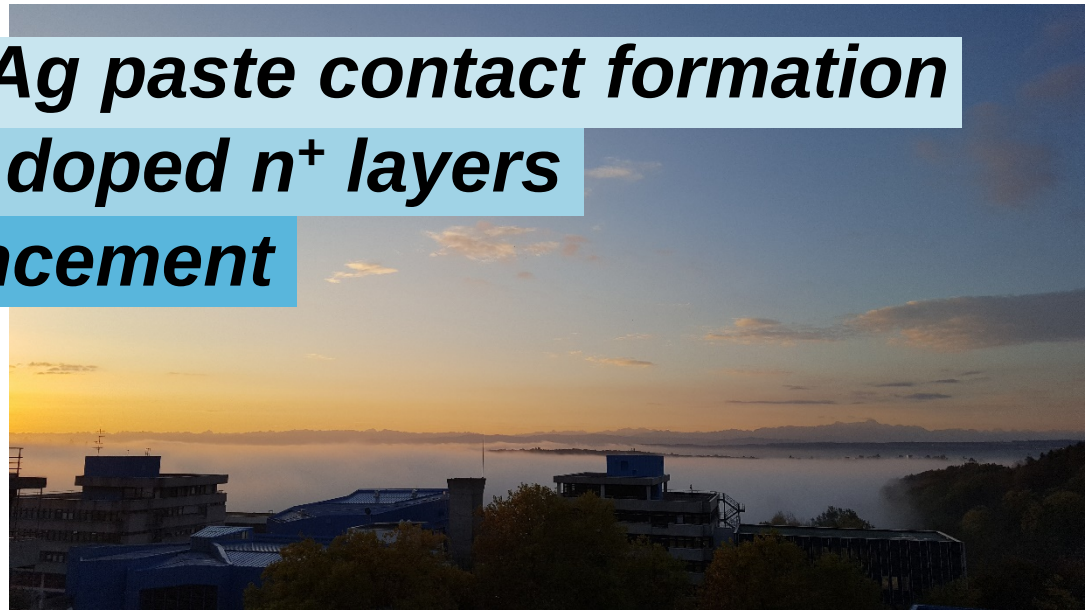
Universität Konstanz

Non-firing-through Ag paste contact formation on selectively laser doped n^+ layers for PERC cell enhancement



J. Engelhardt[1], Ryan Mayberry[2], Markus König[3], Kora Bayer[1], Susanne Fritz[1], Florian Mutter[1], Matthias Heilig[1], Giso Hahn[1] and Barbara Terheiden[1]

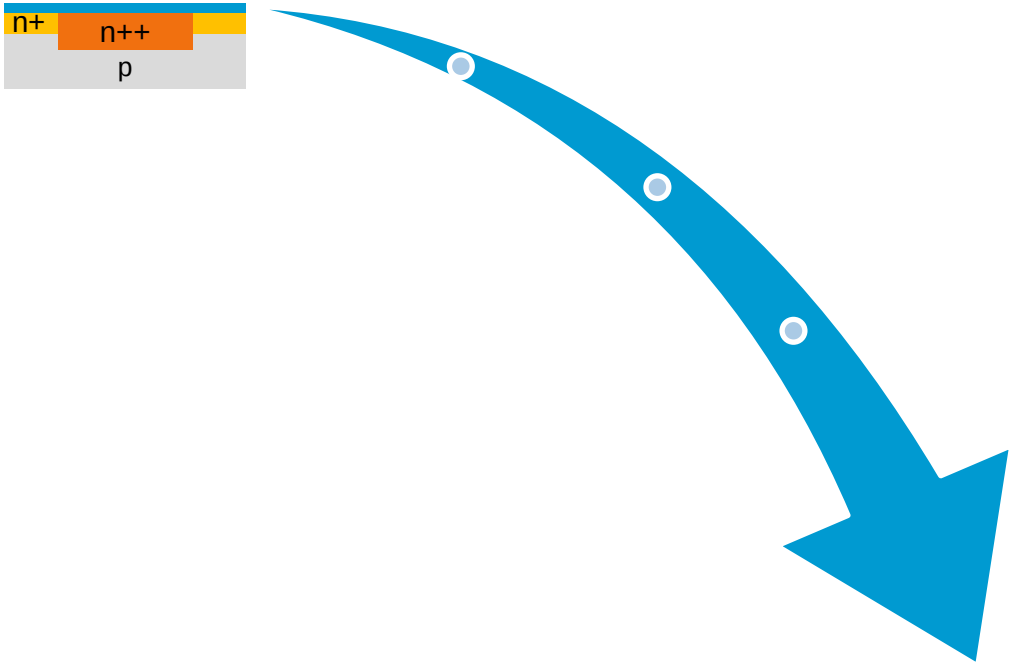
[1]University of Konstanz,

[2]Hereaus Precious Metals North America, [3]Hereaus Deutschland

23.10.2017; 7th Workshop on Metallization & Interconnection for Crystalline Silicon Solar Cells

Idea and approach

Selective emitter



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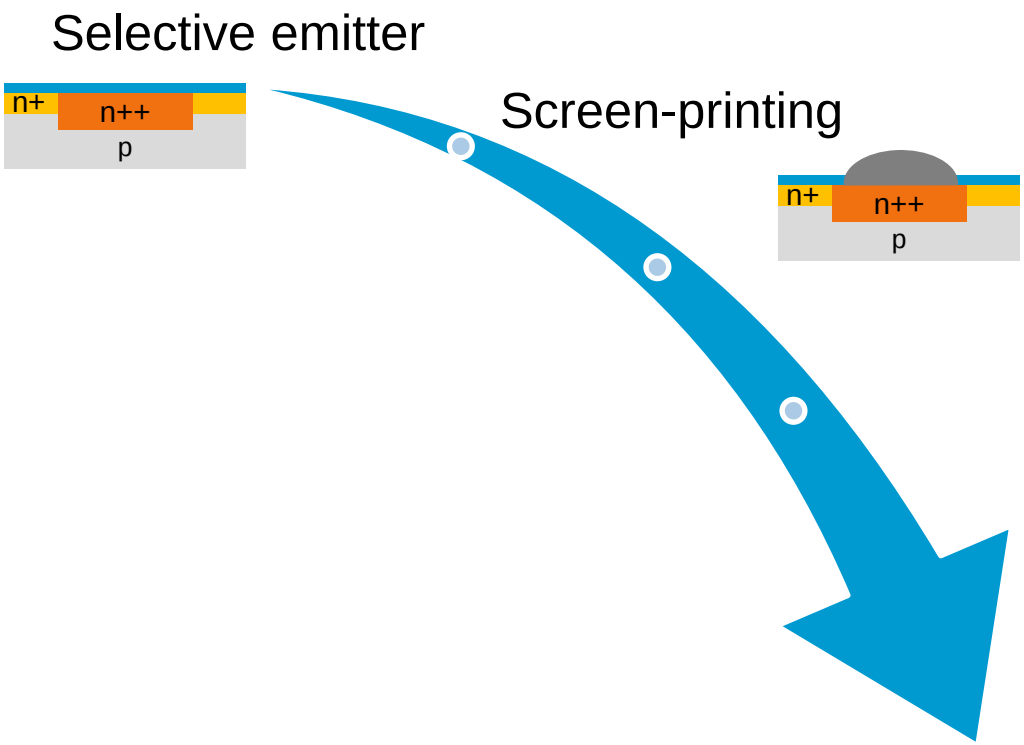

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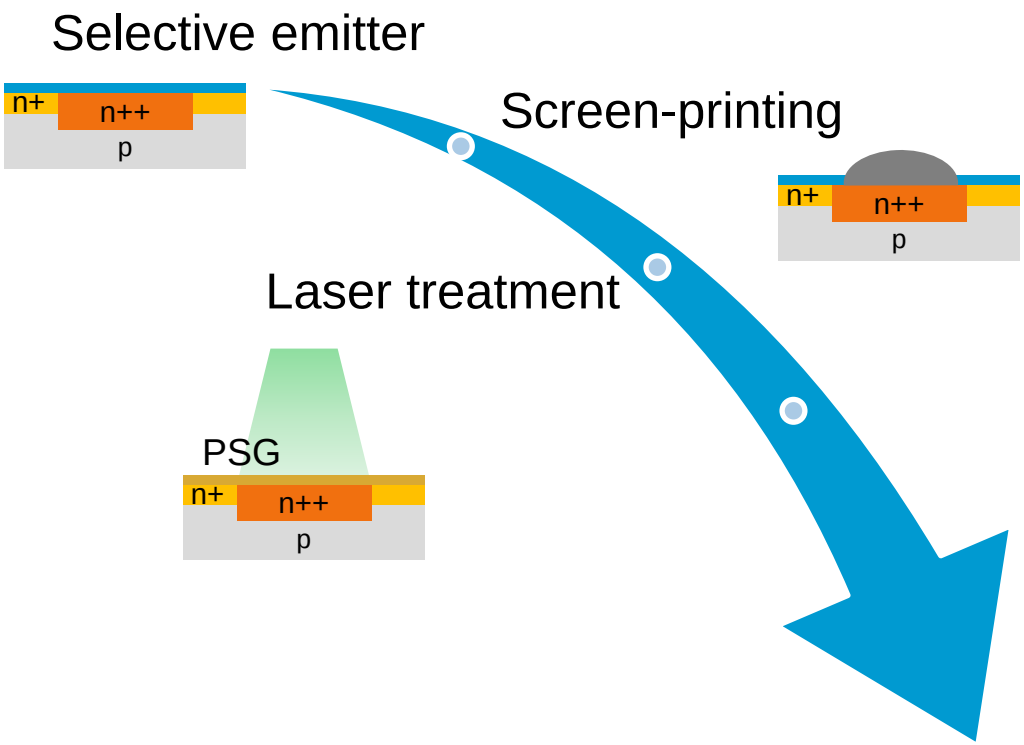

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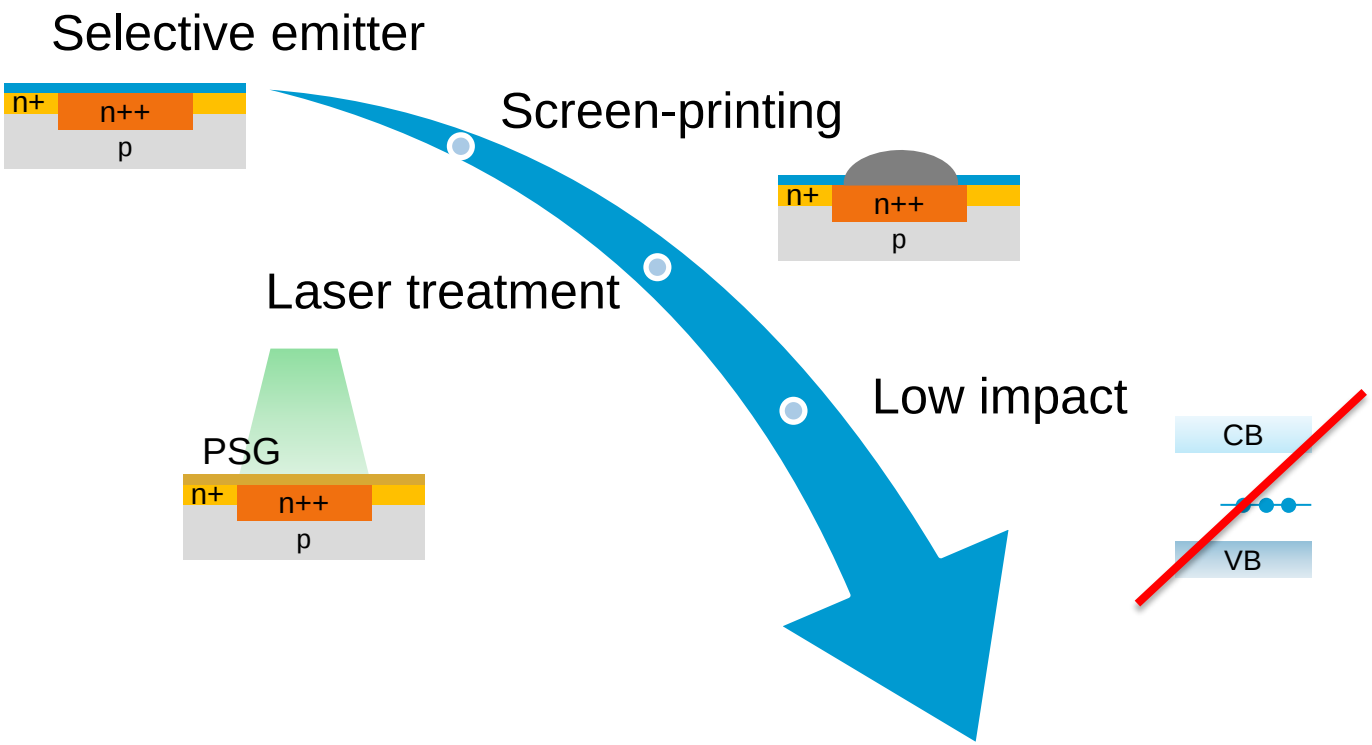

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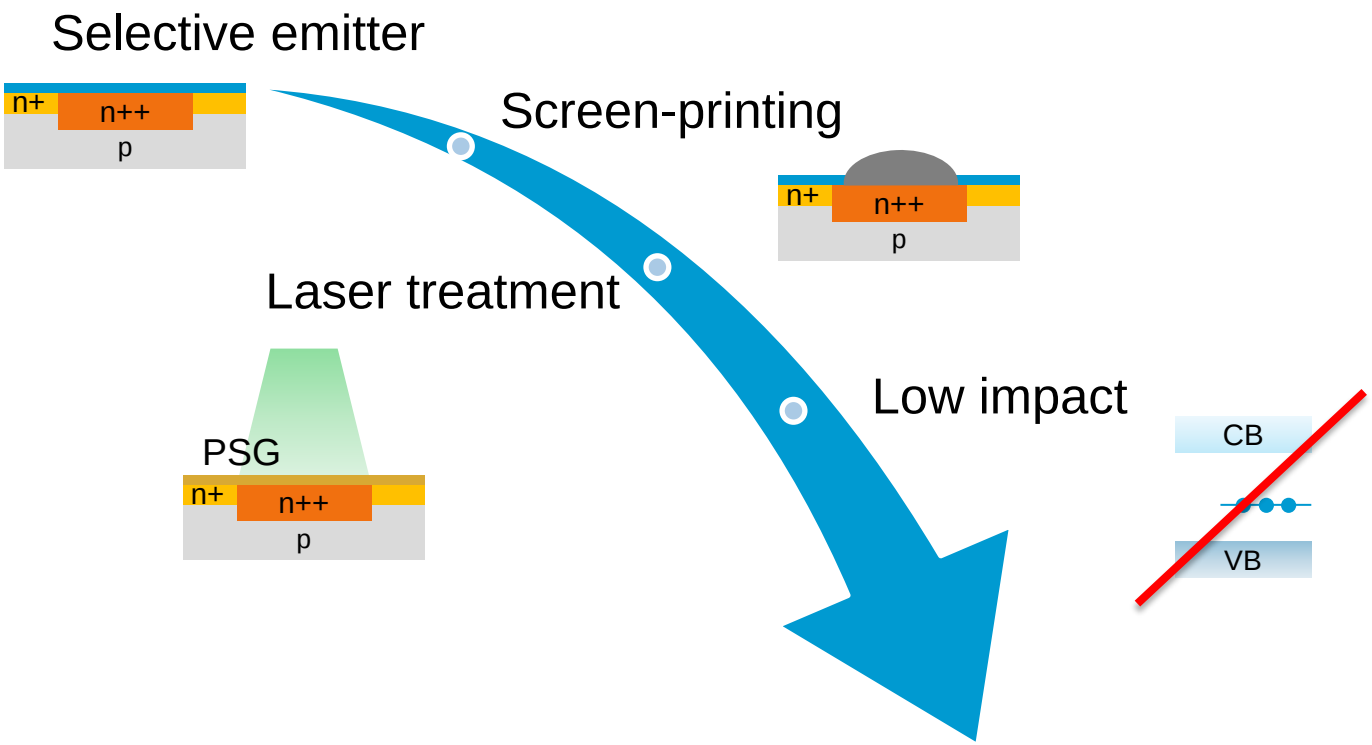
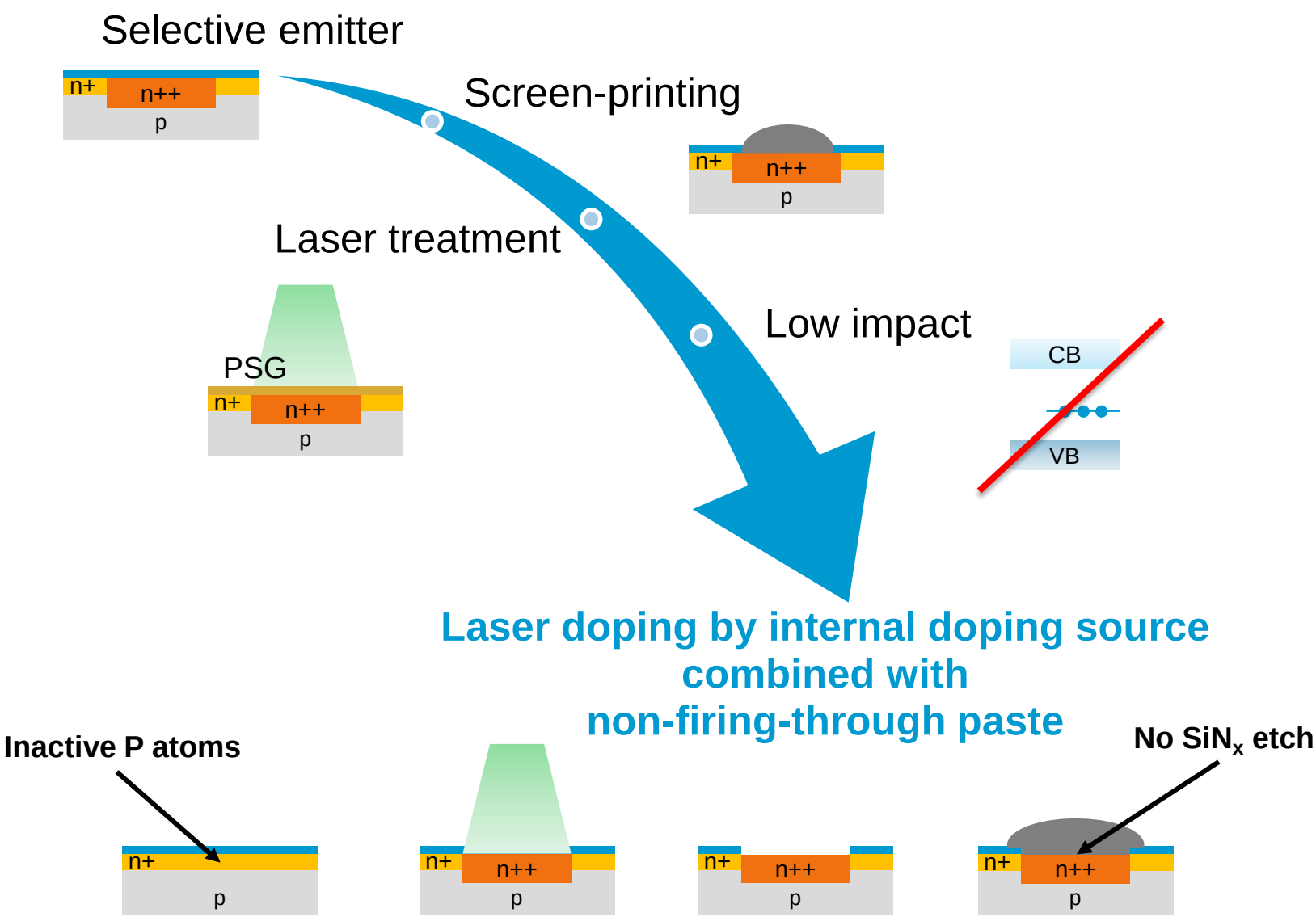


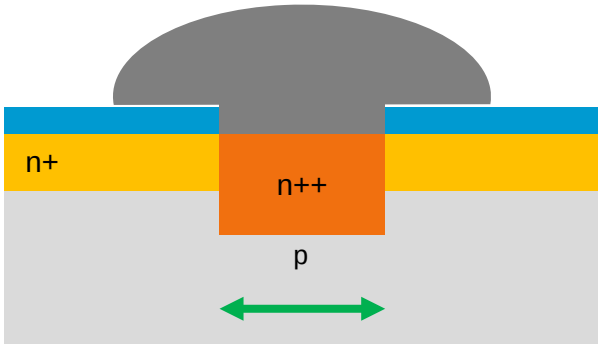
Laser doping by internal doping source combined with non-firing-through paste

Idea and approach

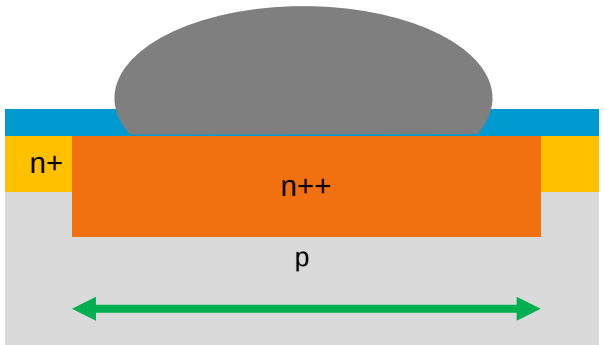


Idea and approach

New concept



Standard sel. Emitter



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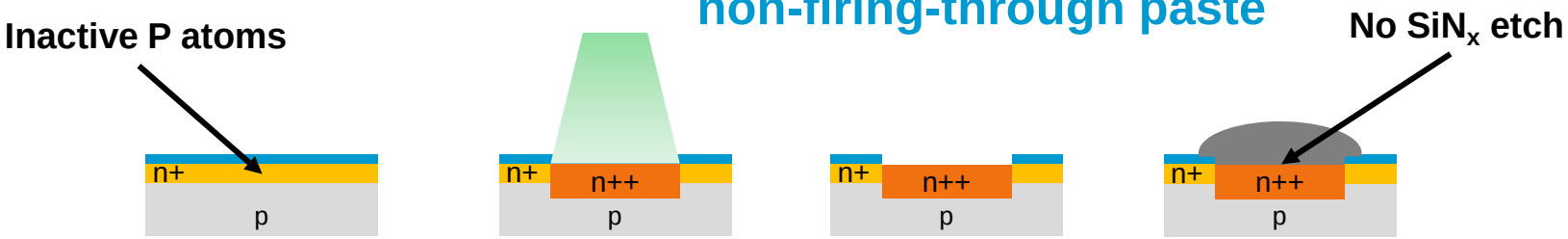

