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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

D8.19- Interconnected thin film modules with up to 50% material saving.

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

Section 1 – Document Status

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Name	Organisation	Date	Visa
Paul Sommeling – WP8 leader	ECN	14.12.17	OK
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Document history

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Section 2 – Table of content

Section 3 – Executive summary

Description of the deliverable content and purpose

This report describes the possible approaches that can be employed in order to achieve interconnected thin film modules **with up to 50 % material saving**. The results are linked to those reported in D8.21 ("First functional, interconnected CIGS micro-concentrator modules demonstrating feasibility of 16 % conversion efficiency.").

The objective is to produce a functional CIGSe module-lens arrangement, with a reduced absorber area. The main objective is to reduce the (absorber) material employed in CIGS module manufacturing. This is for two reasons: (1) reducing cost by reducing deposition of CIGS materials, (2) reducing the consumption of scarce materials (like Indium and Gallium) in order to reduce the supply risk of "critical raw materials" for scaling the CIGS technology to TeraWatt range, as demanded by EU Commission in the Raw Materials Initiative which presents the list of critical raw materials.

By utilizing the modules assessed in task D.8.21, the saving of material to prevent future scarcity addressed by deliverable D8.19 can be evaluated.

The modules presented have been manufactured following the most promising design proposed in milestone report MS8. The objective of the deliverable, up to 50 % material saving, has been met.

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

Multiple mini modules were processed. To manufacture such a device, state of the art $Cu(In,Ga)(S,Se)_2$ stacked layers were used. The interconnection by laser and mechanical scribing is similar to standard CIGSe panel manufacturing, where different materials are deposited and processed onto a substrate forming a stack of materials in specific sequence: Molybdenum, P1 scribe, CIGSe absorber, buffer layer, i-ZnO, P2 scribe, TCO and P3 scribe. However, the main difference is in an additional P3 patterning step, the so called P4 scribe. With the addition of this process step it was possible to limit the commonly used stripe width of 5 mm cell width down to narrower stripes between 50 and 800 µm.

Given the long and well defined geometry of the stripes, 1-dimensional concentration through spherical cylindrical lenses was considered as optimal for the proposed layout. The cylindrical lens is supported by a holder which serves also as positioner. Thus, the CIGSe mini-module, the lens array (or lenticular) and the positioner form the micro-concentrator PV device.

The electrical characteristics of the devices with and without the lens array were measured in a Class AAA solar simulator with simulated 1.5 AM illumination and compared obtaining a substantial increase in both fill factor and efficiency for the devices with lens.

Section 4 – Deliverable report

D8.19- Interconnected thin film modules with up to 50% material saving

Based on the results as reported in D8.21, interconnected thin film modules with up to 50 % material saving could be readily achieved by recycling the "unused" (=non-illuminated) CIGS material between the individual active cells. This approach, however, might not be easy and has not been followed here.

More desirable methods called "bottom-up" approaches (local deposition of the CIGS absorber), can be employed to replace the "top-down" approach (full-area CIGS absorber deposition), thus, maximizing absorber material saving with deposition processes, such as:

- Drop-on-demand inkjet printing of $CuInSe_2$ absorbers
- Local growth of $CuInSe_2$ absorbers

Both of these processes are under development, e.g. in Cheetah WP9. However, at this moment they are not developed enough to be implemented in interconnected modules. Therefore, we decided to utilize the top-down approach for deliverables D8.19 and D8.21. Assuming similar electrical characteristics from bottom-up absorbers, where only the active area is deposited, and top-down approaches, an estimation of absorber material saving for any of the previously mentioned processes can be obtained by employing the empirical data presented in report D8.21, as shown in the following:

	Area	MPP/ cm²	MPP
	[cm²]	[mW/cm²]	[mW]
STD Mod	8.268	11.47	94.90
CPV	0.823	100.70	82.96

11.40% of material (STD/CPV)
88.60% Maximum material saving

Table 1: *Breakdown of possible material savings in terms of output power*

The maximum power output (in MPP) can be expressed relative to the area utilized in mW/cm^2 per module. Therefore, a comparison between the power output of control modules, which are produced with state-of-the-art monolithic interconnection, and the output from modules with 1-D concentration of light from task D8.21 can be made.

Table 1 shows a comparison between a control module and the results obtained with the device as reported in D8.21. Hence it is demonstrated that less than 12 % of CIGSe material is used to produce similar power output by utilizing 1-D concentrators of light on CIGSe. **Thus, it can be concluded that the objective of this deliverable has been met since the total material saving employing these concentrators can be estimated beyond 50 %, if the absorber material would be locally deposited.**