P-IBC: COMBINING PERC AND TOPCON

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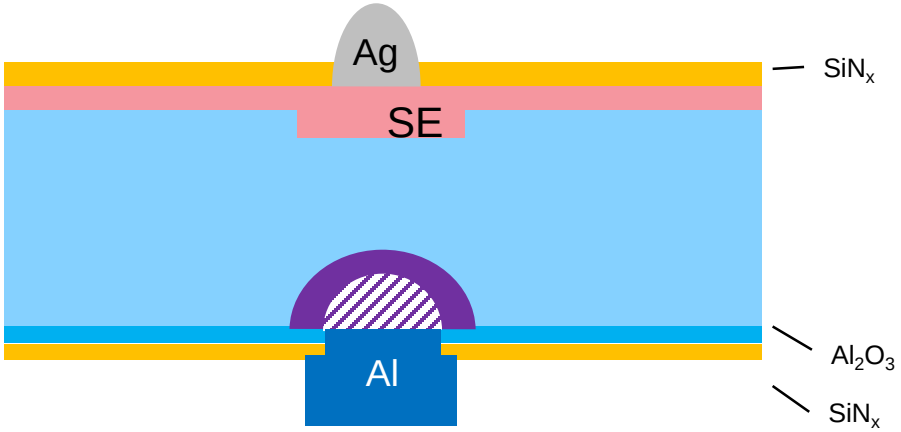
N. GUILLEVIN
A.R. BURGERS
Y. WU

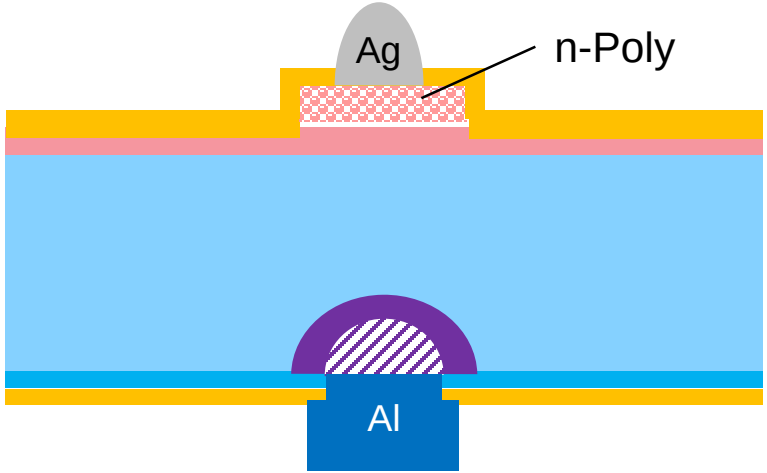
ECN › TNO innovation for life

PERC AND WHAT NEXT?



Industry : ~22.3% efficiency

PERC AND WHAT IS NEXT?



Poly fingers

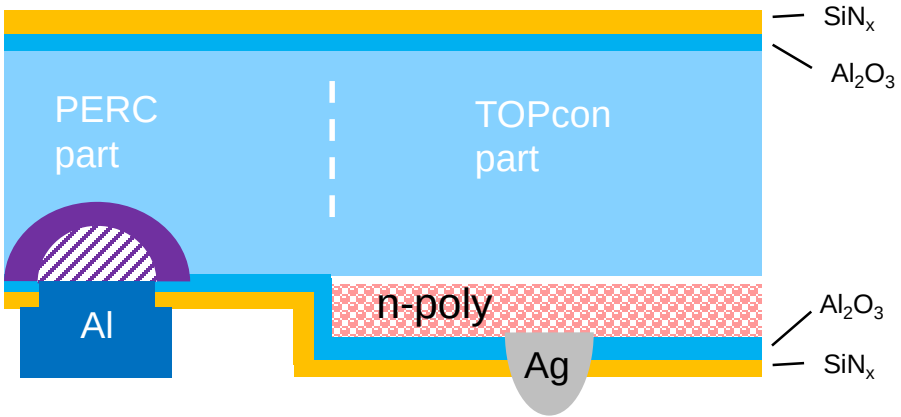
Driver

- $J_{0,Ag}$ reduction

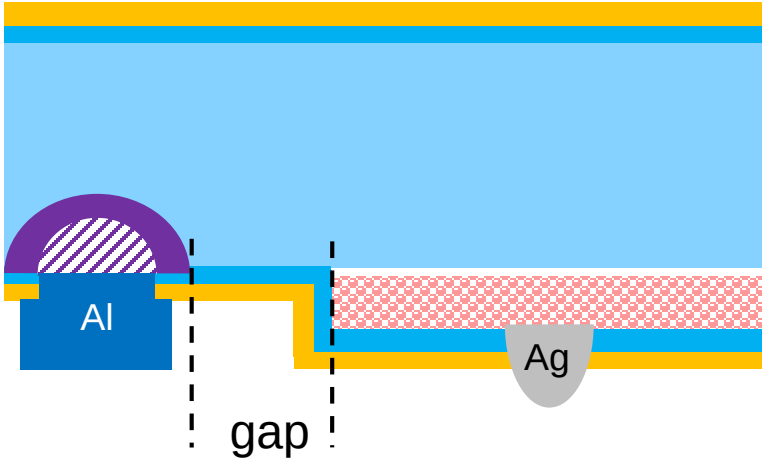
Challenges

- Alignment
- Parasitic absorption
- Processing

P-IBC: COMBINING PERC AND TOPCON



P-IBC



Advantages

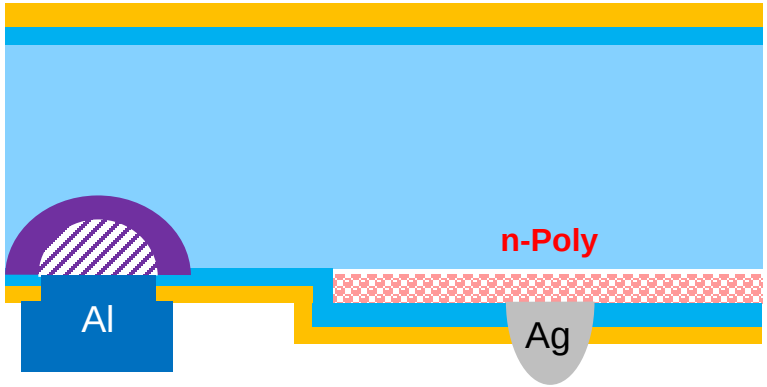
- No front-side shadow
- No Boron-diffusion → gap “for free”
- Ag & Al metallization, like PERC
- n-poly on rear side
  - Low parasitic absorption
- Huge market for “*ultra blacks*”

Requirements

- Modified module interconnection
- Double-sided Al_2O_3
- Patterning n-poly with **simple** process

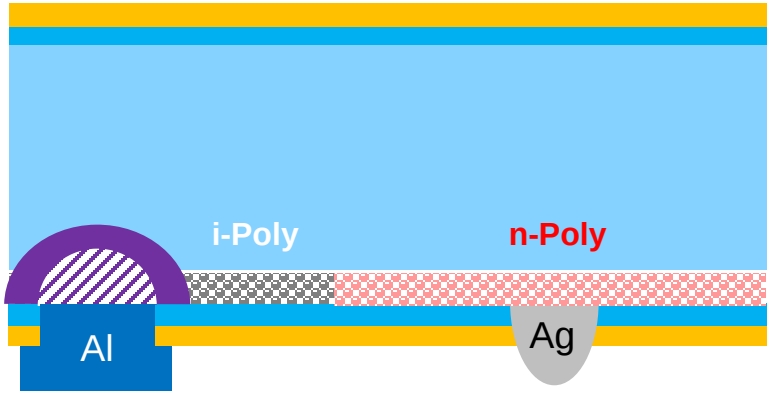
TWO ARCHITECTURES

A



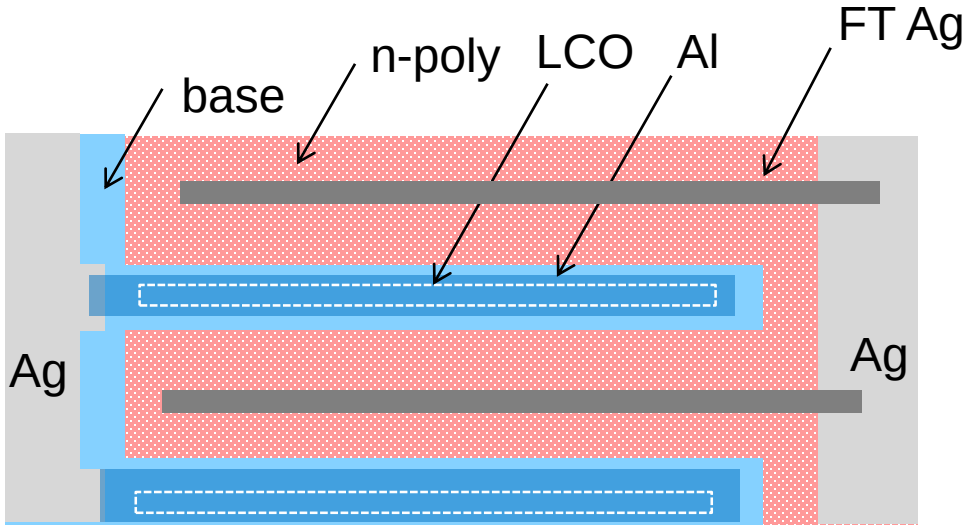
Local etching n-poly

B



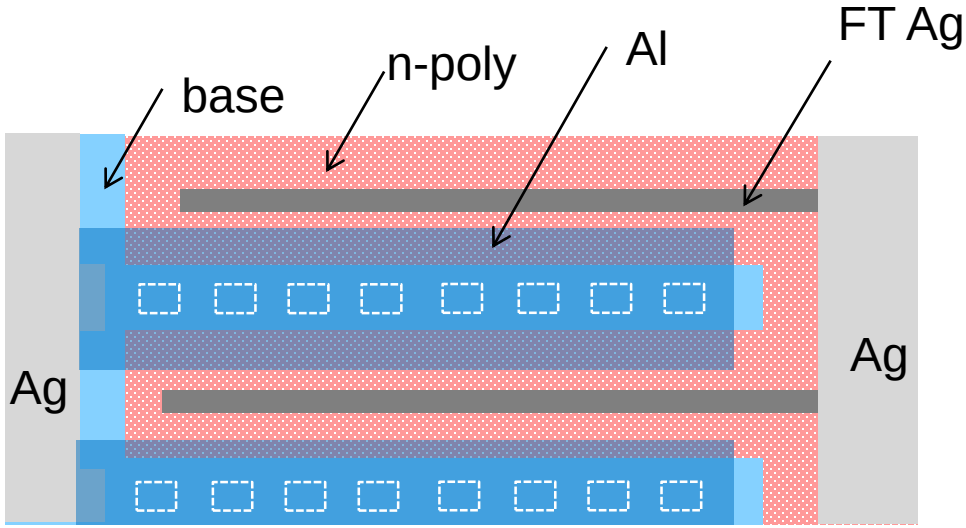
Diffusion barrier process

METALLIZATION OPTION 1



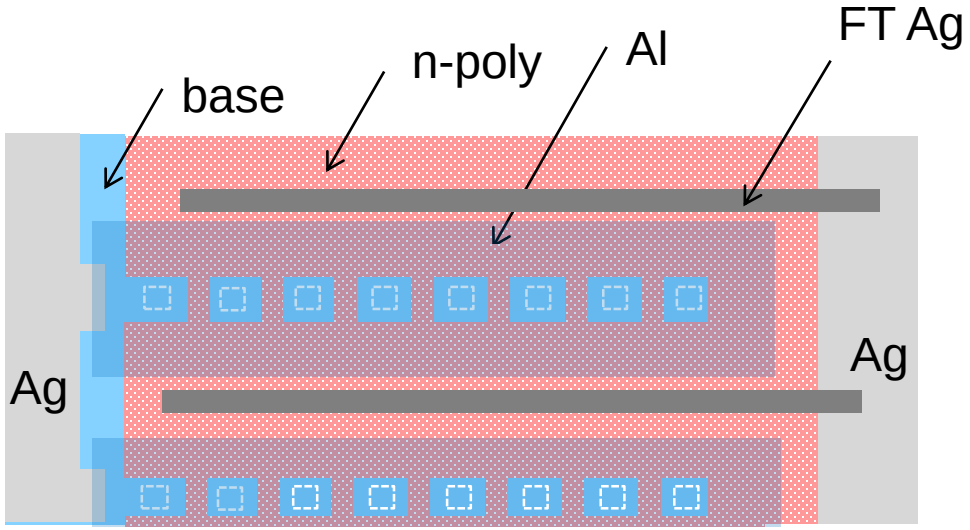
- Base region: line-shaped
- BSF: line-shaped

