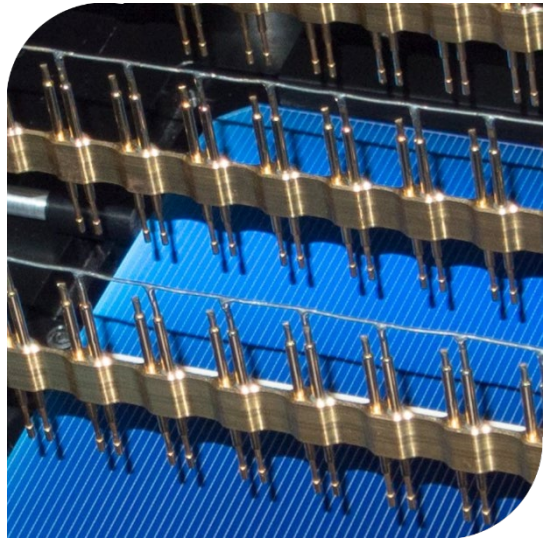



Stringed Zebra IBC modules:
Review and New Applications

A. Halm, T. Timofte, I. Devoto, T. Messmer

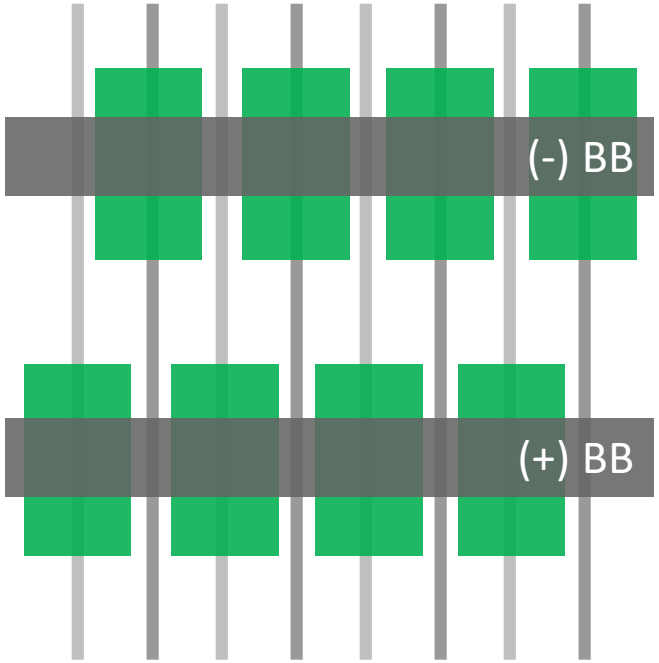
BC Workshop 2024

Delft

21.11.2024

ISC research for a sunny future

Zebra 3D rear metallization scheme



ISC standard 3D metallization layout since 2010

- Continous BB print
- Local insulation pads
- Low T BB ink borrowed from HJT processing

» flexible layout ideal for various interconnection approaches

agenda

- First full size Zebra module
- Classic stringing appraoch
- New applications enabled by single side stringing
- New process approaches

First full size Zebra module

Fully machine assembled at Eurotron´s CBS pilot line 2015

		Isc (A)	Voc (V)	FF (%)	P_{MPP} (W)
Module	**A**	**9.97**	**39.3**	**77.1**	**303**
CTM (%)		-0.6	0.00	1.8	1.1
Module	**B**	**9.94**	**39.2**	**76.5**	**298 ***
CTM (%)		-0.7	-0.05	2.4	1.7
Module	**C**	**9.84**	**39.1**	**76.3**	**294**
CTM (%)		-0.6	0.04	2.3	1.8

*** confirmed by Fraunhofer Callab**

» module process and equipment ready for mass production

Eurostar project “moderNtype” (E!7232)

Why stringing ?

- **Industry demand**
- Compatible with soldering
- Can leverage the momentum of std. PV mass production
- Bifaciality easy to implement

