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

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Idea and approach

Selective emitter

n+  n++  n++  p

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

Selective emitter

Screen-printing

\[ \text{n}^+ \quad \text{n}^{++} \quad \text{p} \]

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Idea and approach

Selective emitter

Screen-printing

Laser treatment

PSG
Idea and approach

Selective emitter

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Laser treatment

Low impact

$p$ $n^{++}$ $n^+$

$n^+$ $n^{++}$ $p$

PSG

$CB$

$VB$
Idea and approach

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Inactive P atoms

No SiN_x etch
Idea and approach

New concept

Standard sel. Emitter

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

Inactive P atoms

No SiNₓ etch
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Laser doping by internal doping source combined with non-firing-through paste

Inactive P atoms

Standard sel. Emitter

No SiN$_x$ etch
532 nm Laser activation

60 Ω/sq P-doped emitter

Variation of laser power
- Fixed defocus height
- Change in $R_{\text{Sheet}}$ measured by 4PP and ECV

Results
- Decrease in $R_{\text{Sheet}}$ for low laser power
- Increase in $R_{\text{Sheet}}$ for further power increase
532 nm Laser activation

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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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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$_2$O$_3$
Laser impact

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**Laser impact**

**Re-passivated PERC precursors**

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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

A B C D E
F G H J Ref
Surface impact for contact formation

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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
Non-firing-through paste

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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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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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- 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)
Sneak peek

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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 $\sim 39 \, \text{mA/cm}^2$
Sneak peek

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    but loss for SEL (660 mV) compared to NCG and R
• $J_{SC}$ values for all groups ~ 39 mA/cm²
• FF gain of NCG of 2%$_{abs}$ compared to R,
  but still less than SEL by ~ 1-2%$_{abs}$
• NCG:
  • $\eta_{max}$ 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
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355 nm Laser activation

75 $\Omega$/sq P doped emitter

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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