METALLIZATION OPTION 2



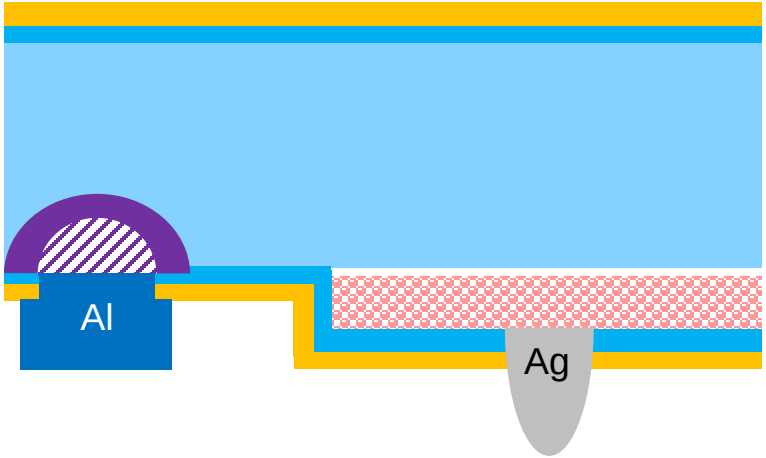
- Base region: line-shaped
- BSF: **dot**-shaped

