CELL SESSION INTRODUCTION

BIFIPV workshop –Miyazaki 29-30/09/2016

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OUTLINE

- **CURRENT TRENDS IN PV CELLS TECHNOLOGY**

- **STATUS OF BIFACIAL CELL TECHNOLOGIES**

  → **Well known players: status & improvement**

  → **A new « challenger »**

  → **Alternatives approaches**

- **CONCLUSION & PERSPECTIVES**

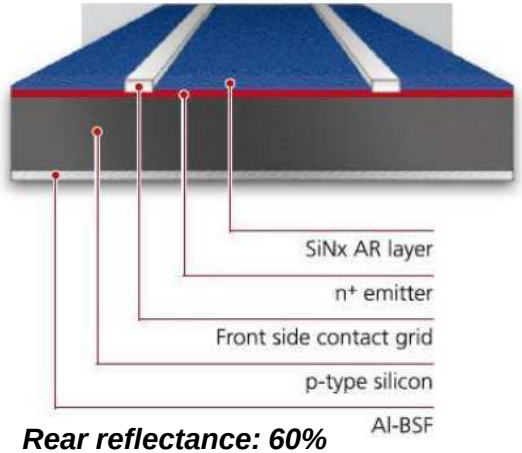
AL-BSF TECHNOLOGY

- 75% of market share in 2016
- Very simple process
- Compatible with p-type mc-Si and mono-Si
- Continuous efficiency improvement

→ *16% - 17% in 2006 on Cz*

→ *19% - 20% in 2016*

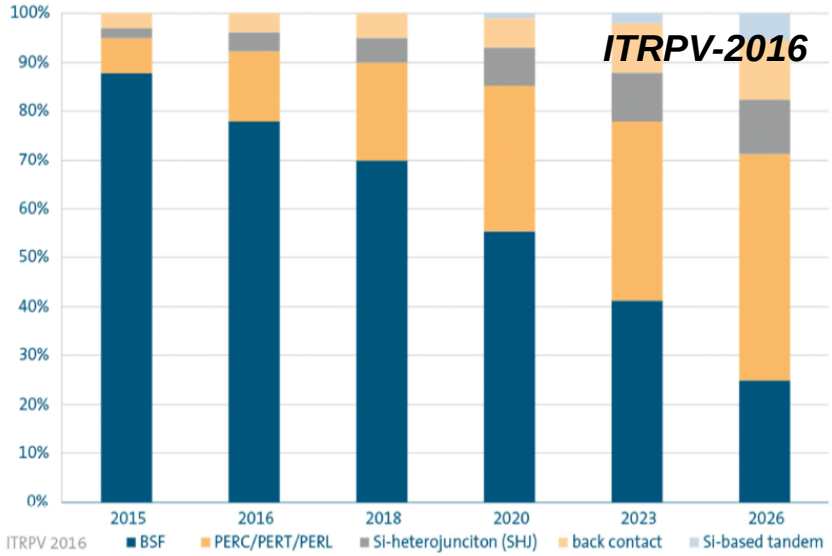
Al-BSF Standard Cell



Rear reflectance: 60%
Rear recombination velocity: 160cm/s

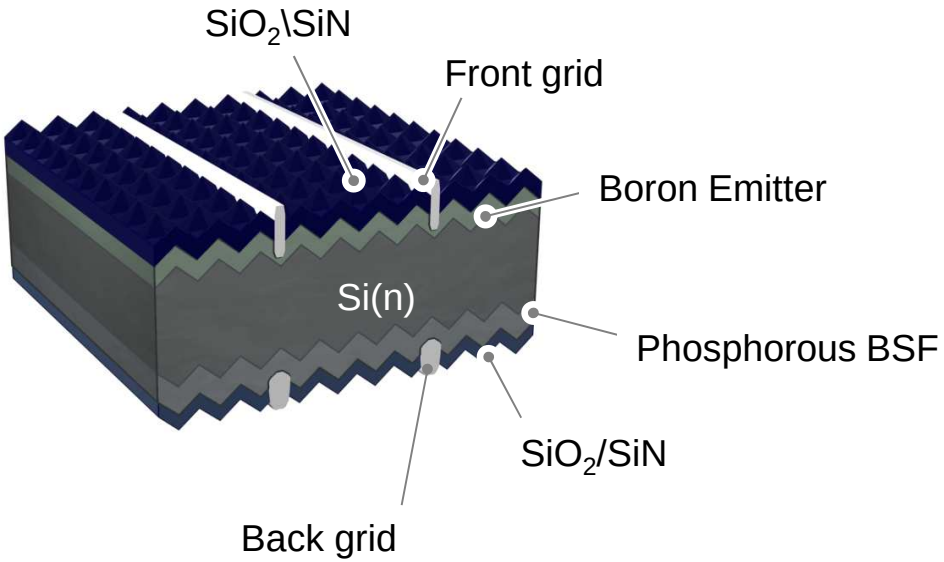
- Al-BSF cell shows now efficiency limitation
- Producers consider alternatives

- <u>Most of the alternatives can be bifacial</u>



PERT CELL

PERT: Passivated Emitter Rear Totally diffused



Mean features:

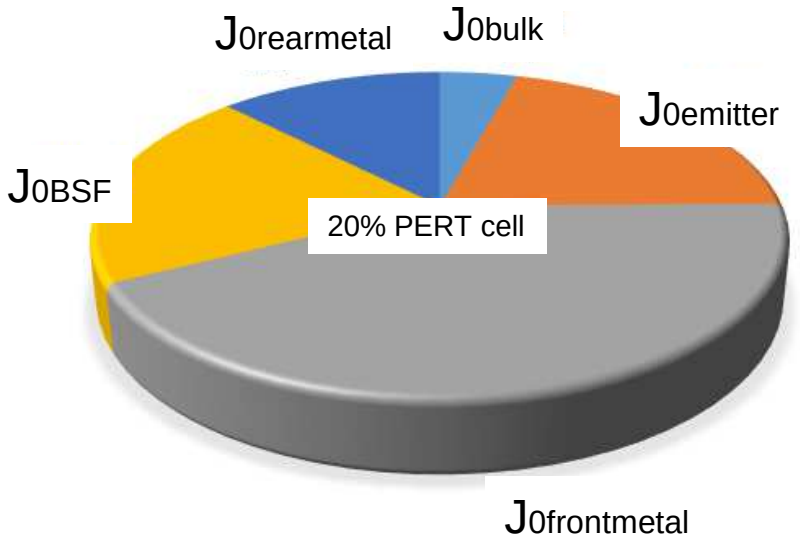
- ✓ Mostly developed on n-type Cz Si
- ✓ Naturally bifacial if metallization are screen-printed
- ✓ High bifaciality: > 90%
- ✓ Good compatibility with existing production lines

Efficiency records:

- → From 18.5% in 2009
- → 20.7% in 2014
- → 21.5% in 2016

- ➢ R&D actors: ISFH, ISC, ECN, CEA, MOTECH, IMEC, SUNIVA, Univ Konstanz, ISE, …
- ➢ Producers: PVGS, NSP, MEGACELL, LG, YINGLI, SNEED,…
- ➢ Estimated world production capacity ~ 1GW up to 1.5 GW

PERT CELL: EFFICIENCY ISSUE



- Recombination at the metal/B-emitter interface has been the main efficiency issue (J0met: 2000-5000 fA/cm²)
- Solutions investigated:

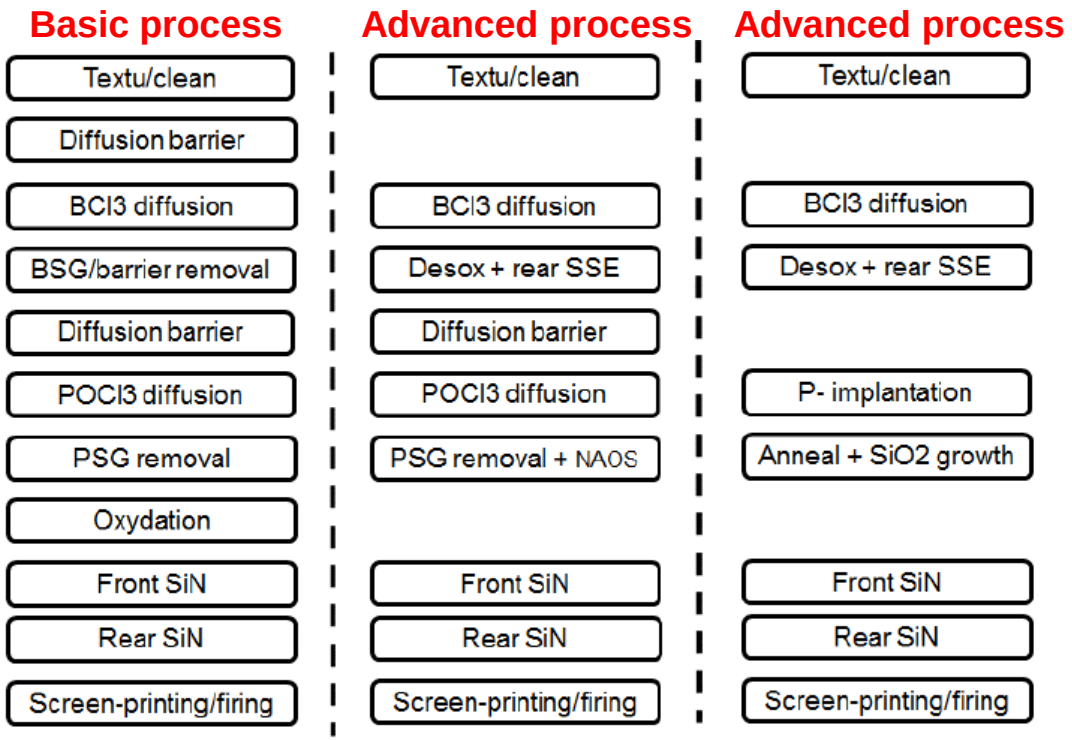
- Modification of emitter profile (Selective Em)
- Limitation of contacting pastes area
- New pastes generation

	Voc (mV)	Jsc (mA/cm²)	FF (%)	Efficiency (%)	Area (cm²)	Specifities
Average current performance	660	39.5	79.0	20.5	239	
LG	≈ 680	≈ 39.3	xxx	21-22	239	Screen-printing
ECN/TEMPRESS	675	38.8	79.1	20.7	239	Screen-printing + back N+ poly-Si
REC				21.5		See presentation BIFI2016
ISFH				~21.5		F. Kiefer, published in Solmat
IMEC	689	40.3	80.9	22.5	239	Cu plating – not bifacial
TRINA	684	41.0	81.2	22.8	149	Cu plating – not bifacial

PERT: SIMPLIFICATION PROCESSES

- PERT process flow potentially quite complexe (= costly)

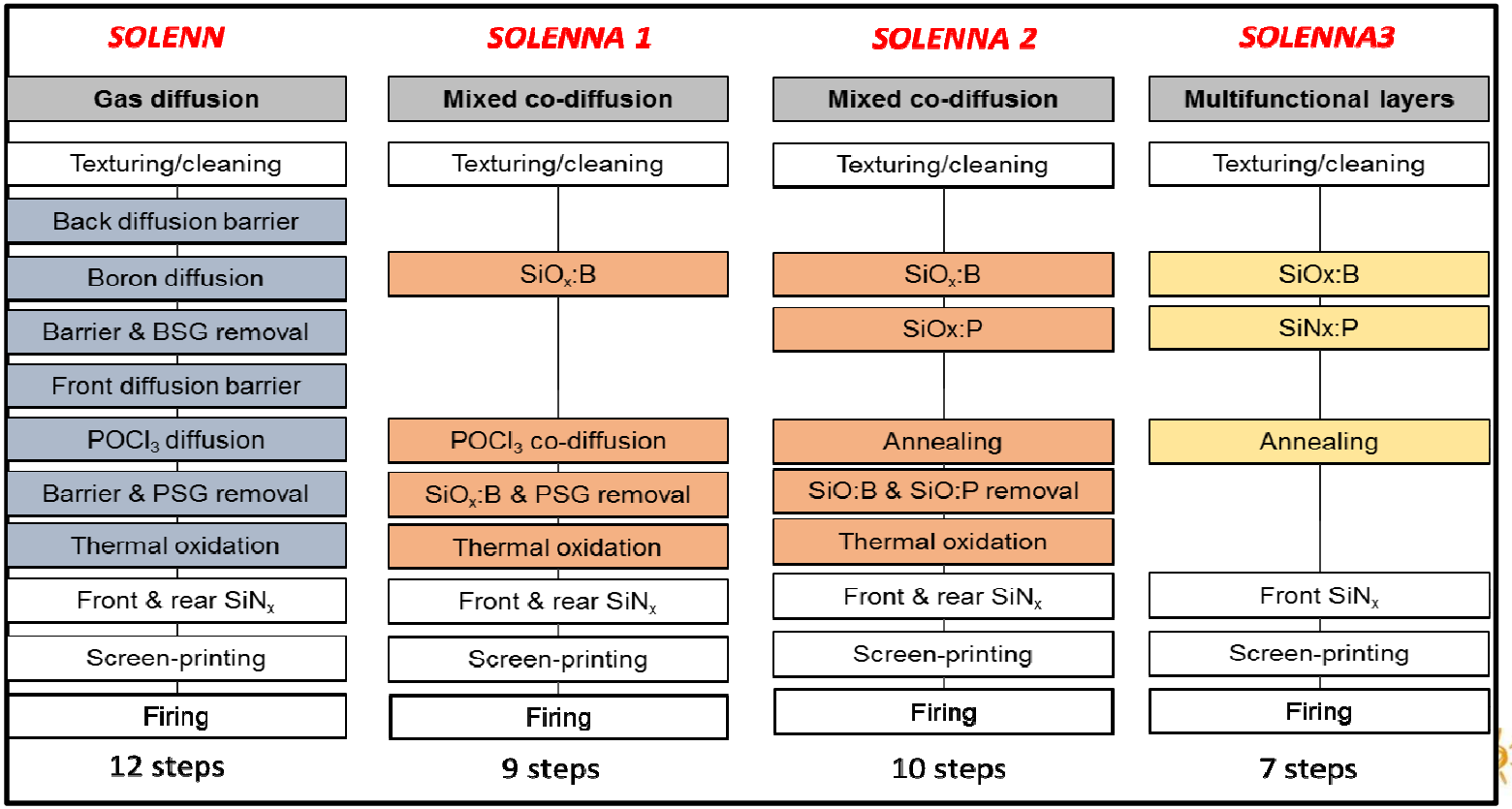
- Gas diffusion: BBr3 mostly used in industry for n-PERT cells
- Simplification processes have been developped **(ISC BiSoN, ECN n-PASHA)**
  - Using the texturing step to etch-off the doped region
  - Conserving the BSG from diffusion as a passivation layer
  - Combination with P-implantation



PERT: SIMPLIFICATION PROCESSES

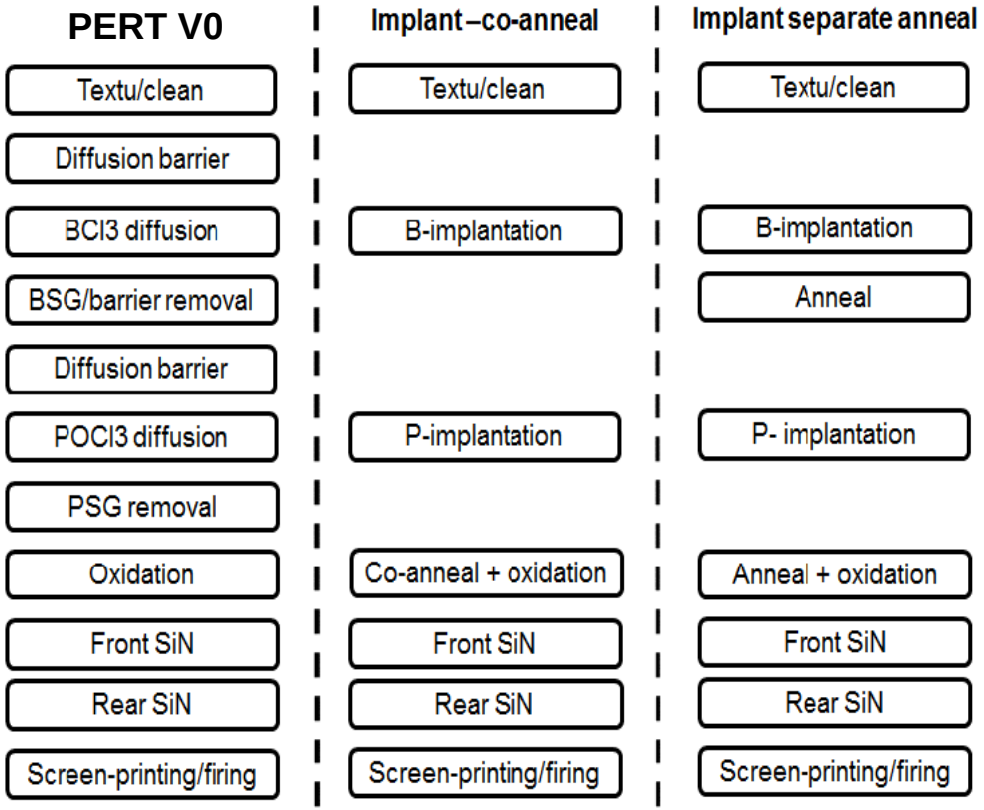
- Solid sources approach: spin-on, PECVD, APCVD
- → Process complexity also reduced for a similar potential in efficiency

Example: ultrasimplified process using multifonctionnal layers with Solenna 3 concept (CEA-INES)

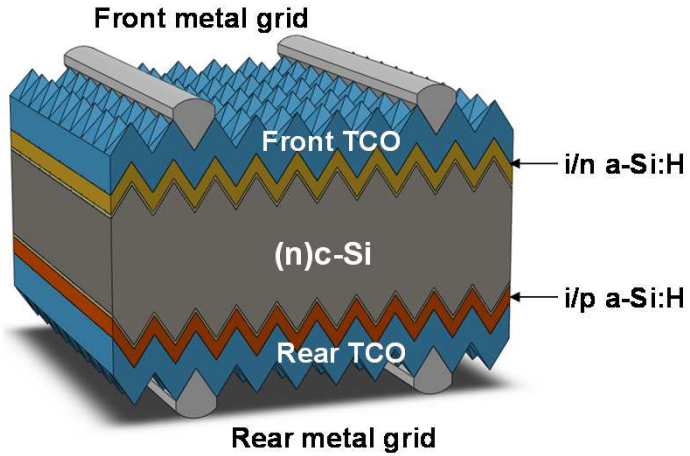


PERT: SIMPLIFICATION PROCESSES

- **Implantation approach:**
- → **High efficiency (> 20.5%) obtained in 2014/15 (ISFH, Bosch) but BL approach too costly (CAPEX)**
- → **Alternatives under development: Ion Shower (Intevac, Ulvac), plasma immersion (IBS)**



A-SI:H/C-SI HETEROJUNCTION SOLAR CELLS (HJT)



Key features:

- ✓ Mostly developed on n-type Cz Si
- ✓ Naturally bifacial if metallization are screen-printed
- ✓ High bifaciality: > 90%
- ✓ Simple process
- ✓ No compatible with existing production lines
- ✓ Excellent T coeff (-0,25%/°C)

Efficiency records:

- → 24.7% (Sanyo-Panasonic)
- → Production efficiency: 21%-22%

- ➢ R&D actors: CEA-INES, CSEM, KANEKA, CHOSCHU,
- ➢ Industrial actors: SANYO-PANASONIC, SILEVO, SUNPREME, ECOSOLIFIER, AUO, MEYER-BURGER
- ➢ Estimated world production capacity ~ 1200MW

EFFICIENCY RECORD FOR HJT BIFACIAL CELLS

Institut/ Industrial	Efficiency (%)	area (cm^2)	Description	Bifacial	Pays
Panasonic	24.7	100 Thickness 100µm	**Ag screen-printing, low damage TCO**	✓	JP
Choshu	24.1	239 GT, BB less	**Ag screen-printing, low damage TCO**	✓	JP
AUO	23.1	240	**Ag screen-printing, low damage TCO**	✓	TW
SILEVO	23.1	240	**Cu plating, low damage TCO**	✓	USA
R&R MB	23.3	240 GT, BB less	**Ag screen-printing**	✓	CH
CSEM	22.8	239 GT, BB less	**Ag screen-printing**	✓	CH

- Many existing pilot-lines ~ Meyer Burger, INES, ENN solar, …
- Improvements on alternatives to high metalized fraction → Smartwire (SWCT), > 5 busbars

<u>Remaining challenges:</u>

- Efficiency: Optical losses & lateral carrier transport: a-Si:H, TCO
- High bulk lifetime required: cost of n-type premium wafer
- CAPEX of production line

