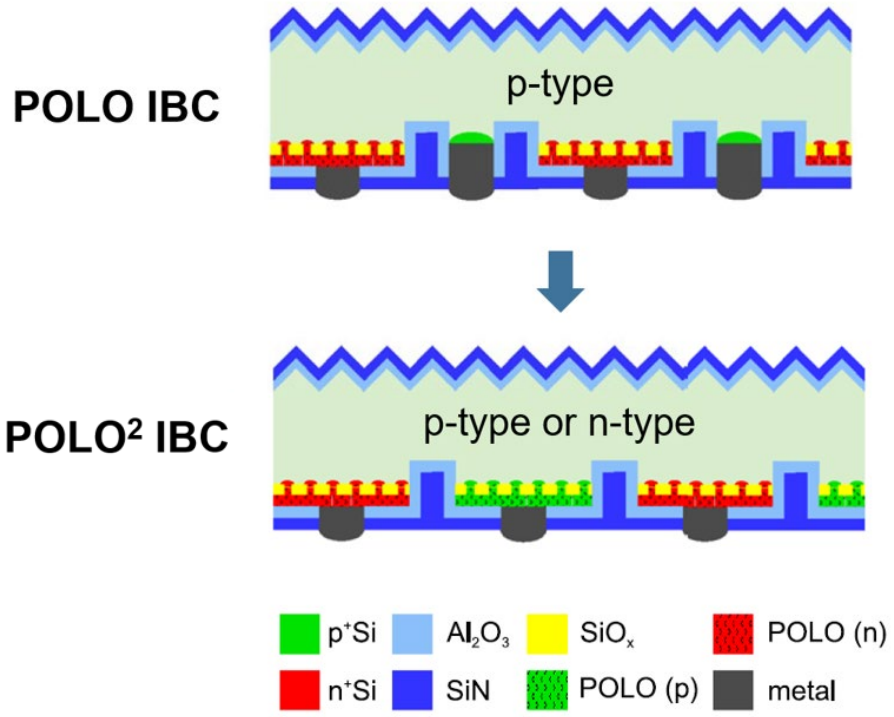


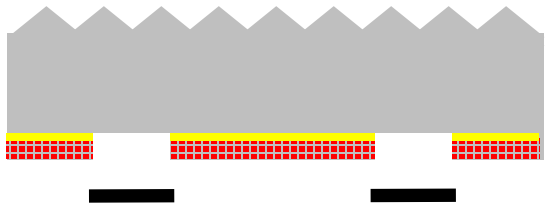
Industrial IBC cell technologies developed at ISFH

P. Jäger, Y. Larionova, T. Dullweber

Institute for Solar Energy Research Hamelin (ISFH), Germany

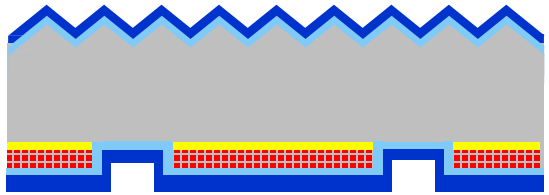
POLO IBC process flow with shadow mask

Texture &
rear polish

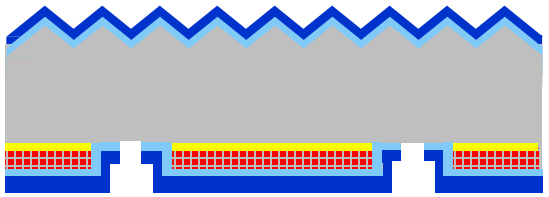


PECVD
SiO_xN_y/n-a-Si
w/ shadow mask

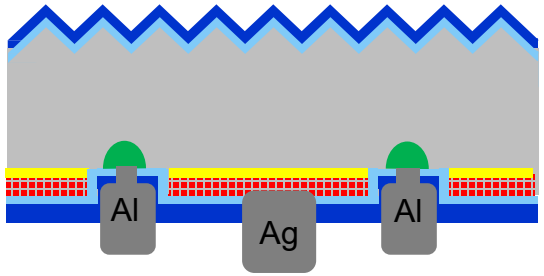
& Anneal



AlO_x/SiN
both sides



Laser contact opening

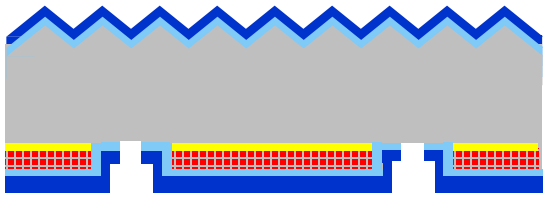


Ag and Al screen print
& firing

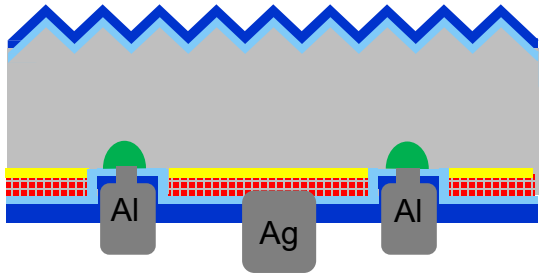
- Very lean POLO IBC process flow by ISFH[1],[2]

[1] T. Dullweber et al., 8th WCPEC (2022), p. 35 - 39
[2] V. Mertens et al., 40th EUPVSEC (2023), p. 020015