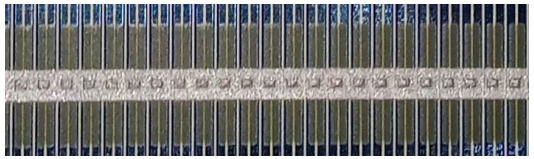
Enablers

- Transition to half cell technology (bow)
- Adaption of stringing tools

Classic stringing approach

State of the art stringing of Zebra cells

Teamtechnik TT2100 adapted for Zebra



Screen printer for ECA or solder paste available

IR soldering of half cells

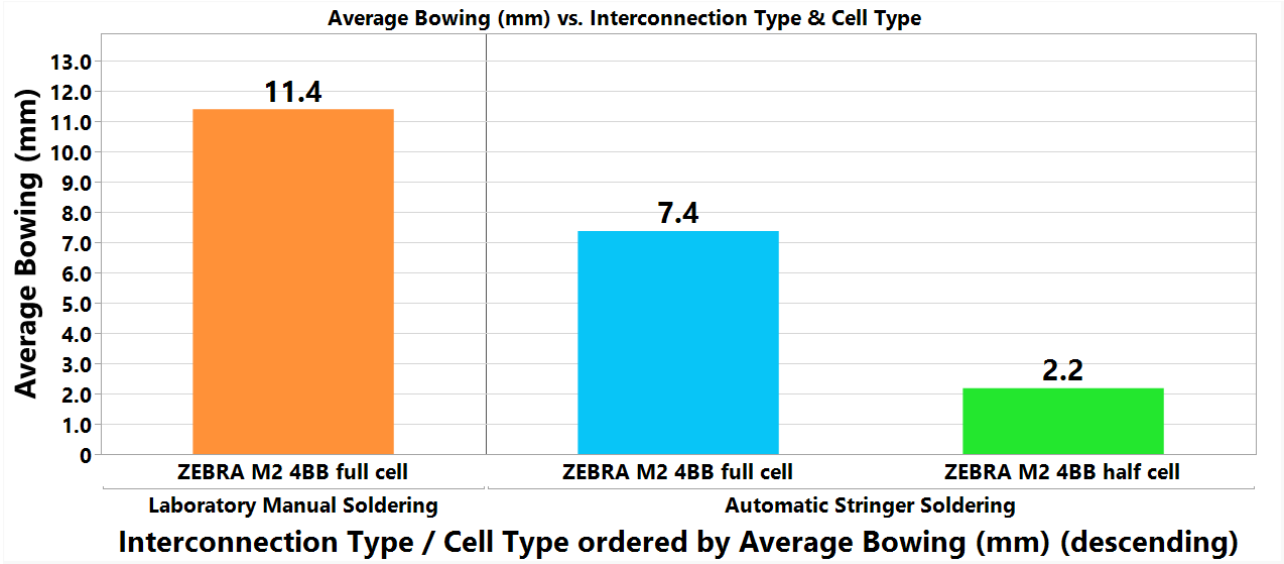
Developed and implemented in mass production @ SPIC solar 2019 with alternative stringer supplier

Developed @ ISC in cooperation with Teamtechnik

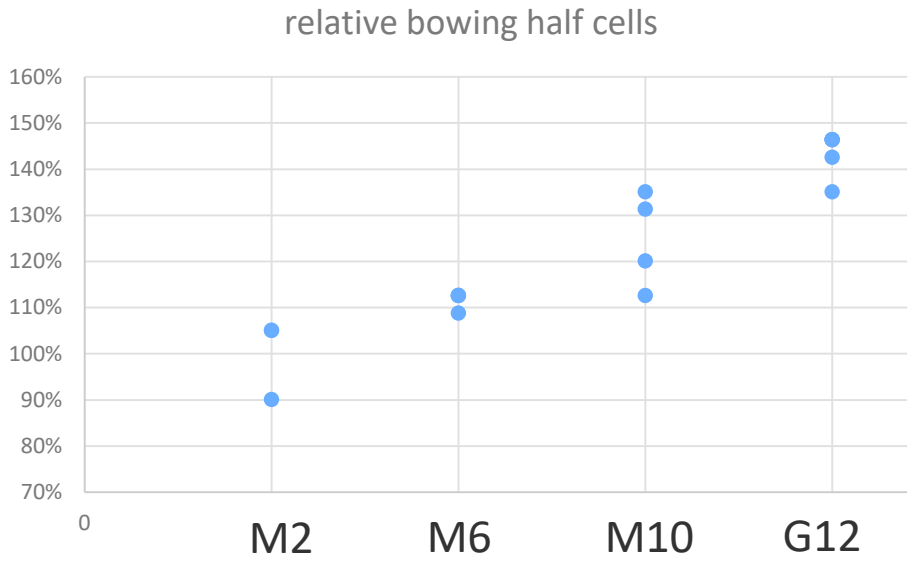
Most stringer supplier will offer an IBC solution today

see e.g.: T. Timofte; Feasibility study of synergistic back-contact silicon solar cells metallization and electrically conductive adhesive interconnection approach", WCPEC-8, 2022

State of the art stringing: bow



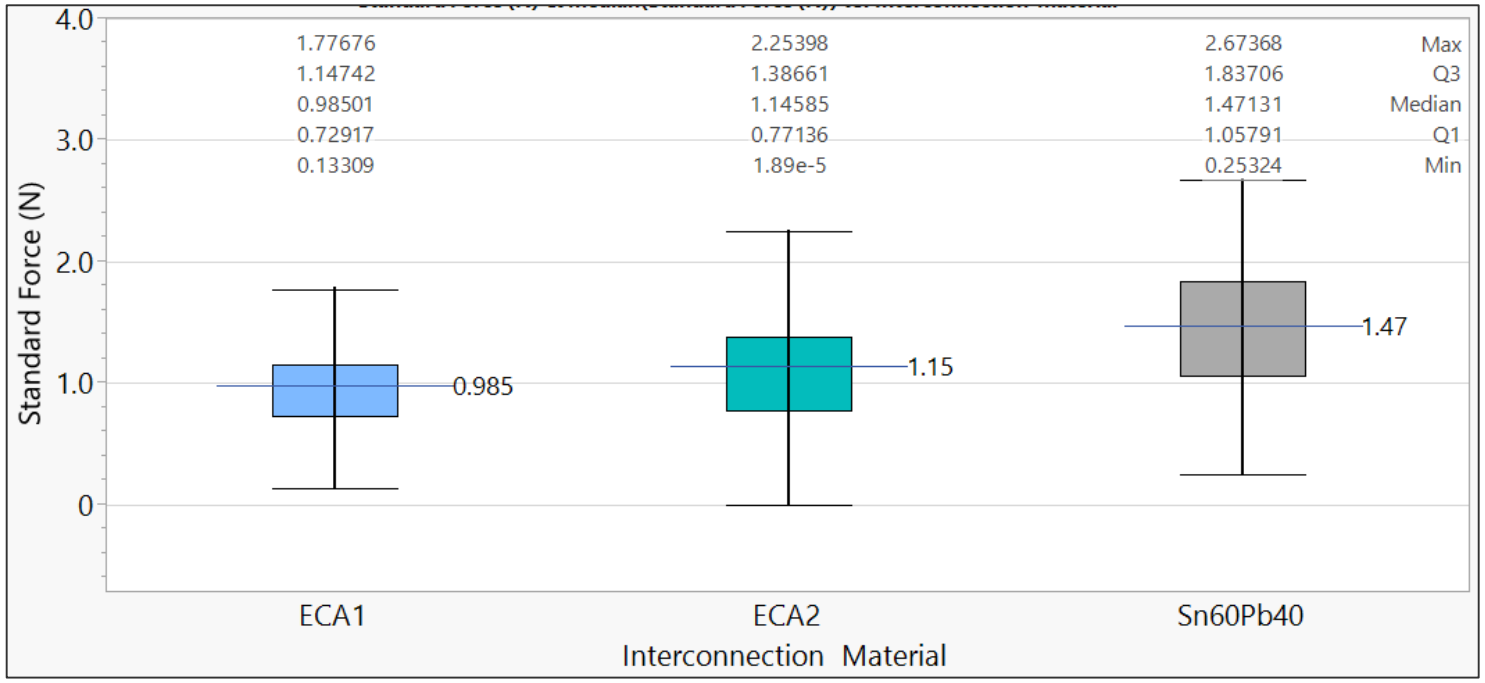
T. Timofte: "**Stringing technology for bifacial ZEBRA (IBC) modules" Bifacial Workshop 2022**



