Non-contacting Busbars for Advanced Cell Structures using Low Temperature Copper Paste

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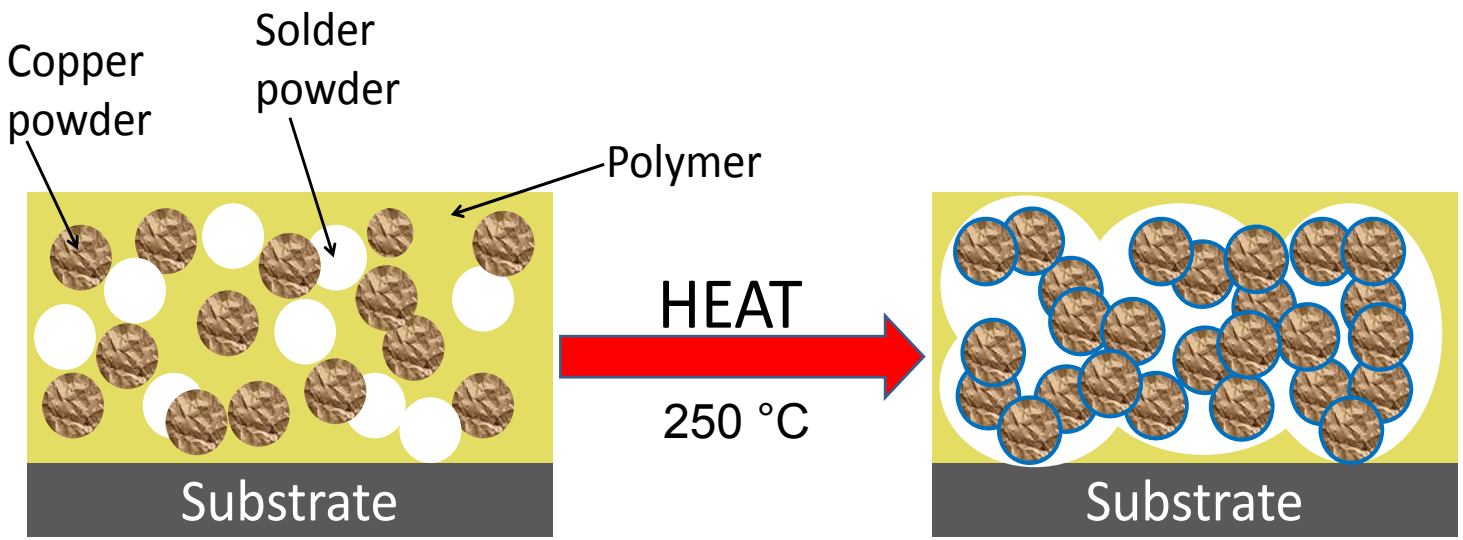
Dow Corning Cu paste : good conductivity at low cost