POLO IBC process flow with shadow mask



Laser contact opening

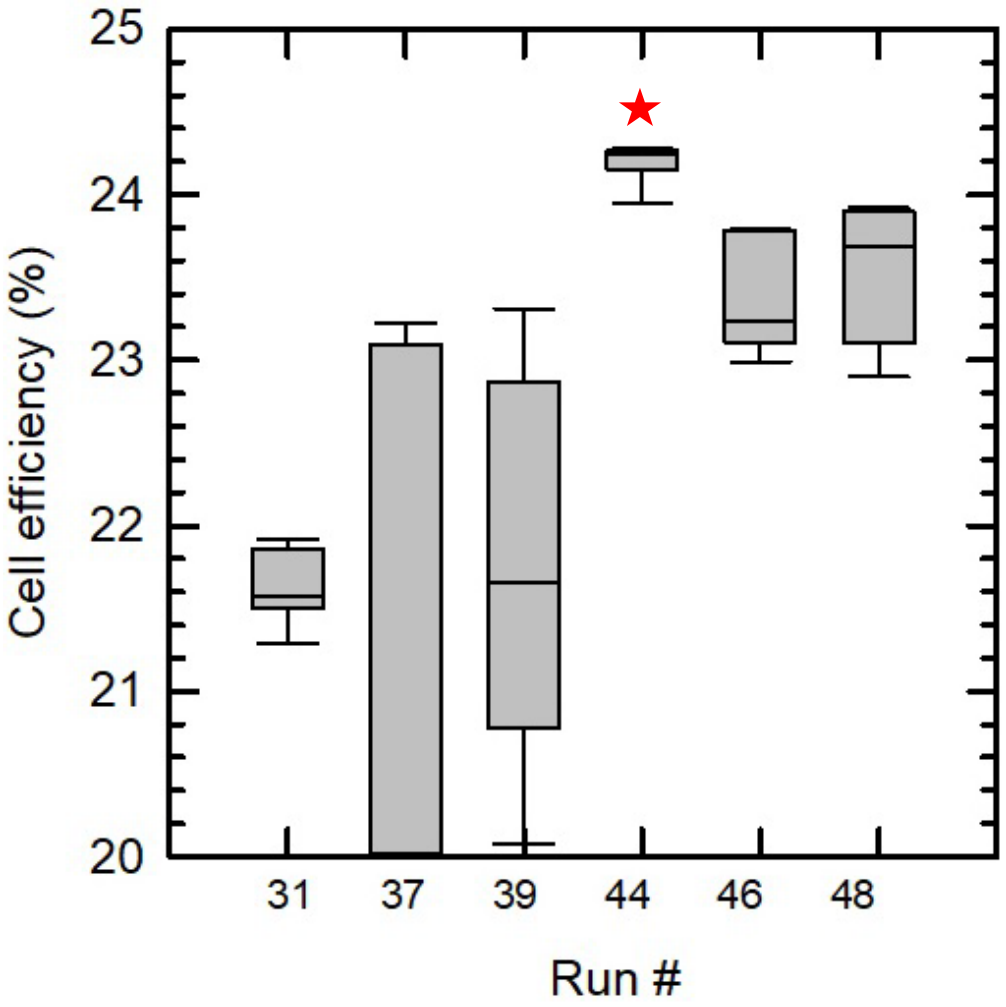


Ag and Al screen print & firing

- Very lean POLO IBC process flow by ISFH[1],[2]
- POLO IBC cells processed in ISFH SolarTeC on M2 wafer size. Upgrade to M10 in 2026

[1] T. Dullweber et al., 8th WCPEC (2022), p. 35 - 39
[2] V. Mertens et al., 40th EUPVSEC (2023), p. 020015

POLO IBC improvements of past 6 months

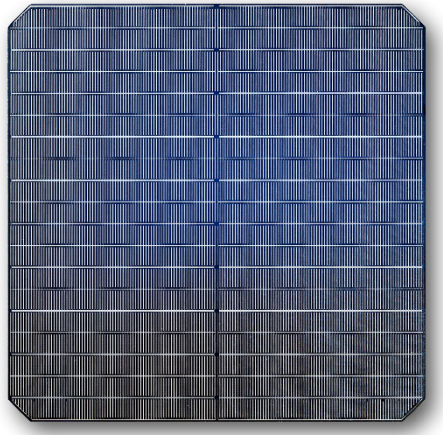


POLO IBC efficiency improvements:

- Reduced shunting by new mask conditioning
- Reduced reflection by optimizing ARC
- Optimized Ag finger profile

★ 24.5% measured by ISFH CalTeC

POLO IBC best efficiencies

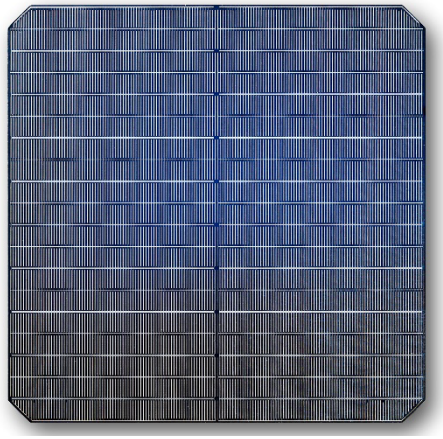


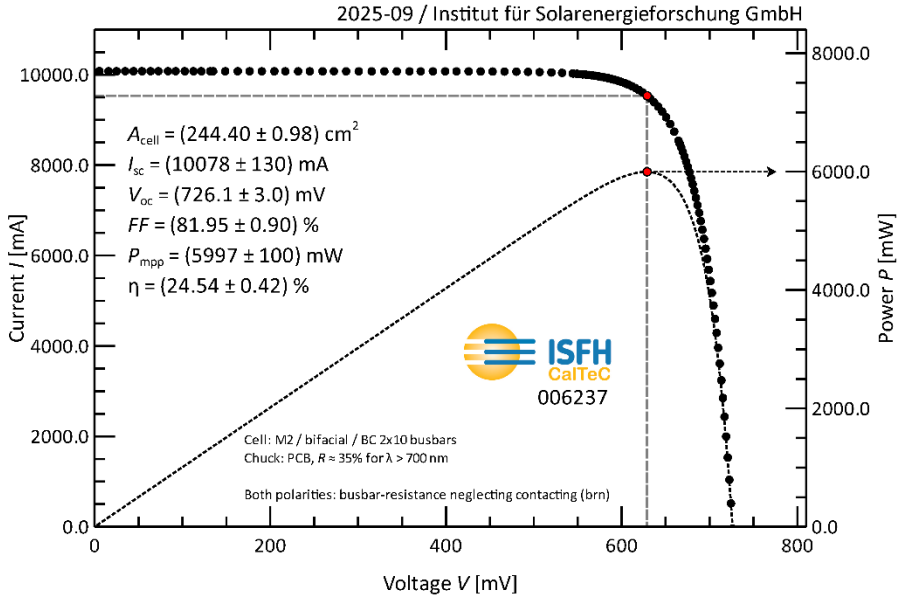
Date	Efficiency [%]	V_{oc} [mV]	J_{sc} [mA/cm^2]	FF [%]
08/2024	23.9	720	41.1	80.5
01/2025	24.1*	723	40.8	81.5