» typical bow on M6 6BB half cells is 1.9 mm
» projected bow for M10 half cells is 2.3 mm

Based on M2 cells cut in corresponding wafer size pieces

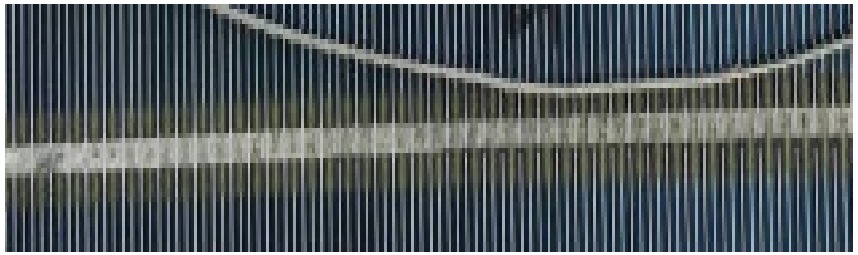
State of the art stringing: peel force



	Ribbon type (copper core size and coating)
Inter-Connection	**Automatic Process**
ECA1	1,2x0,22mm Ag100
ECA2	1,2x0,22mm Ag100
$Sn_{60}Pb_{40}$	1,2x0,24mm $Sn_{60}Pb_{40}$

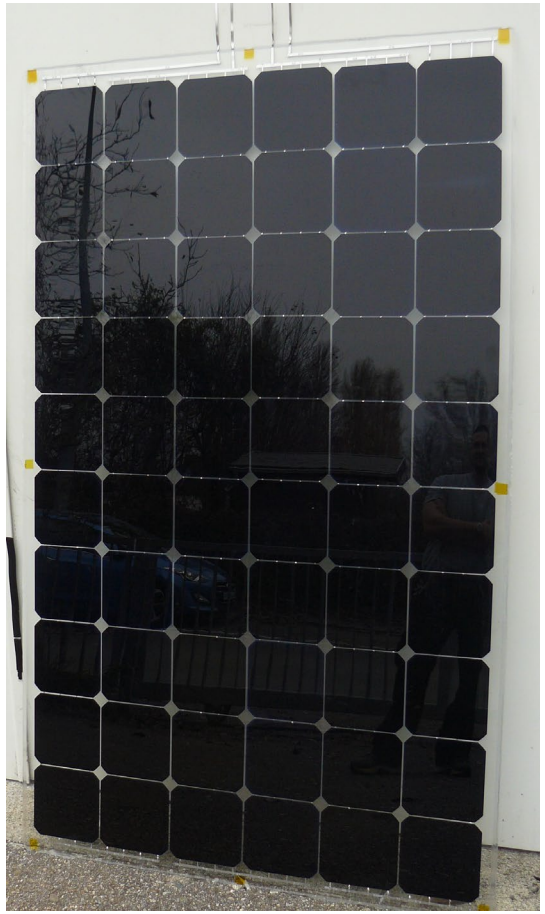
T. Timofte: “Reliability assessment for industrial soldered and glued BJ-BC solar cell interconnections”, 38th PVSEC 2021

Peel forces sufficiently high for soldering and ECA gluing (between 1 and 1.2 N/mm)

