EC Grant Agreement n°609788

CHEETAH

Cost-reduction through material optimisation and Higher EnErgy outpuT of solAr pHotovoltaic modules - joining Europe's Research and Development efforts in support of its PV industry

Deliverable

D8.18 – Encapsulated thin film module with new light trapping architecture that is stable under damp-heat conditions during operation (less than 5% power loss after 1000 h)

WP8 – Module development for ultrathin x-Si cells and thin-films

Section 1 – Document Status

Document information

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Document validation

Name	Organisation	Date	Visa
Paul. M. Sommeling –WP8 leader	ECN	15.01.2018	OK
Jan Kroon - Coordinator	ECN	19.01.2018	OK

Document history

Version	Date	Modifications	Name
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V3	17.01.18	Final clarification and clean versions	N. Wyrsch
VF	19.01.18	Final version approved by Coordinator	J. Kroon

Section 2 – Table of content

Section 3 – Executive summary

Description of the deliverable content and purpose

The intrinsic stability of silicon thin-film modules reduces the needs for barriers and encapsulations allowing low-cost approaches. As proposed and demonstrated in deliverable D8.15 and Cheetah published results [1], thin-film a-Si:H/µc-Si:H modules can survive damp heat (DH) test (85°C with 85% humidity for 1000 h) without protection against the environment. This allows the possibility of a simple encapsulation that provides a mechanical and electrical safety protection of the module but that is not moisture tight. As LPC-Si cells and modules are using similar materials, it was anticipated that such modules could behave similarly and that concepts envisioned for thin-film Si could also be applicable for LPC Si.

Due to the lack of LC Si modules, no further tests could be performed to validate the assumption that the concept developed for thin-film Si may also apply for LPC-Si. However DH tests were performed at cell level to check that assumption. This is a first and very important condition to be met for the validation of the concept. As materials involved in modules are the same as the one at cell level, the validation at cell level gives a good indication of the behavior at module level.

Brief description of the state of the art and the innovation brought

Standard encapsulation schemes using a glass/glass configuration have two drawbacks: (1) EVA used as an encapsulant/adhesive could release acetic acid which may react with the cell TCO (especially in the case where no sufficient protection at the edge, i.e. edge sealant, is used) and induce cell degradation(water ingress accelerates this effect) (2) the encapsulation is relatively water tight keeping the water out of the module, but will restrict the release of the water in which is trapped into the device. Indoor and outdoor test performed on non-protected thin-film Si cells/modules have demonstrated that these configurations may survive long term humidity exposure (including damp heat) without degradation.

Indoor tests have demonstrated that state-of-the-art LPC-Si cells do not show degradation upon damp heat test (85°C with 85% humidity for 1000 h). This is a first proof that a simple and low-cost encapsulation concept may be possible for this technology.

1 J. Hüpkes et al., "Thin-Film Barrier for Durable Thin-Film Modules", Proc. of the 32nd EU Photovoltaic Solar Energy Conf., (2016), pp 173-175, 10.4229/EUPVSEC20162016-1BV.5.35.

Section 4 – Deliverable report

1. Methodology

Due to the lack of modules for testing, it was decided to focus on individual cells. Results obtained on cells should reflect those to be obtained on mini-modules given the fact that the cells and mini-modules comprises the same materials and differ only in terms of contact geometry.

State-of-the-art LPC Si cells have been prepared by HZB. The sample consists of 11 1x0.6 cm cm^2 interdigitated back contacted (IBC) cells deposited on a 5x5 cm^2 glass superstrate. A picture of the sample is shown in Fig.1. The cells comprise interdigitated contacts as described in Fig. 2 and exhibit variable emitter to cell area ratio, given by changing the width of the back surface field (BSF) W_{BSF} (in Fig. 2). Cells under investigation were 11 µm thick with an interlayer (between the glass superstrate and LPC- SI absorber) consisting of a SiO/SiON/SiON stack. Details on the cell fabrication and structure are given in ref. [2].

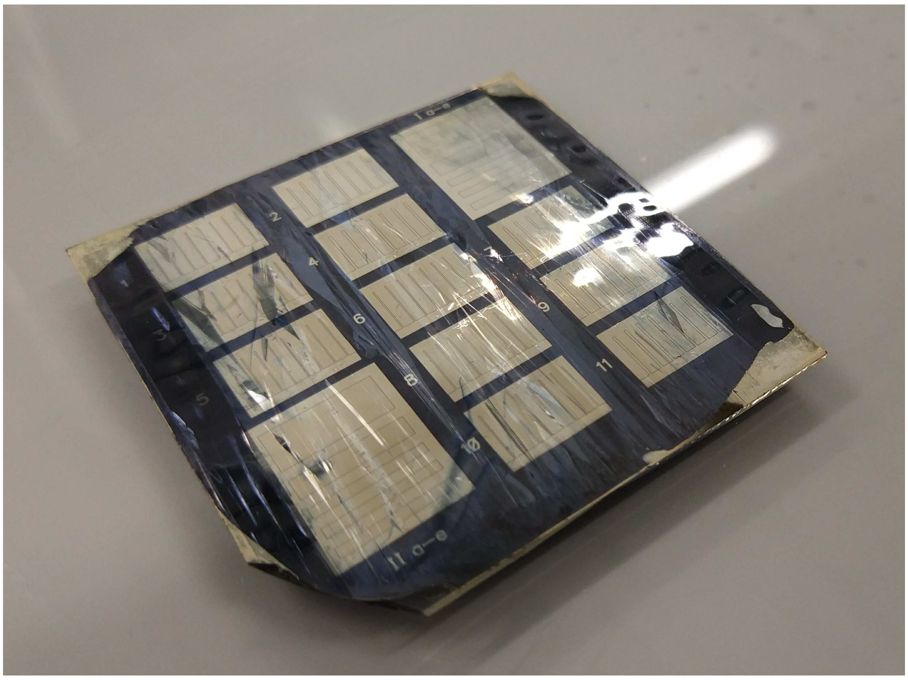

Figure 1. *Picture of the device fabricated at HZB for the damp heat test at EPFL.*

2 C. H. Trinh et al., “Potential of interdigitated back-contact silicon heterojunction solar cells for liquid phase crystallized silicon on glass with efficiency above 14%”, Solar Energy Materials and Solar Cells 174 (2018) 187–195, doi:10.1016/j.solmat.2017.08.042.

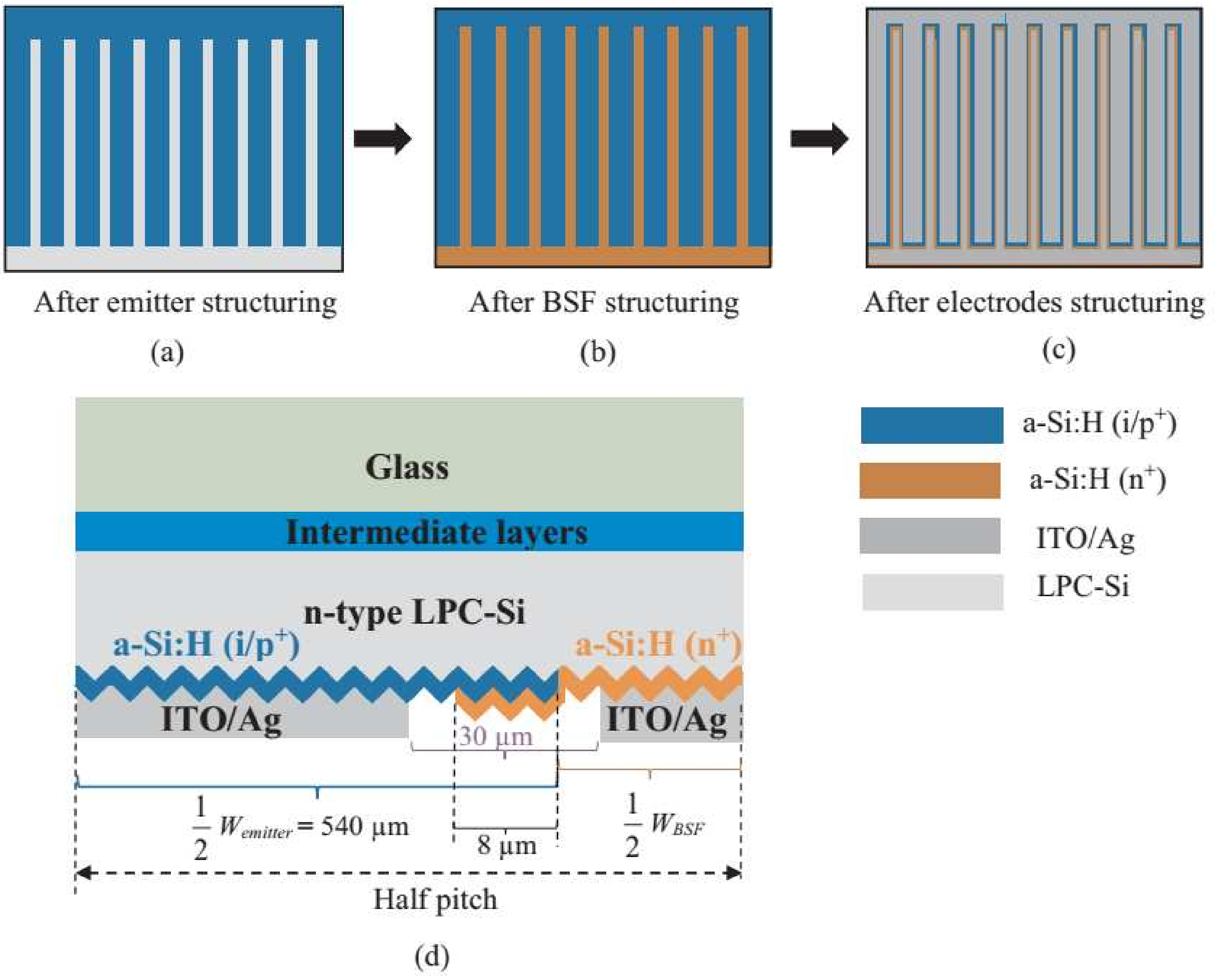

***Figure 2**. Top-view from back side of a sample after (a) emitter structuring (b) back surface field structuring (c) electrodes structuring. (d) Cross sectional structure of an IBC-SHJ cell*

The materials and layers exposed at the back of the cells are the same as the ones of modules as described in deliverable D8.20 with a monolithic interconnection scheme. The degradation behavior observed upon damp heat testing is expected to be the same in cells and modules.

