Fraunhofer ISE

FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Interface studies on laser structured plated solar cells

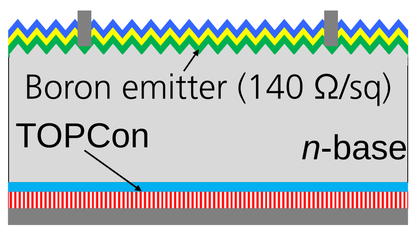
A. Büchler, B. Grübel, S. Kluska, F. Feldmann, B. Steinhauser, G. Cimiotti, A. A. Brand, F. Meyer, V. Arya, J. Bartsch, M. Glatthaar
Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49 761/4588-5019, andreas.buechler@ise.fraunhofer.de

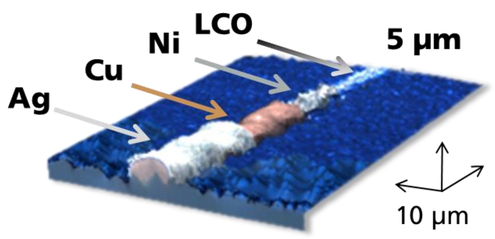
MOTIVATION

- High requirement for plated contacts on high efficient solar cells
- Electrical and mechanical properties are determined on the contact interface
- Goal: Improvement of laser structured plated contacts by improved understanding of the interface

TOPCon CELL WITH PLATED CONTACTS: 22.9 %

- 10x10cm² TOPCon cells with laserstructured plated contacts
- 5 µm laser contact opening width, 3 busbar, 1.3mm finger pitch

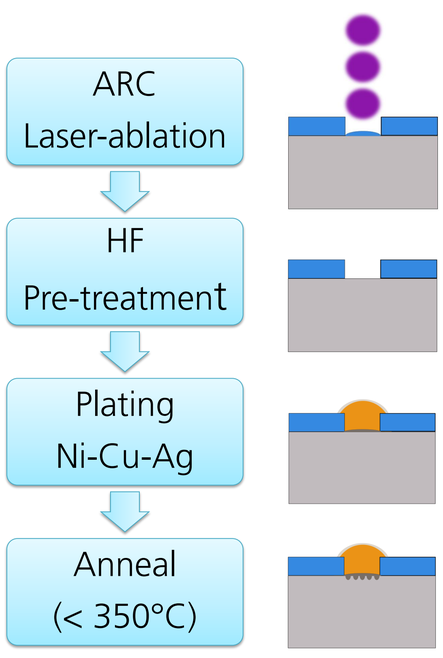




Cell	V_{OC} (mV)	J_{SC} (mA/cm²)	FF (%)	pFF (%)	η (%)
Best	694	40.8	81	83.9	22.9

DIRECT PLATING ON LASER STRUCTURED SILICON

- Process sequence at Fraunhofer ISE for laser-structured plated contacts



Process step / **Impact on the interface**

Intention	Parasitic effect
• Ablation of ARC • Roughening	• Increase of J_0 • Oxidation • Amorphization
• Removal of interface oxides	• Exposition of ARC defects (Parasitic Plating)
• Modification of interface oxide • Silicide-formation	• Risk of nickel silicide spiking

CONTACTING LOWLY DOPED EMITTERS

	Dopant	Surface Doping (cm⁻³)	Sheet resistance (Ω/sq)	ρ_C (mΩ·cm²) Before anneal	After anneal
Plated TOPCon solar cell	Phosphor	$1.30 \cdot 10^{19}$	141	-	0.6 ± 0.2
	Bor	$1.60 \cdot 10^{19}$	137	0.8 ± 0.3	0.4 ± 0.3
	Bor	$6 \cdot 10^{18}$	140	0.5 ± 0.2	-

