csem

www.csem.ch

MEYER BURGER · HERCULES · SWISS INNO HJT · Schweizerische Eidgenossenschaft / Confédération suisse / Confederazione Svizzera / Confederaziun svizra · Swiss Federal Office of Energy SFOE

SmartWire Solar Cell Interconnection Technology

A. Faes[1], N. Badel[1], M. Kiaee[1], M. Despeisse[1], J. Levrat[1], J. Champliaud[1], A. Hessler-Wyser[2], J. Cattin[2], Y. Baumgartner[2], B. Strahm[3], P. Papet[3], D. Lachenal[3], G. Wahli[3], Y. Yao[5], J. Ufheil[4], T. Söderström[5], R. Grischke[5], M. Gragert[5], J. Fleischer[6], P. V. Fleischer[6], C. Ballif[1,2]

[1] PV-Center, CSEM, Rue Jaquet-Droz 1, CH-2002 Neuchâtel, Switzerland, ***Contact: antonin.faes@csem.ch***

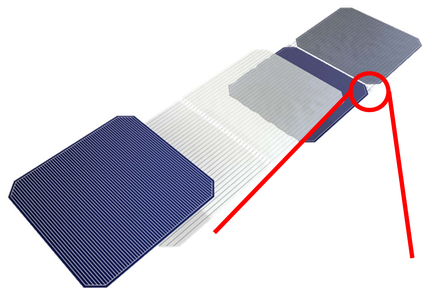
[2] PV-Lab, IMT, EPFL, Rue de la Maladière 71b, CH-2002 Neuchâtel, Switzerland

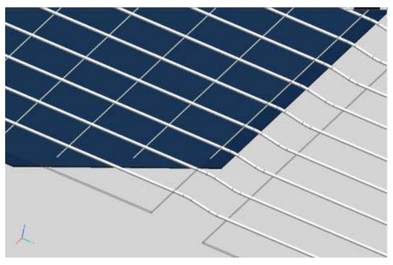
[3] Roth & Rau Research SA, Innoparc, Rouges Terres 61, CH-2068 Hauterive, Switzerland

[4] Somont, Im Brunnenfeld 8, D-79224 Umkirch, Germany

[5] Meyer Burger AG, Schorenstrasse 39, CH-3645 Gwatt, Switzerland

[6] PVF-Vertriebs GmbH, Oskar-von-Miller-Ring 24, D-85464 Neufinsing, Germany





Cell assembling using SmartWire connection

The SmartWire Contacting Technology (SWCT) is an innovative interconnection technology for crystalline silicon solar cells: standard busbars and ribbons are replaced by copper wires coated with a thin low melting point alloy layer and supported by a polymer foil. It was started by Day4 Energy, in Canada, and is now developed and industrialized by Meyer Burger. SmartWire provides key advantages like, increase in efficiency, cell contacting at low temperature, reduced consumption of silver, enhancement of module reliability and improved aesthetics (as more described below). Today Meyer Burger propose fully automatized SmartWire module line with 90 MW/y capacity.

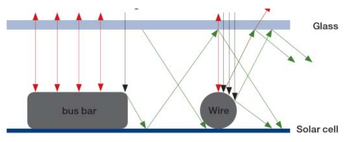
This work presents the last achievement of the SmartWire Contacting Technology and the new results for low silver screen printing and indium-free coating.

SmartWire advantages

SmartWire provides key advantages like:

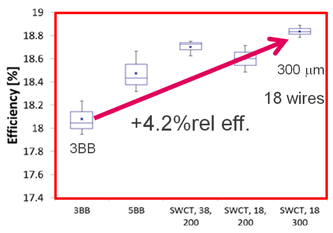
1. Increase in efficiency by lowering ohmic losses and improved light management (reflection on the wire)
2. Low temperature contacting during module lamination (less thermo-mechanical stresses) [1]
3. Reduced consumption of silver by 85 % or more (see below: Low silver screen-printing part) [2]
4. Enhancement of module reliability (1000 to 2000 electrical contact points on each cell) [1]
5. Improved aesthetics

1

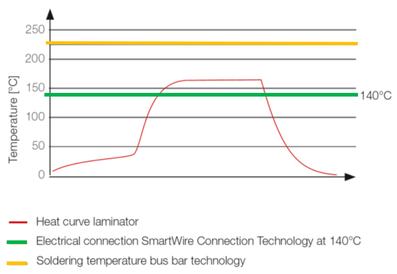


$$P_f \propto \frac{J^2 L}{12 n_f} \frac{R_f}{n_{BB}^2} \propto C \frac{R_f}{n_{BB}^2}$$

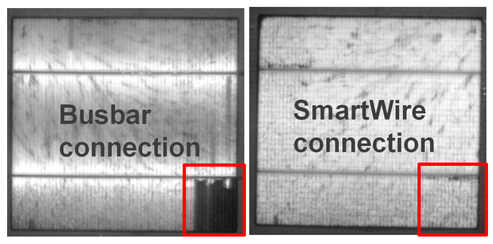
With power dissipation within the fingers (P_f), the finger line resistance (R_f), number of busbars (n_{BB}),



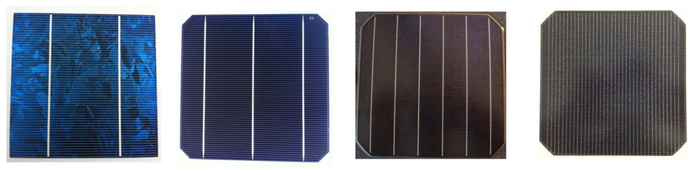
2



3



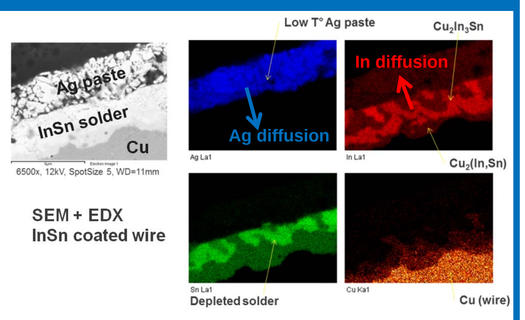
5



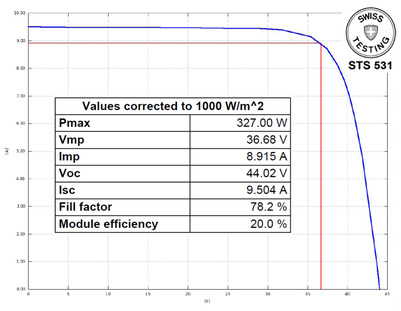
[1] T. Söderström et al., Proceedings of the 28th EU-PVSEC, Paris (2013), pp. 495-499.

Today SmartWire

The typical SmartWire structure based on indium-tin coating is composed of: (1) Cu wire, (2) $Cu_2(In,Sn)$ (3) Cu_2In_3Sn, (4) remaining solder alloys (5) finally the cell metallization. For Ag front metallization, metallurgical bonding is evidenced with In diffusion in Ag and Ag diffusion in the Cu_2In_3Sn phase, enabling high bonding strength at the coating – metallization interface.



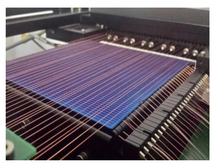
SEM + EDX
InSn coated wire



Values corrected to 1000 W/m^2	
Pmax	327.00 W
Vmp	36.68 V
Imp	8.915 A
Voc	44.02 V
Isc	9.504 A
Fill factor	78.2 %
Module efficiency	20.0 %

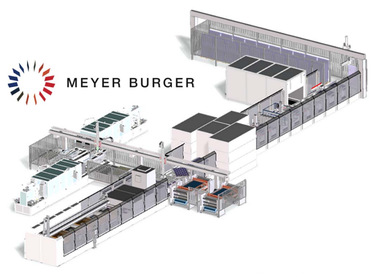
IV curve and parameters for the record module

Record module is based on 60 full square c-Si heterojunction 6" cells without busbars measured using the GridTouch® developed by PASAN with 22.3% efficiency. The record module demonstrates a very high performance with a certified MPP of 327 Wp, corresponding to 20% module efficiency, one of the highest certified efficiency for a 60 cells modules.



GridTouch® from PASAN

SmartWire stringer



SmartWire 90 MW/y line from Meyer Burger

Glass-glass (GG) module interconnected with the SWCT demonstrate high reliability, with modules passing 4 times the IEC test standards (800 TC and 4000h DH).

Meyer Burger proposes SmartWire GG module line of 90 MW/y. This includes the new electrode foil fabrication and SmartWire stringer.

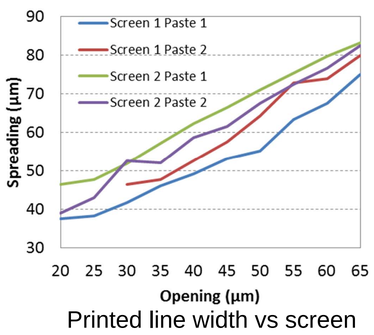
Low silver screen-printing

The use of Meyer Burger's SmartWire Connection Technology (SWCT) change the need in the finger line resistance by increasing the number of busbars (n_{BB}) – wires from 3 to > 18. To keep the same power dissipation within the fingers P_f, the finger line resistance R_f can be multiplied by 36 compared to 3 busbars design (see equation 1), then practically a line resistance up to 10 Ω/cm could be used without change in ohmic losses [2]:

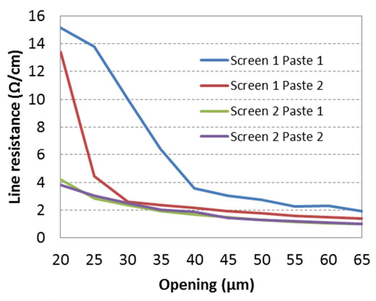
Equation 1 $$P_f \propto \frac{J^2 L}{12 n_f} \frac{R_f}{n_{BB}^2} \propto C \frac{R_f}{n_{BB}^2}$$

$R_{f,3BB} \approx 0.3$ Ω/cm

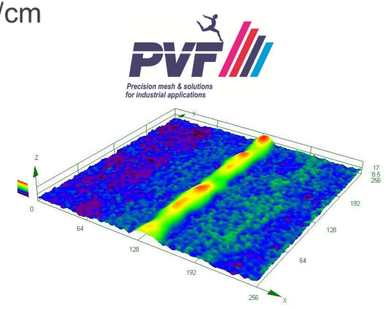
$R_{f,18wires} < 10$ Ω/cm



Printed line width vs screen opening



Line resistance measurement vs screen opening



3D confocal laser image of 20 µm line opening print. Finger height = 7 ± 2 µm

Print design with 62 and 77 fingers with screen openings of 30 µm are used to print bifacial cells. With 62 fingers at front and 77 at the back need only 25 mg of silver in total. The cost of silver represent only 0.21 €ct/Wp.

Measured with GridTouch®	Eff (%)	FF (%)	Isc (A)	Voc (V)
25 mg Ag total	21.9	76.4	9.53	0.7336

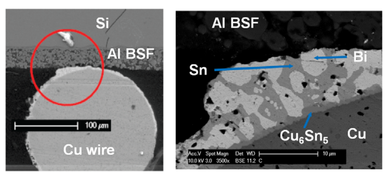
Cost of silver only 0.21 €ct/Wp

With silver price 445 €/kg (09.10.2014).

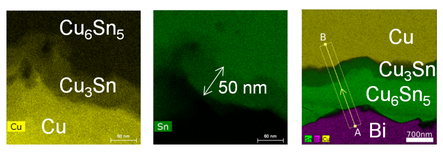
[2] P. Papet, *et al. Front grid metallization and module interconnections of industrial heterojunction solar cells*, Metallization Workshop, Konstanz 2013.

Indium-free coating

A BiSn alloy coating is developed and tested to replace the InSn coating. Bismuth-tin alloys are about 70 times more competitive in costs compared to indium-based alloys. A typical BiSn eutectic coating contains 58 wt% Bi and 42 wt% Sn, it has a melting point of 138 °C, a bulk resistivity twice higher than InSn alloy, and a coefficient of thermal expansion close to pure copper [3].

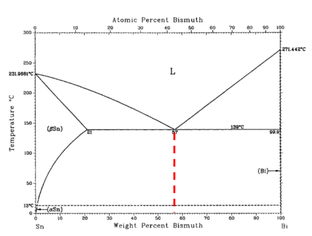


BiSn coated wire in contact to Al BSF



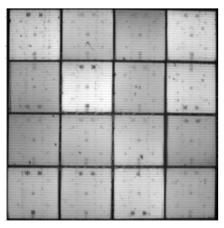
Initially After 1000h DH

Growth of the Cu_3Sn intermetallic phase during damp-heat



Phase diagram of BiSn alloys

Cu_3Sn intermetallic phase is measured by TEM before and after the IEC damp-heat degradation test. The layer growth from 50 nm to 320 nm during 1000h at 85°C. This has no impact on the module output as the two modules pass IEC degradation test. 16 c-Si heterojunction cells modules with 18 wires of 200 or 300 µm coated with BiSn show active area efficiency conversion of more than 21%.



EL image of BiSn coated wire module

16 HJT cells 18 wires G/G	Voc (V)	Isc (mA)	FF (%)	Power (W)
200 µm BiSn	11.6	9.4	75.2	82
300 µm BiSn	11.6	9.4	77.1	84

IV properties of modules made of SmartWire coated with BiSn

Pass IEC degradation test 200TC & 1000h DH

[3] J. Glazer, *Metallurgy of low temperature Pb-free solders for electronic assembly*, International Materials Reviews, 1995;40,2:65-93.

This work was supported by the Swiss Commission for Technology and Innovation with funding of the SmartWire project, by the Swiss Federal Office of Energy with funding of the Swiss Inno-HJT project, and by the European Union's Seventh Program for research, technological development and demonstration under grant agreement No 608498, with funding of the HERCULES project. CSEM acknowledges Choshu Industry Co., Ltd. for the cell precursors.