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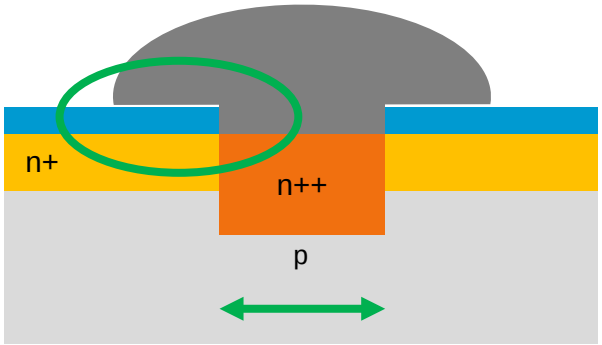

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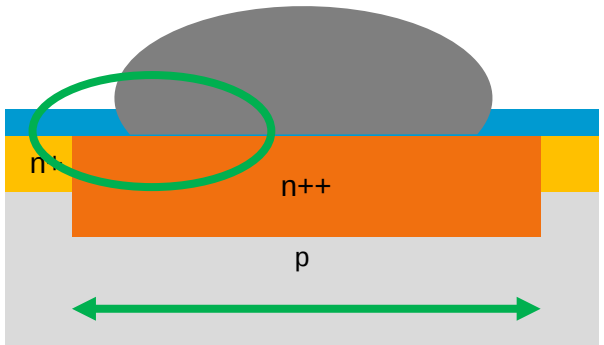
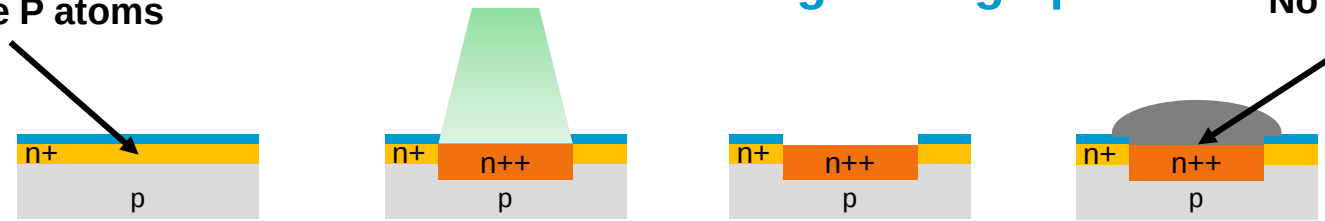


Laser doping by internal doping source combined with non-firing-through paste

Inactive P atoms

No SiN_x etch



532 nm Laser activation

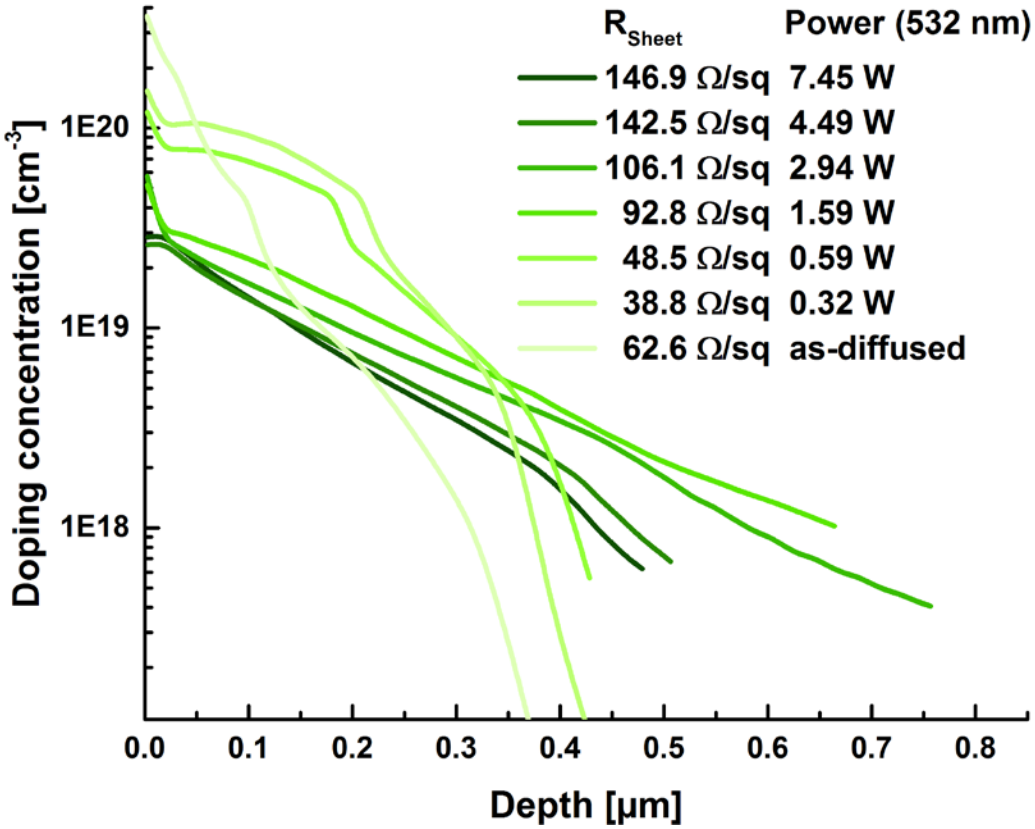
60 Ω/sq P-doped emitter

Variation of laser power

- Fixed defocus height
- Change in R_{Sheet} measured by 4PP and ECV

Results

- Decrease in R_{Sheet} for low laser power
- Increase in R_{Sheet} for further power increase



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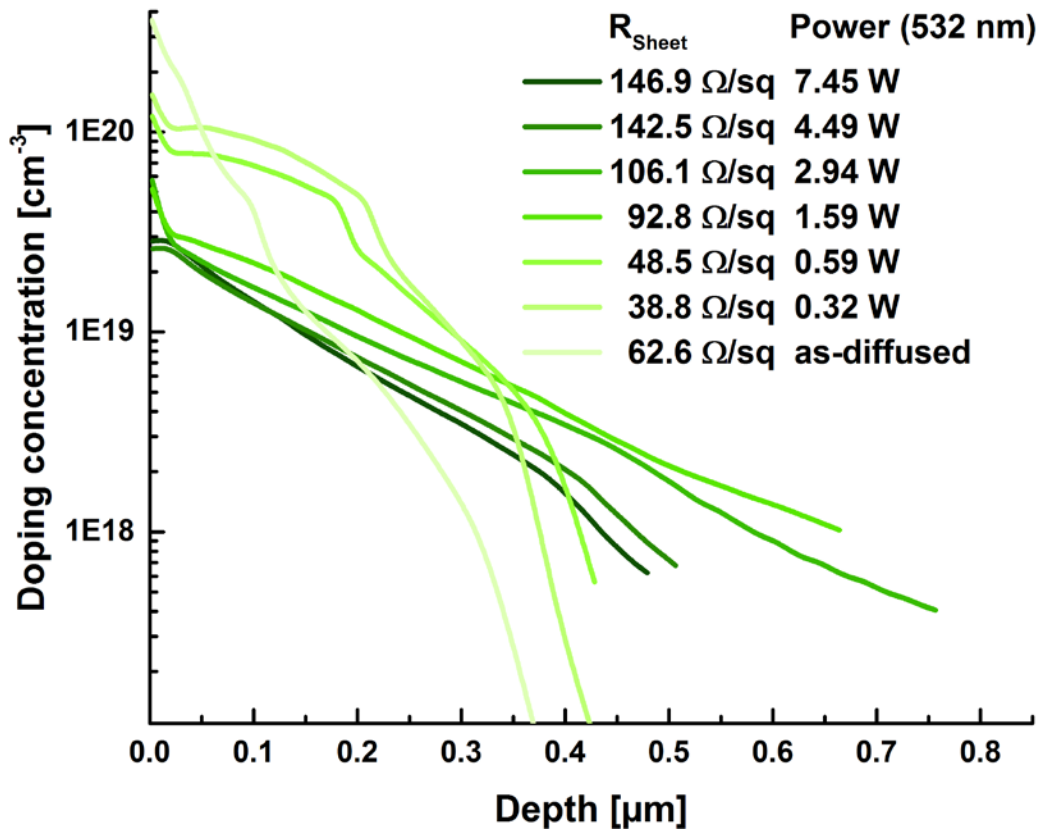

Internal doping source

- Overall doping concentration increases → inactive P atoms are activated
- Profile deepens with higher laser power
- Ablation occurs for even higher laser power → overall dopant conc. decreases
- Less power required compared to laser doping from external source
- No electrically active defects affecting doping measurement

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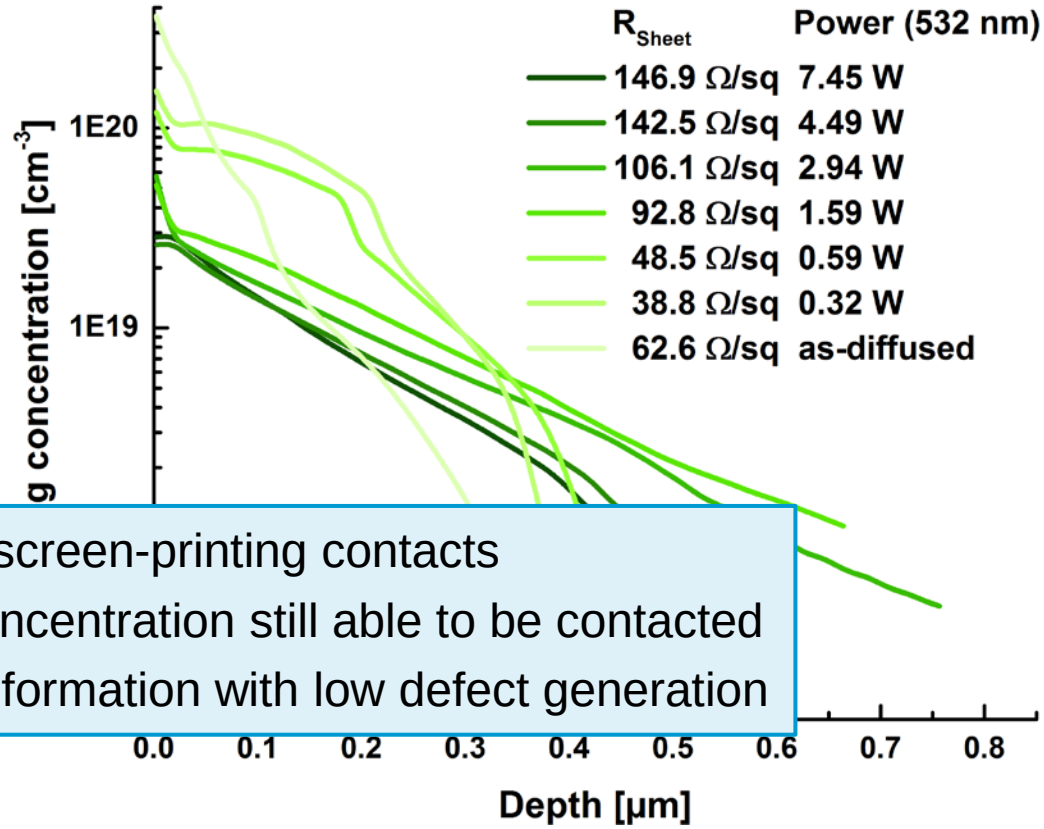

- ✓ Higher depth for screen-printing contacts
- ✓ Lower surface concentration still able to be contacted
- ✓ Selective emitter formation with low defect generation

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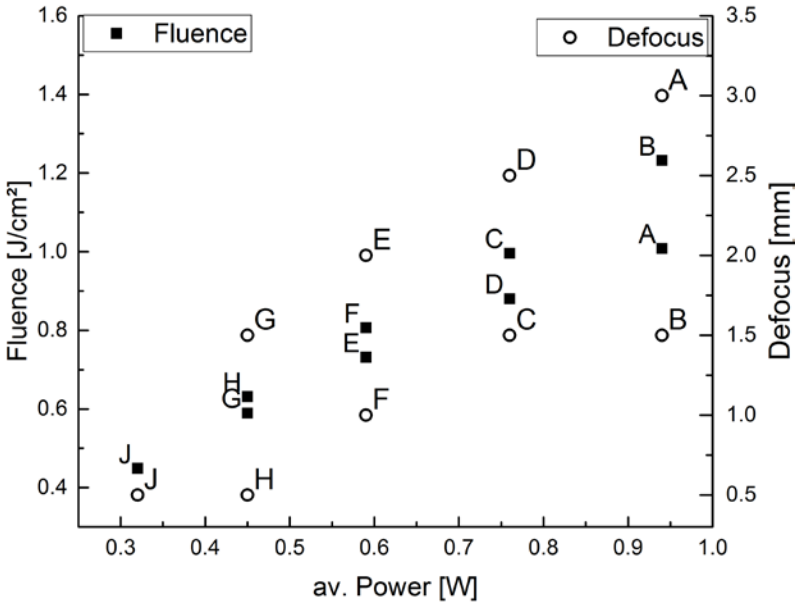
Fluence vs. doping profile

Fluence is laser power / area

Variation of laser fluence



Fluence vs. doping profile

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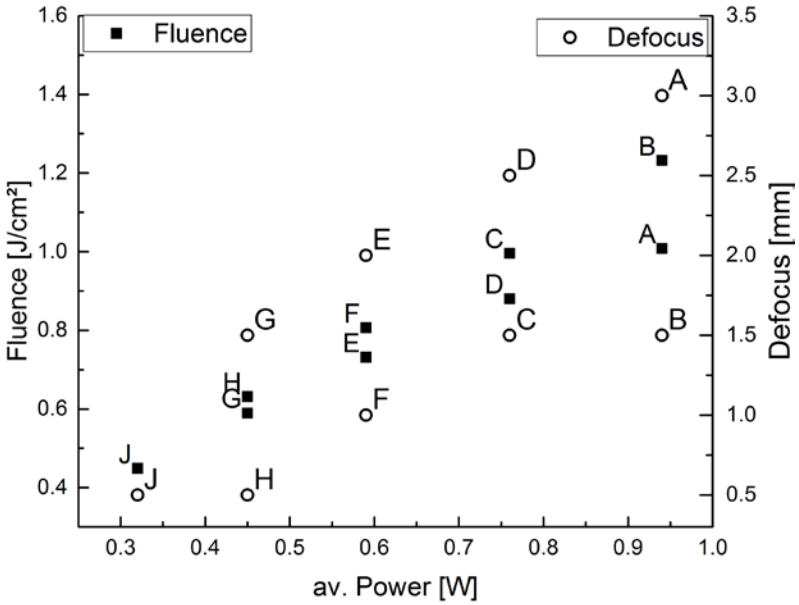
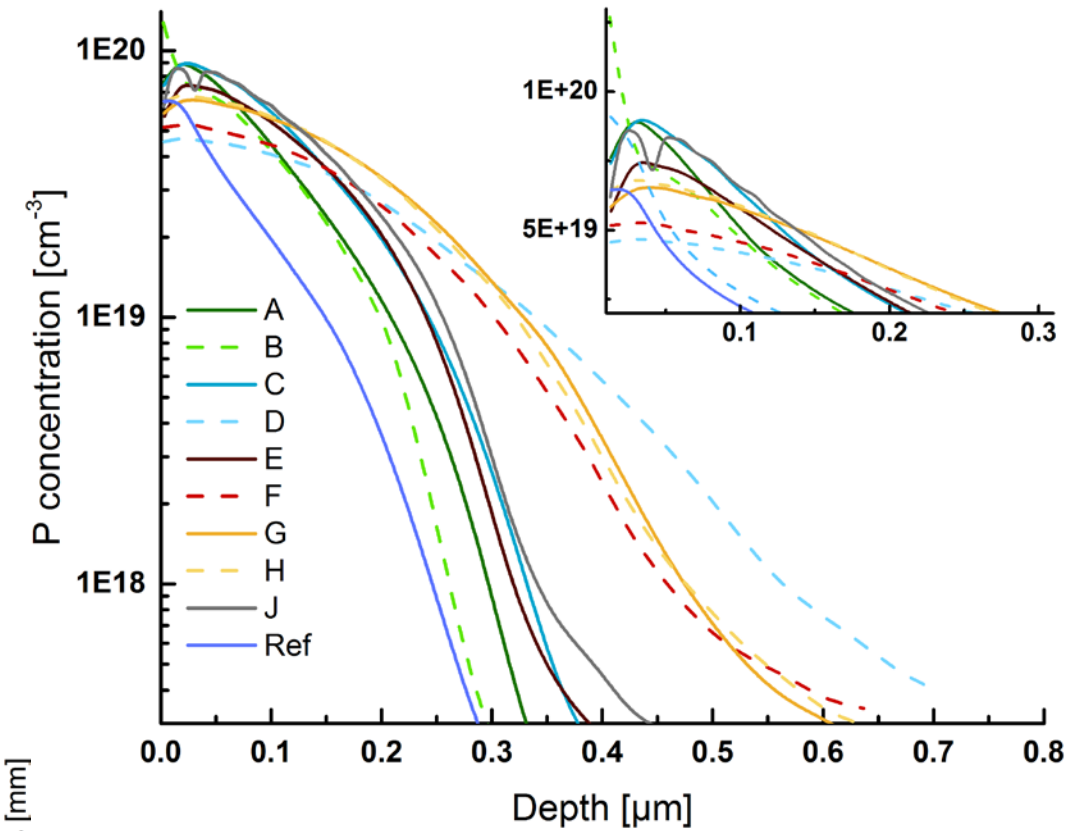
Variation of laser fluence

- Low fluence sufficient to activate P atoms





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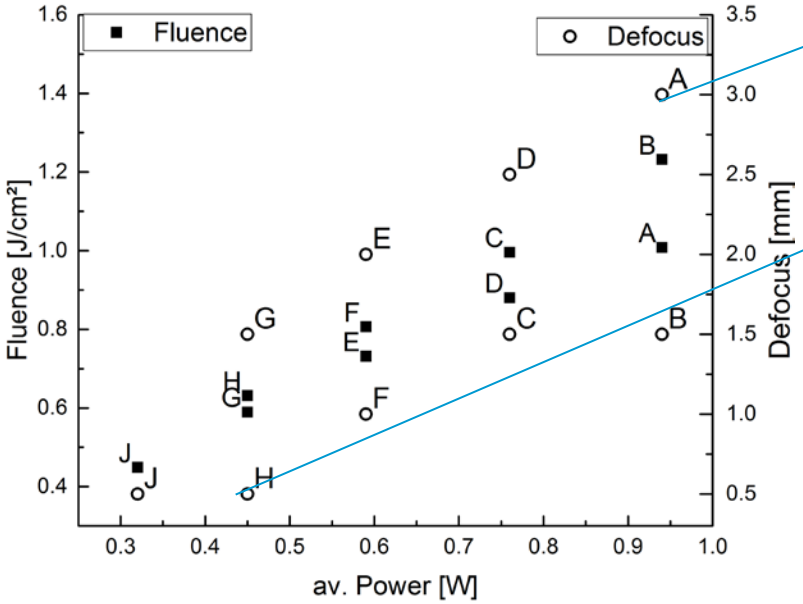
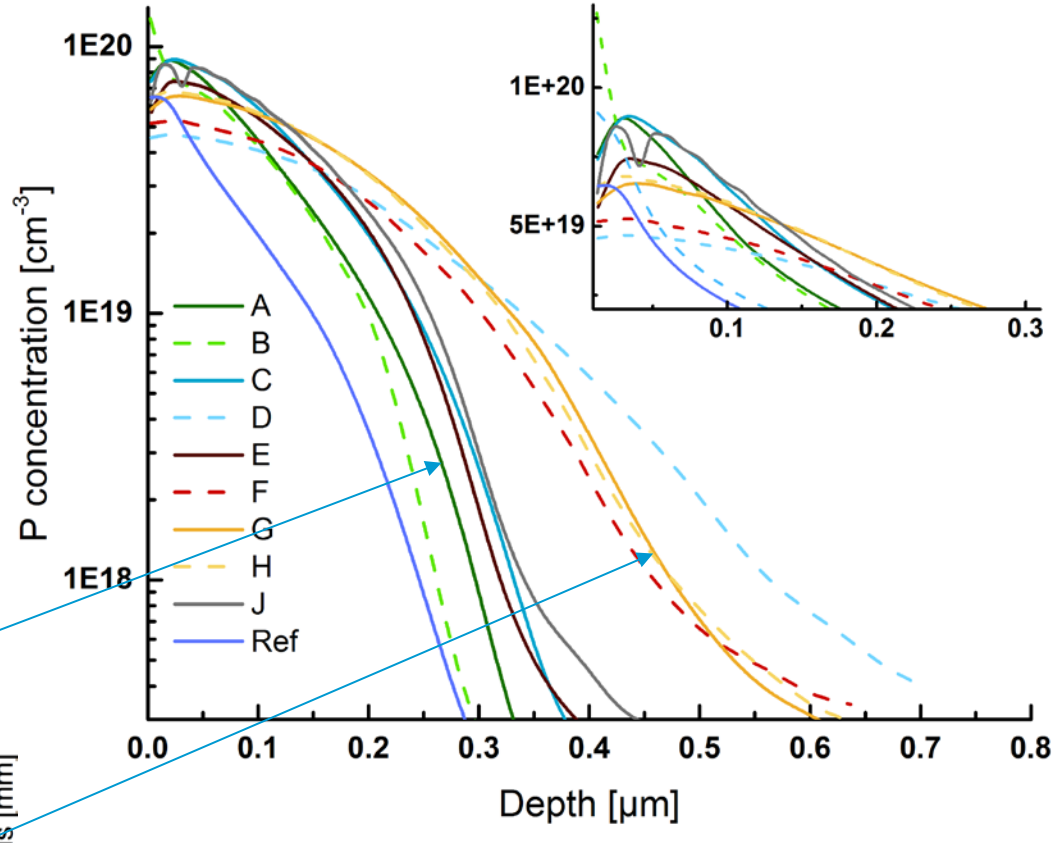


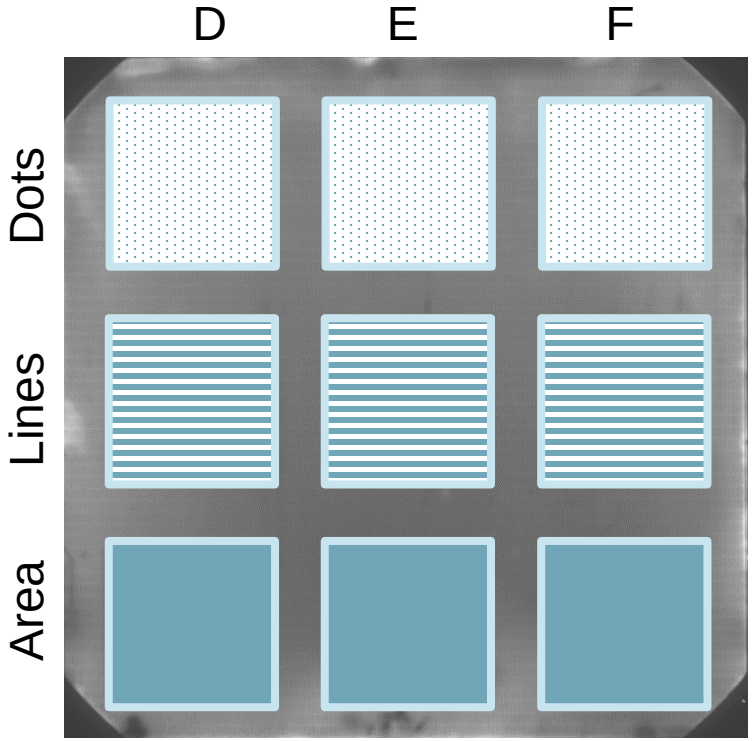


Laser impact

Re-passivated PERC precursors

PERC precursor

- Front side lasered
- Re-passivated using Al_2O_3



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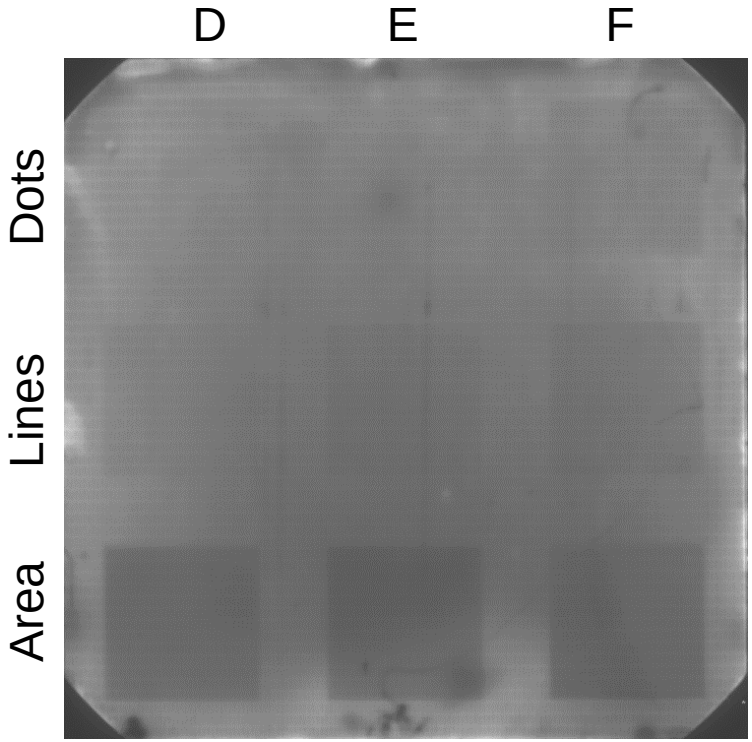

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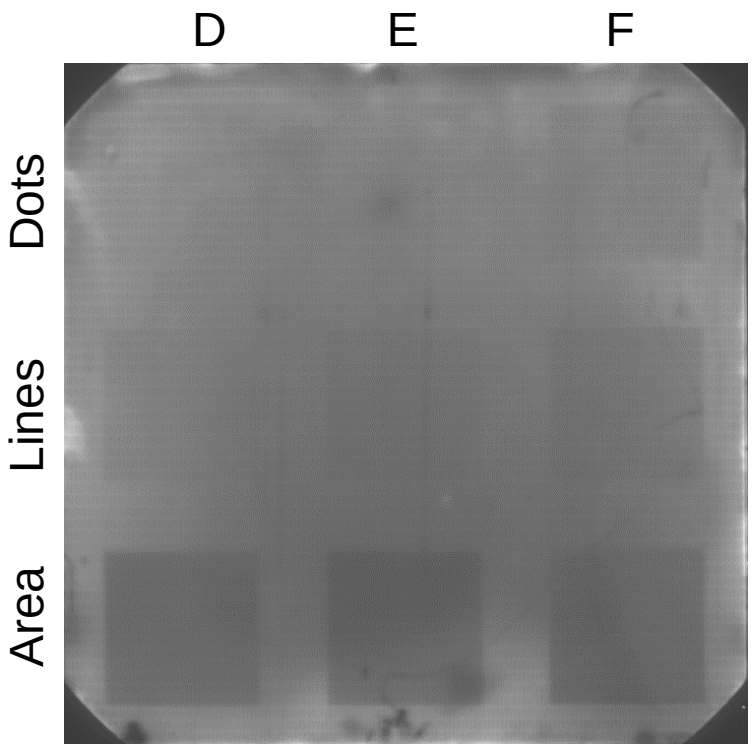
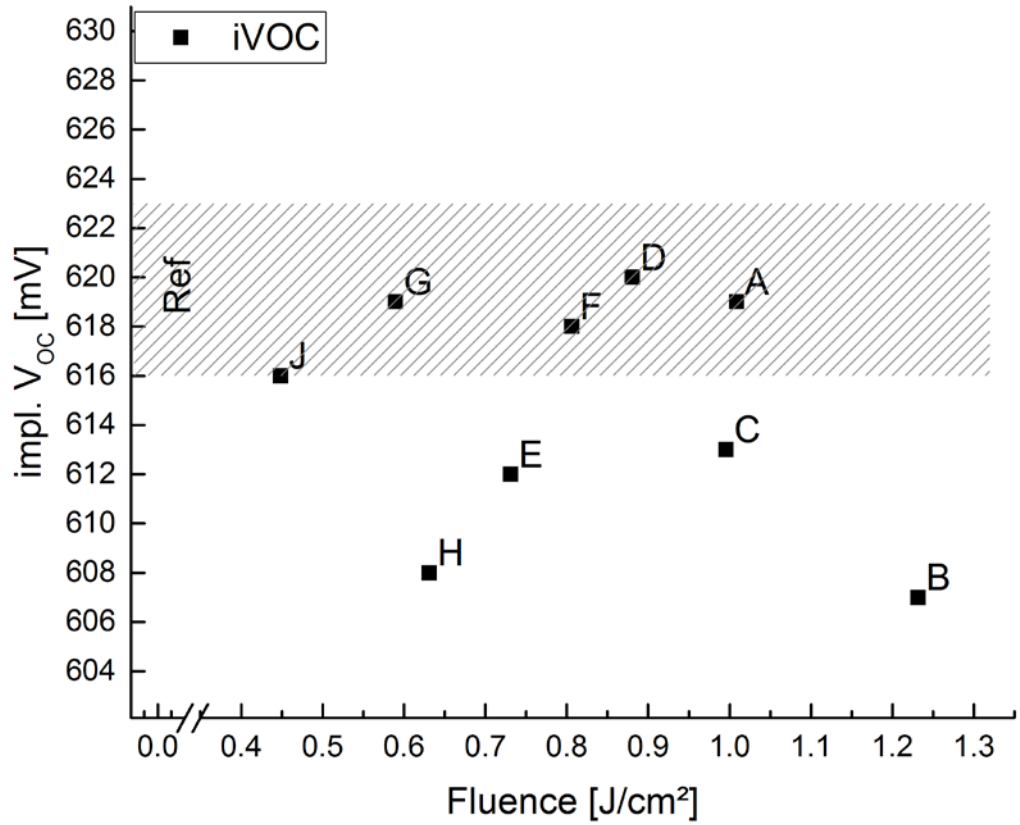




Results

- Impact for certain laser parameters within reference iV_{OC} window
- Low iV_{OC} values for laser treatment near laser focus

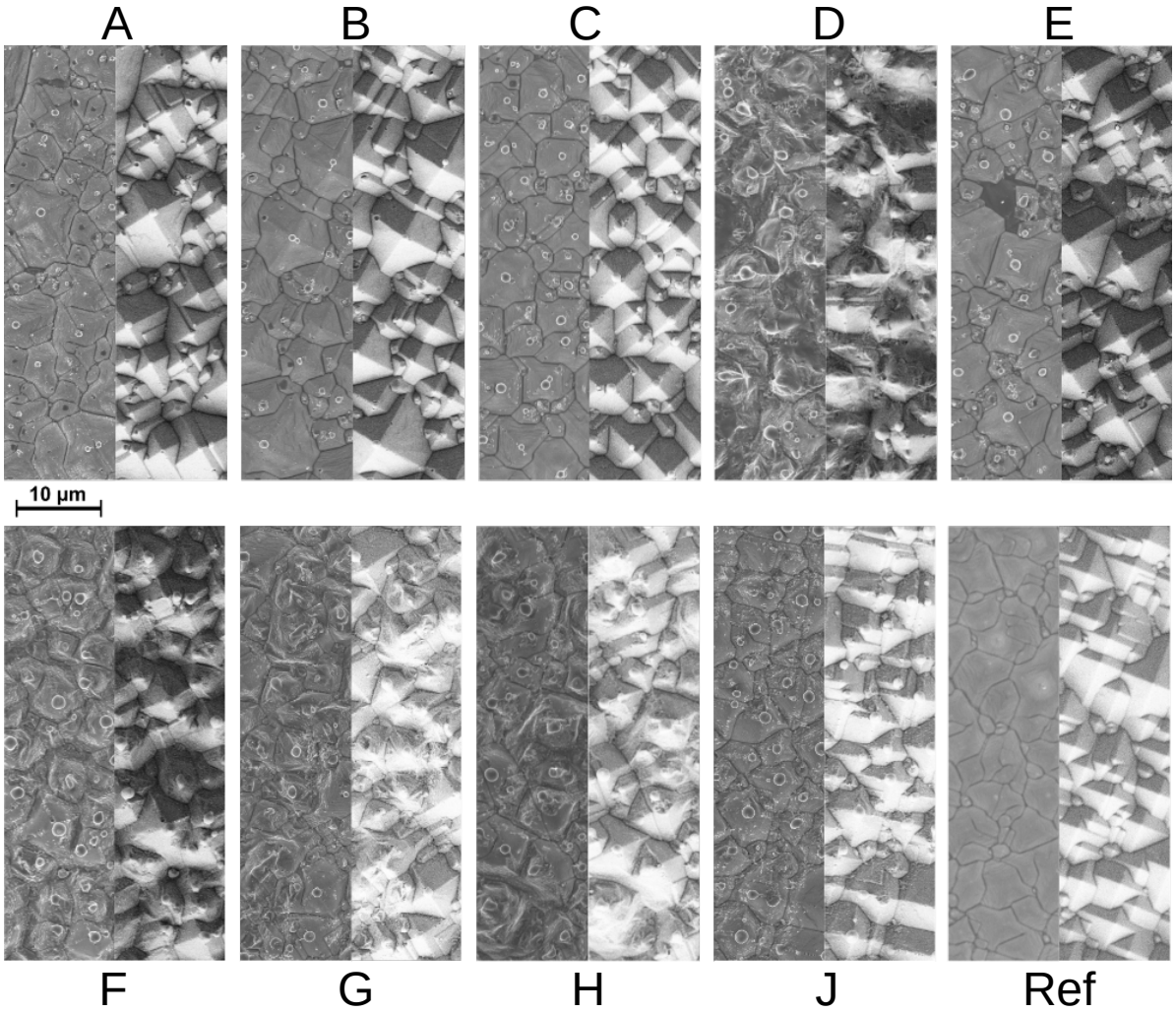
Laser damage can be minimized

Surface impact for contact formation

Textured PERC precursor: SEM investigation

SEM imaging

- Left: Inlens detector
- Right: SE detector



Surface impact for contact formation

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SEM imaging

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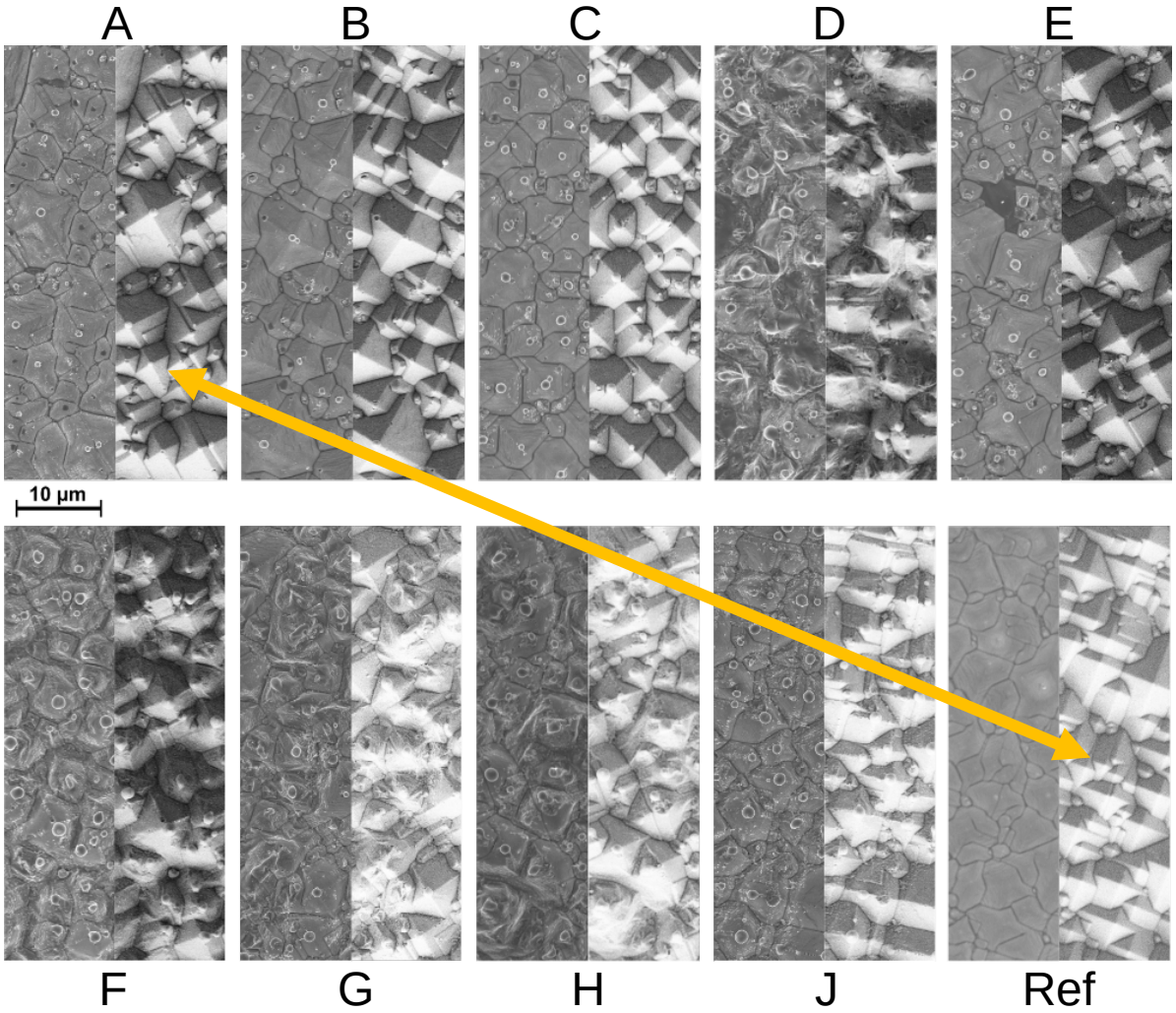
Laser interaction for more focused laser treatment visible as molten/fused pyramid remnants

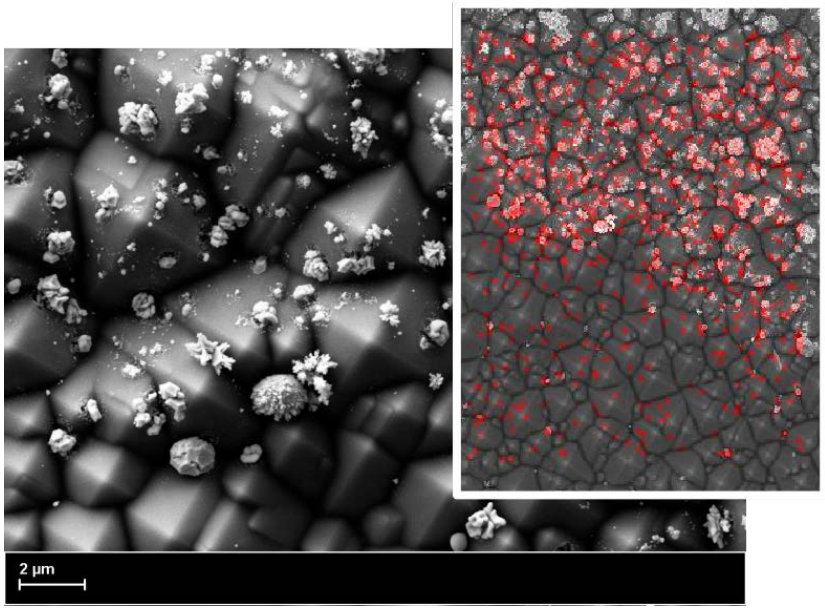


Non-firing-through paste

75 Ω/sq P doped emitter

SiN_x:H coated sample

- Large contact crystals through pinholes in SiN_x:H
- Higher density of Ag in contact area



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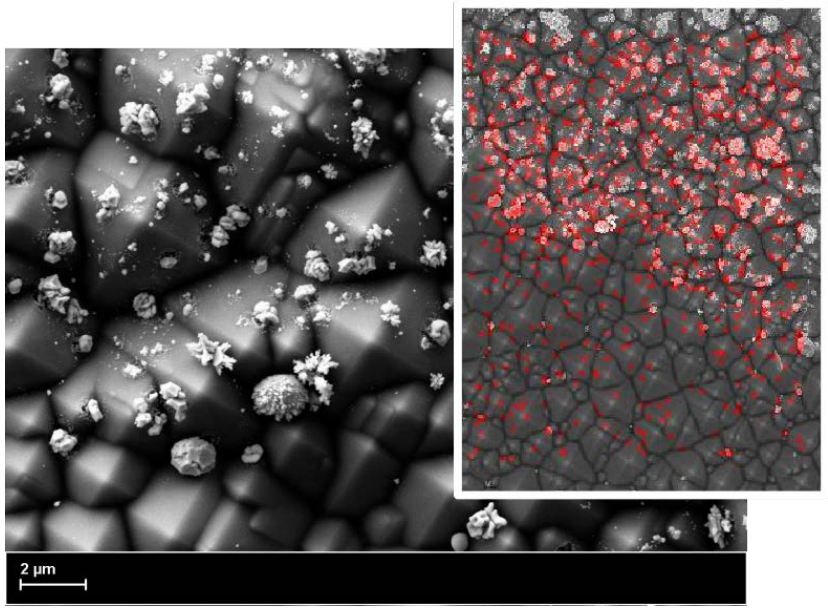
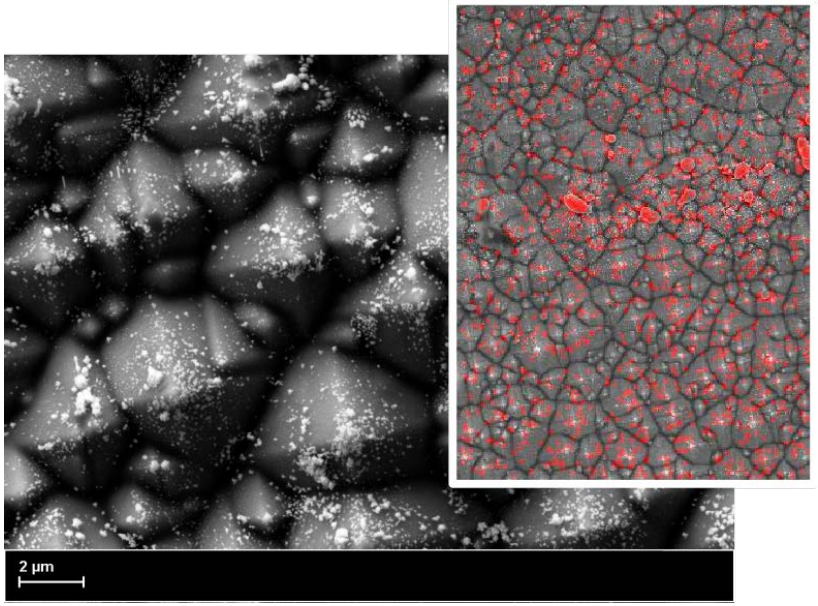


Uncoated sample

- High density of small crystals
- No significant Ag density difference in/out of contact area



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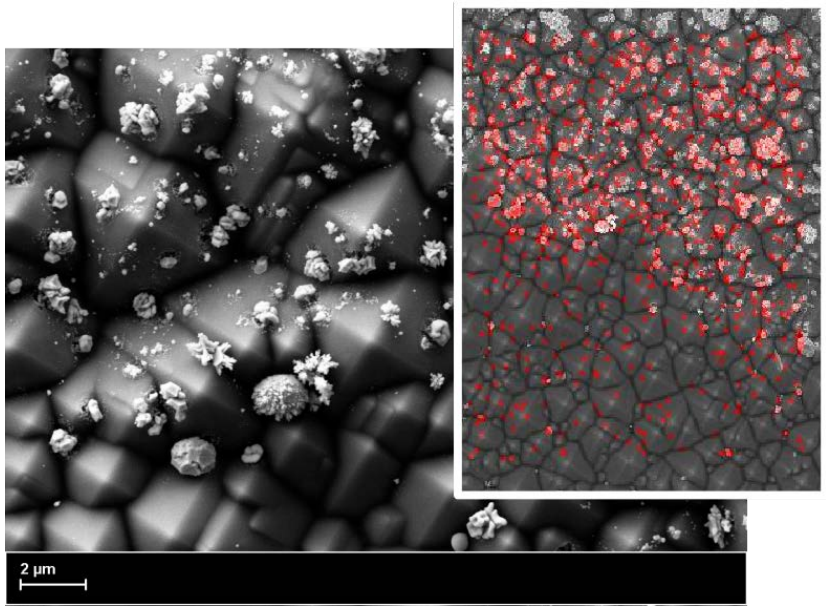