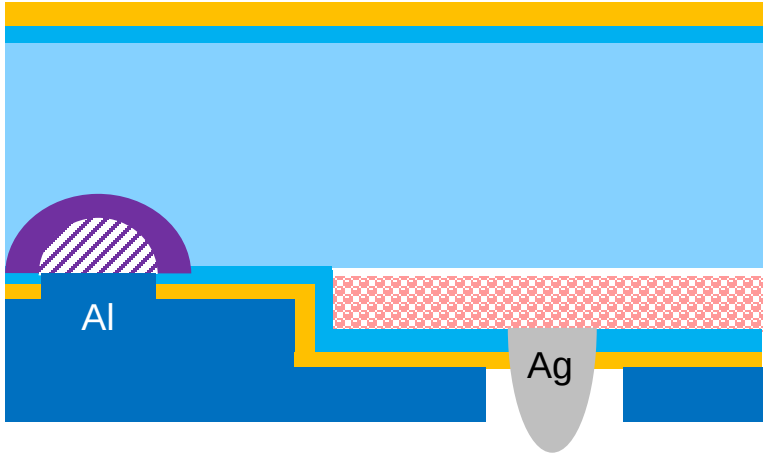
METALLIZATION OPTION 3



- Base region: **dot**-shaped
- BSF: **dot**-shaped

FREEDOM IN METALLIZATION

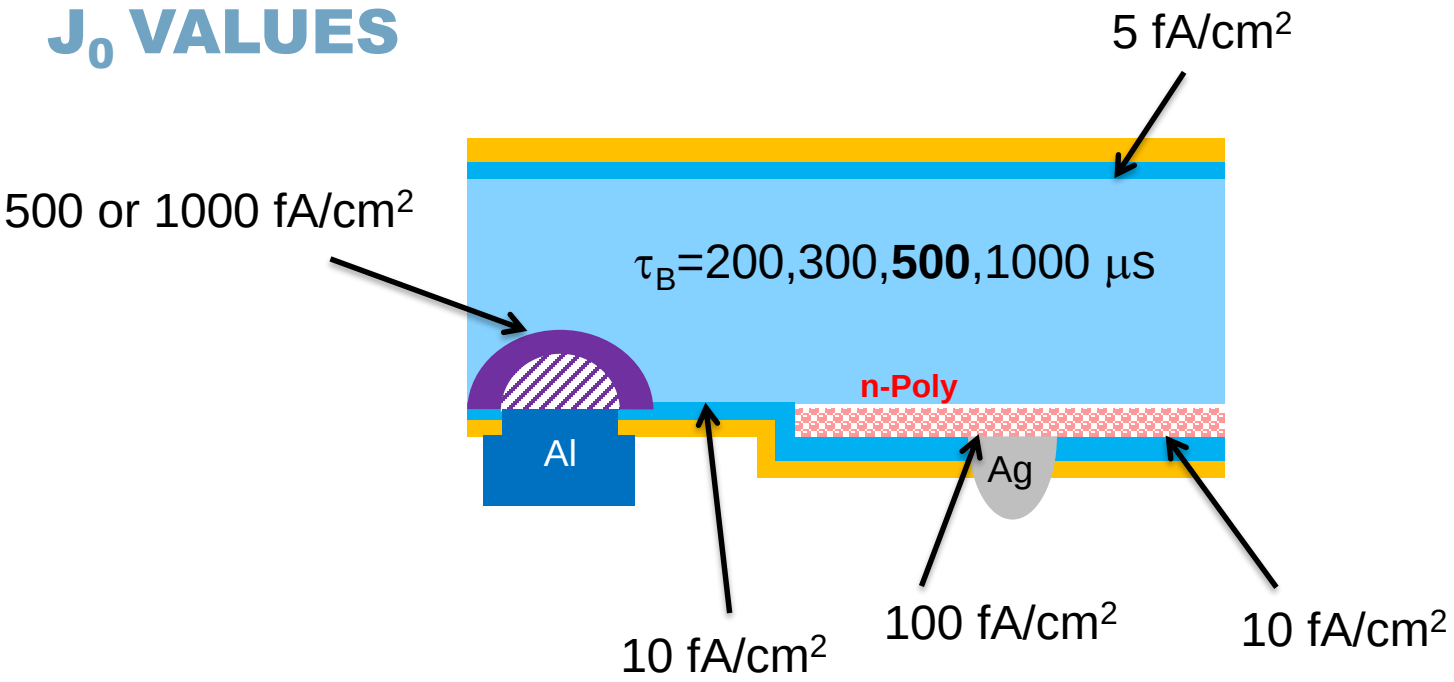




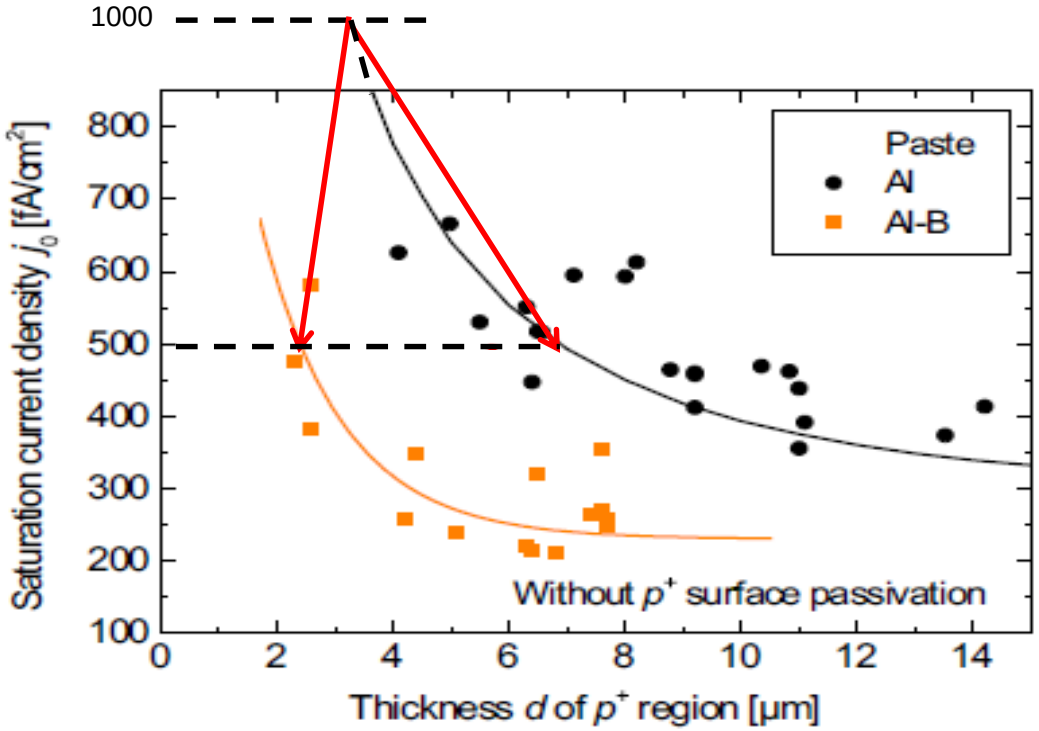
- No shunt
- Alignment requirement

- Measures to prevent shunt required
- Relaxed alignment
- Better conduction

QUOKKA 3D J_0 VALUES



REDUCING $J_{0,AL}$

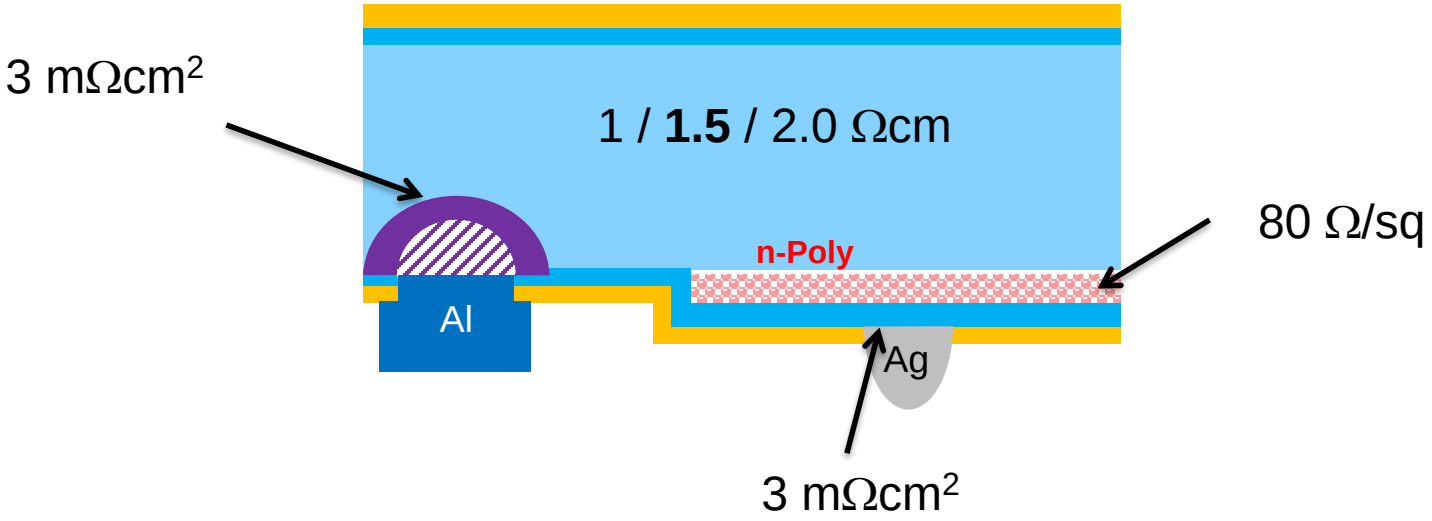


500 fA/cm^2

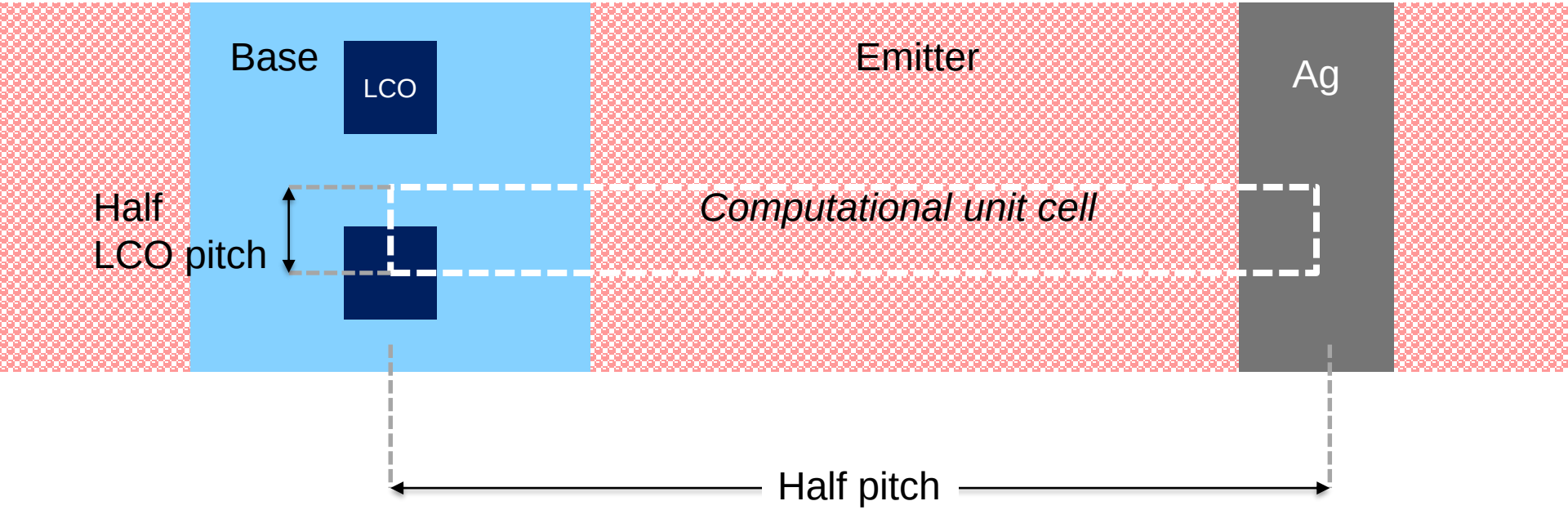
- 7 um Al-BSF
- 2.5 um B-Al BSF

M. Rauer et al, IEEE JPV, 2013

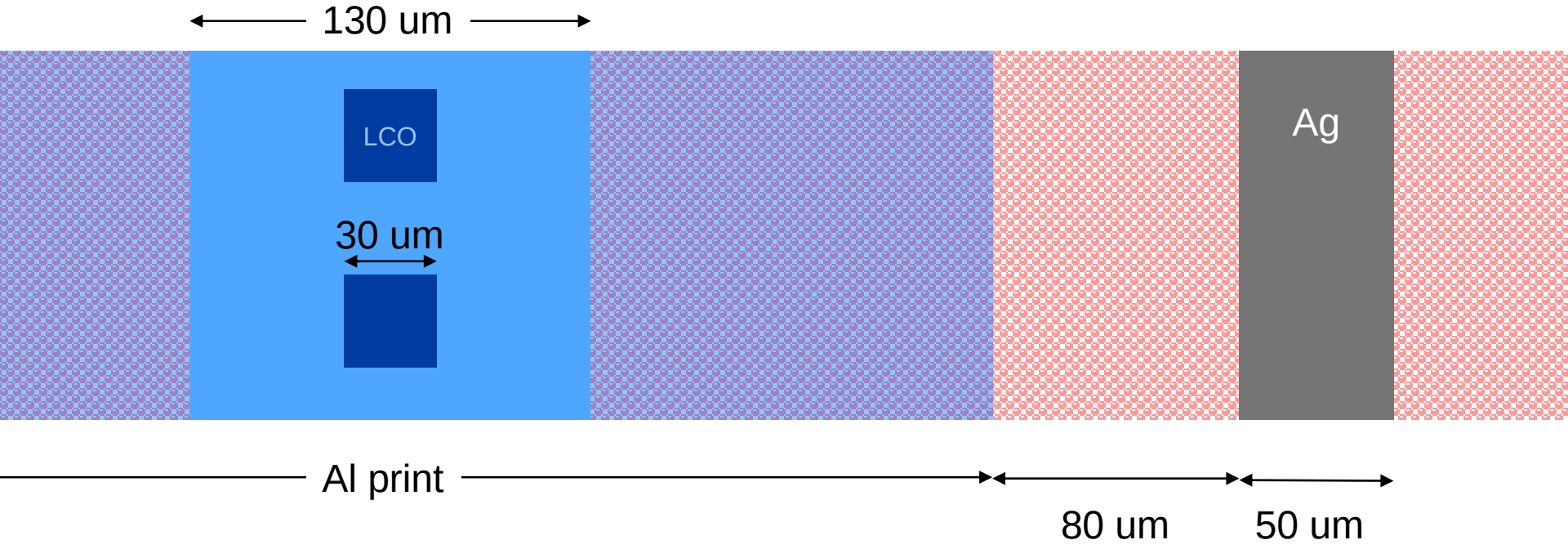
QUOKA 3D RESISTANCES



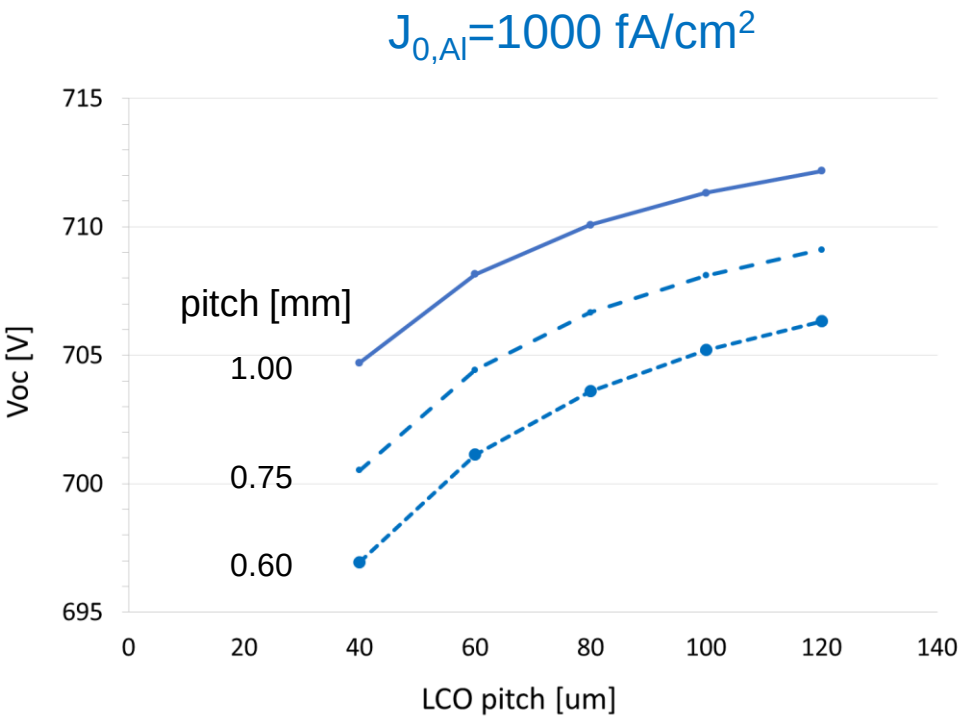
QUOKKA 3D METALLIZATION OPTION 2

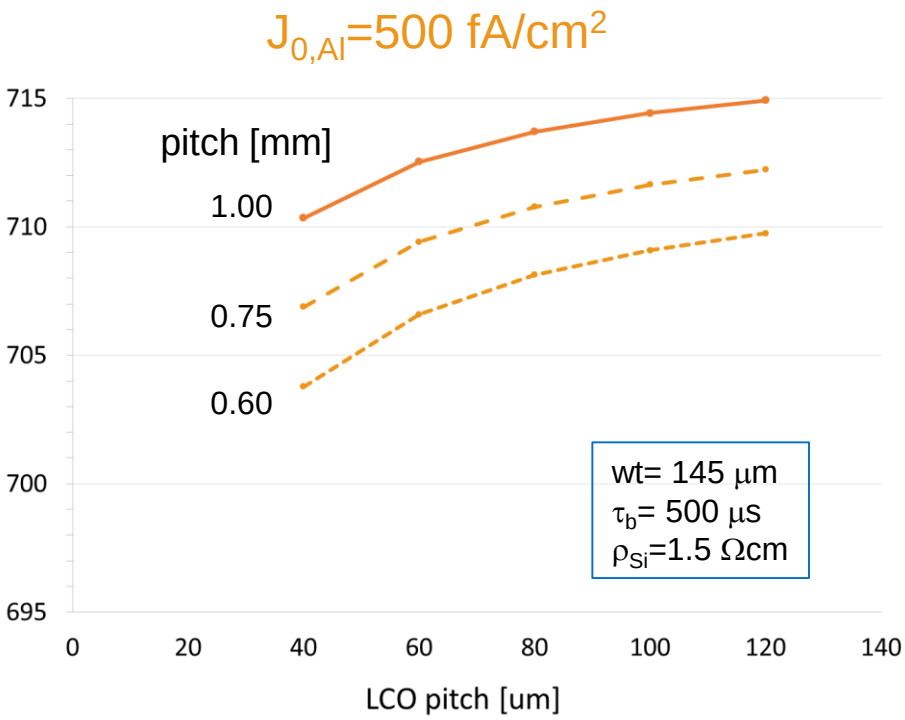


ASSUMED AL COVERAGE



Voc


$J_{0,Al}$=1000 fA/cm^2
715
710
705
700
695
Voc [V]
pitch [mm]
1.00
0.75
0.60
0
20
40
60
80
100
120
140
LCO pitch [um]

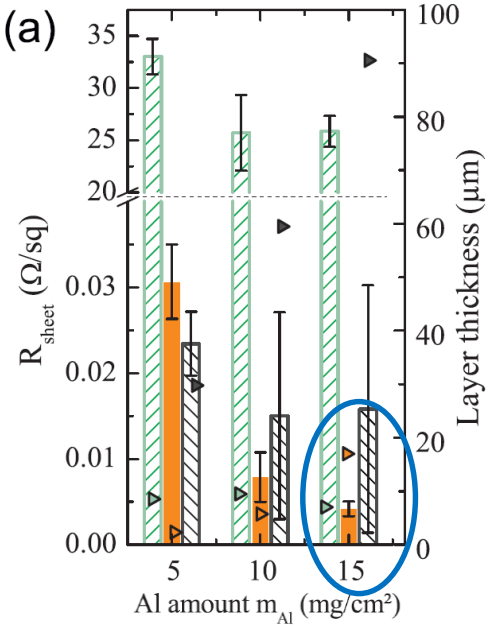

$J_{0,Al}$=500 fA/cm^2
715
710
705
700
695
pitch [mm]
1.00
0.75
0.60
wt= 145 µm
τ_b= 500 µs
ρ_{Si}=1.5 Ωcm
0
20
40
60
80
100
120
140
LCO pitch [um]

AL CONDUCTION

Assumptions

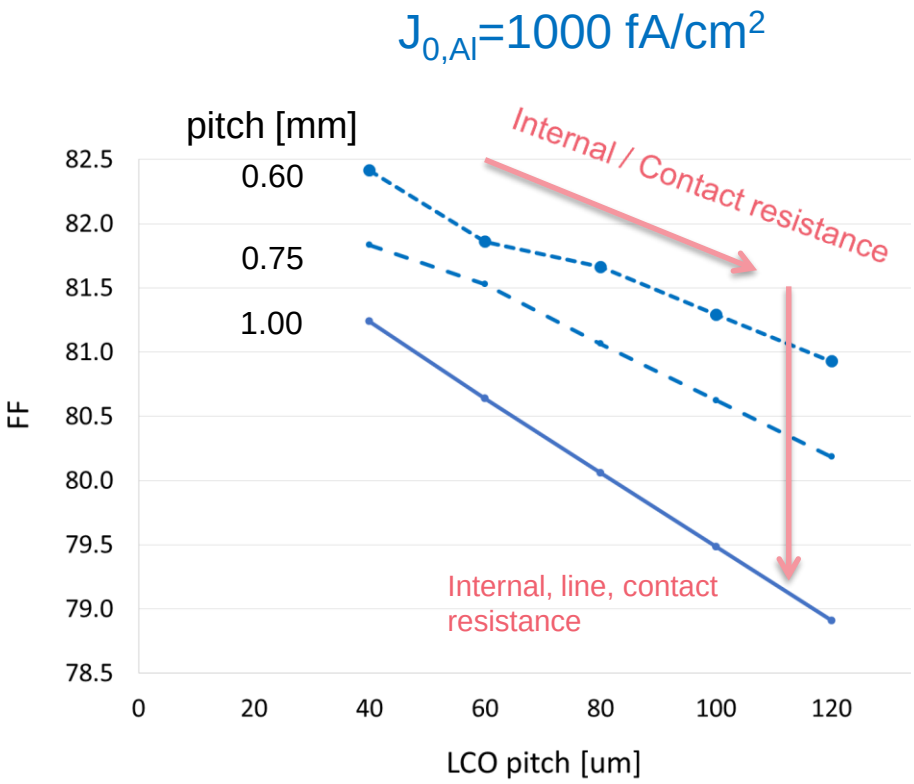
R_{sh} [mΩ/sq]

