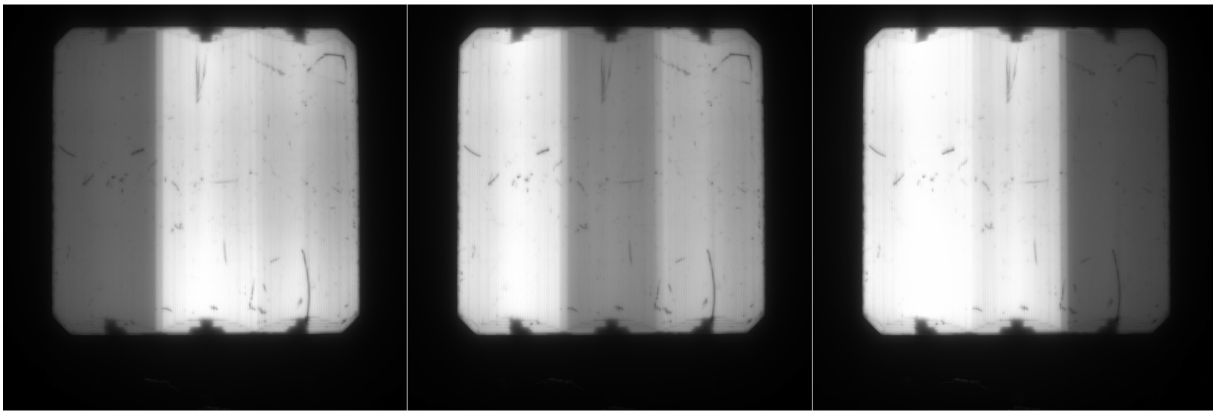

Figure 6. *EL images at 6 amperes with a couple of pads disconnected: pads 1 & 6 (LEFT), pads 2 & 5 (CENTRE) and pads 3 & 4 (RIGHT).*

4. Conclusions

We have implemented a small prototype to measure IBC cells with connection failures. The circuit allows the disconnection of each of the 6 pads, individually or in groups. EL measurements have proven to be sufficient for a connection fault detection in a panel. By simple processing of the luminescence images, connection faults can be identified in an automated way. This detection could be applied to the panels before encapsulation. This would avoid efficiency losses in the panel output and added stress on the misconnected cell.

5. Future work

The analisys performed were meant to show how a fast EL adquisition and a simple image processing can be used to an automated detection of connection failures. However, further information can be extracted from more detailed inspection. Figure 7 shows how precise information of the emitted luminescence and its horizontal variation (meaning variation in the surface of the cell) can be obtained. Localized cell parameters can be extracted from the processing of this information like in previous works [15].

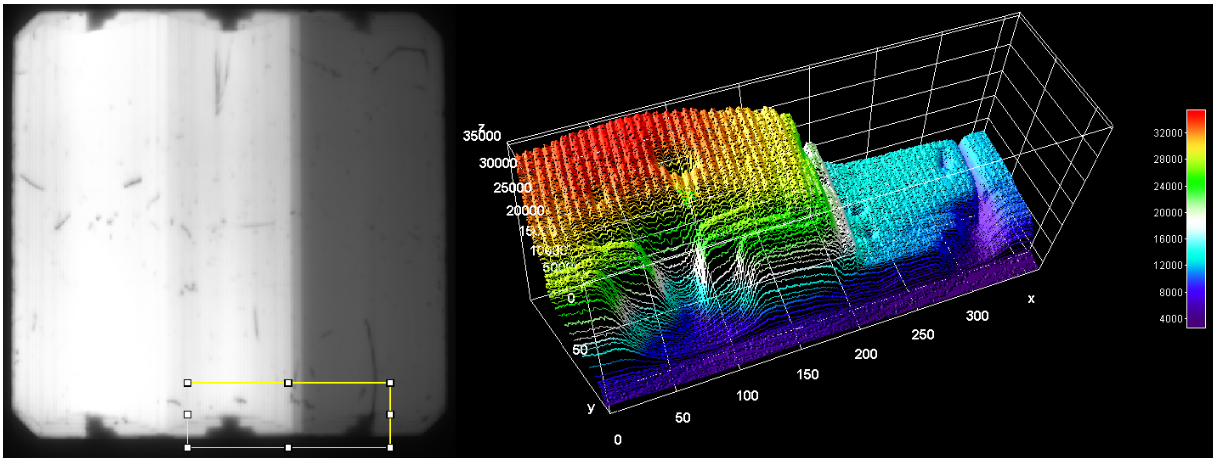

Figure 7. *EL image at 6 amperes with pads 3 & 4 disconnected and the 3D surface plot of the area between the contacts (yellow box).*

Data availability statement

All the EL images mentioned and/or used in this article are openly available from https://doi.org/10.5281/zenodo.15118586

Author contributions

Conceptualization A. Otaegi, V. Fano and E. Ortega; data curation Y. Mateos; funding acquisition J. C. Jimeno; methodology E. Cereceda & N. Azkona; supervision A. Otaegi & N. Azkona; writing – original draft Y. Mateos; writing – review & editing - A. Otaegi & N. Azkona. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare that they have no competing interests.