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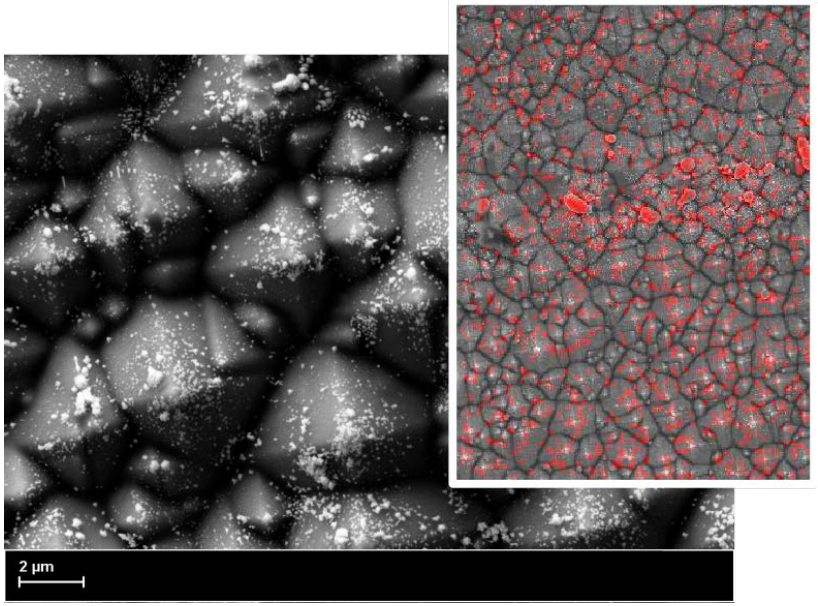


Paste contact behavior

➢ Paste composition can be adjusted to contact small, open areas better

TLM – Spec. contact resistivity

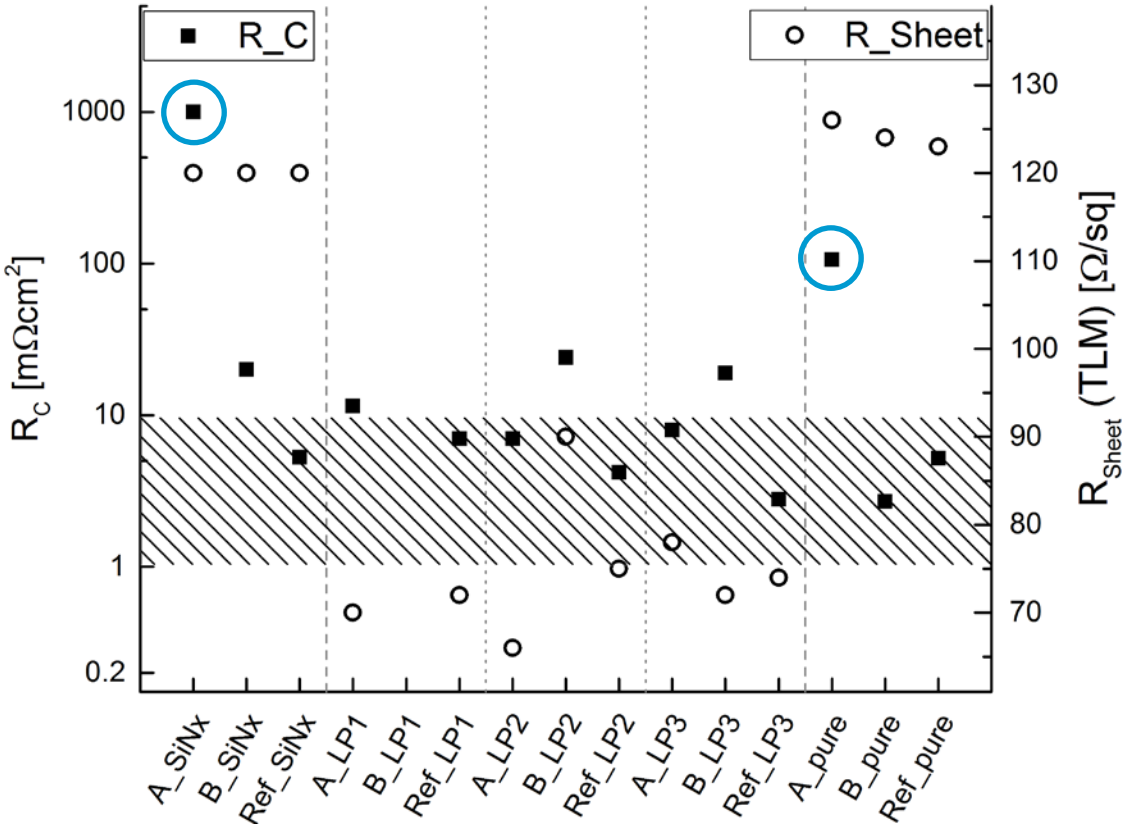
PERC precursor

Ag pastes

- A – exp. non-firing-through
- B – exp. non-firing-through
- Ref – comm. firing-through

Samples

- SiNx – SiN_x:H coated
- LP – laser activated
- pure – uncoated



Contact comparison

➢ Paste A does not contact through SiN_x:H or on open areas

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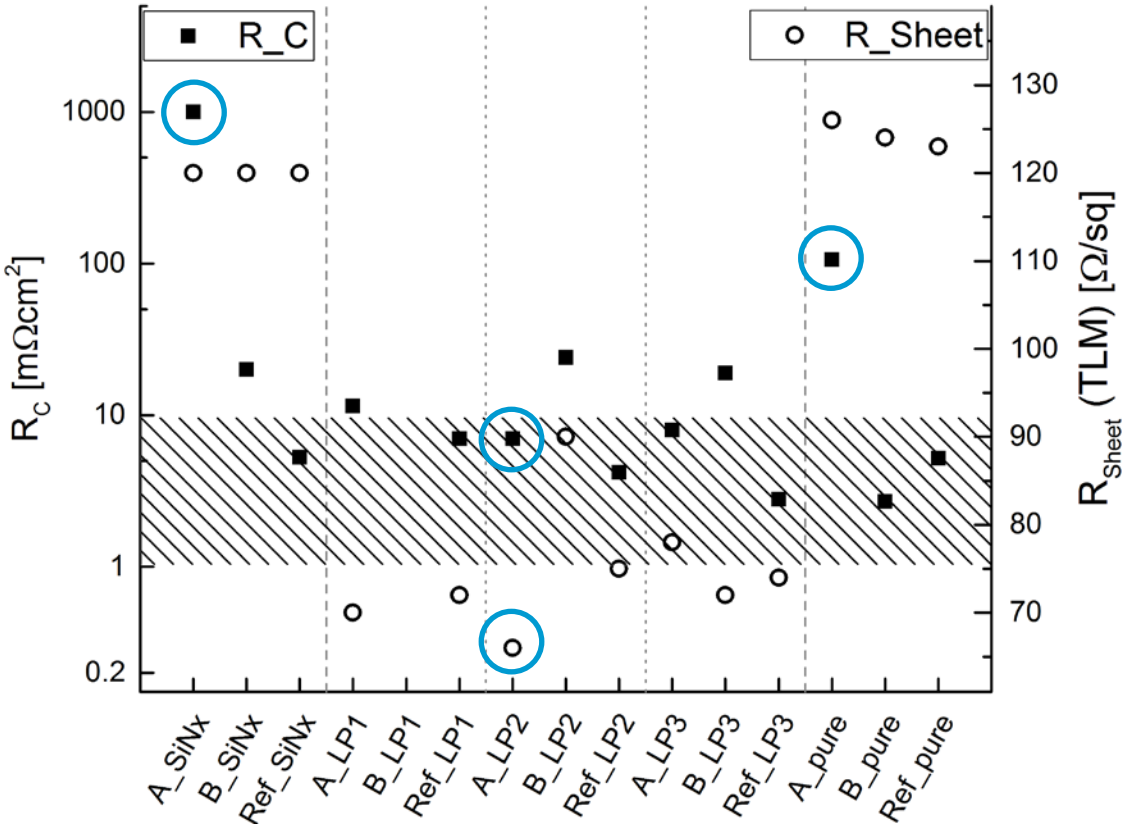

Contact comparison

- ➢ Paste A does not contact through SiN_x:H or on open areas, but on laser activated (R_{Sheet} ↓), opened areas R_C is sufficiently low

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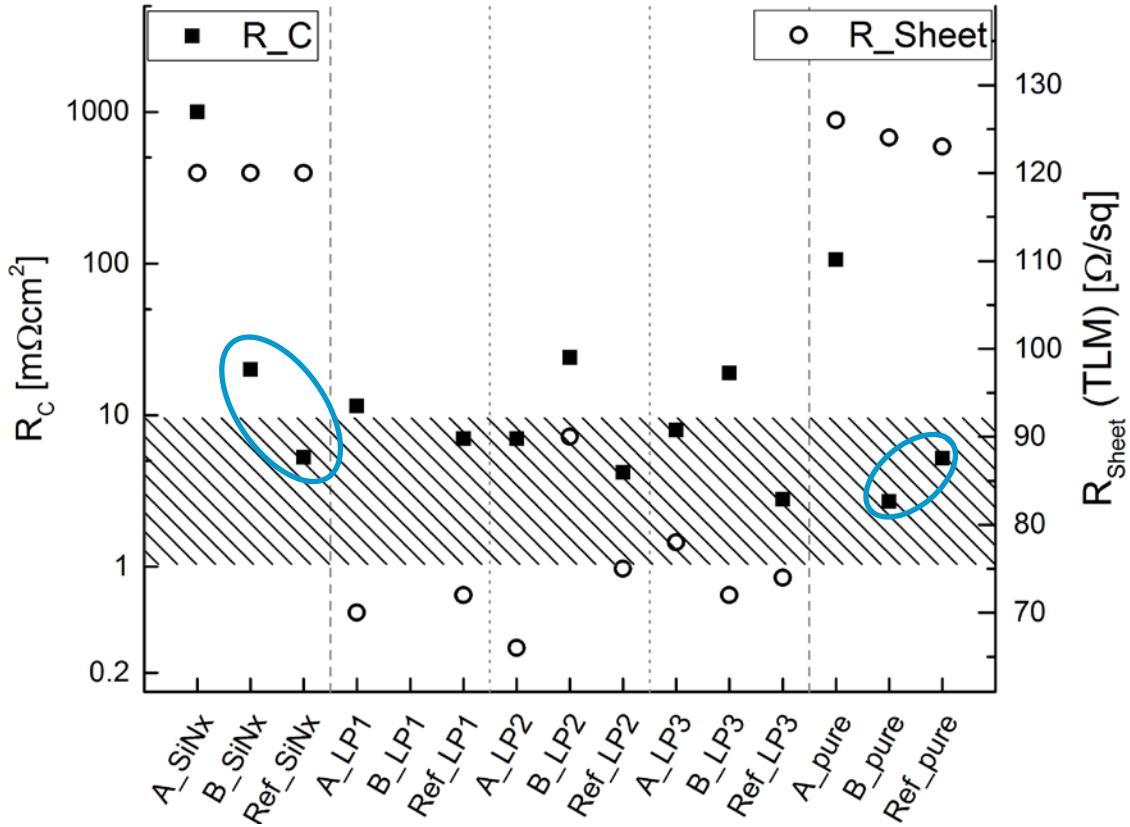