ρ = 20 – 40 μΩ cm

Combination Ag screen printing – Cu paste

Texturing

Emitter formation

Junction isolation

PECVD SiN_x front

Screen printing Ag fingers and BB

Screen printing Ag fingers

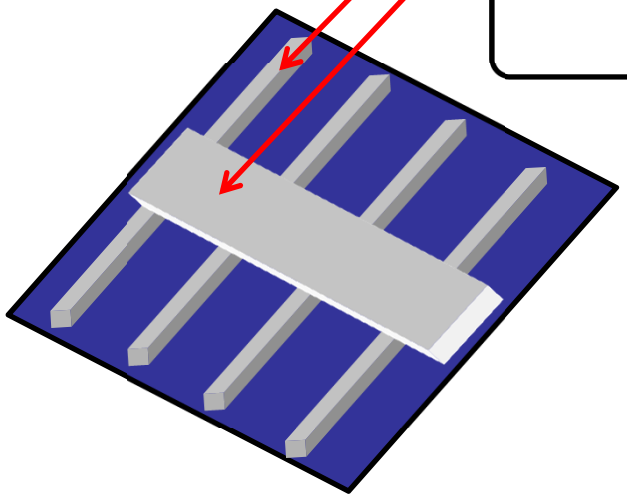
Printing rear

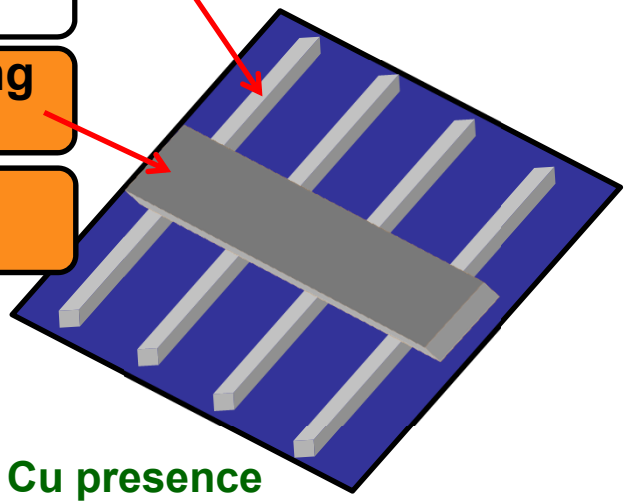
Co-firing

Screen printing low-T Cu BB

Cure in N_2

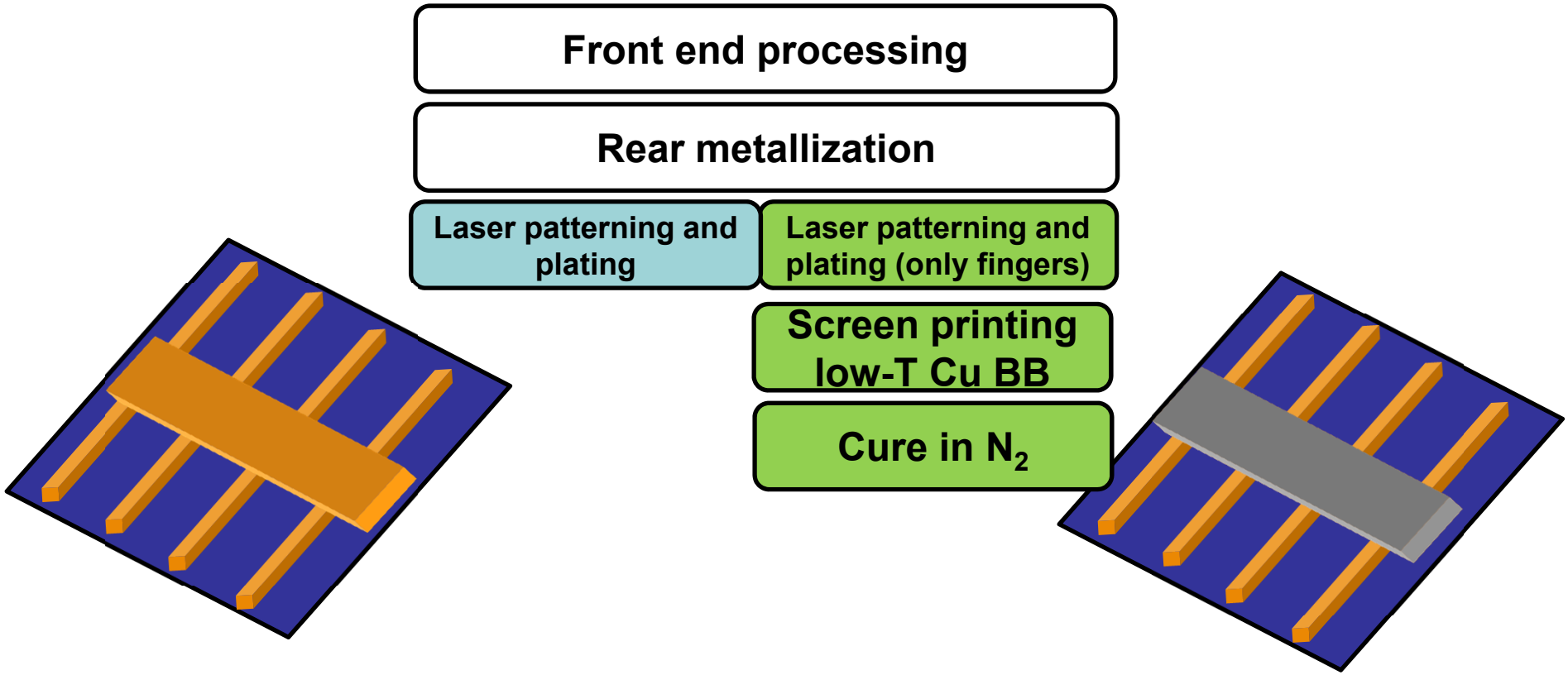
Wood et al.
Silicon PV 2014
Energy Procedia Vol.55





- Equivalent cell performance
- No detrimental impact due to Cu presence
- Full size modules passing 1 x IEC *Wood et al. , Energy Procedia Vol.55*

Cu paste can also be combined with plated cells



- Cure at 200 to 300 ºC
  ⇨ temperature-sensitive structures can be preserved

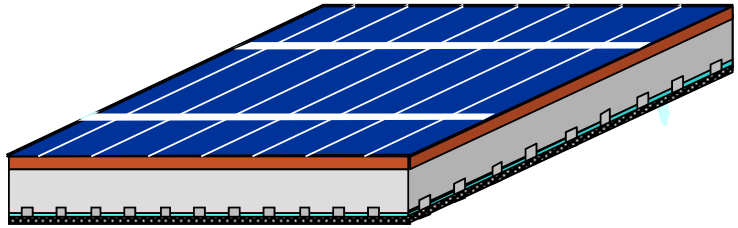
- Ni silicide formation/anneal and busbar curing can be done simultaneously

Does a hybrid Cu plating – busbar printing process make sense ?

yes !

- Capex and maintenance
  - o No laser capacity needed for ablation of busbar area
  - o Screen printer much less capital intensive than laser system
  - o Fewer lasers → less maintenance
- Expected performance
  - o Less Si – metal interface area → less recombination → higher Voc
  - o Lower probability of shunting caused by laser damage
- Interconnection
  - o Traditional soldered interconnection can be applied
  - o Alternative to new, emergent but as of yet unproven interconnection technologies

p-type PERC cells with plated fingers



p-Cz (Ga), 156mm-sq, 180um, 1.8 Ohm-cm

Texturing front and polishing rear

$POCl_3$ target 130-140 Ohm/sq emitter + junction isolation

Clean and oxidation (target 120 Ohm/sq)