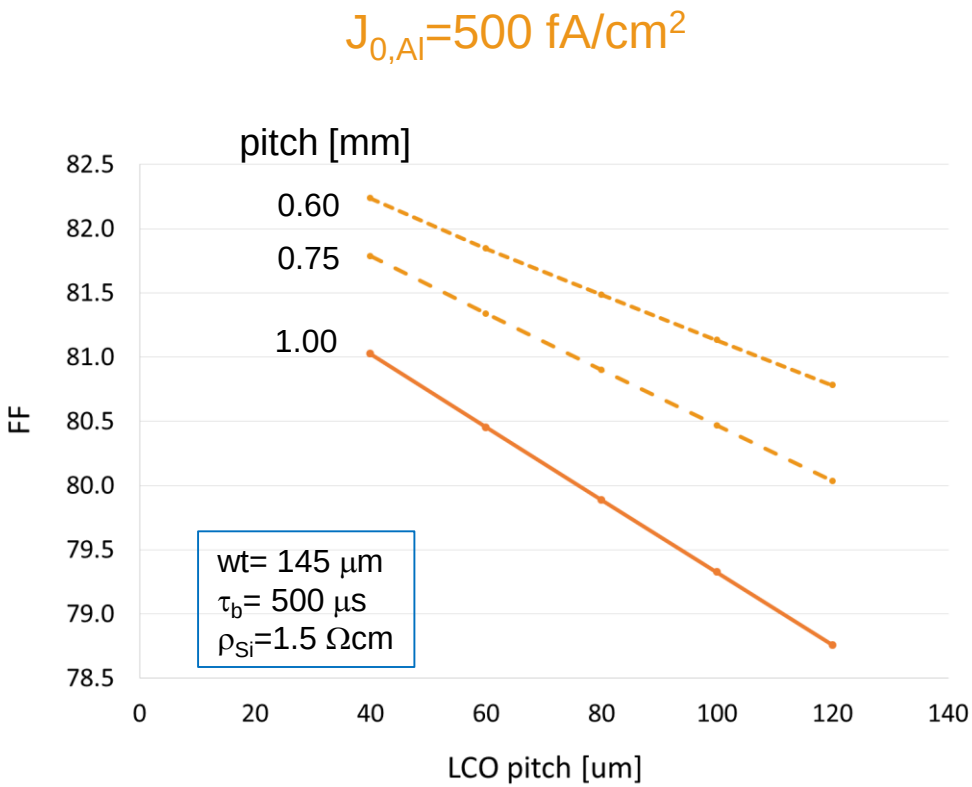
BSF:	25,000
Al-Si alloy:	4
Al-bulk:	16



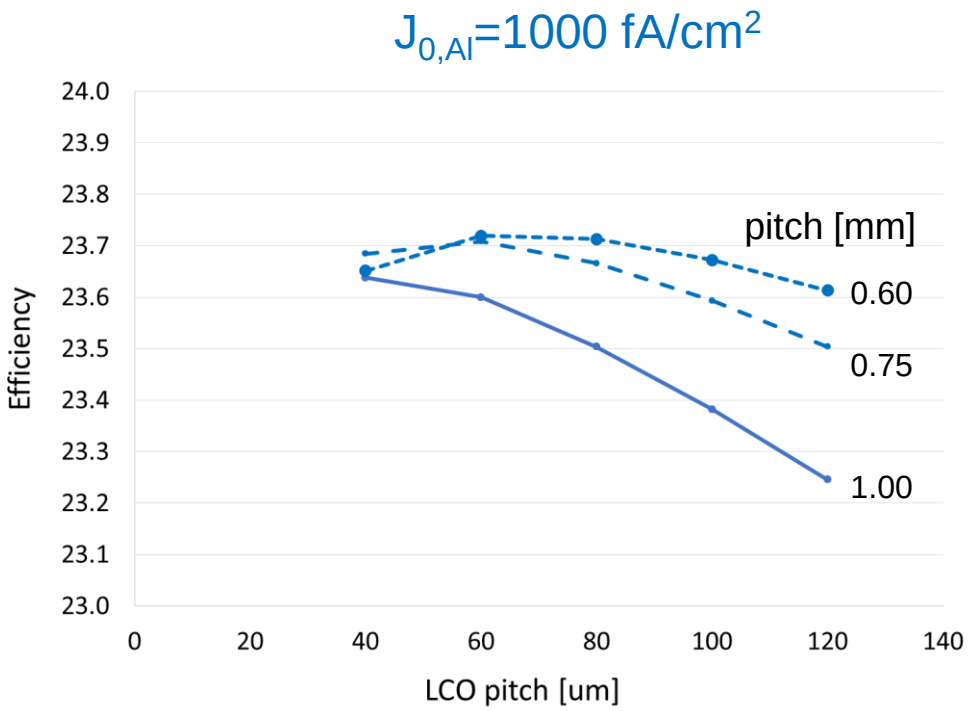
J. Krause et al., Sol. Mat. 95 (2011)

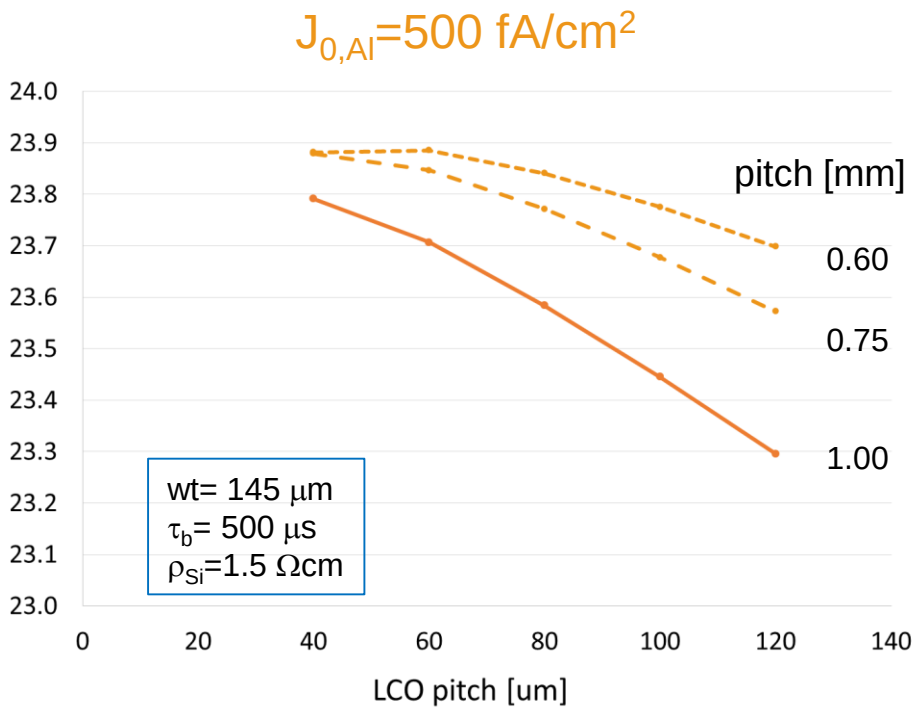
FF


$J_{0,Al}$=1000 fA/cm^2
pitch [mm]
0.60
0.75
1.00
Internal / Contact resistance
Internal, line, contact resistance
FF
82.5
82.0
81.5
81.0
80.5
80.0
79.5
79.0
78.5
0
20
40
60
80
100
120
LCO pitch [um]

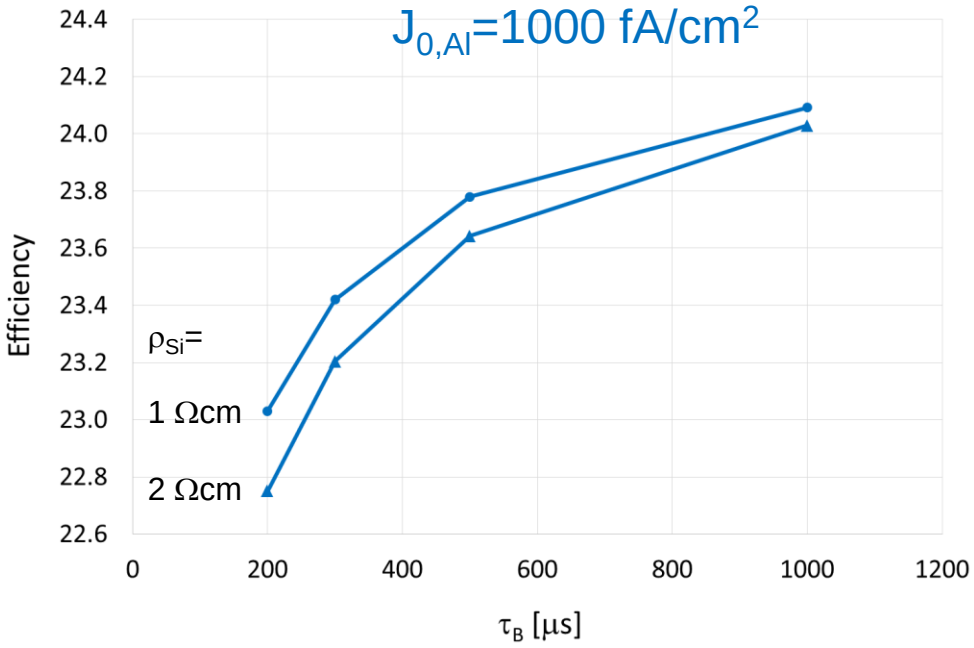

$J_{0,Al}$=500 fA/cm^2
pitch [mm]
0.60
0.75
1.00
wt= 145 μm
τ_b= 500 μs
ρ_{Si}=1.5 Ωcm
FF
82.5
82.0
81.5
81.0
80.5
80.0
79.5
79.0
78.5
0
20
40
60
80
100
120
140
LCO pitch [um]

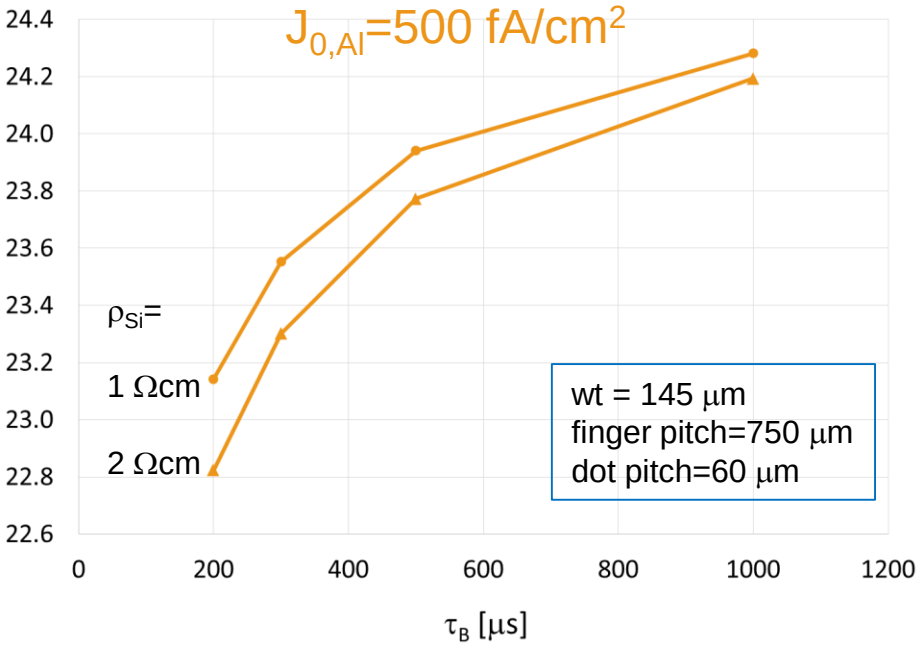
EFFICIENCY


$J_{0,Al}$=1000 fA/cm^2
Efficiency
24.0
23.9
23.8
23.7
23.6
23.5
23.4
23.3
23.2
23.1
23.0
0
20
40
60
80
100
120
140
LCO pitch [um]
pitch [mm]
0.60
0.75
1.00


$J_{0,Al}$=500 fA/cm^2
24.0
23.9
23.8
23.7
23.6
23.5
23.4
23.3
23.2
23.1
23.0
0
20
40
60
80
100
120
140
LCO pitch [um]
pitch [mm]
0.60
0.75
1.00
wt= 145 μm
τ_b= 500 μs
ρ_{Si}=1.5 Ωcm

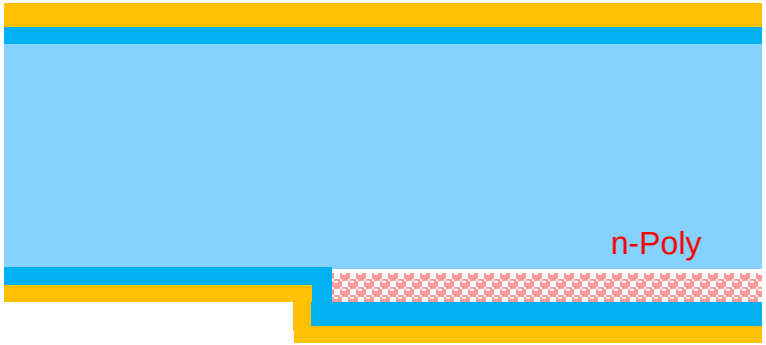
EFFICIENCY


$J_{0,Al}$=1000 fA/cm^2
Efficiency
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
0
200
400
600
800
1000
1200
τ_B [µs]
ρ_{Si}=
1 Ωcm
2 Ωcm