Lower poly anneal temperature and contact pads

* Independently confirmed by ISFH CalTeC

POLO IBC best efficiencies





Date	Efficiency [%]	V_{oc} [mV]	J_{sc} [mA/cm²]	FF [%]
08/2024	23.9	720	41.1	80.5
01/2025	24.1*	723	40.8	81.5
09/2025	24.5*	726	41.2	82.0

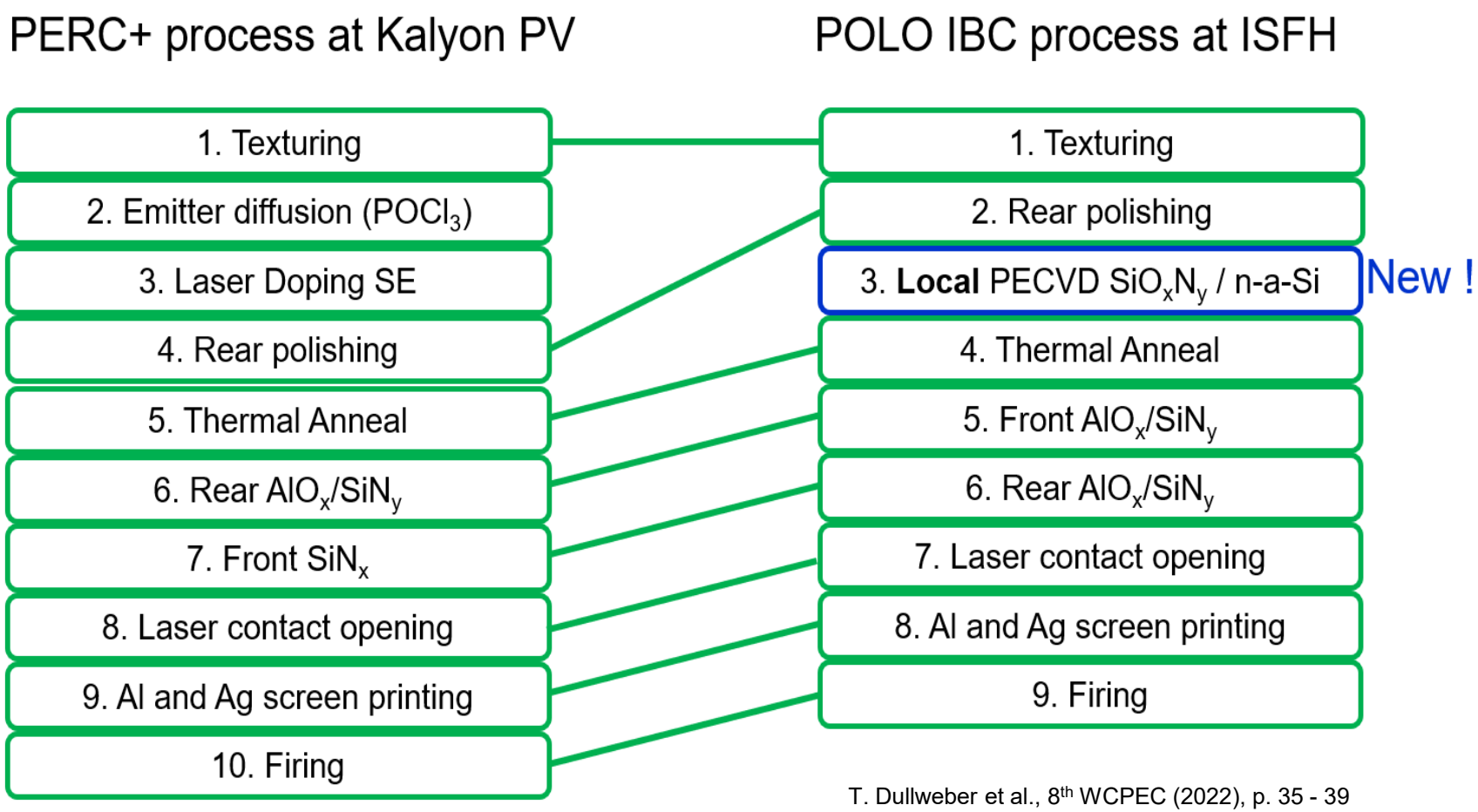
- Lower poly anneal temperature and contact pads
- Improved ARC and improved metallization

* Independently confirmed by ISFH CalTeC

POLO IBC transfer to Kalyon PV production line

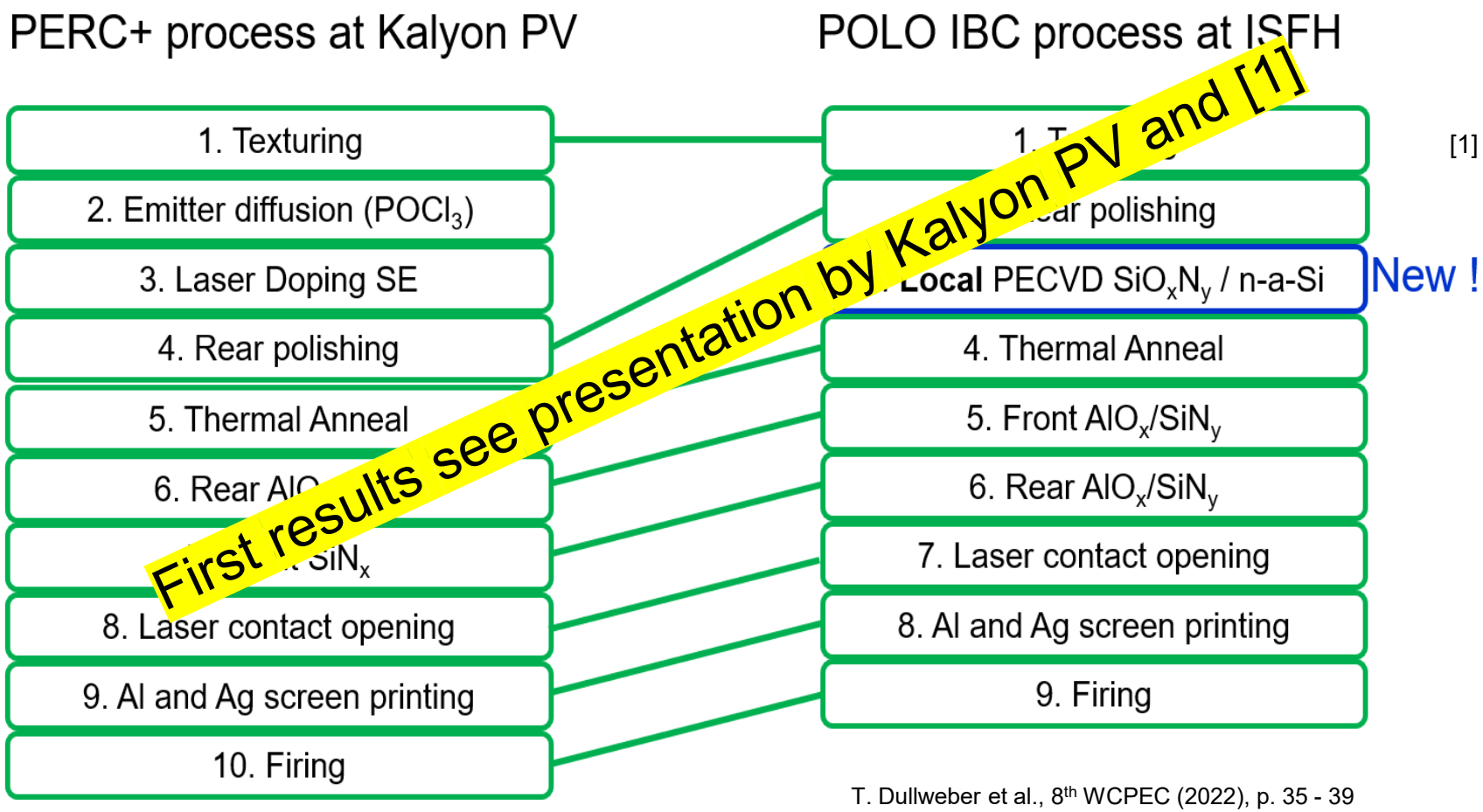
- Kalyon PV operates a 2 GWp fully integrated production facility for ingot, wafer, cell, module
- Presently, mass production of M10-sized PERC+ cells is ongoing and an investment in G12R-sized TOPCon+ technology is planned
- POLO IBC is a potential $\Delta\eta = 1\%_{abs}$ efficiency upgrade
- POLO IBC technology licensed by ISFH to Kalyon PV in 2024. Technology transfer started.

POLO IBC transfer to Kalyon PV production line



T. Dullweber et al., 8th WCPEC (2022), p. 35 - 39

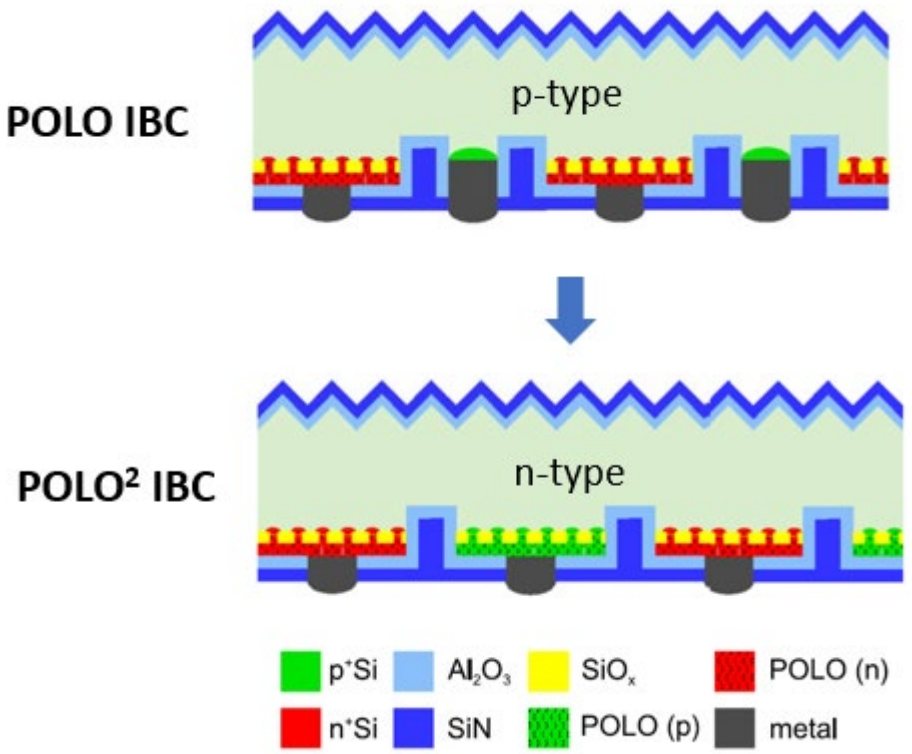
POLO IBC transfer to Kalyon PV production line



T. Dullweber et al., 8th WCPEC (2022), p. 35 - 39

[1] T. Dullweber et al., EPJ Photovoltaics 16, 30 (2025)