ALTERNATIVES APPROACHES

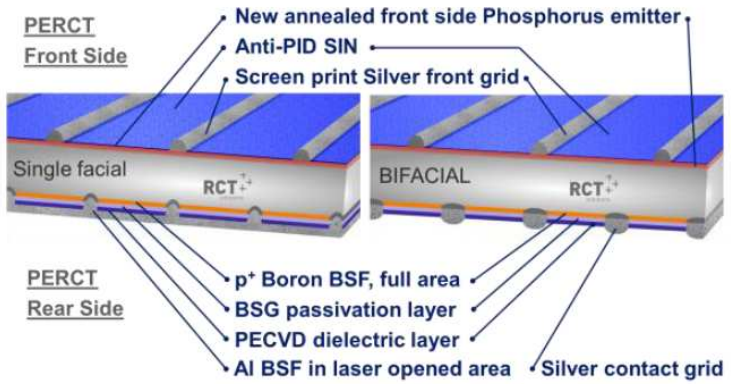
- Currently, cost of n-type wafer higher than p-type (10% up to 20%)
- → Very strong limitation for competitiveness of n-PERT or HJT

- **Existing alternatives:**

1. PERCT technology (RCT)

→ mc-BIFACIAL cells got average 18.56% with 87% bifaciality on pilot line

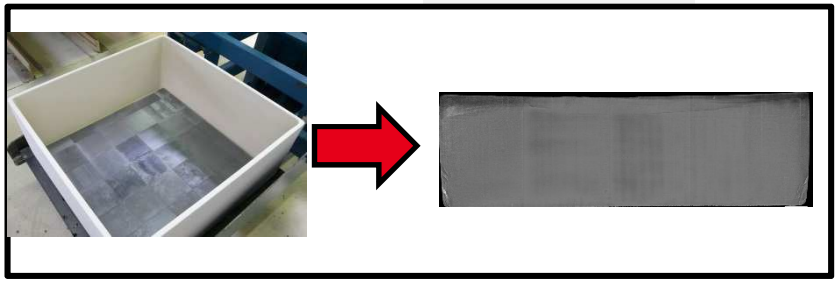
Andreas Teppe et al. 31st European Photovoltaic Solar Energy Conference and Exhibition



2. N-PERT on monolike silicon (CEA-INES & ECM GreenTech)

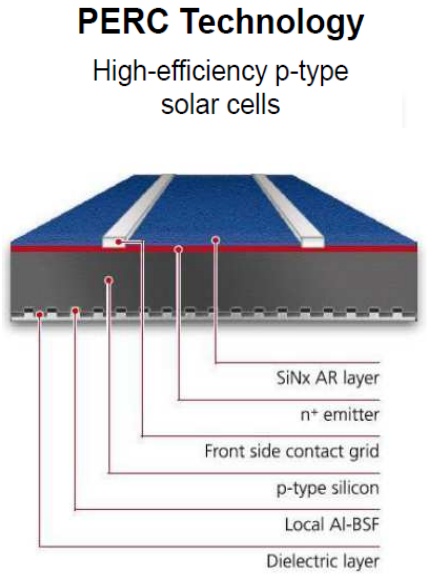
- → Average efficiency = 19% on entire brick of G5 ingot
- → Adpated process to limit dispersion (dislocation impact)

Crystalmax



R.Cabal et al. 20% PERT technology adapted to n-type monolike silicon, 29th European Photovoltaic Solar Energy Conference and Exhibition

PERC+: A NEW CHALLENGER

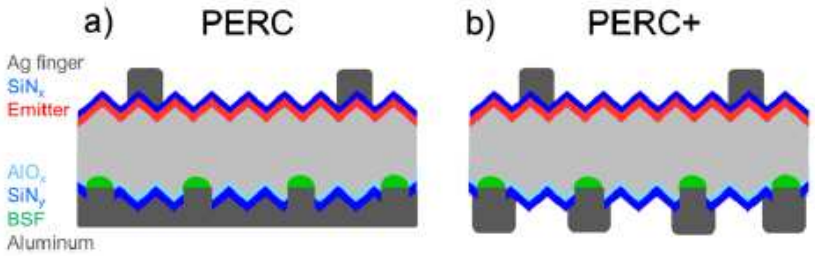


Rear reflectance: 90%
Rear recombination velocity: 60cm/s

Key features of PERC cell:

- Mass production: ŋ > 20.5%
- Record lab: ŋ = 22.1%
- p-type Cz
- 3 additional steps
- LID is not an issue anymore