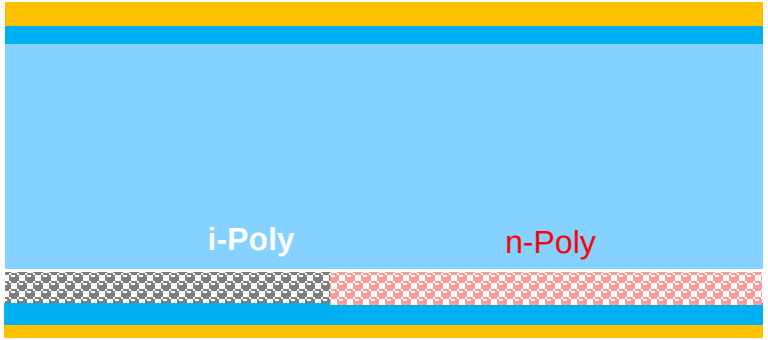

$J_{0,Al}$=500 fA/cm^2
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
0
200
400
600
800
1000
1200
τ_B [µs]
ρ_{Si}=
1 Ωcm
2 Ωcm
wt = 145 µm
finger pitch=750 µm
dot pitch=60 µm

LAB PROCESS RESULTS

A

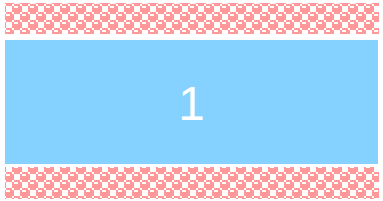


B

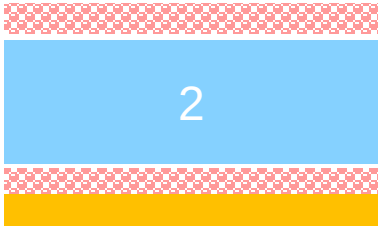


PROCESS A1 (ETCH BARRIER PRINT)

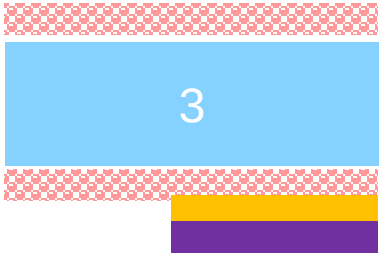
Oxide & n-poly



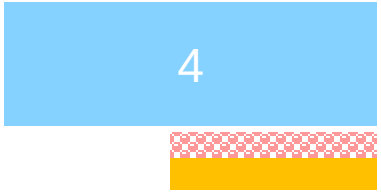
Etch barrier dielectric



Barrier printing



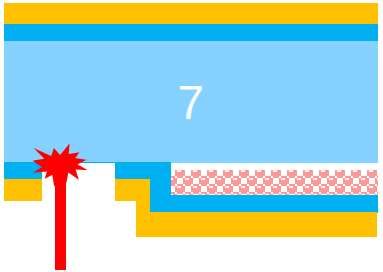
Etch n-poly



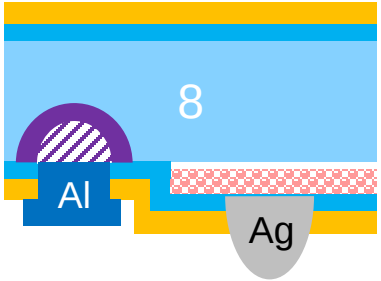
Etch barrier removal

Double-sided
Al_2O_3-SiN_x

PERC-like
laser contact opening



PERC- like
Metallization & co-fire



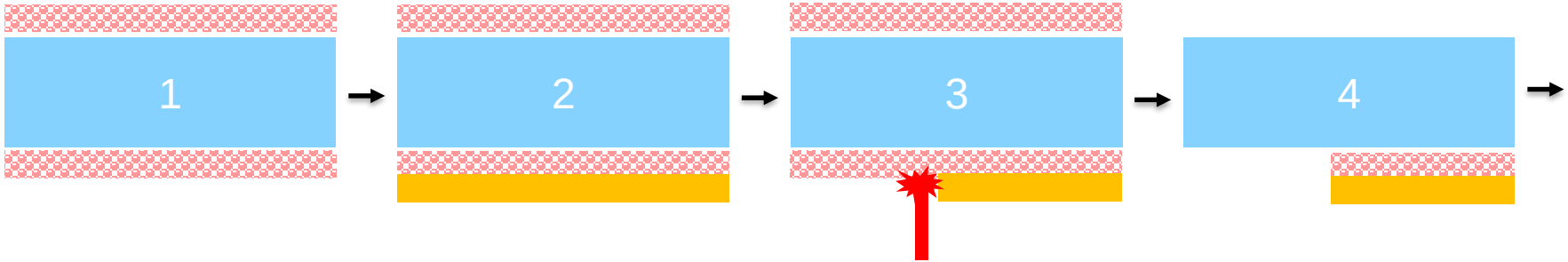
PROCESS A2 (ALL LASER)