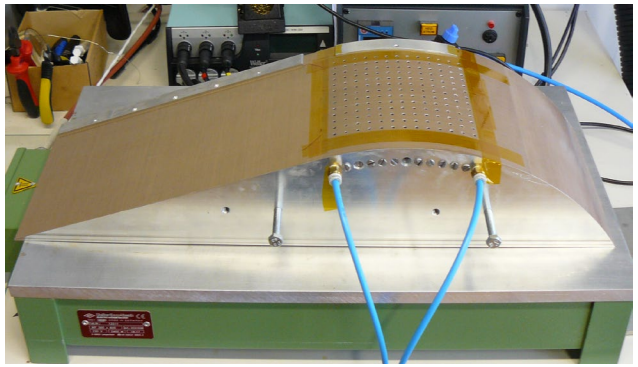


New applications for stringed Zebra cells

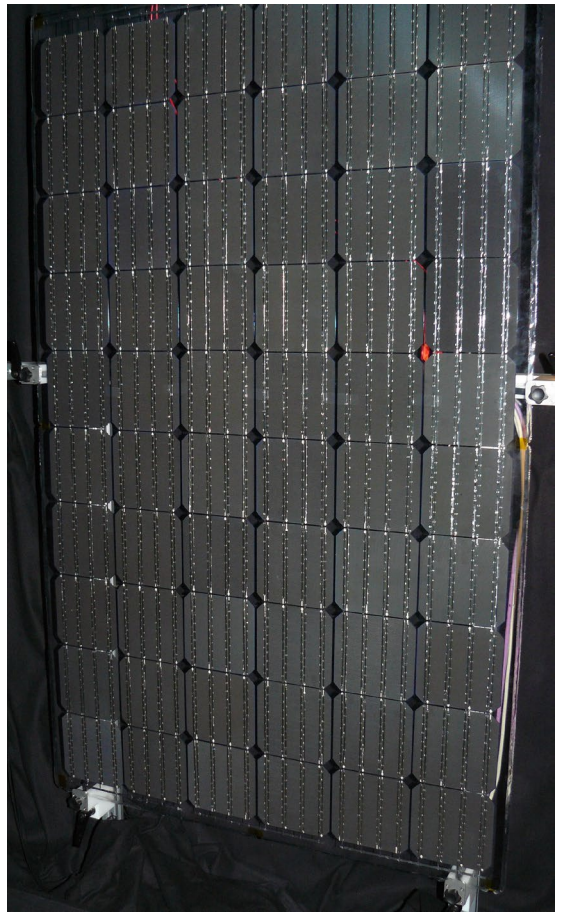
First stringed full size Zebra module (2017)



It is bifacial !!



	Isc (A)	Voc (V)	FF (%)	P_{MPP} (W)
IV front	9.8	40.9	76.4	305
IV rear	7.5	40.4	77.3	234
BiFi factor: P rear / P front = 0.77				

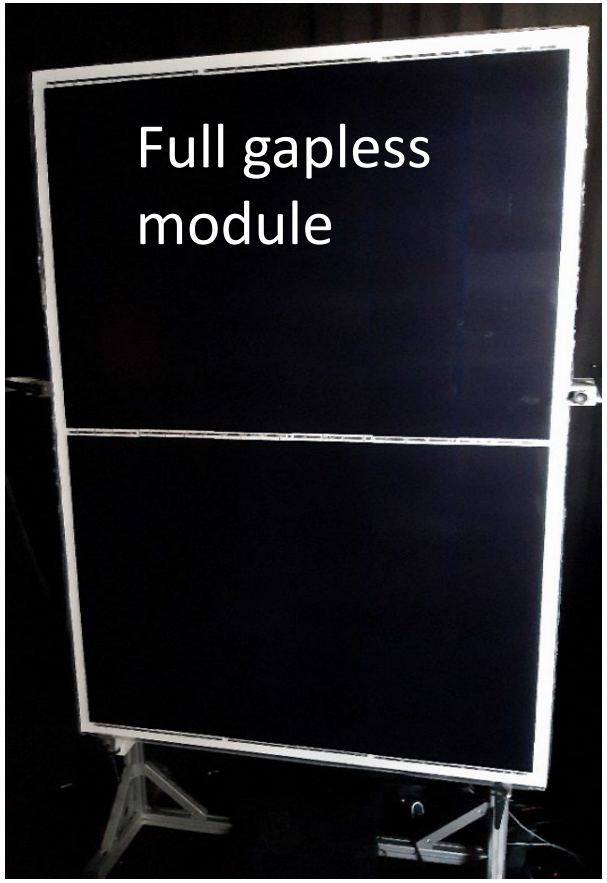


Solar-Era.Net-Projekt: U-Light (0325886A)

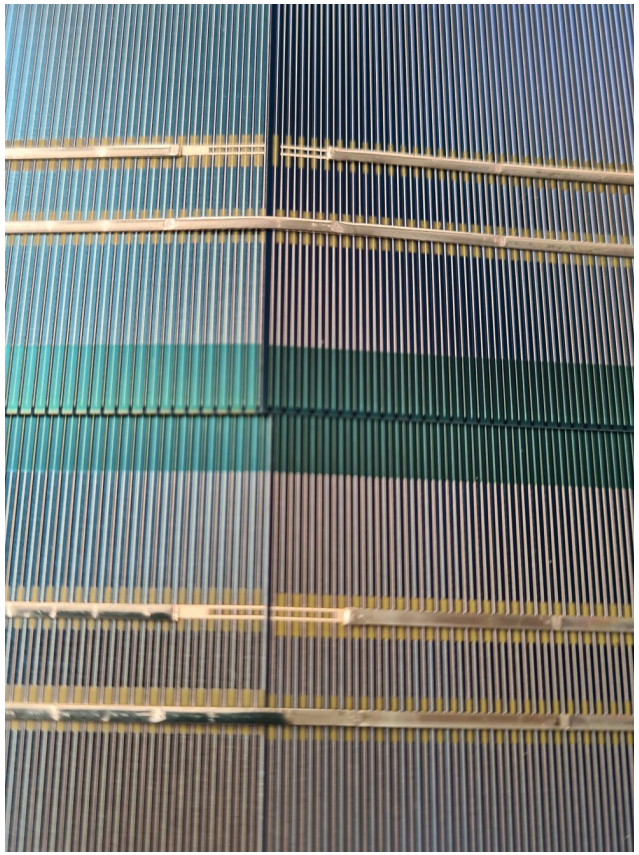
Gapless stringing

- Small cell to cell overlap during stringing (0.5 to 1mm)
- Shadowing of cut edge reduces edge cutting losses
- No ribbon visible in cell gap
- Maximized active area
- Fully IEC 61215 certified product available from SPIC solar

From gapless to full gapless



Full gapless module



100 x Zebra half cells M6

1mm string overlap

1mm cell overlap

HighLite

Full gapless module

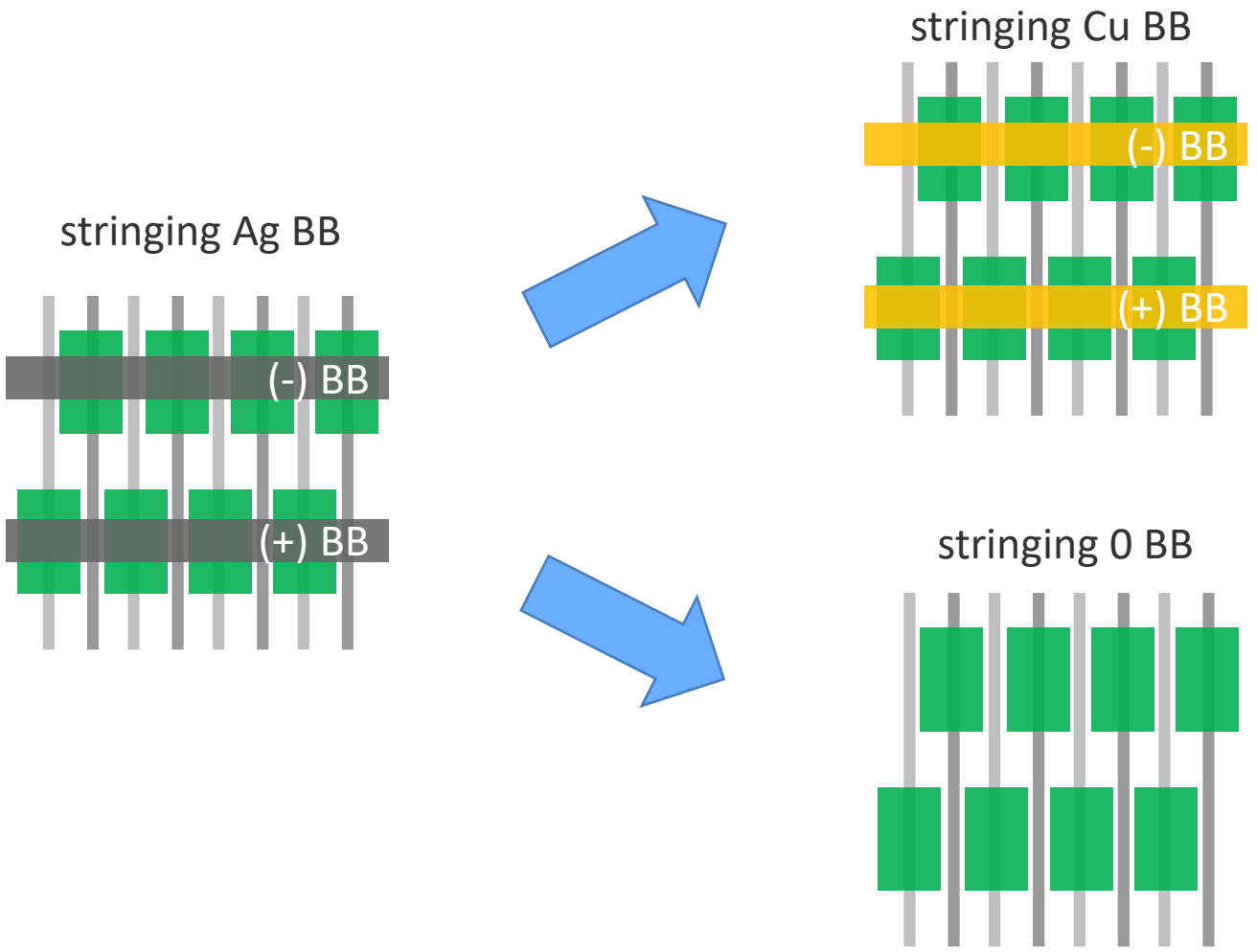
	η (%) cell	CTM power (%)	Module power (W)	module area (m²)	η (%) module full area	CTM η (%)
white backsheet std. Zebra module produced at ISC	22.8	0.5	373	1.78	21.0	7.8
black backsheet full gapless module produced at ISC	22.8	2.9	364	1.71	21.3	6.6

Scaled result from 100 to 120 half cells

» full gapless module enables lower CTM in efficiency compared to white bs Zebra reference

New processes for stringed Zebra cells

New applications currently in R&D @ ISC



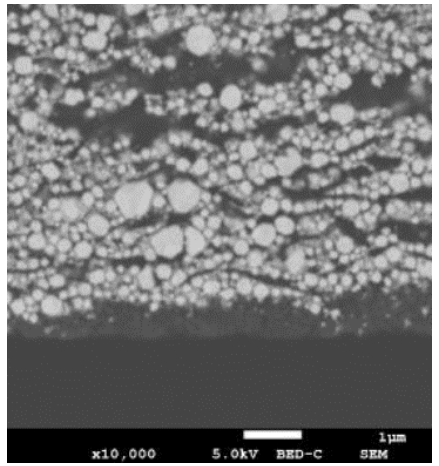
- drop in solution
- Screen printable Cu ink