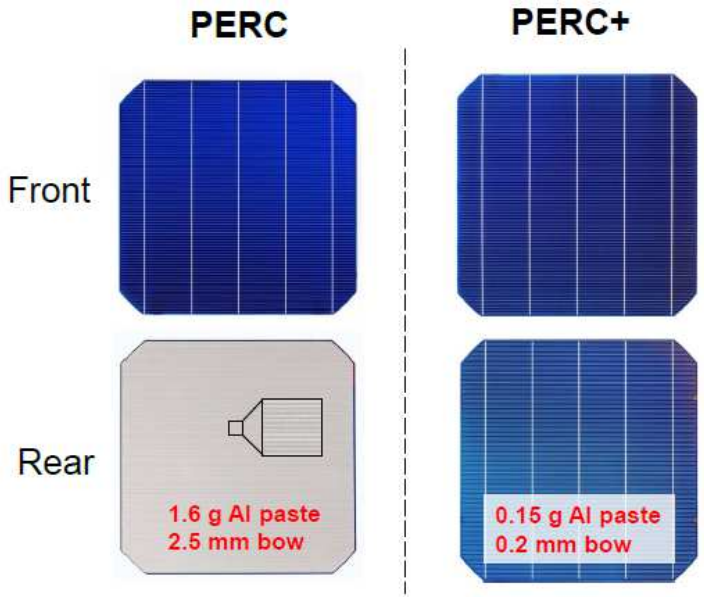
PV-Tech.org (05/07/2016)
Trina Solar pushes average P-type mono PERC cell efficiencies to 21.1%



- Conversion from PERC to PERC+
- In 2015: eta = 21% on large area
- In production @ Solarworld

Thorsten Dullweber et al. PERC+: industrial PERC solar cells with rear Al grid enabling bifaciality and reduced Al paste consumption, Prog. Photovolt: Res. Appl. (2015)

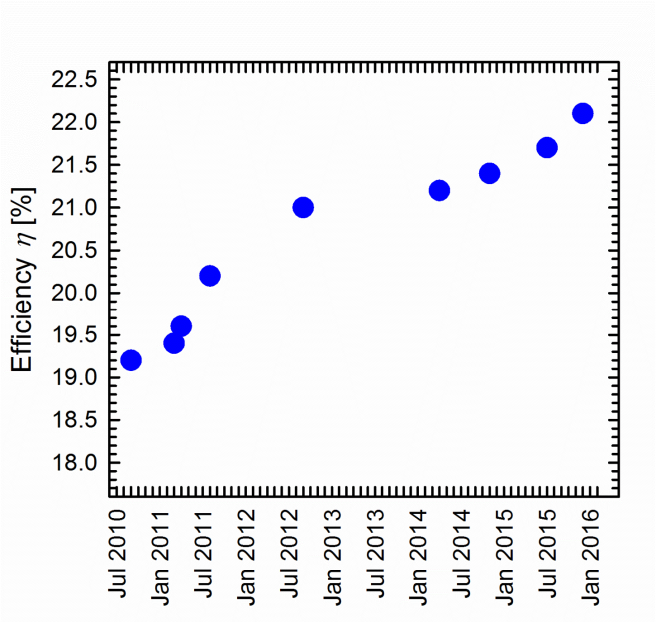
BIFACIAL PERC = PERC +



PERC+ @ ISFH

- η_{front} = 21.5%
- η_{rear} = 16.7%
- Bifaciality 80%

PERC+ in pilot production @ SolarWorld



- Improvement in PERC+ efficiency: 21.5%
- Expect 23% efficiency in 2 years
- More and more Al-BSF fabs are upgraded to p-PERC.

Thorsten Dullweber, NREL Workshop 2016

CONCLUSION

- **Larger choice in bifacial cell technologies**
- **Since 2014, regular improvements on PERT and HJT cells**
- **2015: PERC+ is one more serious competitor**
- **Alternatives: p-PERT, PERCT, n-PERT ML, Bifacial IBC**

- **Development of bifacial will be related to the race for higher efficiency and cost reduction.**
- **Bifaciality factor/rear efficiency is probably not the main driver**
- **Optimization for bifaciality can justified the path to > 5 busbars/half cells**

- **<u>Perspectives:</u>**
- → **In a short term and for efficiency < 22%, PERC is relevant**
- → **PERT could compete but cost n-type wafer and efficiency limitation are issues**
- → **For ŋ > 23%, heterojunction could be the best candidate**
- **Improvements in high quality wafers and production cost will be strong influents factors.**

MERCI POUR VOTRE ATTENTION

THANKS FOR YOUR ATTENTION

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