PECVD SiNx on the front + PECVD stack on the rear

Rear laser ablation, Al sputtering and co-firing

Front laser ablation fingers and BB

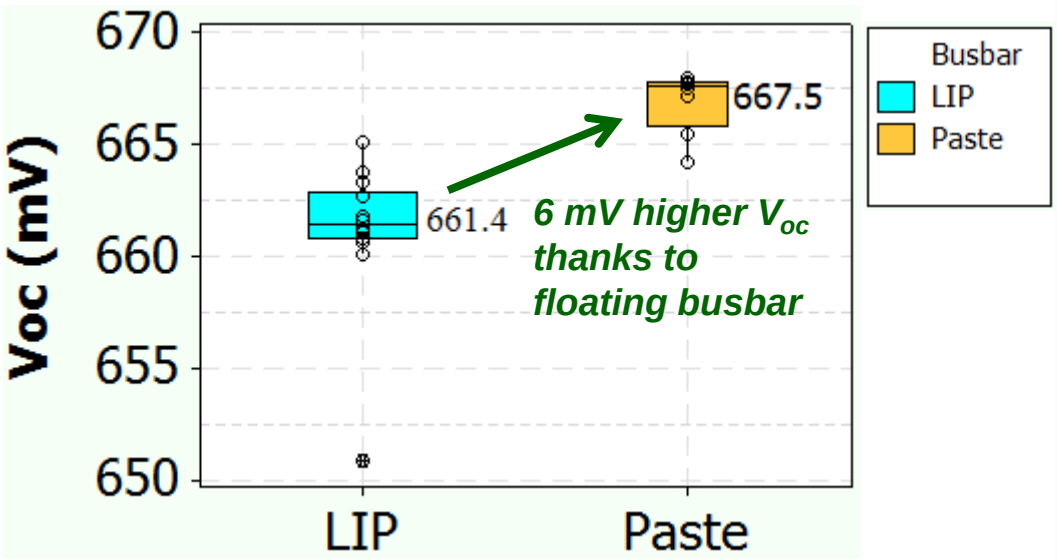
Front laser ablation – only fingers

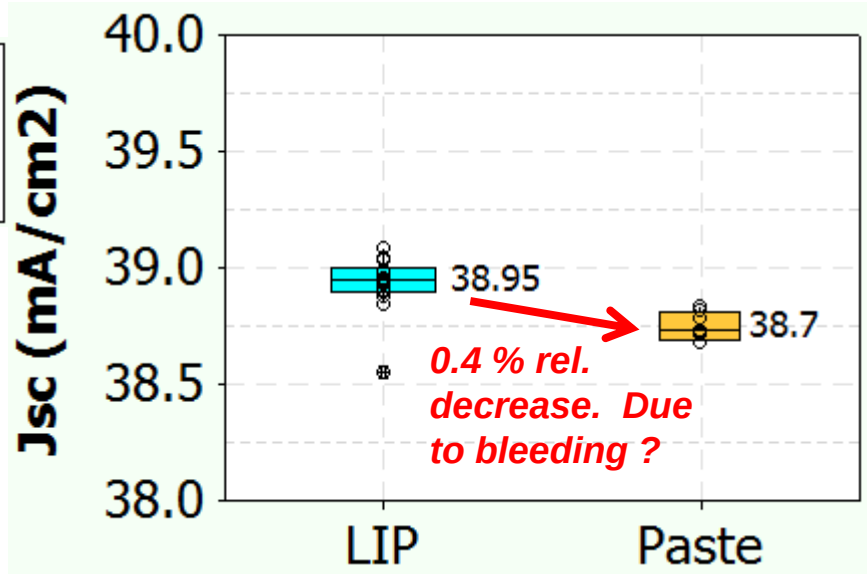
LIP Ni-LIP Cu-LIP Ag plating

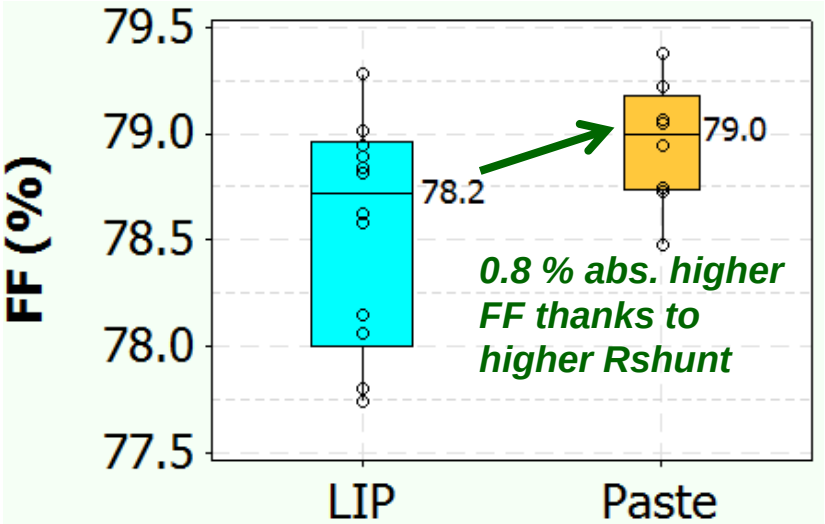
Cu BB Printing

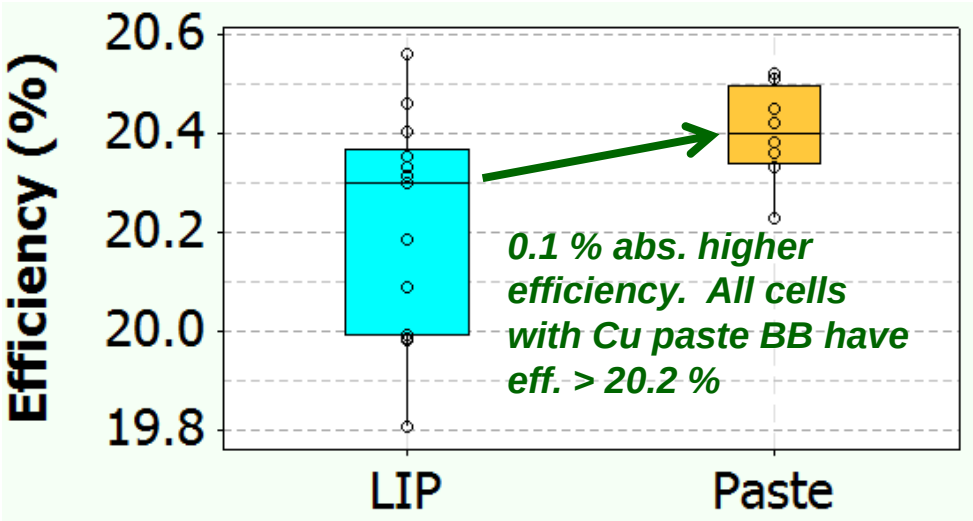
Full stack sintering

Nett performance increase with Cu paste busbar

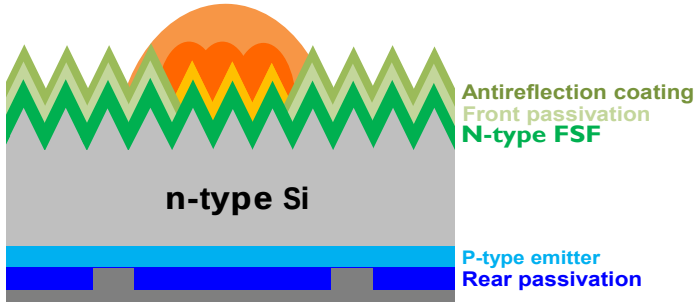








n-PERT cells with plated fingers



n-Cz (P), 156mm-sq, 180um, 3.5 Ohm-cm

Integration flow- front -end

- TMAH SDR/polishing
- Boron diffusion- emitter
- BSG removal +Wet oxidation
- Front oxide removal
- TMAH texturing
- $POCl_3$ diffusion - FSF
- PSG removal +Dry oxidation
- ARC front-PECVD SiNx
- Rear PECVD SiOx

Integration flow- back-end

- Laser ablation - rear
- AlSi PVD
- FG-anneal- contact formation
- Front Laser: fingers and BBs
- Front Laser: fingers only
- Ni/Cu/Ag plating
- Cu BB printing
- Contact co-sintering

N-PERT cells with Cu paste busbar: cell results

Std structure- 3BB PLATED

	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF (%)	Efficiency (%)	SunsVoc (mV)	pFF (%)
Average	39.2 ± 0.1	**663.3 ± 1.1**	79.5 ± 0.4	20.7 ± 0.2	**666.5 ± 1.0**	83.4 ± 0.1
Best	39.2	664.9	80.1	20.9	668.0	83.4

