OPTICAL AND ELECTRICAL CHARACTERIZATION OF PEROVSKITE MINI-MODULES

R. Ebner[1], G. Ujvari[1], A. Mittal[1], M. Hadjipanayi[2], V. Paraskeva[2], M. Hadjikypris[2], G. E. Georghiou[2], A. Hadipour[3], A. Aguirre[3]
[1]AIT Austrian Institute of Technology, Center for Energy, Giefinggasse 2, 1210 Vienna,
Austria, T +43 50550-6628, F +43 50550-6390, rita.ebner@ait.ac.at, www.ait.ac.at
[2]University of Cyprus, 1 Panepistimiou Avenue, 2109 Aglantzia, Nicosia, Cyprus, www.foss.ucy.ac.cy
[3]imec, Kapeldreef 75, 3001 Leuven, Belgium, www.imec.be

ABSTRACT: Commercially available solar modules undergo a series of characterization procedures that analyze their properties and ensure quality. However, these procedures cannot simply be applied to perovskite solar cells. Perovskites are inorganic-organic materials for a new generation of solar cells that have only been studied for about eleven years [1]. Perovskite solar cells achieve very high efficiencies (world record for perovskite-silicon tandem cell: 29.52% [2]) and can be applied as extremely thin films at extremely low cost. The main challenge for a successful commercialization of perovskite solar cells is to achieve long lifetimes with good stability at module level [1] [3]. More advanced characterization methods are needed to understand the degradation mechanisms that occur. In this context, optical and electrical measurement methods are effectively used in quality control and development support and are important characterization tools in industry and research.

KEYWORDS: Perovskite, Optical and electrical characterization

1 INTRODUCTION

In the proposed work, the degradation of perovskite solar cells and mini modules was investigated by using optical and electrical characterization methods.
Electroluminescence (EL), photoluminescence (PL) and dark lock-in thermography (DLIT) are non-destructive measurement techniques. These optical measurements provide high-resolution images that show a two-dimensional distribution of the characteristic features of PV cells and allow the investigation of cracks, defects, shunts, and stacking faults in the cells [4]. Measurements of power output (IV) and external quantum efficiency (EQE) measurements help to provide a complete picture of solar cell or (mini) module power conversion efficiency. IV measurements indicate the current generated by the cell under simulated solar irradiance conditions and EQE measurements provide quantification of the current generated at each wavelength wherein the ratio of extracted free charge carriers to incident photons was determined.

2 EXPERIMENTS

A 2-cation perovskite active layer with the composition $\mathbf{Cs_{0.18}FA_{0.82}PbI_{2.82}Br_{0.18}}$ was used. In order to make large area devices, so called mini-modules were produced by laser scribing, to generate 7 sub-cells connected in series. In order to prevent penetration of metallic particles of the top electrode into the soft perovskite layer, ITO was used. ITO was also selected as a top electrode to obtain semi-transparent modules. The module stack was as follows:
glass/ITO/PTAA/Al2O3/550nm 2C Perovskite with bandgap of 1.6 eV/LiF/C60/BCP/ITO/glass. Fig.1 shows the structure of the perovskite sub-cell and Fig. 2 shows the cross-section of the mini-module. Fig.3 shows two images of the front and back sides of one perovskite mini-module (size: 3cm x 3cm). 4 perovskite mini-modules ("B", "D", "E" and "F") were produced and characterized by applying DLIT-, EL- and PL methods alongside IV and EQE measurements. The results are presented in point 4.

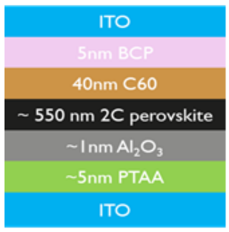

FIG.1 PIN-structure of each sub-cell.

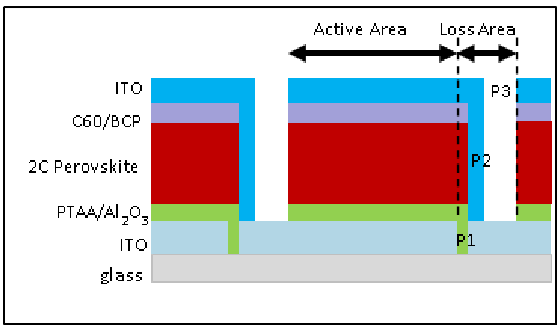

FIG.2 Cross-section of the mini-module.

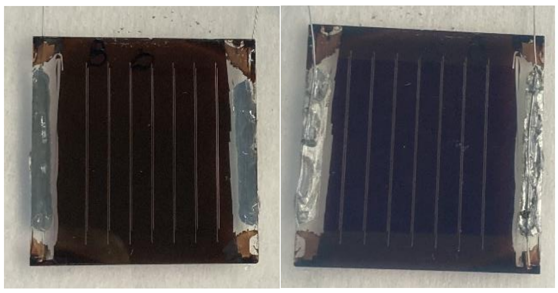

FIG.3 Perovskite mini-module: Front side (left), Back side (right).