- No classic soldering
- ECA or solder paste as electrical contact agent

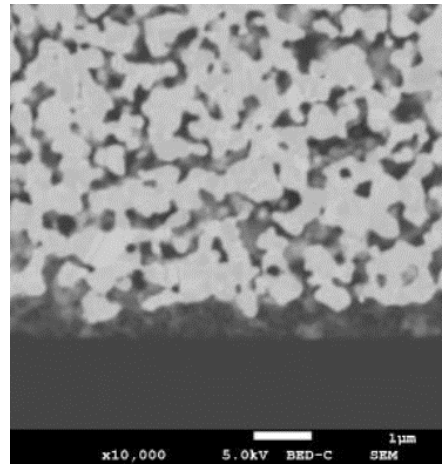
Copper busbars for Zebra cells

Screen printable Cu-ink/paste from Copprint

- Based on Cu nano particles
- Rapid sintering at low temperature
- Sintering agent prevents oxidation



SEM Cross section
LF-350 before sintering



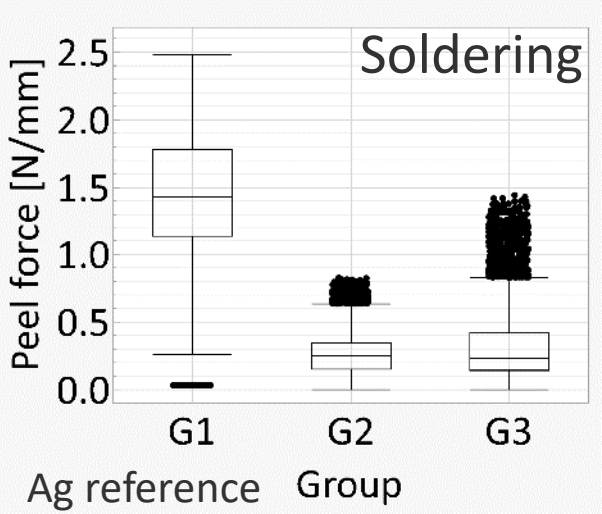
SEM Cross section
LF-350 after sintering

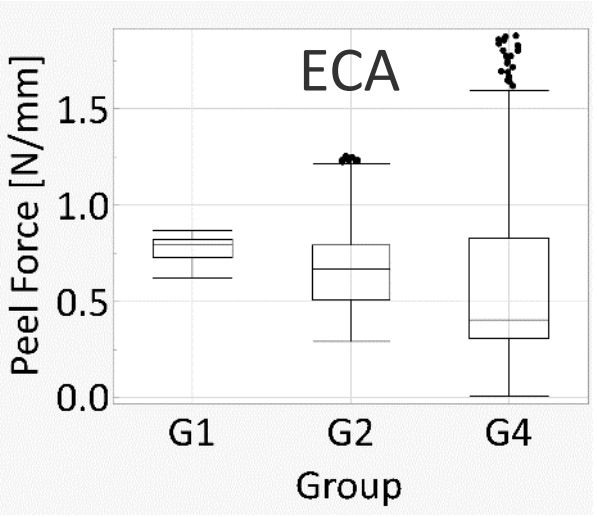
Copper busbars for Zebra cells

Solderability is given for SnPb coated ribbon yet peel forces low

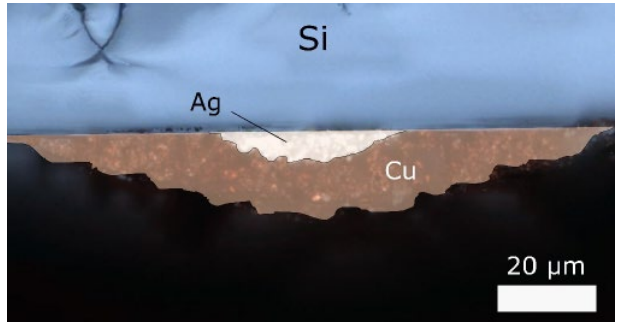
» Adhesion issues are currently solved in cooperation with Copprint

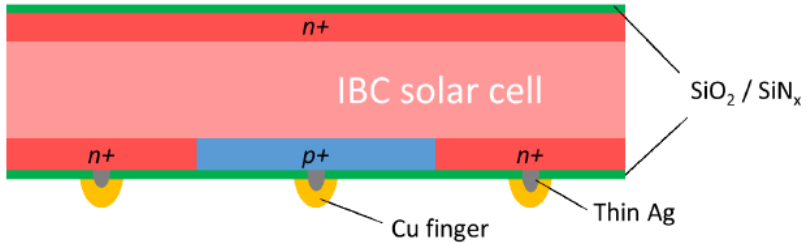
ECA gluing is applied to have initial mini modules to probe Cu in diffusion