Cells were then exposed to damp heat (85°C with 85% humidity) in a climatic chamber for up to 1000 h. Samples were periodically removed from the chamber for a short time to record their IV characteristics and determine the degradation, if any. Note that in order to pass a standard IEC damp heat (DH) test, the degradation of the module efficiency should be lower than 5% after 1000 h.

2. Results

Fig. 3 exhibits the cell IV characteristics of all 11 cells present on the sample (in fact only 10 as one cell was shunted) as a function of the time in DH conditions. The difference in the starting efficiency is due to the BSF area ratio as explained in ref. 2. The best efficiency is given for the

cell with a rather short W_{BSF} compared to the emitter width. It can be observed that all cell IV characteristics remain constant during the experiment up to an exposure of 700 h in DH. Small variations are observed but that does not exhibit any clear trend. They are most probably due to effects of the measurements of the cells such as difference in the measurement temperature, or in the placement of the contacts, etc. Data at or after 1000 h were not available at the time of the writing of the present report, but no significant change is expected, and if any much lower than the maximum allowed change of 5%.

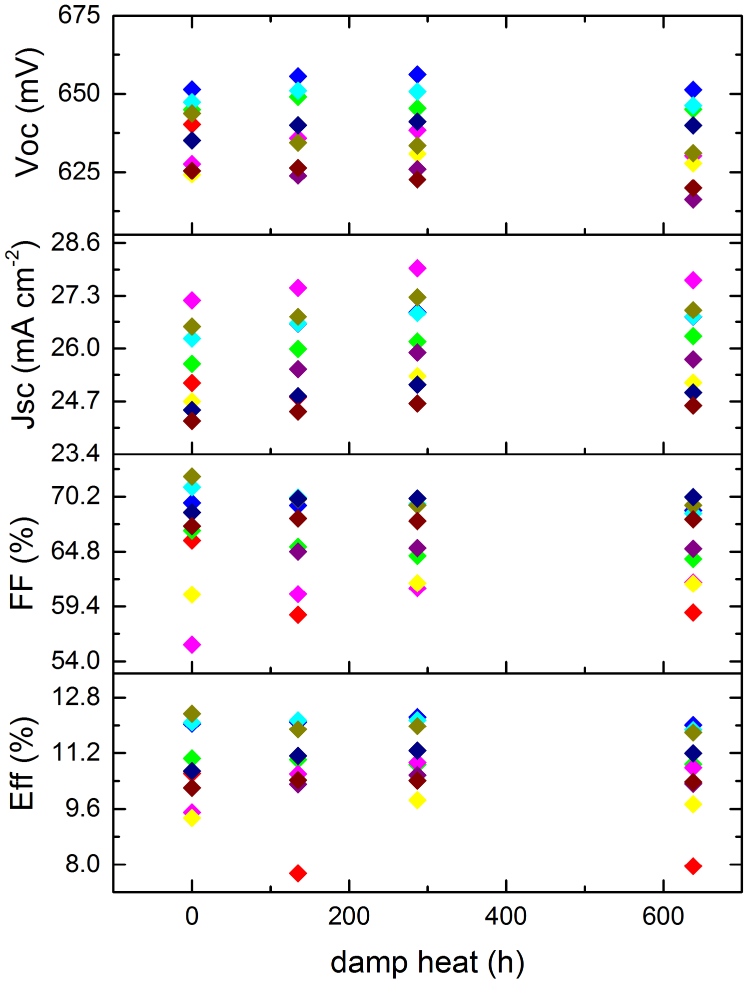

Figure 3. *IV characteristics of IBC LPC-SI cells with various geometries exposed to damp heat as a function of damp heat exposure. See section 5.1 of the text for details on the cells.*

3. Conclusions

The present experiment indicates that LPC-Si cells (and doubtless modules also) are intrinsically resistant to damp heat test conditions up to 700 hours without encapsulation. These characteristics would allow a simple and low cost encapsulation scheme that offer sufficient mechanical and electrical protection but with no need to be fully tight against moisture ingress. Without the last requirement, one can use simple and low cost encapsulation materials such as PET for example. The objective of the deliverable has thus been achieved, even though a DH test on encapsulated LPC-Si module (with a simple low-cost encapsulation) should still be carried out for full and final validation.