Oxide & n-poly

Etch barrier dielectric

Etch barrier
laser 1 opening

Etch n-poly

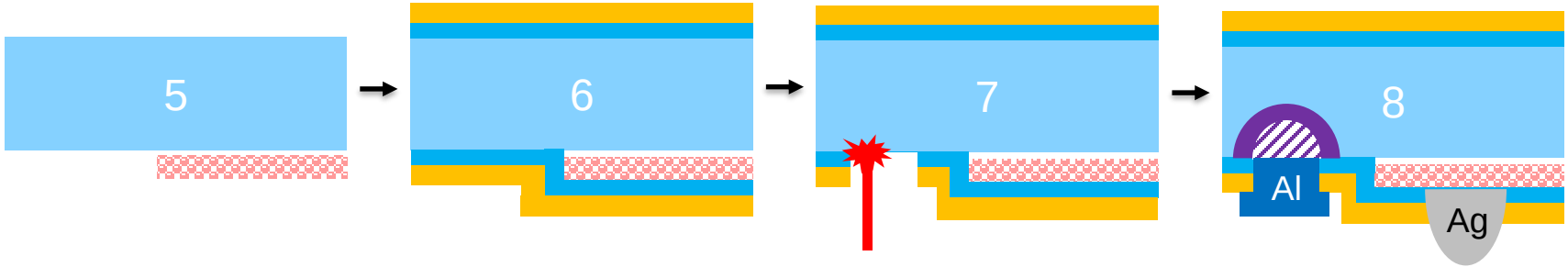


Etch barrier removal

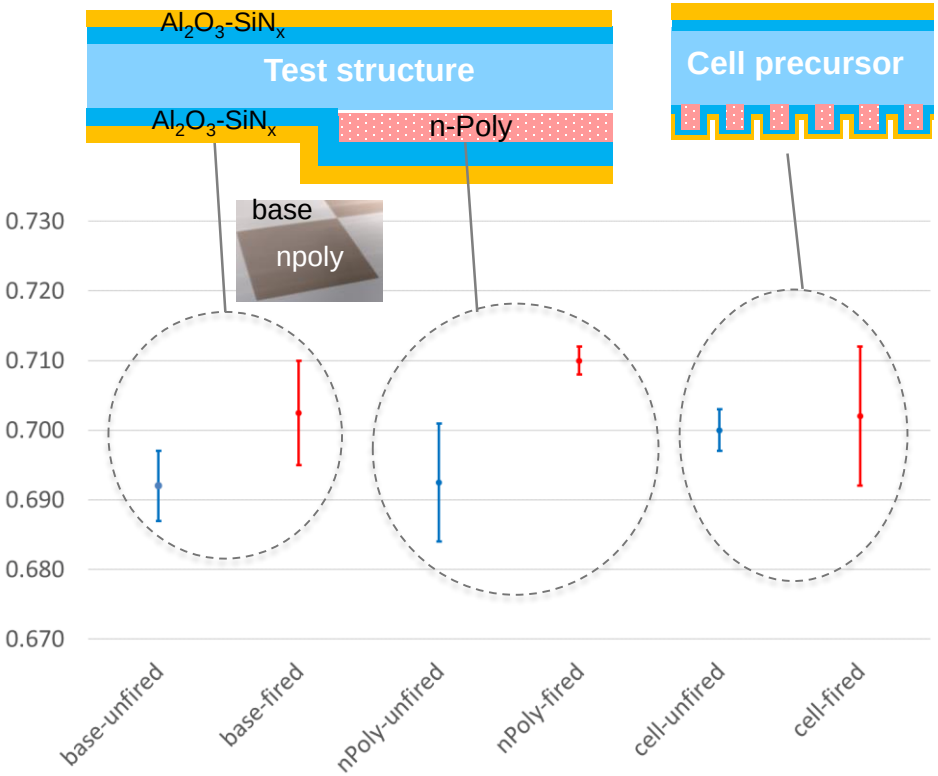
Double-sided
Al_2O_3-SiN_x

PERC-like
laser 2 opening

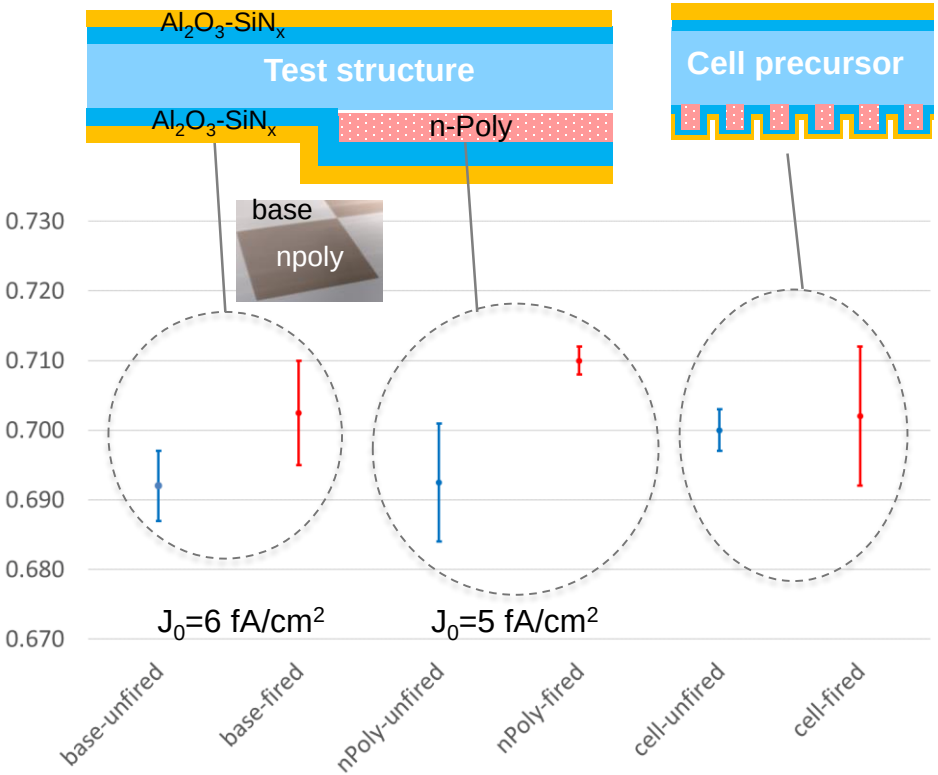
PERC- like
Metallization & co-fire



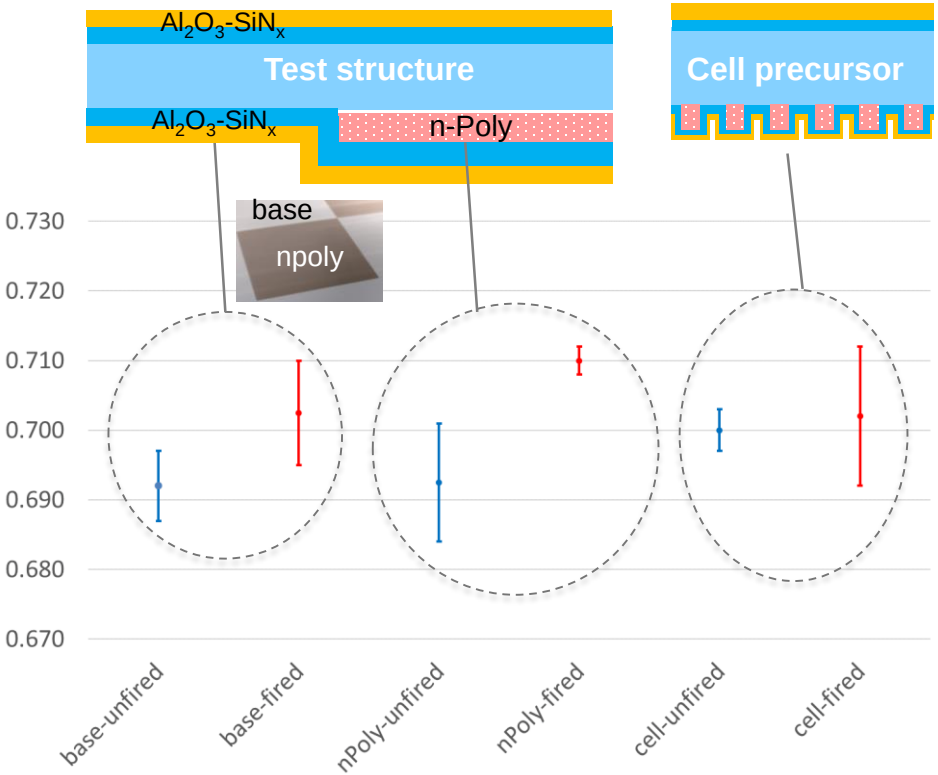
IMPLIED-VOC

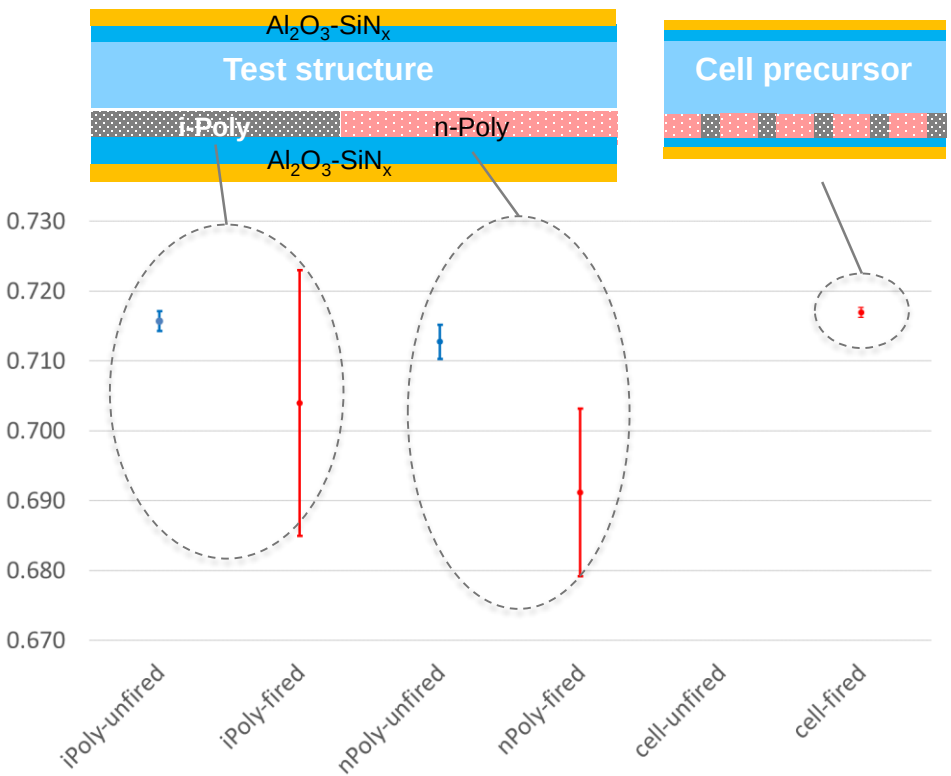

Al_2O_3-SiN_x
Test structure
Al_2O_3-SiN_x
n-Poly
Cell precursor
base
npoly
0.730
0.720
0.710
0.700
0.690
0.680
0.670
base-unfired
base-fired
nPoly-unfired
nPoly-fired
cell-unfired
cell-fired

IMPLIED-VOC


Al_2O_3-SiN_x
Test structure
Al_2O_3-SiN_x
n-Poly
Cell precursor
base
npoly
0.730
0.720
0.710
0.700
0.690
0.680
0.670
J_0=6 fA/cm^2
J_0=5 fA/cm^2
base-unfired
base-fired
nPoly-unfired
nPoly-fired
cell-unfired
cell-fired

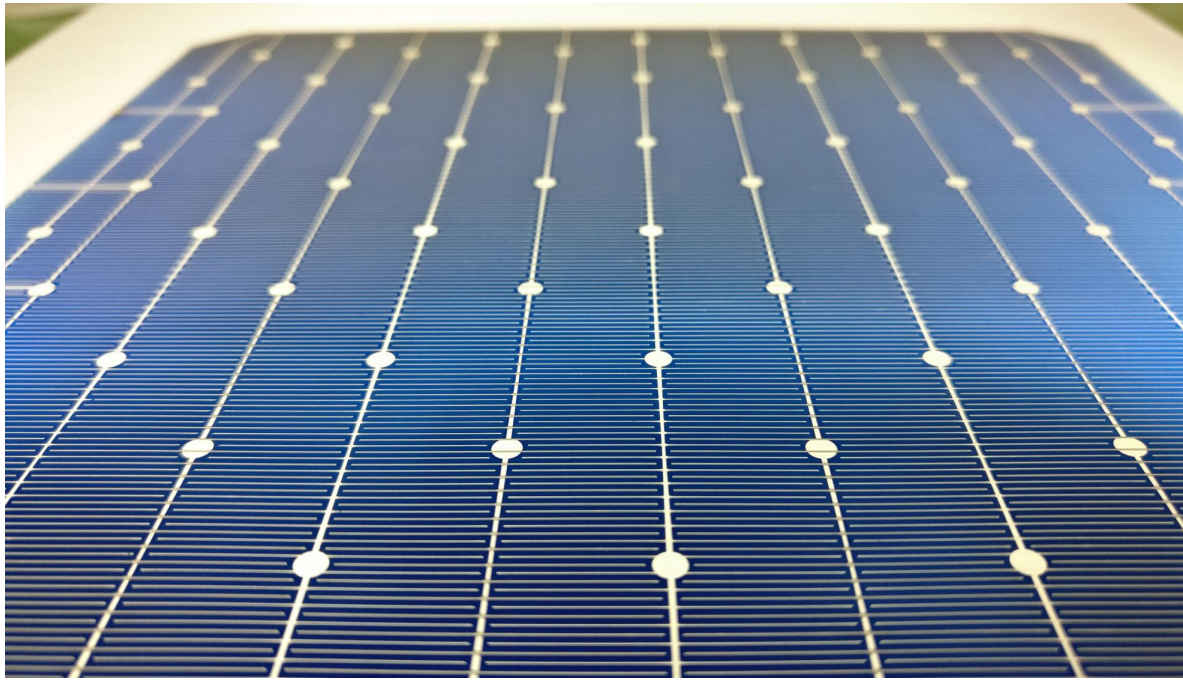
IMPLIED-VOC


Al_2O_3-SiN_x
Test structure
Al_2O_3-SiN_x
n-Poly
Cell precursor
base
npoly
0.730
0.720
0.710
0.700
0.690
0.680
0.670
base-unfired
base-fired
nPoly-unfired
nPoly-fired
cell-unfired
cell-fired

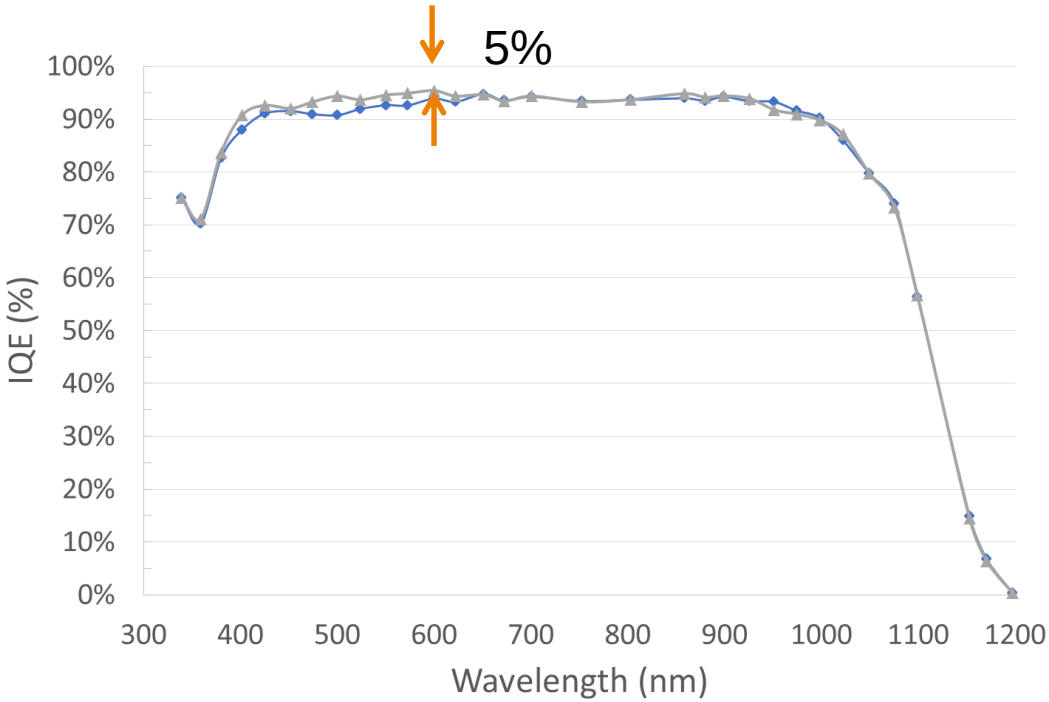

Al_2O_3-SiN_x
Test structure
i-Poly
n-Poly
Al_2O_3-SiN_x
Cell precursor
0.730
0.720
0.710
0.700
0.690
0.680
0.670
iPoly-unfired
iPoly-fired
nPoly-unfired
nPoly-fired
cell-unfired
cell-fired

P-IBC CELL PROCESS RESULTS

- Two runs
  - Voc = 680 mV
  - Shunt issues
- Challenges
  - Pinholes

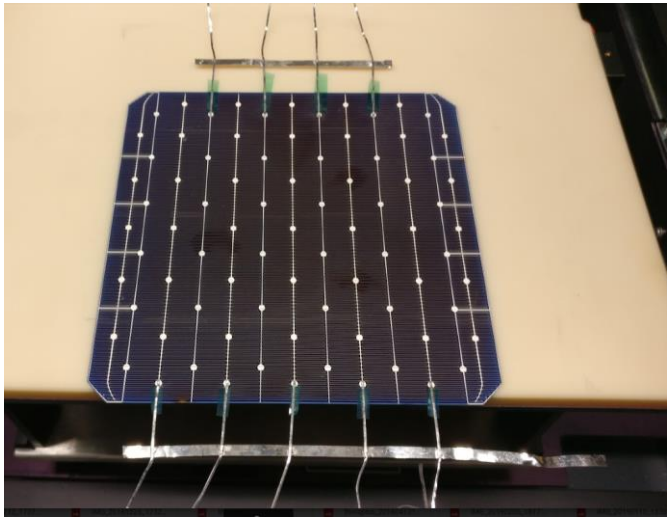


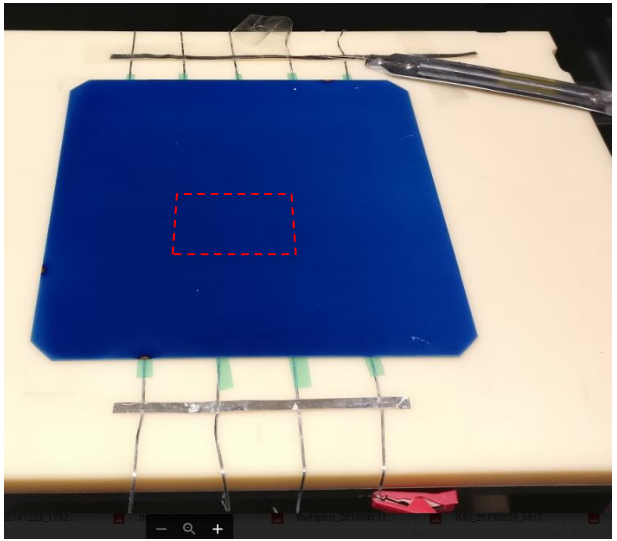
IQE



- Where does the loss come from?