3 RESULTS

3.1 Mini-module “B”

Fig.4 shows the EL images (front side and back side) of mini-module "B" with an inactive cell. The IV measurement results of mini-module "B" are shown in Table 1. The EQE measurement results are shown in Fig.5.

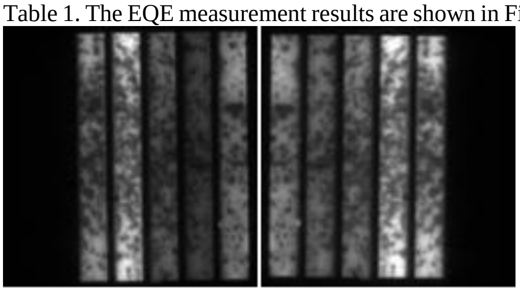

FIG.4 Perovskite mini-module “B”: Front side (left) and back side (right).

Table 1:
IV-measurement results, Perovskite mini-module “B”

I_{SC} [A]	V_{OC} [V]	FF [%]	P_{MPP} [W]	Jsc [mA/cm²]
0.0094	6.1879	39.92	0.0233	12.049

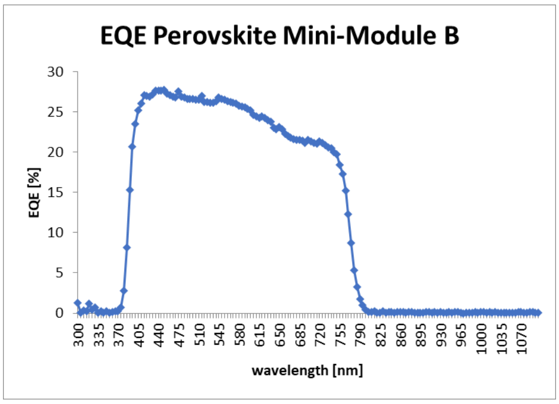

FIG.5 EQE Perovskite mini-module “B”

3.2 Mini-module “D”

Fig.6 shows the EL images of minimodule "D" with one defective and one inactive cell. The IV measurement results of minimodule "D" are shown in Table 2. The EQE measurement results are shown in Fig.7.

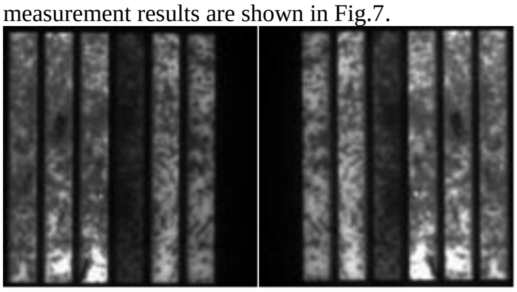

FIG.6 Perovskite mini-module “D”: Front side (left) and back side (right).

Table 2:
IV-measurement results, Perovskite mini-module “D”

I_{SC} [A]	V_{OC} [V]	FF [%]	P_{MPP} [W]	Jsc [mA/cm²]
0.0093	7.5501	35.35	0.0247	11.831

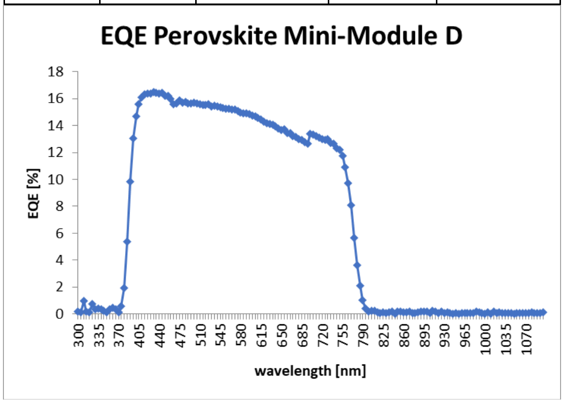

FIG.7 EQE Perovskite mini-module “D”

3.3 Mini-module “E”

Fig.8 shows the EL recordings of the minimodule "E" with a defective cell. The IV measurement results of the minimodule "E" are shown in Table 3. The EQE measurement results are shown in Fig.9.

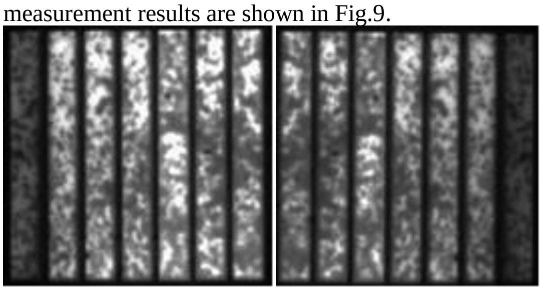

FIG.8 Perovskite mini-module “E”: Front side (left) and back side (right).