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References

[1] J-S. Jeong, N. Park and C. Han, "Field failure mechanism study of solder interconnection for crystalline silicon photovoltaic module", Microelectronics Reliability, Vol. 52, pp. 2326-2330 (2012) https://doi.org/10.1016/j.microrel.2012.06.027

[2] M. Boussaid, A. Belghachi, K. Agroui, M. Abdelaoui & M. Otmani, "Solar cell degradation under open circuit condition in out-doors-in desert region", Results in physics, vol. 6, pp. 837-842 (2016) https://doi.org/10.1016/j.rinp.2016.09.013

[3] I. Zafirovska, M. K. Juhl, & T. Trupke, "Comparison of line scan luminescence imaging techniques for defect characterisation in crystalline silicon solar modules". In 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion, pp. 1364-1369, (WCPEC) *A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC*. (IEEE 2018) DOI: 10.1109/PVSC.2018.8547434

[4] E. Annigoni, A. Virtuani, J. Levrat, A. Faes, F. Sculati-Meillaud, M. Despeisse, C. Ballif, "Quantifying and modeling the impact of interconnection failures on the electrical performance of crystalline silicon photovoltaic modules", Progress in Photovoltaics, vol. 27, 424-432, (2019) https://doi.org/10.1002/pip.3111

[5] Y. E. Hu & R. H. French, "Degradation and failure mechanisms of PV module interconnects" in Durability and reliability of polymers and other materials in photovoltaic modules, Country: William Andrew, ch. 5, sec. II, pp. 119–134, (2018). https://doi.org/10.1016/C2016-0-01032-X

[6] B. V. Stefani, M. Kim,Y. Zhang, B. Hallam, M. A. Green, R. S. Bonilla, F. Christopher, G. J. Wilson, Wright. Joule, 7(12), 2684-2699, (2023).

[7] "Photovoltaic Magazine" https://www.pv-magazine.com/2022/11/03/ibc-solar-modules-may-drive-topcon-out-of-market-by-2028-says-tech-expert/ (March 2025)

[8] "Maysun solar" https://www.maysunsolar.com/ibc-technology/ (March 2025)

[9] J. D. Huyeng, A. Spribille, L. C. Rendler, C Ebert, U. Eitner, and R. Keding, "Influence of interconnection concepts for IBC solar cell performance by simulation", AIP Conference Proceedings 1999 (1):020011, https://doi.org/10.1063/1.5049250, (2018).

[10] "Maxeon Solar Technologies" https://sunpower.global/es/sites/default/files/2022-03/sp_max3_104c_390-400_res_dc_ds_es.pdf (March 2025)

[11] "Solar Cell Cracks and Finger Failure Detection Using Statistical Parameters of Electroluminescence Images and Machine Learning" Applied Science, vol. 10, no. 24, pp. 8834, *Appl. Sci.* (2020) https://doi.org/10.3390/app10248834

[12] F. G. Rosillo, M. B. Nieto-Morone, J. Benavides-Esteva, F. Soriano, S. Temprano, C. González, M. delC. Alonso-García, "Repairing ribbon bus bar interruptions in photovoltaic modules using non-intrusive interruption location", Renewable Energy, Vol. 23, 120012 (2024).

[13] "ImageJ" https://imagej.net/ij/ (March 2025)

[14] ENF solar https://cdn.efsolar.com/Prduct/pdf/Cell/5b91fcf3916df.pdf?_ga=2.129740875.699501378.1555670092-1288217596.1555670091 (March 2025)

[15] E. Cereceda, V. Fano, A. Otaegi, N. Azkona, J. R. Gutiérrez & J. C. Jimeno, "Spatially Resolved Local Ideality Factor by means of Differential Electroluminescence Imaging," IEEE 48th Photovoltaic Specialists Conference (PVSC), pp. 1534-1536 Fort Lauderdale, FL, USA, (2021) doi: 10.1109/PVSC43889.2021.9518676.