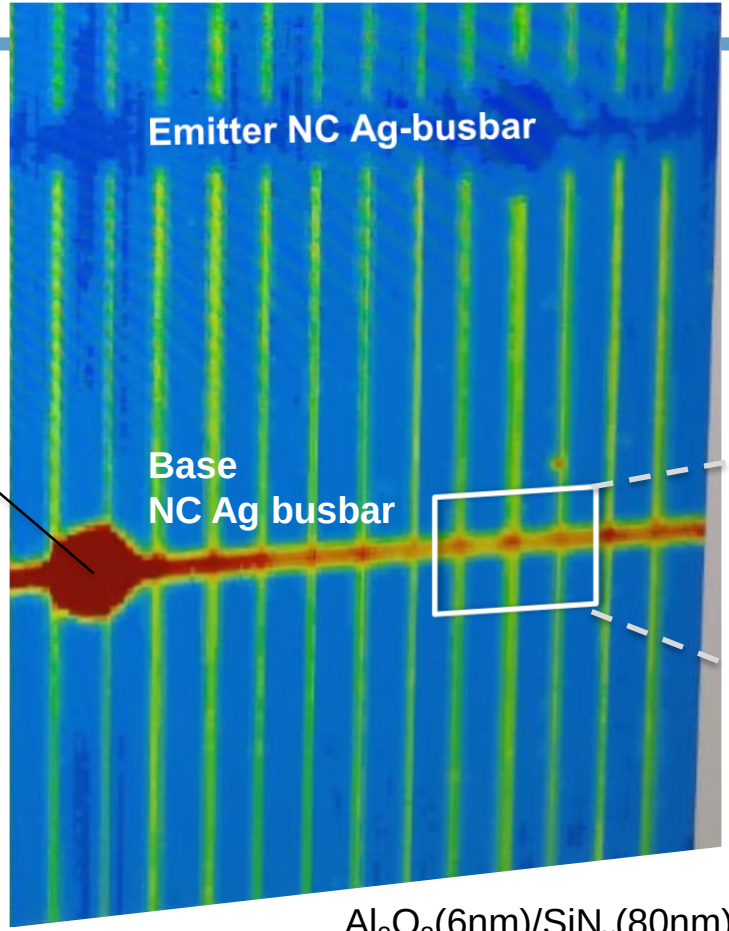
LBIC MEASUREMENT





- Contacting
- LBIC area

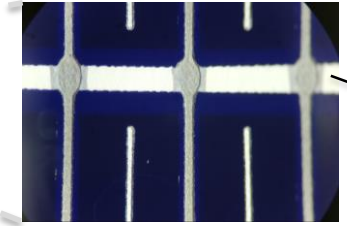
LBIC



Electrical shading

Toyo Al paste
Al finger

FT Ag finger



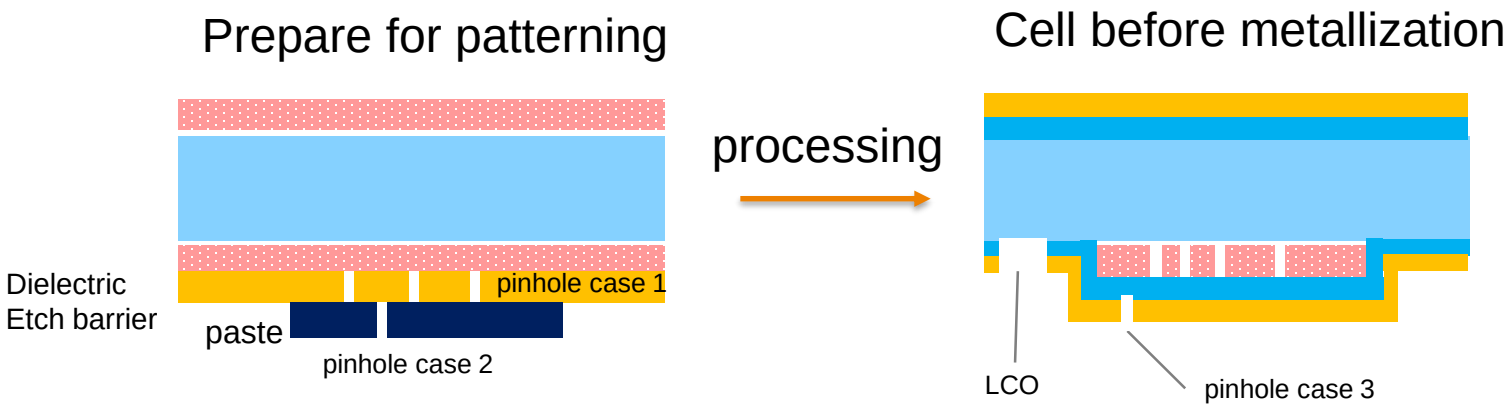
3rd party
NC paste

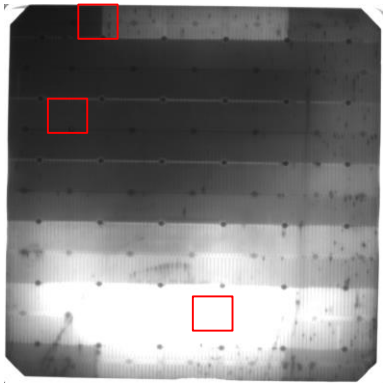
Glass frit migration issue due to non-compatibility

Al_2O_3(6nm)/SiN_x(80nm)

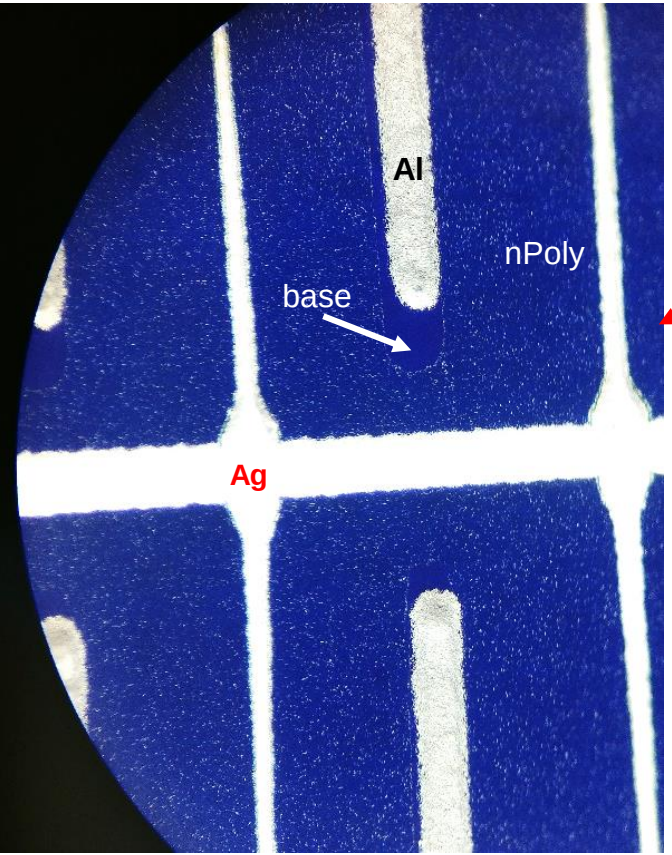
- Emitter BB has strong LBIC signal
- Base BB causes electrical shading
- Ag FT fingers not visible (passivatived contact)
- Al has lowest signal as expected
- Al and Ag show a reaction that adversely affect Al_2O_3/SiNx passivation

PINHOLES

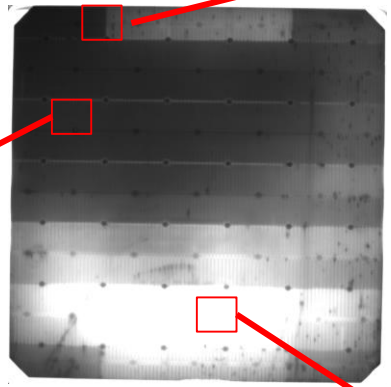

Prepare for patterning
Dielectric
Etch barrier
pinhole case 1
paste
pinhole case 2
processing
Cell before metallization
LCO
pinhole case 3



PL



Pinholes visible on n-Poly, **not** at base



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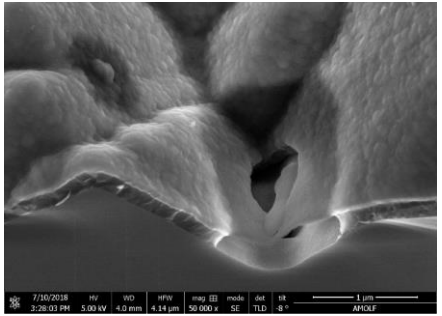
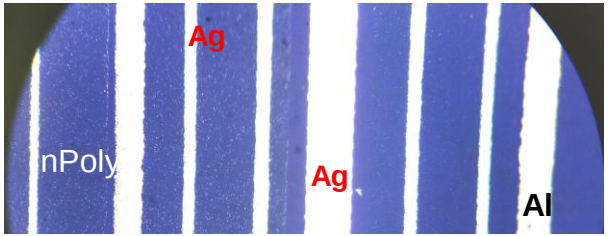
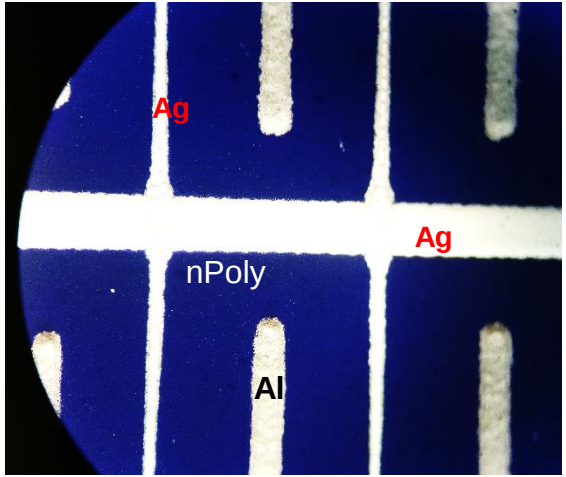


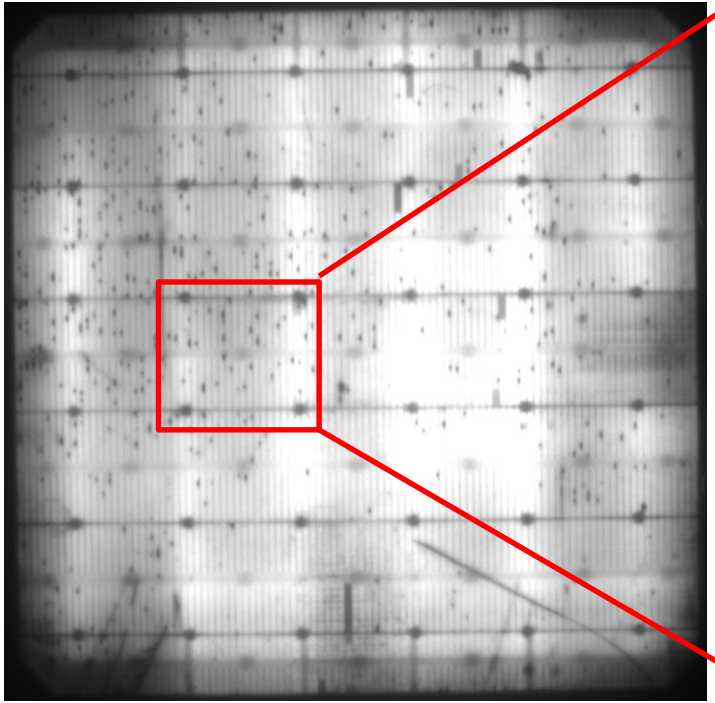


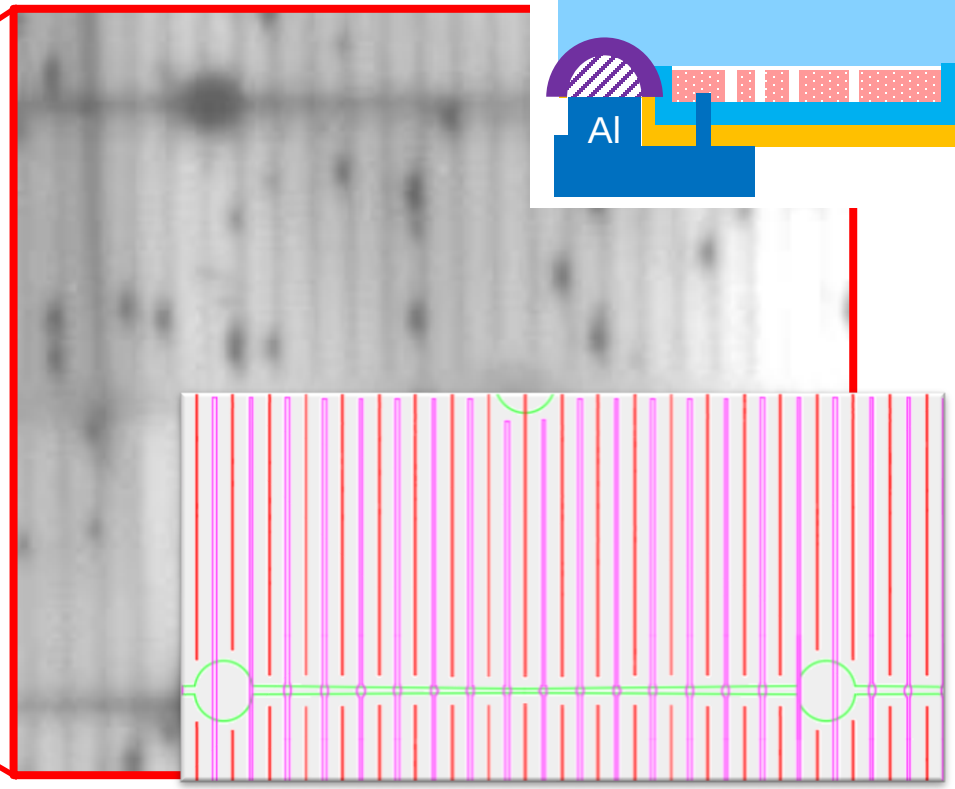
Sharp transition from “dirty” to “clean” n-Poly