Table 3:
IV-measurement results, Perovskite mini-module “B”

I_{SC} [A]	V_{OC} [V]	FF [%]	P_{MPP} [W]	Jsc [mA/cm²]
0.0097	7.8345	36.70	0.0280	12.419

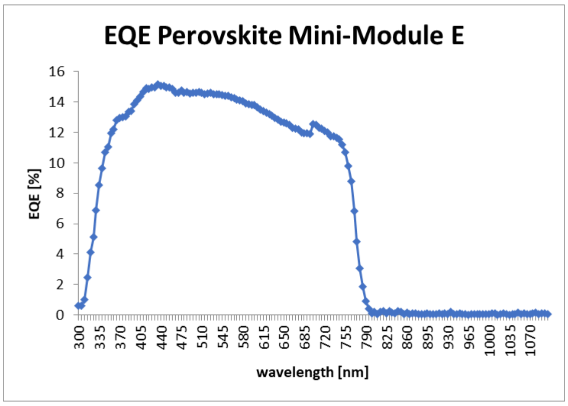

FIG.9 EQE Perovskite mini-module “E”

3.4 Mini-module “F”

Fig.10 shows the EL images of the minimodule "F" with an inactive cell. The IV measurement results of the minimodule "F" are shown in Table 4. The EQE measurement results are shown in Fig.11.

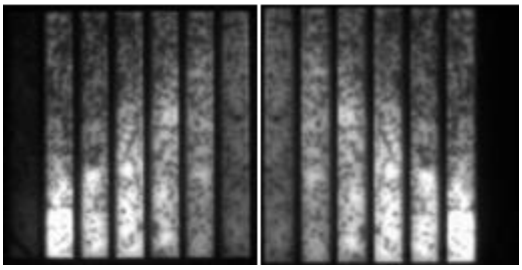

FIG.10 Perovskite mini-module "F": Front side (left) and back side (right).

Table 4:
IV-measurement results, Perovskite mini-module "F"

I_{SC} [A]	V_{OC} [V]	FF [%]	P_{MPP} [W]	Jsc [mA/cm^2]
0.0094	7.7664	34.13	0.0249	12.006

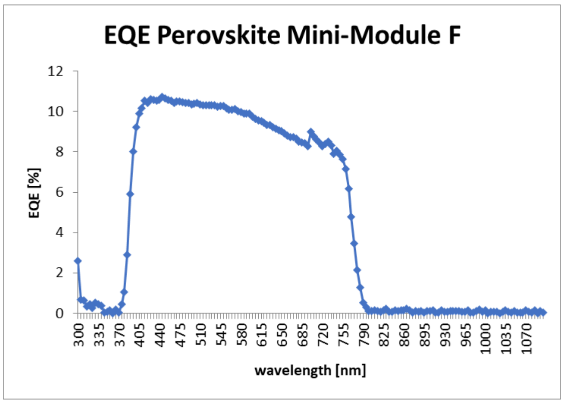

FIG.11 EQE Perovskite mini-module "F"

4 CONCLUSION

First defects and shunts were identified by EL, PL and DLIT measurements. The EQE measurements gave very high values for perovskite cells (e.g. about 90%, cell size:0.13cm^2 see Fig.12), but still too low values for perovskite mini modules (see Fig.5).

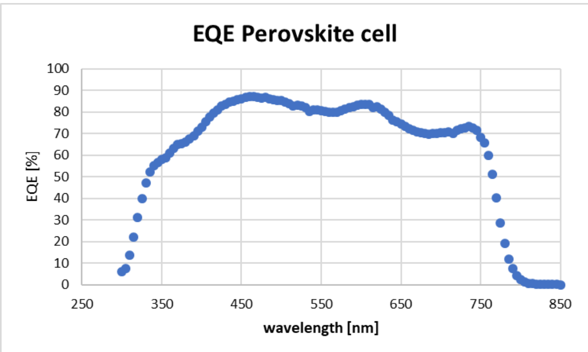

FIG.12 EQE Perovskite cell

Further indoor tests and outdoor tests of differently structured perovskite samples and also perovskite tandem cells have to be performed in order to identify more defects and thus be able to improve the perovskite cell and module structure. In addition, measurement protocols for indoor and outdoor tests of perovskites will be established.

5 REFERENCES

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Acknowledgement:
This work was funded through the European Regional Development Fund and the Republic of Cyprus in the framework of the project "DegradationLab" with grant number INFRASTRUCTURES/1216/0043.
http://www.foss.ucy.ac.cy/degradationlab/