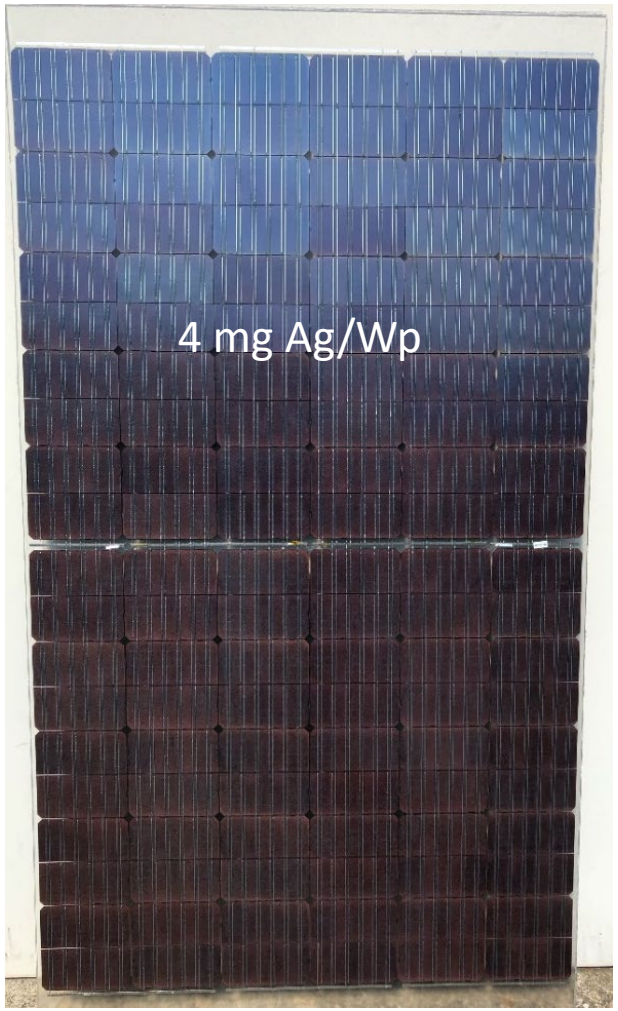




Stringing of Zebra cells with Cu busbars





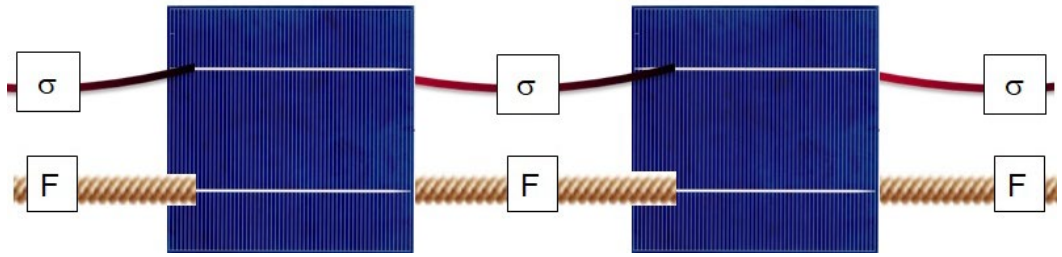


N. Chen, 8th Solar Cell Paste and Metallization Forum , 2022

	Isc [A]	Uoc [V]	FF [%]	Pmpp[W]
Cu BB module	11,11	41,54	79,31	365,94
Ag BB reference	11,17	41,44	79,73	369,24

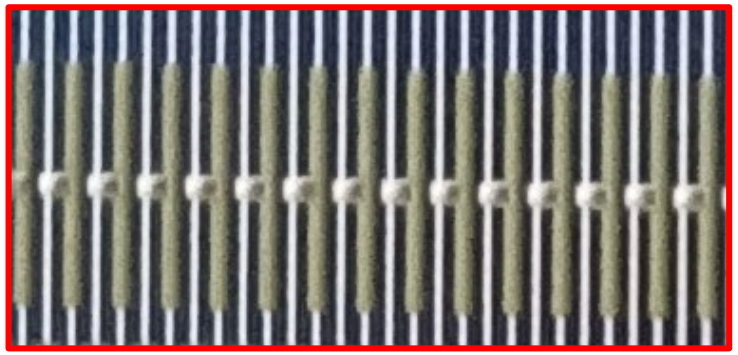
0 BB stringing for Zebra: Indifiduell process

Requirements for cell to cell connection



Electrical connection

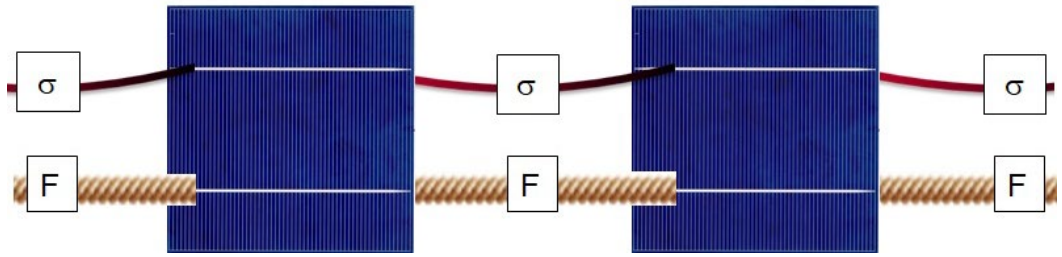
Mechanical connection



Reduced material deposition of electrical contact agent (ECA or solder paste)

0 BB stringing for Zebra: Indifiduell process

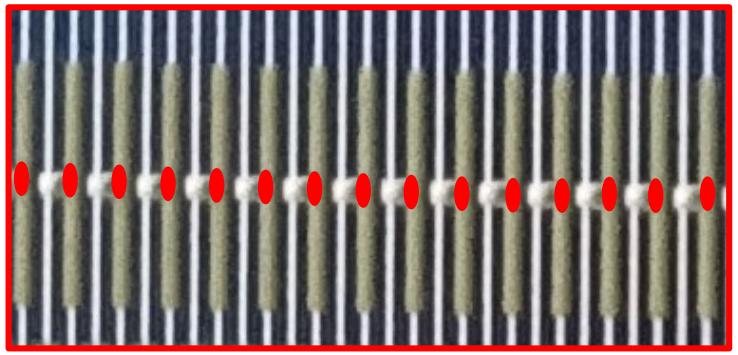
Requirements for cell to cell connection