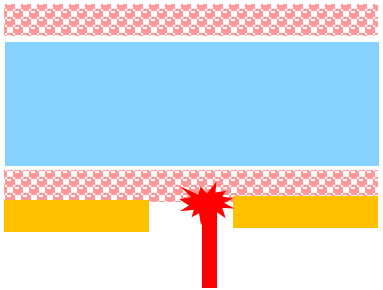
No pinholes visible

SHUNT OF AL FINGERS ON N-POLY

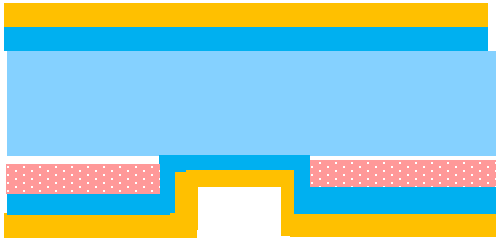




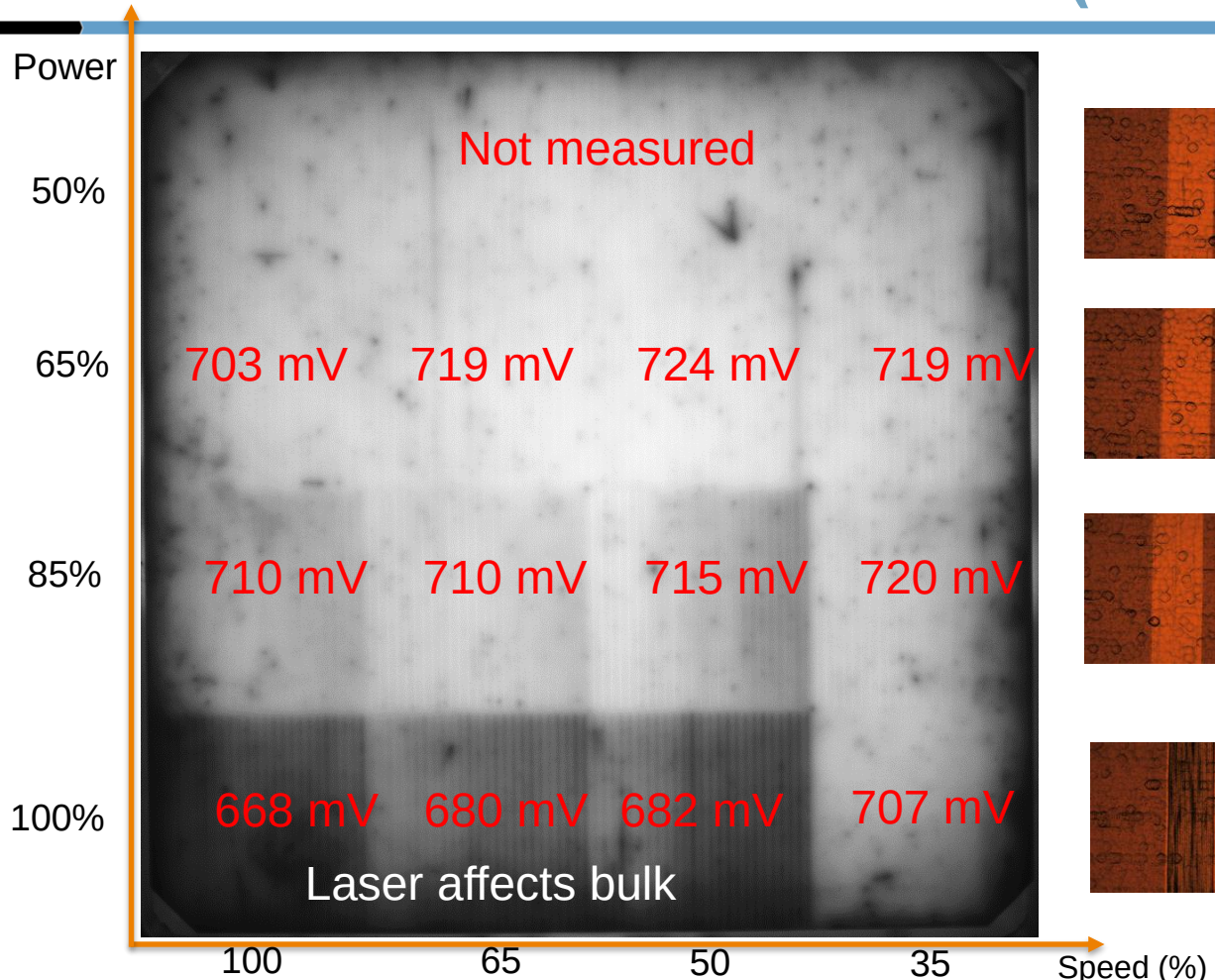
LASER PATTERNING

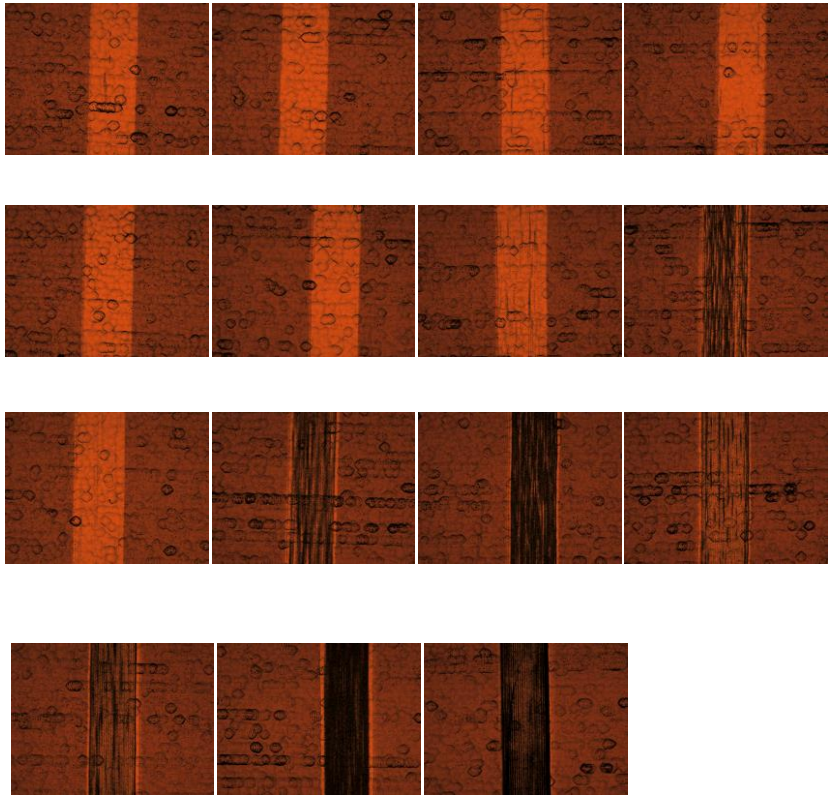


processing



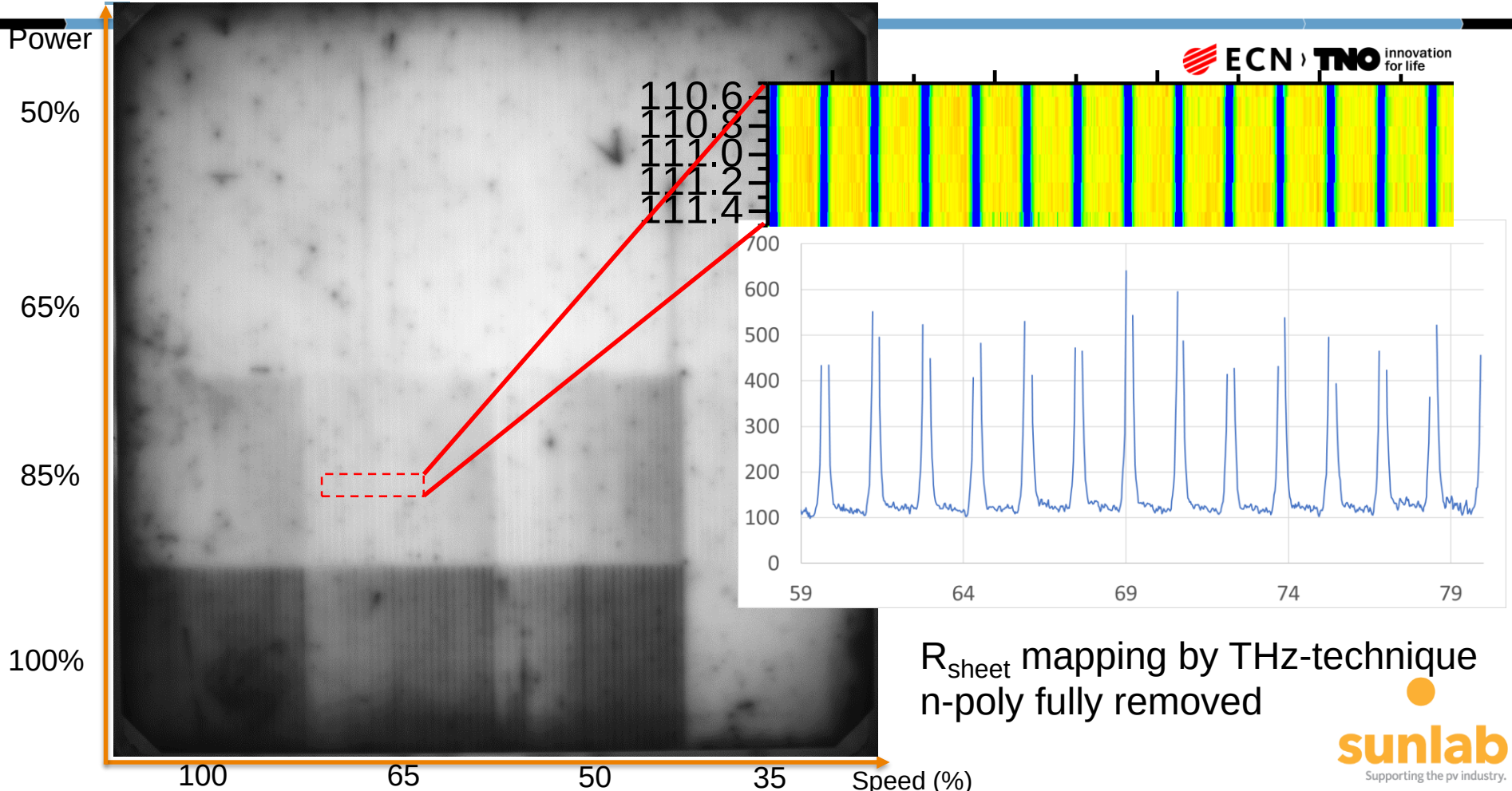
LASER OPENING BASE AREA (N-POLY PATTERNING)





Optical microscope

R SHEET MAP



R_{sheet} mapping by THz-technique
n-poly fully removed

CONCLUSION

- p-IBC combines PERC & TOPcon
- Implied-V_{oc} values from 690-720 mV (after firing)
- Laser patterning has high potential for solar-cell processing
- R&D focus on preventing shunt
  - thicker SiNx
  - no tail in base region
  - no pinholes
- p-IBC is a high-potential candidate as follow-up for PERC in industry

ECN.TNO seeks industrial collaboration to bring this or other concepts further
evert.bende@tno.nl
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THANK YOU FOR YOUR ATTENTION

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- Toyo Aluminium

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