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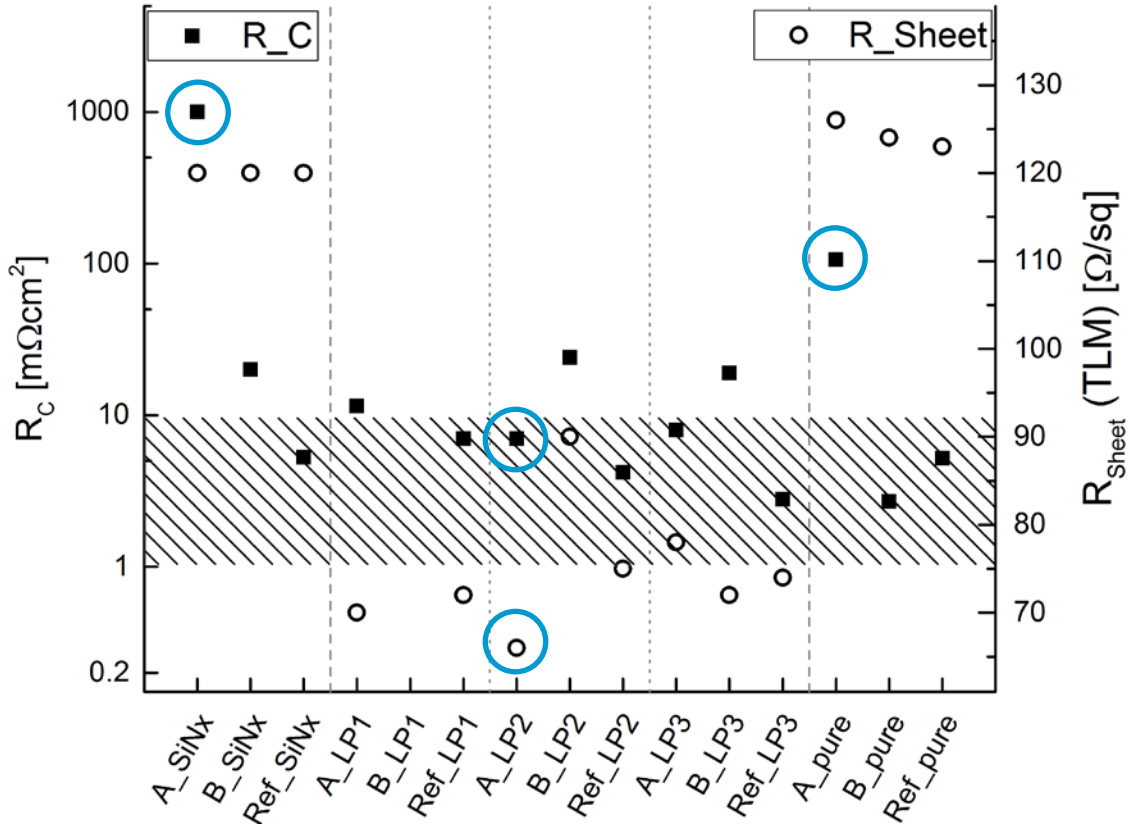

Contact comparison

- Paste A does not contact through SiN_x:H or on open areas, but on laser activated (R_{Sheet} ↓), opened areas R_C is sufficiently low
- Paste B and Ref show no such selectivity
- Paste A advantageous for selective contacting in opened AND doped areas
  - Gain in V_{OC} expected

Sneak peek

Proof of concept: PERC solar cells with presented concept
First attempt without optimized laser parameters!

Three groups

- Reference group (R) with homogeneous emitter (~ 120 Ω/sq)
- Selective emitter group (SEL) with laser doping from PSG layer (~ 60/120 Ω/sq)
- New concept group (NCG) with activated P atoms (~ 80/120 Ω/sq)

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Results

- V_{OC} values
  - No loss in V_{OC} for NCG (665 mV) compared to R (665 mV), but loss for SEL (660 mV) compared to NCG and R
- J_{SC} values for all groups ~ 39 mA/cm^2

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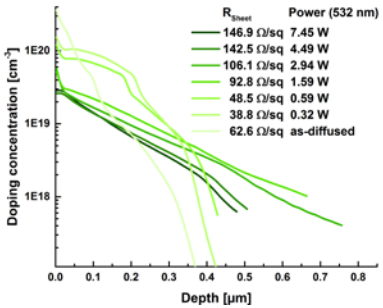
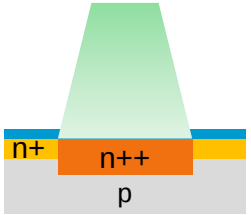
- J_{SC} values for all groups ~ 39 mA/cm^2
- FF gain of NCG of 2%$_{abs}$ compared to R, but still less than SEL by ~ 1-2%$_{abs}$
- NCG:
  - η_{max} of 19.3%

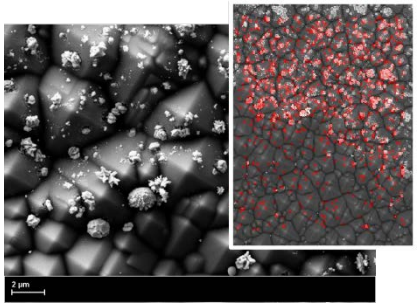
Summary

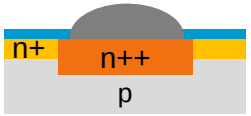
- ✓ Activation of P from internal source combined with ablation



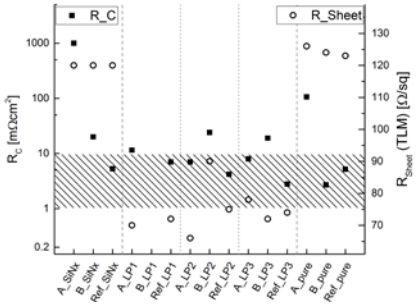


- ✓ Non-firing-through Ag paste for lower paste impact





- ✓ Selective contact behavior



- ✓ Proof-of-concept PERC cells with 19.3% efficiency

Universität Konstanz

Thank you for your attention!

Corresponding author: josh.engelhardt@uni-konstanz.de

The authors would like to thank SolarWorld Innovations GmbH for providing precursors and support with fruitful discussions. Part of this work was financially supported by the German Federal Ministry for Economic Affairs and Energy (FKZ 0324001 IMPULS and 0325777B HELENE). The content is the responsibility of the authors

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

355 nm Laser activation

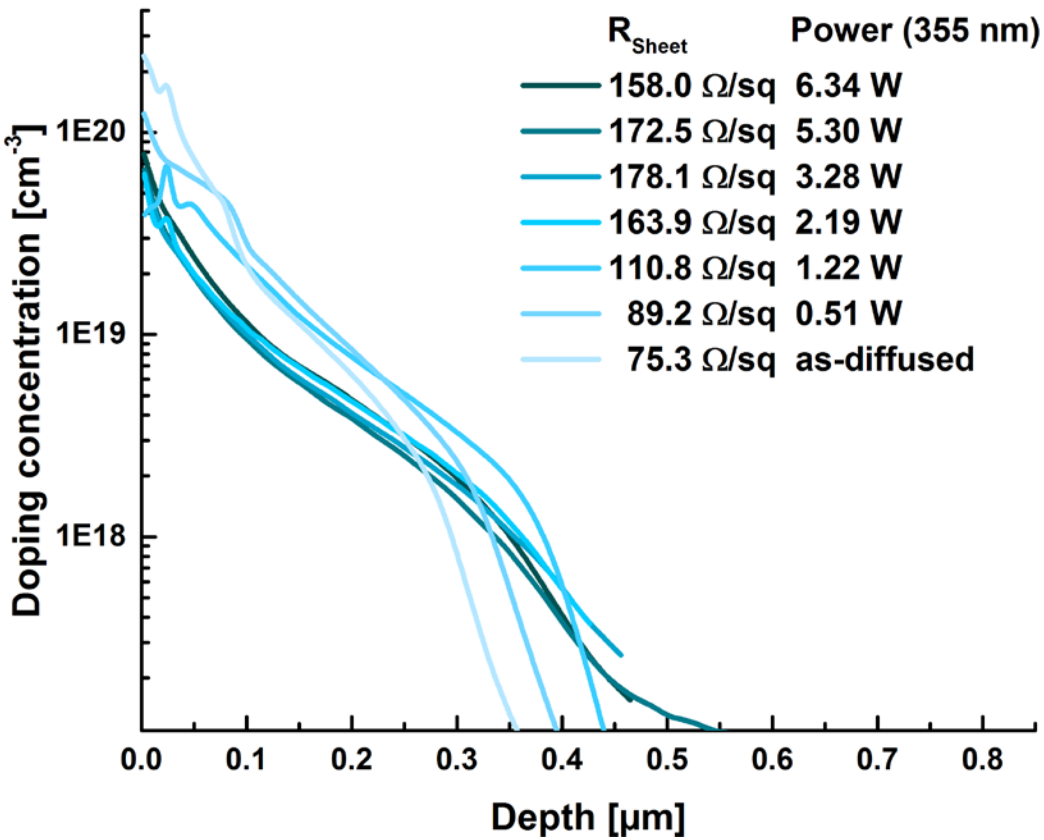
75 Ω/sq P doped emitter

Variation of laser power

- Fixed defocus height
- Change in R_{Sheet} measured by 4PP and ECV

Results

- Increase in R_{Sheet} even for low laser power
- Decrease of profile for higher laser power



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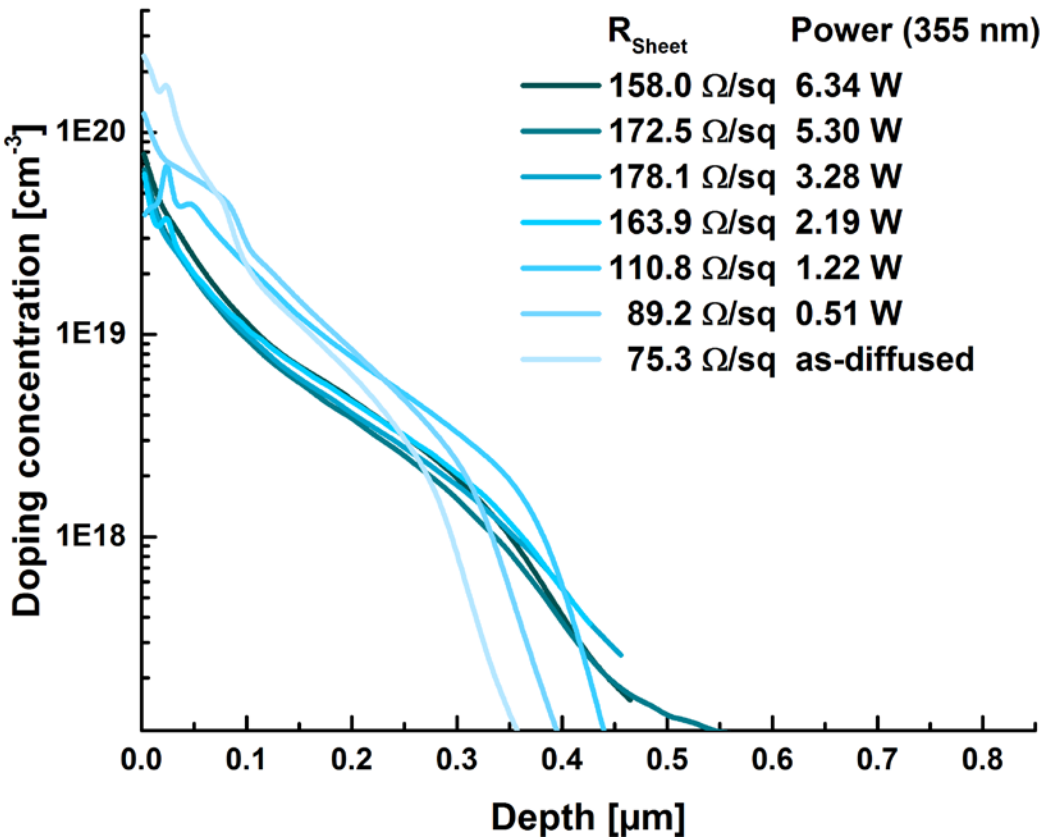

Internal doping source

- Overall doping concentration decreases → inactive P atoms are not activated
- Ablation occurs even for low laser power → overall dopant conc. decreases
- Not suitable due to lower ablation threshold and low absorption depth, as well as cold ablation process instead of heat induction to activate P atoms