ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

99-26

LESO-PB

New Generation of Solar Hybrid Collectors Absorption and High Temperature Behaviour Evaluation of Amorphous Modules

Affolter P.
Haller A. - Schweizer AG
Ruoss P.
Toggweiler P. ENECOLO

Conférence CISBAT'99

Sept. 1999

NEW GENERATION OF SOLAR HYBRID COLLECTORS

ABSORPTION AND HIGH TEMPERATURE BEHAVIOUR EVALUATION OF AMORPHOUS MODULES

P. Affolter[1]; A. Haller[2]; D. Ruoss, P. Toggweiler[3]

1: LESO-EPFL, Bâtiment LESO, CH-1015 LAUSANNE, Switzerland

2: ERNST SCHWEIZER AG, Metallbau, CH-8908 HEDINGEN, Switzerland

3: ENECOLO AG, Lindhof 235, CH-8617 MÖNCHALTORF, Switzerland

ABSTRACT

Although the idea of producing a solar collector for both electricity and hot water is not new, this new generation is based on a very innovative concept. At the feasibility study [1] we have collected a lot of information about all-important aspects (costs, technology, market, contacts with industries, ...) to prove that further development is worth being done. The results are encouraging since they show:

- A potential market does exist for the several specific applications (about 10 MW in 2005)
- The photovoltaic (PV) thin film technology is likely to be suited for this application from a technical and an economical point of view, provided that the long term stability of the cells at temperatures above 100°C are confirmed
- Several photovoltaic industries are ready to collaborate in this development at different levels of participation
- The several technical concepts proposed are suited for the concerned application.

The feasibility study showed that the competitiveness of a hybrid collector depends on several technical requirements of the integrated PV-module. The most prominent aspects are high solar absorption and the compatibility with high temperatures.

The goal of the present study is to verify if these technical conditions are met for the available amorphous silicon (a-Si) technology. Measurements on commercial unencapsulated samples from 6 different manufacturers based on different substrates (glass, stainless steel, polyimide) were performed. Absorption values are comprised between 78% and 90%. Some samples heated up to 170°C during one hour kept their original properties while the others showed modified characteristics. Further measurements during increased periods and non-oxidizing conditions have to be done before choosing the most suited technology.

INTRODUCTION

The results from the feasibility study phase show that the competitiveness for a water based photovoltaiv-thermal (PV/T) collector depends on several requirements. They are:

- The **absorption coefficient** for high thermal efficiency (value of absorption over the whole solar spectrum) of the photovoltaic absorber should be higher than 80% (the photovoltaic absorber will be the photovoltaic device which replaces the absorber of a conventional thermal collector).
- The **stability of a- Si cells at temperatures** of 100-160 °C (stagnation situation of the thermal collector)

The needed information for a better understanding of these two points is available neither in technical documents and scientific literature nor by the PV companies in question having the best know-how. For these reasons, the development of the PV/T collector must proceed with a

series of measurements and more detailed work on these two subjects before going into product design.

METHOD

Absorption assessment

Few data are available from PV manufacturers concerning solar absorption; basic seeking in the feasibility study returned ~65 % absorption for a commercial module. 1996 Ernst Schweizer AG measured a solar absorption coefficient of ~72 % on a commercial Tefzel-EVA-amorphous module [1]. The IMT (Institut de Microtechnique) at the University of Neuchâtel did more precise measurements in 1997 with a "Perkin Elmer" spectrometer [2]. Coefficients ranging from 78% (a-Si, one layer) to 90% (c-Si) have been measured on special manufactured samples and also on commercial modules.

A series of measurements on photovoltaic raw material (plates or encapsulated modules) of standard devices (glass-substrate, steel and polyimide) provided by 6 different manufacturers were performed in order to show the effective reflections of the different optical layers of photovoltaic devices.

Two different measuring methods were used to offer a better understanding of the samples properties. The first was based on **spectrometry**. It yields a wavelength-resolution. This was subcontracted to the IMT. They used a Perkin Elmer UV/VIS/NIR spectrometer (type Lambda 900) to measure the reflection. The measurement is performed using an Ulbricht integrating sphere, therefore direct and diffuse reflection is summed up to yield the total reflection of the sample. The instrument baseline is taken prior to the measurement using a white standard of the same material as the interior of the Ulbricht sphere, assuming the reflectivity of this material to be 100%.

The second one was based on **calorimetry** and yields a global value. It was subcontracted to the IOA (Laboratory of Applied Optics of the Microtechnic Department of the EPFL). The experimental apparatus consists of a thermal flux sensor (Episensor type A 02-050 or Peltier element of type TEC1-12714, both of a surface of 50x50 mm). As the Episensor type thermal flux sensor has an ill-defined surface, a copper plate of a thickness of 1mm has been glued to the surface with a high thermal conductivity adhesive (Omegabond 200). The samples are then fixed on the sensitive surface with a heat conductive paste (HTC 35SL) and illuminated by the source. The illumination aperture has been provided with the upper surface constituted with mirrors, to avoid at maximum thermal radiation from the aperture frame to the cell under investigation. The illumination source is a dichroic halogen lamp (Philips, 150W nominal, type 13117), powered by a stabilized power supply under constant voltage (15.20V), at a distance of 400 mm, resulting in a fairly constant light intensity over the aperture of 20cm^2. The incident power has been measured with a pyroelectric wide band laser power meter (Ophir Nova) and yields 2.48W for 20cm^2 (1240 W/m^2), respectively 1.99W for 16 cm^2 (1244 W/m^2).

Thermal stability of a-Si cells

The lack of data about stability of thin film PV-cells at temperatures above 100 °C makes necessary to proof the suitability of such cells for an application in a PV/T collector. Therefore long time temperature tests have to be performed.

Since there are no guidelines for such tests with amorphous silicon, it is first necessary to work out a testing program. Amorphous silicon is well known in the chip industry and thus we should also pursue a specific study of scientific literature (a-Si in general) in order to gain as much data and experiences as possible for defining these tests. The literature study has also the task to prepare the final concept for the accelerated aging tests which will be done on

laminated samples (PV cell and thermal exchanger) planned to be build in in the next project phase.
Based on the results of the absorption measurements, two important parameters of the PV/T collector can be evaluated (modeled); these are the stagnation temperatures of a normal flat plate collector with this absorber type and its thermal efficiency.
The testing procedure has the following features:

- Raw materials are thermally stressed by thermal cycles with different durations (1-1000 h) and at different temperatures (100°C, 120°C, 140°C, 160°C, etc.)
- Testing place: automatic oven with a computer controlled temperature curve for heating (no active cooling)
- The samples are periodically measured with a constant lamp simulator (7 dichroic halogen lamps with good approximation of the solar spectrum: Philips, 150W nominal, type 13117)

RESULTS

Spectrometry measurements

The transmission of all samples is equal to zero, due to metallization of the back surface. Therefore the absorption of the samples is given as $\alpha(\lambda)=(1-\rho(\lambda))$ where $\rho(\lambda)$ is the wavelengths dependant reflection.

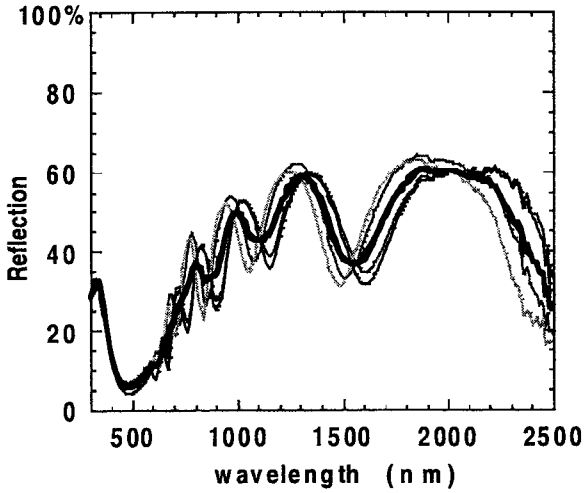

Figure 1 shows a typical reflection spectrum as measured on one of the samples. Thin lines are measurements on different spots on the same sample; the thick line is the mean at each wavelength.

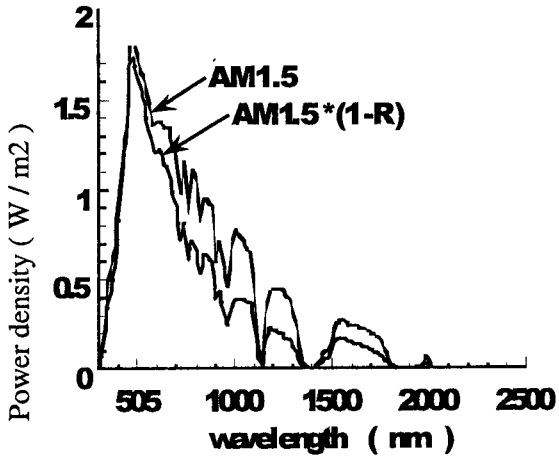

Figure 2: this mean spectrum is multiplied with the AM1.5 spectrum. The total absorbed power corresponds to the surface under the curve, i.e. is obtained by integrating over all wavelengths.

Multiplication of the absorption spectrum $\alpha(\lambda)$ with the spectral power density in a standard AM1.5 solar spectrum and integration over all wavelengths yields totally absorbed power in the sample (see figures 1 and 2).
Detailed values of the absorption coefficients measured on the various module types are given at the table 1.

Measurements based on calorimetry

Each sample has been measured several times and the mean value has been reported. No divergence larger than a few percents have been encountered. The heat absorption of the samples has been determined according to the following formula, by taking the nominal value of the black coated surface of the reference sample (absorption = 94.0%).

$$\alpha_{sample} = \alpha_{\text{référence}} (U_{epis} - U_{backgr})/(U_{ref} - U_{backgr})$$

Results from the absorption measurements

Measurements results of the α- coefficient are presented in the table 1.

No	Encapsulation	IMT (spectrometry)	IOA (microcalorimetry)	Difference
Reference	None	95%	94%	1%
No1	None	82%	83%	-1%
No2	None	90%	88%	3%
No3	None	78%	80%	-1%
No3	Laque	78%	81%	-2%
No4	None	89%	94%	-5%
No5	None	85%	91%	-6%
No5	Tefzel/EVA	83%	91%	-8%
No6	Tefzel/EVA	82%	86%	-4%
No6	None	74%		
No6	None	73%	69%	4%

Table 1: Absorption measurement results (reference: piece of selective absorber, courtesy from Energie Solaire SA, Sierre, Switzerland)

Calorimetric measurements

Comparison of the two methods from IMT and IOA shows that a very precise relation is resulting. The difference of the majority of the samples is in a range of –4 to +6%, which is absolutely tolerable and shows the reliability of both measurement methods.

Absorption values are comprised between 73%and 90% for the IMT method, respectively. 69% and 94% for the IOA method. The lower limit established in the feasibility is overcome. It means several kinds of a-Si modules are suited for the hybrid application as far as absorption is concerned.

Manufacturer No2 with a glass substrate technology shows, with close to 90% α- coefficient, a perhaps well-suited solution for the project. Also manufacturers No5 and No6 are in further evaluation and will be considered for the prototype work.

Thermal behavior of amorphous technology samples

The samples of each manufacturer were dispatched into 2 groups:

- samples to be warmed up to 120° for several days (100h)
- samples to be warmed for one hour up to the failure temperature.

The fill factor (FF) represents a good way of checking how much the sample characteristics change. During the first series of cycles, the FF's don't change a lot. One product shows even slight improvements in several cases due to an annealing that reverses the Staebler-Wronski degradation. During the second series of cycles, the FF changes are much stronger. This is summarized at the fig. 3. For four manufacturers, the FF doesn't change significantly. One is

based on stainless steel substrate Nr. 6), one is based on a polyimide substrate (No 5/2) and the two others present glass based technology (No. 2 and 3). For the samples of the company 1, 4 and sample No. 2 of the company 5, the fill factors decrease significantly. The samples are destroyed.

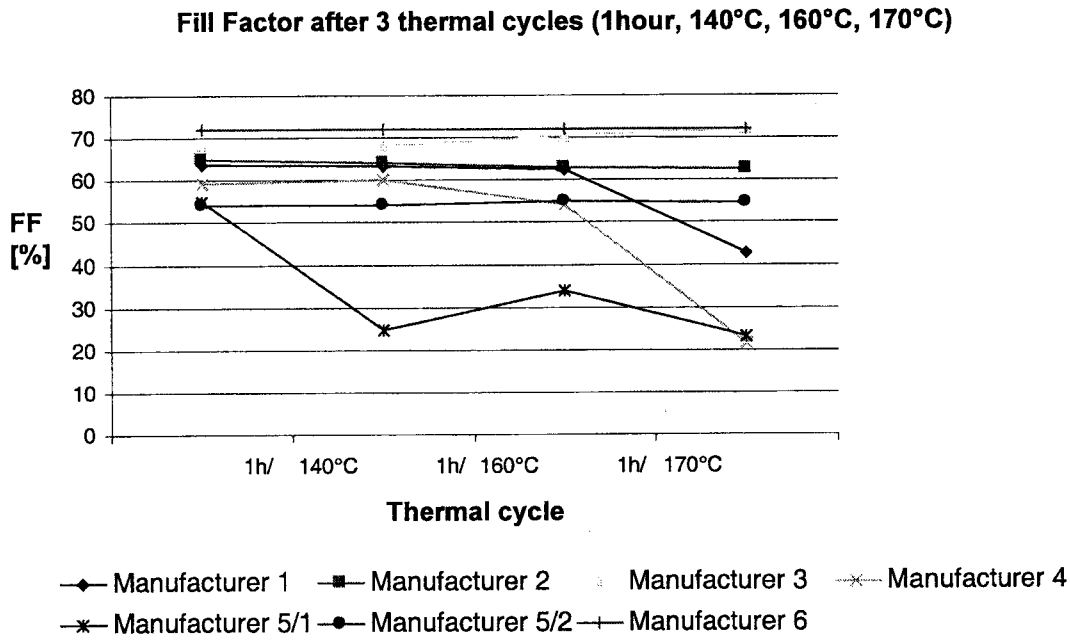

Figure 3: Measured fill factors after three thermal cycles

The figure 4 and 5 presents the corresponding I-V curves for the samples of the manufacturer No. 1 and manufacturer No. 2. For each sample, the measured I-V curve is given before thermal cycling, after the second (1h/140°C and 1h/160°) and after the third cycle (1h/170°C). One can observe that the sample of the manufacturer No. 2 has an excellent behaviour under such hard conditions. Further measurements will be done in order to check the failure temperature and if the sample afford same temperature for longer cycles.

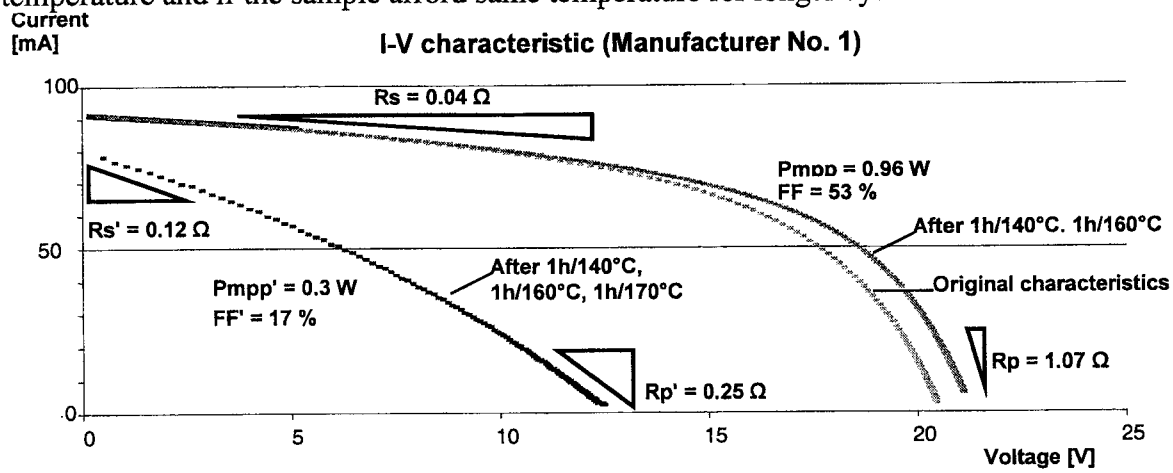

Figure 4: Measured fill factors after three thermal cycles (manufacturer No. 1)

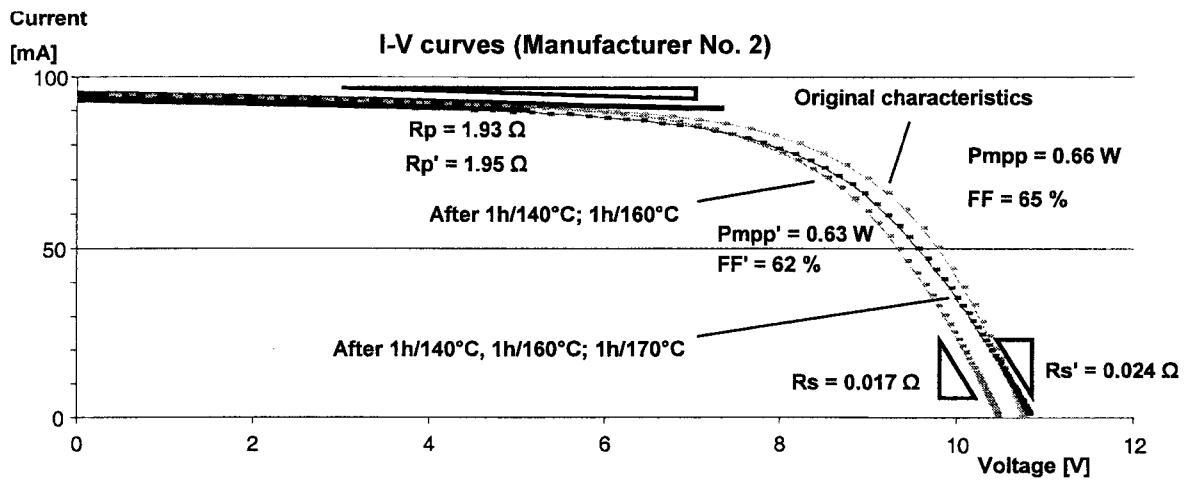

Figure 5: Measured fill factors after three thermal cycles (manufacturer No. 2)

CONCLUSION

The goal of this study is to verify if commercial amorphous PV modules can be directly used as absorber of a water based PV/T collector. In order to have good thermal efficiency and reduced risk of damage, the absorber should have sufficient absorption and withstand stagnation temperature of about 150°C for several hours. The obtained results are totally new in the solar technology field and show that:

- absorption values between 78% and 90% was measured. This is more than acceptable for the PV/T application
- several samples withstand thermal cycling of 1 hour at 170°C without sensitive characteristic change. Further investigations will be done in order to precise define the realistic maximal temperature.

ACKNOWLEDGEMENTS

The work done until now was only possible thanks to the funding of the Swiss Federal Office of Energy (OFEN/BFE). We would like to thank also the two institutes who were involved in this project phase and who did measurements of high quality in the frame of planning and budget. The follow-up of this project will lead to the build-up of prototypes. This could be done in the framework of a European project (proposal sent June 1999) or in the framework of any other financial scheme.

REFERENCES

1. "Feasibility study Phase 1, Final Report", P. Affolter, D. Ruoss, H.J. Althaus, et. al., , OFEN, November 1997-January 1998
2. " Long Term Behaviour of Passively Heated or Cooled a-Si :H modules ", C. Hof, M. Lüdi, M. Goetz, D. Fischer, A. Shah, Institute of Microtechnology, University of Neuchâtel, A.-L. Breguet 2, 25th IEEE PVSC, Washington DC, May 13-17, 1996