Electrical connection

Mechanical connection

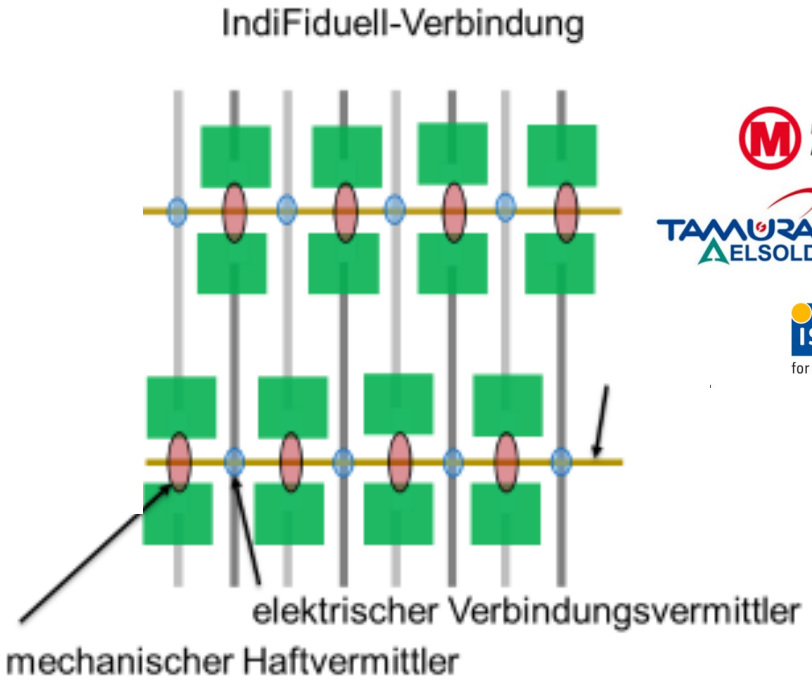
Mechanical connection supported by NCA (non conductive adhesive)

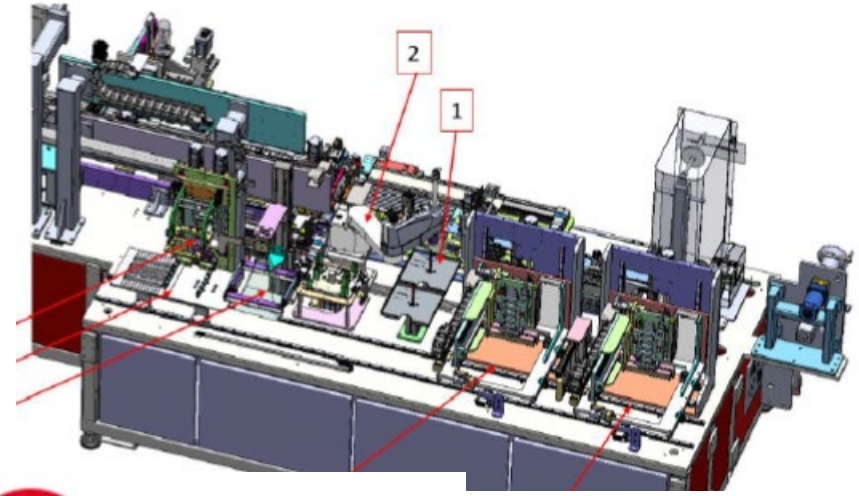


Reduced material deposition of electrical contact agent (ECA or solder paste)

0 BB stringing for Zebra: Indifiduell project

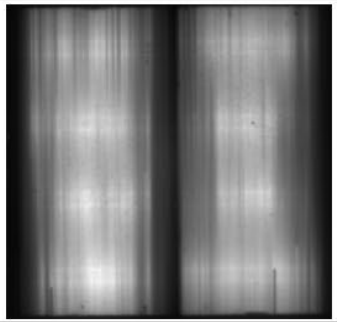
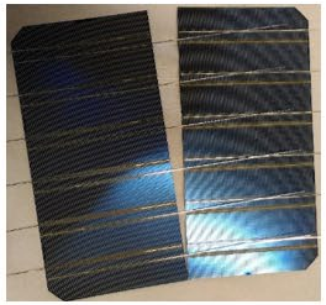
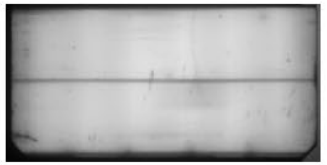
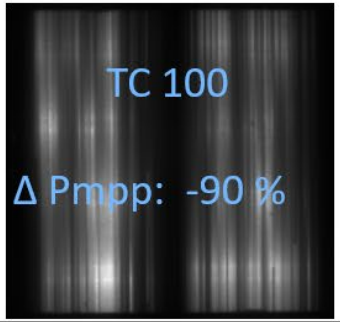
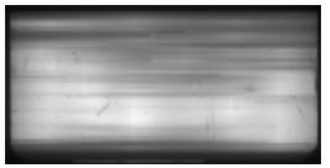
0 busbar interconnection with ECA/NCA or solder paste/NCA for classic





New flexible stringer tool specified and ordered !
IR soldering and deposition of 2 media possible !

0 BB stringing for Zebra: Indifiduell project

	Busbarless cells 21 mg ECA/Wp	Busbarless cells 12 mg ECA/Wp	Busbarless cells 20 mg ECA/Wp + NCA	Busbarless cells 12 mg ECA/Wp + NCA
Initial				
TC			TC 25 Δ Pmpp: -2.1 % 	TC 25 Δ Pmpp: -8.7 % 

T. Meßmer, Metallization and Interconnection Workshop, Chambéry, 2024

First lab results - room for optimization

summary

- Zebra cell stringing (and IBC stringing in general) by IR soldering is state of the art
- Production solutions for ECA or solder paste stringing are commercially available
- IBC stringing enables bifacial and full active area modules
- Cu BB and 0 BB are in development (not only) at ISC

ISC research
for a sunny future

Thank you

For the attention