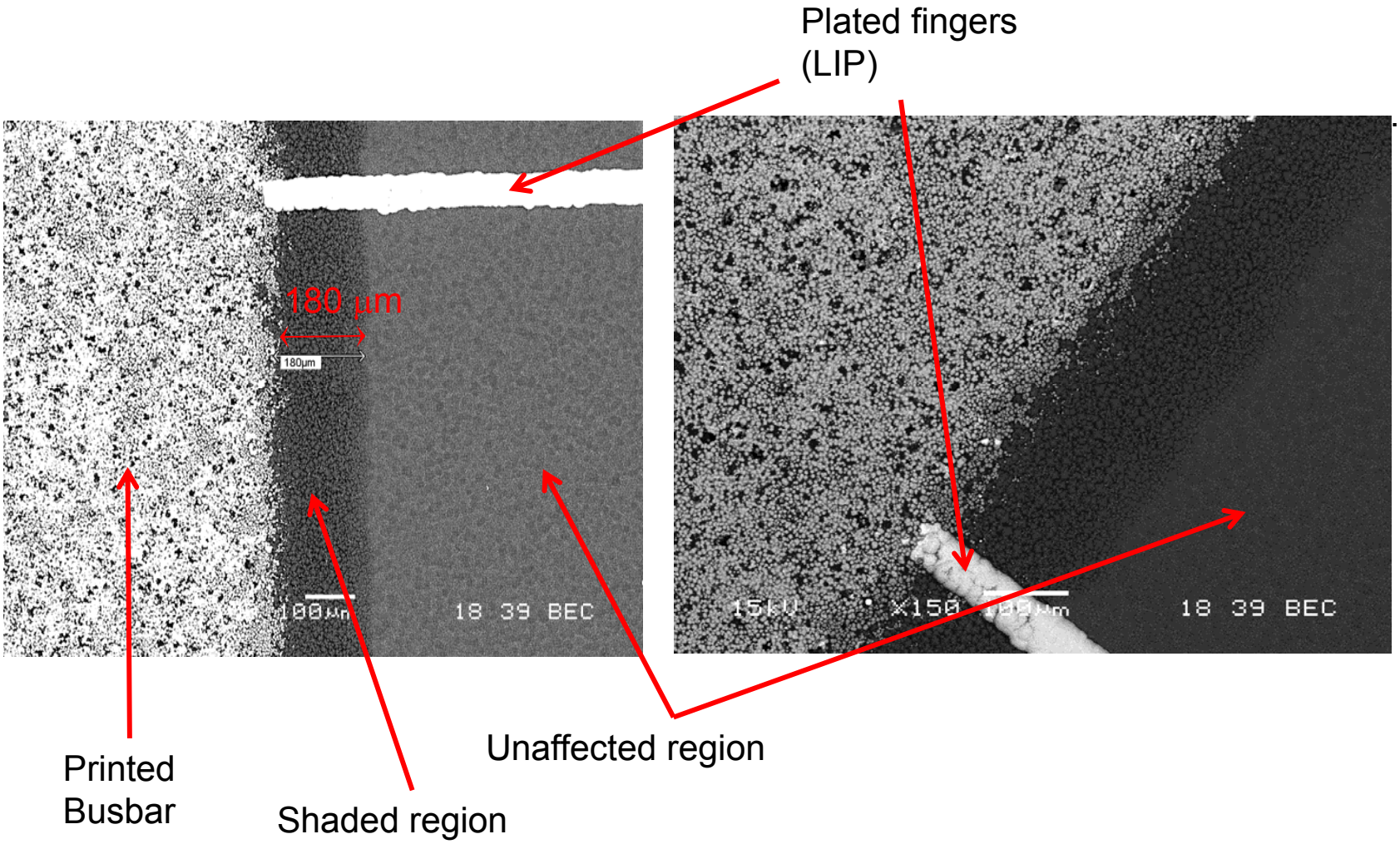
Floating BB

	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF (%)	Efficiency (%)	SunsVoc (mV)	pFF (%)
Average	38.9 ± 0.1	**668.2 ± 1**	79.4 ± 0.5	20.7 ± 0.2	**670.1 ± 1.1**	82.9 ± 0.6
Best	39.0	667.9	80.1	20.9	671.7	83.5

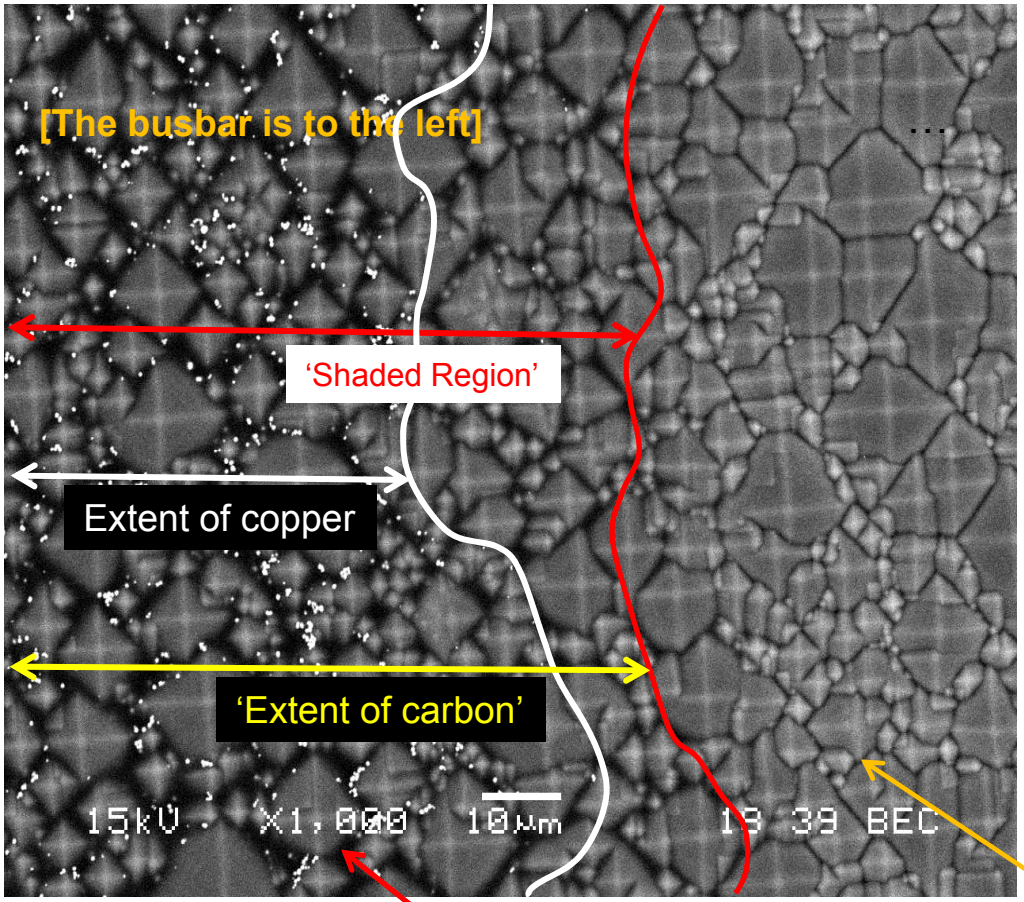
Δ 5mV average gain for floating BB

Drop in J_{sc} leads to same efficiency

Suspected reason for lower J_{sc} : bleeding



Bleeding : a closer look



- Wider regions between pyramids in carbon shaded region vs unaffected region
- Small copper particles present at the base of the pyramids, carried by solvent
- Both copper and carbon cause shading loss
- Bleeding issue has been addressed in subsequent formulations and does not appear a fundamental problem

Summary

- A low-temperature screen printing paste based on Cu particles was developed
- The Cu paste was applied to front busbars in PERC and n-PERT solar cells with Ni/Cu-plated fingers
- Consistent V_{oc} increase thanks to lower recombination under busbars
- Efficiencies up to 20.5 % (PERC) and 20.9 % (n-PERT) have been obtained for 156 mm Cz wafers
- Cu paste busbar process results in solderable and easily measurable cells
- Good control of bleeding desired to make use of full efficiency increase potential