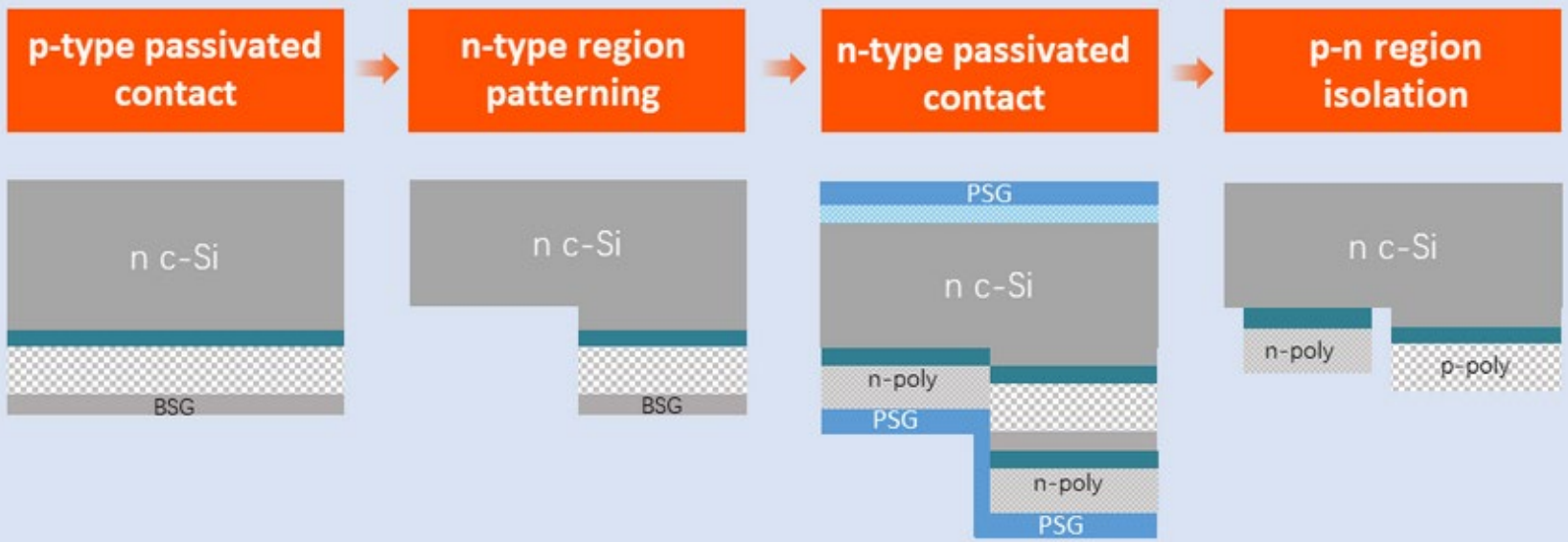
POLO IBC upgrade to POLO² IBC



- Al-BSF contact limits POLO IBC efficiency to < 25.5%[1]
- Wet chemical SiO_x and LPCVD p-poly-Si stack developed[2] with $J_{0,p\text{-}poly}$ = 2 fA/cm²
- Development of novel industrial POLO² IBC process with target efficiency > 26.0%

[1] C. N. Kruse et al., Scientific Reports, 11, 996 (2021)
[2] E. Hoffmann et al., Proc. 41st EUPVSEC (2024), p. 020020

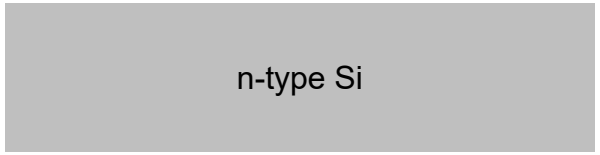
POLO² IBC: how to manufacture it best ?



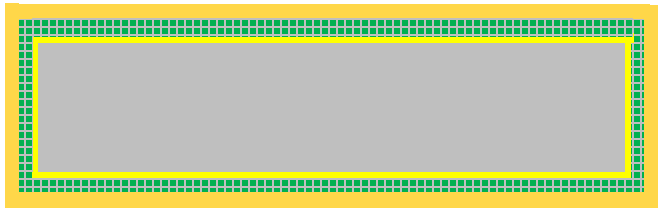
[1] https://aikosolar.com/en/the-worlds-most-efficient-solar-technology/
[2] Taiyang News, Solar Cell Production Equipment Report 2025, page 11

- IBC process sequence proposed in Asia [1,2]
- n-poly removal above p-poly challenging since laser or etch could damage p-poly
- Our approach: leave n-poly on top of p-poly as tunnel junction and only insulate trench region between n-poly and p-poly

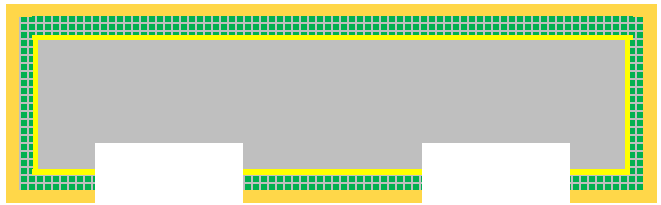
POLO² IBC industrial process flow with novel trench insulation[1]



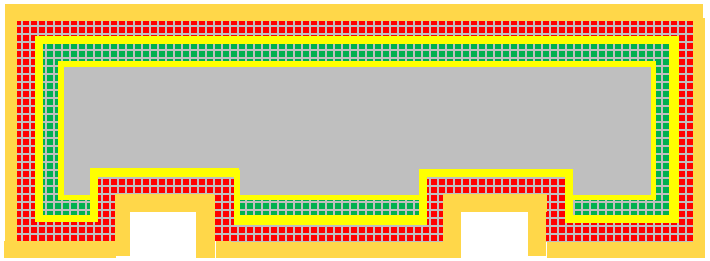
1. SDE, wet chemical oxide



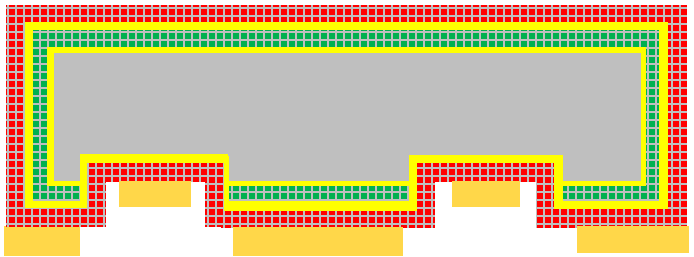
2. LPCVD p-poly-Si
3. Anneal incl. oxidation



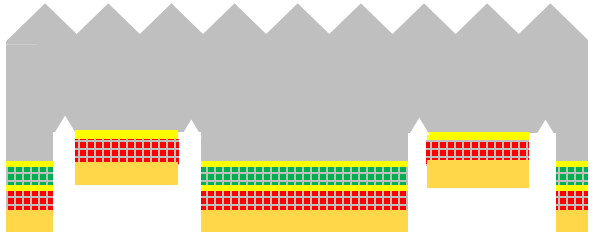
4. Laser ablation
5. Wet etch, wet chemical oxide



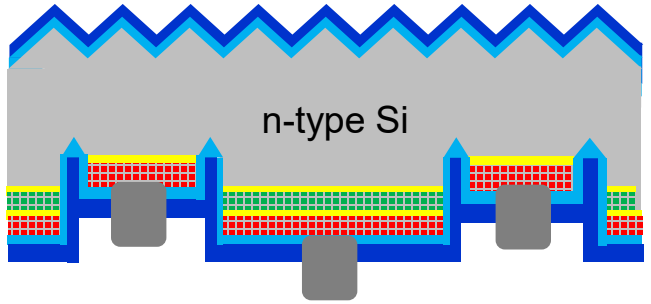
6. LPCVD or PECVD n-poly-Si
7. Anneal incl. oxidation



8. Single-sided etch front
9. Laser ablation trench



10. Texture and barrier removal



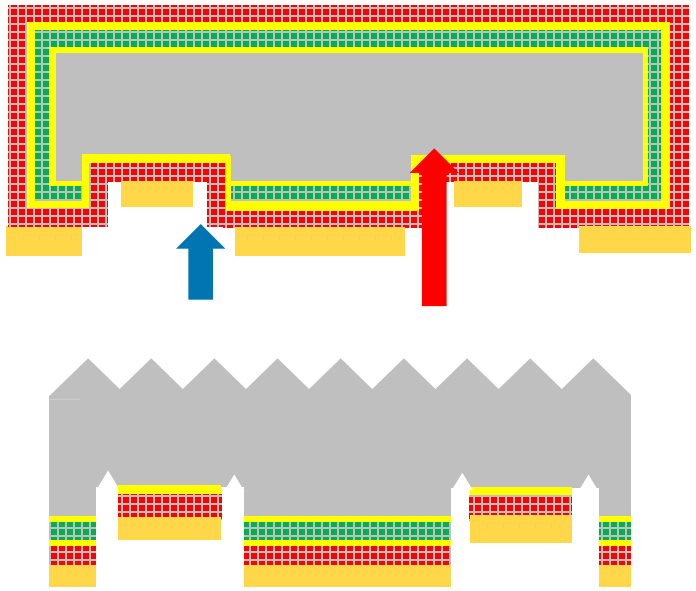
11.+12. PECVD AlO_x/SiN both sides
13 - 15. Screen printing of Ag paste and firing

[1] ISFH Patent pending

POLO² IBC industrial process flow with novel trench insulation[1]

Advantages of trench insulation

- Laser ablation allowed to damage p-poly-Si → cheap IR laser



8. Single-sided etch front
9. Laser ablation trench

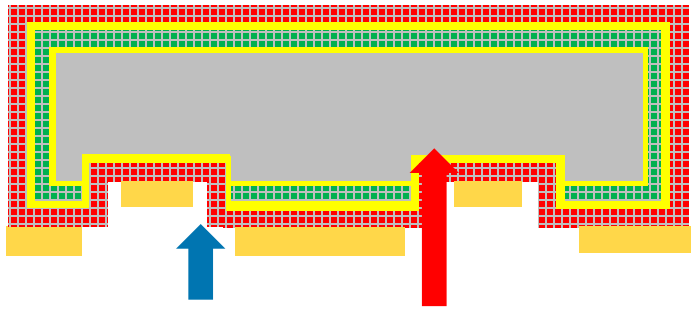
10. Texture and barrier removal

[1] ISFH Patent pending

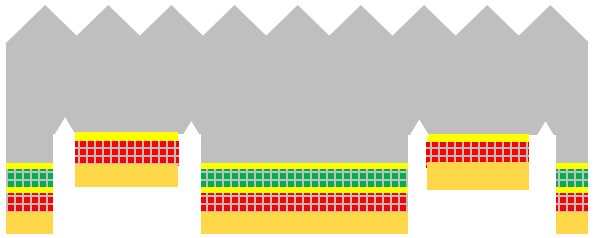
POLO² IBC industrial process flow with novel trench insulation[1]

Advantages of trench insulation

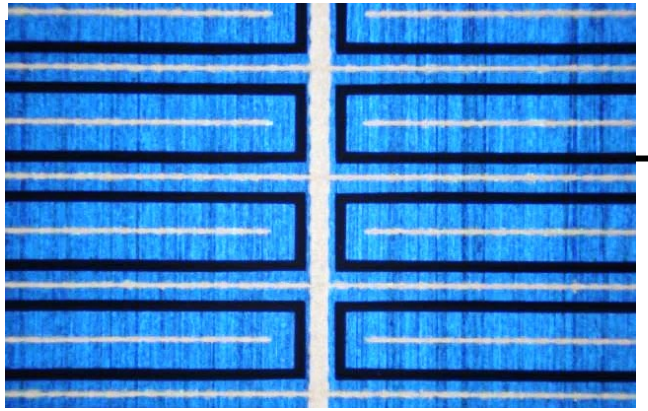
- Laser ablation allowed to damage p-poly-Si → cheap IR laser
- Only about 10% of the wafer surface is lasered → short process time
- n-poly-Si etch does not have to stop on p-poly → no etch stop layer required
- Short IBC process sequence by etching with texture



8. Single-sided etch front
9. Laser ablation trench



10. Texture and barrier removal

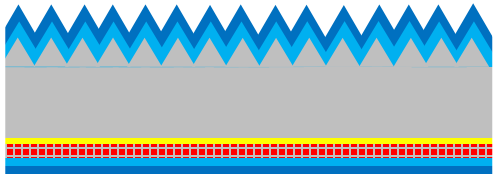


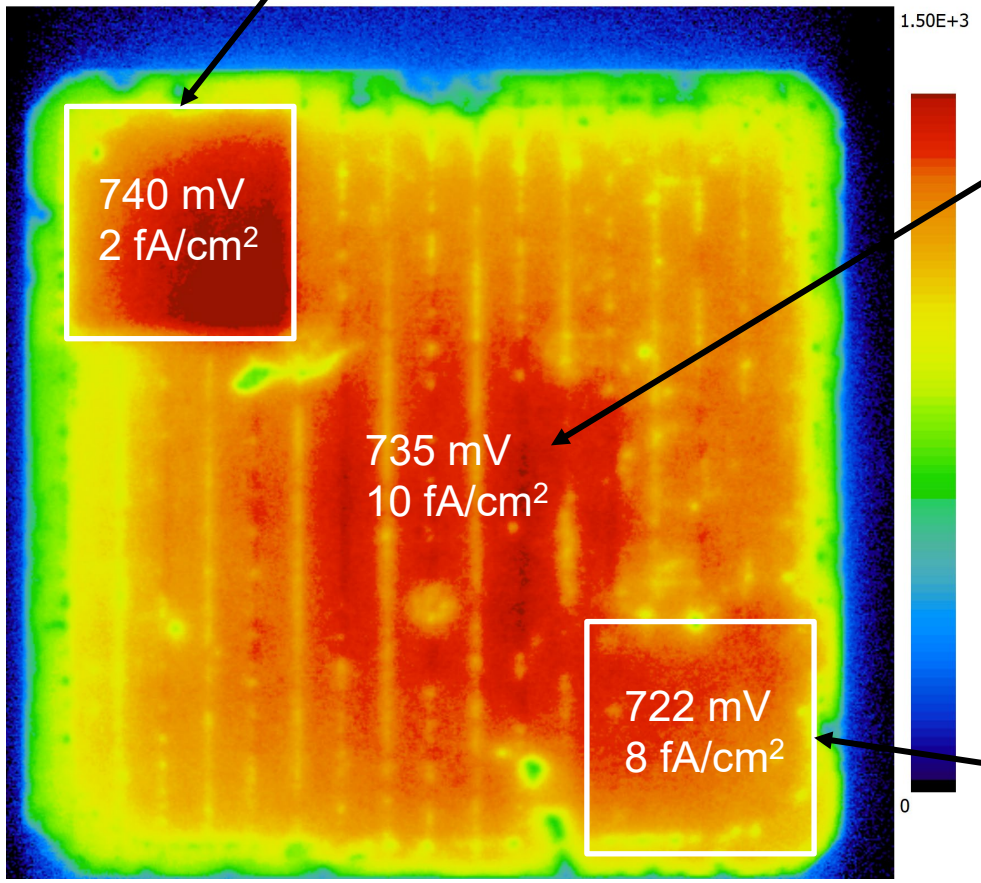
Trench insulation

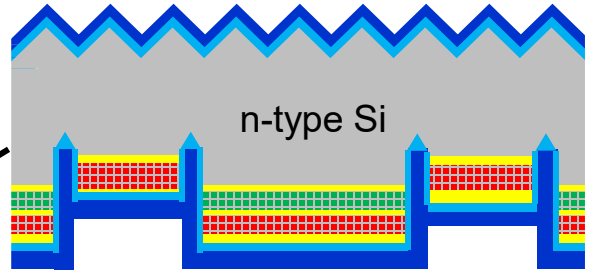
[1] ISFH Patent pending

POLO² IBC cell precursor results

n-poly field







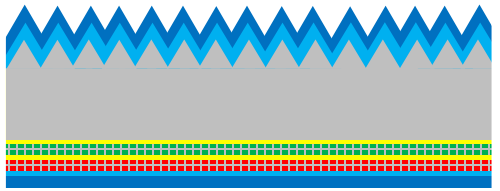
Fully processed

$$i\eta = iV_{oc} \times iFF \times J_{sc} / P_{light}$$

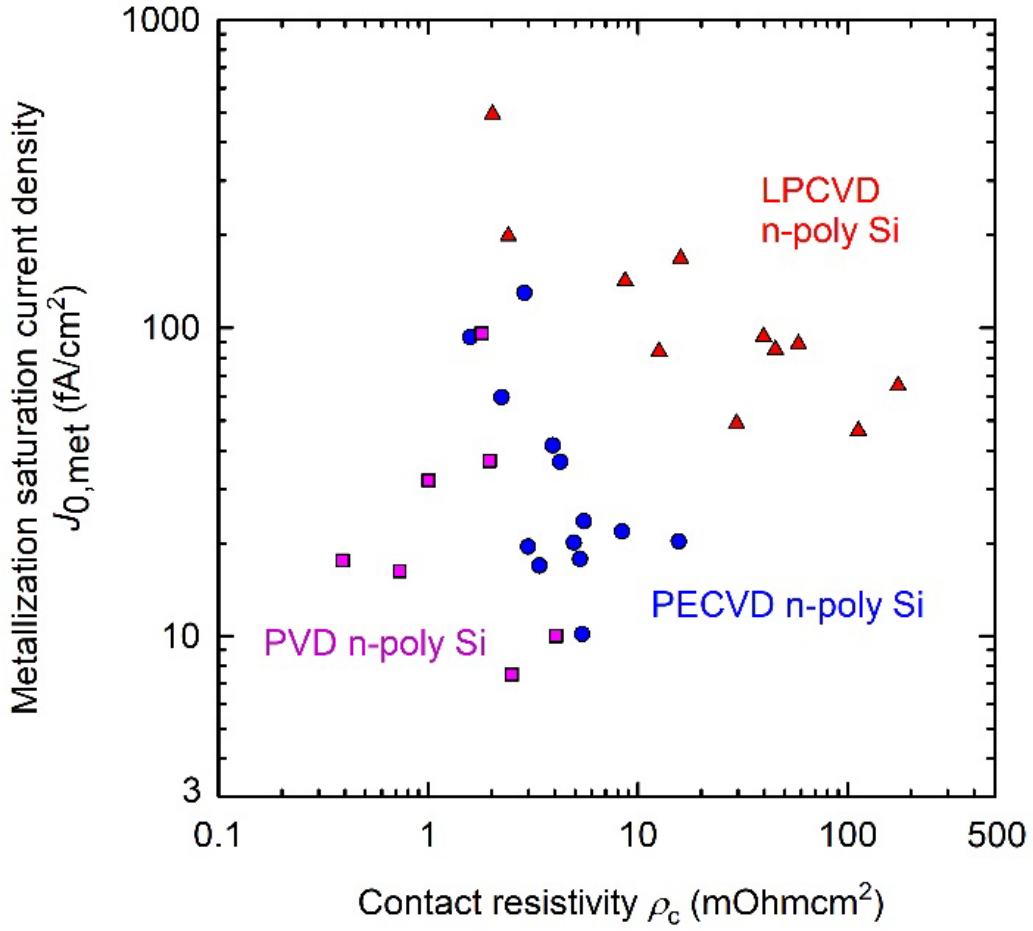
= 735 mV × 86.0% × 41.7 mA/cm² / 100 mW/cm²

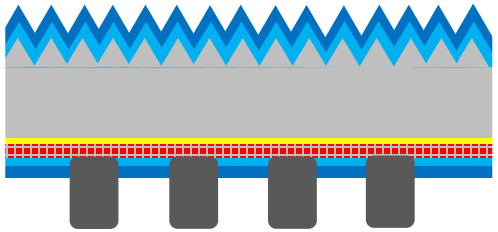
= 26.4%

p-poly / n-poly stack



Evaluation of screen-printed Ag contacts

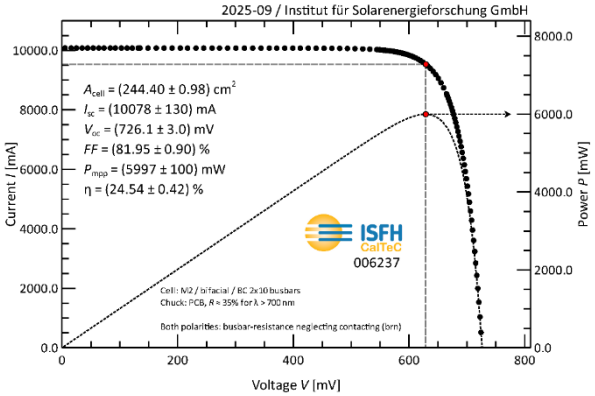




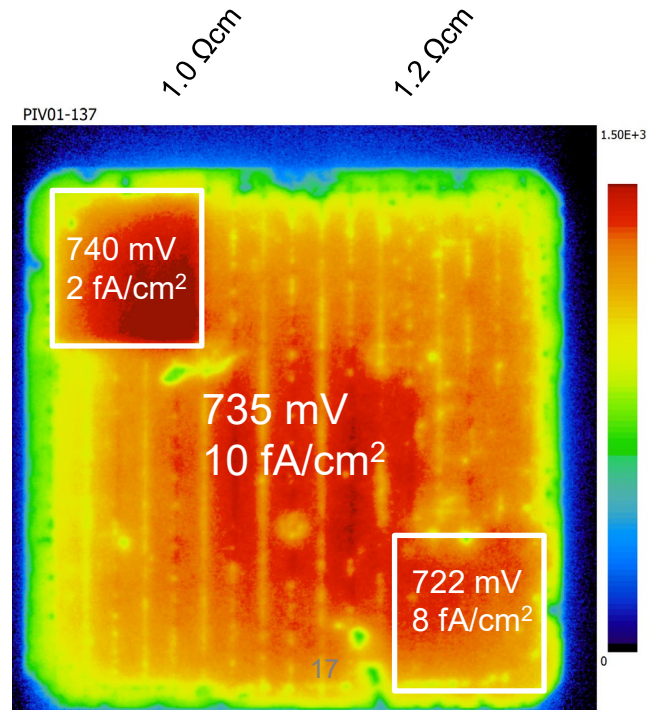
- Evaluation of different Ag pastes and different deposition methods for n-poly contacting
- $J_{0,met}$ and ρ_c determined by PL and TLM test structures
- Ag contact properties strongly depend on n-poly deposition method.
- PECVD good candidate chosen for first POLO^2 IBC cell run, currently in processing

Conclusions

- POLO IBC efficiency improved to 24.5% @ ISFH SolarTeC
- POLO IBC technology transfer to Kalyon PV production line ongoing



- $POLO^2$ IBC cell technology with novel trench insulation in development at ISFH SolarTeC
- Lifetime precursors demonstrate iV_{oc} = 735 mV and iFF = 86.0% corresponding to $i\eta$ = 26.4%
- Ag contact properties strongly depend on n-poly deposition method. First cell run with PECVD n-poly ongoing



Acknowledgements

- Funding was provided by the European Union (IBC4EU project), the German Federal Ministry for Economic Affairs and Energy (Olivia project), by the State of Lower Saxony, Kalyon PV and EnPV.

- **Thank you for your attention !**

IBC4EU

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

State of Lower Saxony, Gemany