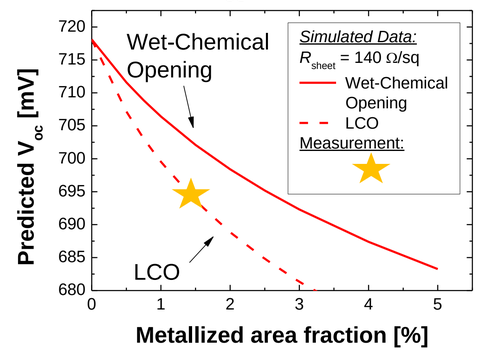
- Demonstration of low ρ_C on lowly doped n- and p-type silicon
- Ni allows for ρ_C, silicidation not mandatory

CONTACT RECOMBINATION

- Influence of laser damage depends on doping profile
- To minimize loss
  - Laser parameters
  - Selective emitter
  - Annealing of LCO
- **Plated TOPCon solar cell**:
  - $J0$,laser : 2700 fA/cm²
  - Total $J0$: 59 fA/cm²

➡ To lower damage: Adjust emitter profile to penetration depth

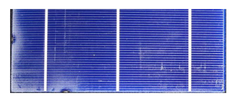
Simulated V_{OC} for TOPCon Cells



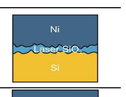
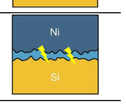
AVOIDING PARASITIC PLATING

- Parasitic plating (PP) promoted by ARC defects
- Harms aesthetic, pFF, V_{OC} and J_{SC}
- PP can by surpressed by
  - Avoiding ARC defects
  - Electrical Insulation of ARC defects
  - Skipping HF („Easy Plating")
- Easy Plating: allows good contact resistance without HF-dip
  - Limited time between ablation and deposition
  - Post-Plating anneal required
  - No effect of silicidation

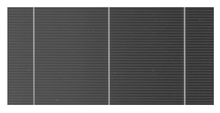
Plating after HF-Dip



Easy Plating

Easy Plating	ρ_C(mΩ·cm²)	
Before Anneal	10 ± 2	
After Anneal	0.8 ± 0.3	

Plated TOPCon Cell

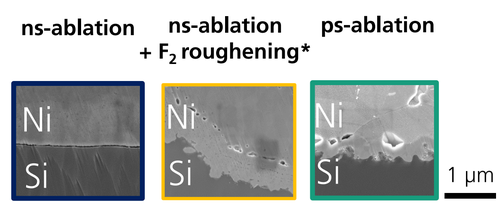


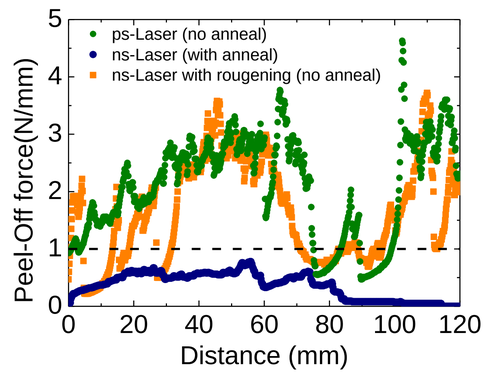
- **Plated TOPCon solar cell**: Avoid ARC defects by double layer ARC

ENSURING CONTACT ADHESION

- Two established ways to ensure adhesion
  - Mechanical solution: Topography
  - Chemical solution: Silicidation
- Silicidation
  - Necessary: Removal of all interface oxides
  - Risk of nickel spiking (pFF-loss)
- Topography
  - Ps-/fs-pulsed laser ablation on textured surface
  - Rougening of contact opening (first 50-200nm ➔ emitter!)
- **Plated TOPCon solar cell**: ps-laser ablation

Adhesion without silicide formation





* Atmospheric pressure dry etch (Patent pending)

CONCLUSION

- Low contact resistivity on lowly doped emitters without silicide formation
- Emitter profile and penetration depth of laser need to be adjusted
- To avoid parasitic plating: no ARC defects or skipping HF-dip
- For contact adhesion: Ensure nano-roughness or silicides

This work was funded by the German Federal Ministry for the Economic Affairs and Energy in the frame of the "Groschen" project (0324012) and "PEPPER" (03225877D)

Supported by: Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag