THE
WET PROCESSING
COMPANY

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6th Workshop on Metallization &

Interconnection for Crystalline

Silicon Solar Cells

Transition to 4 and 5 BB designs for Ni/Cu/Ag plated cells

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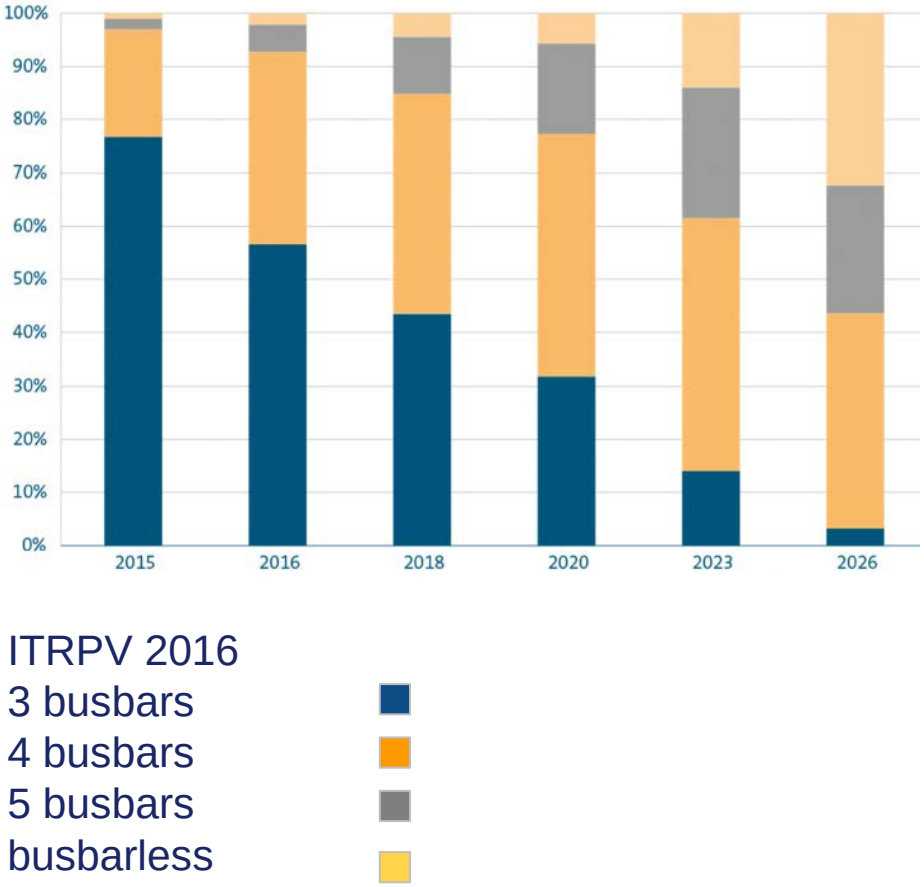
Overview

- Motivation
- Process sequence
- Simulation
- Optimal metal mass
- Comparison of simulation and experimental results
- Finger and solder adhesion
- Total cost of ownership
- Conclusion

Motivation

- Advantages of more busbars
  - Shorter effective finger length – reduced Rs
  - Potential metal reduction
- Advantages of an electroplated grid
  - Narrow finger width achievable
  - Copper substitutes silver – reduced material costs



Process sequence

Process Sequence

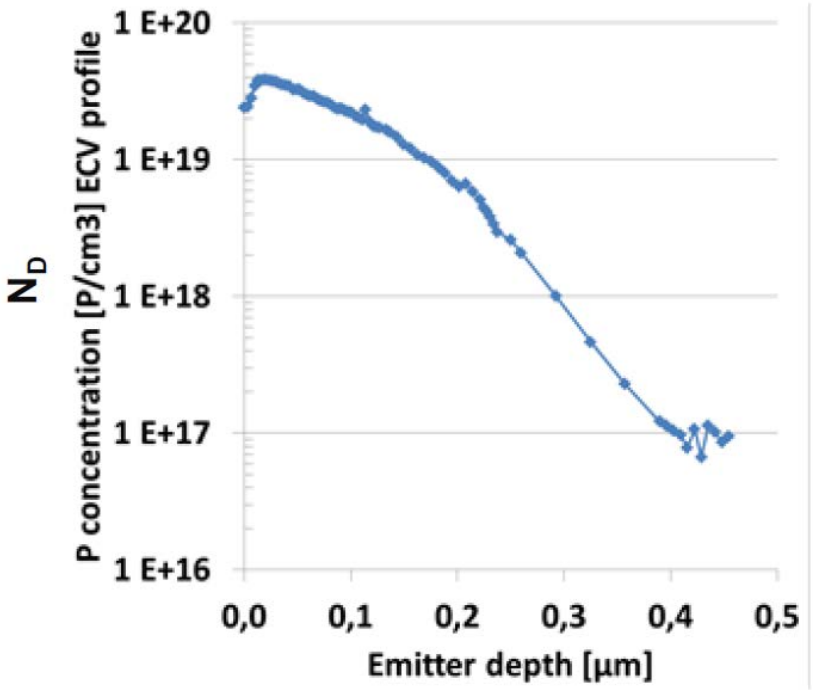
- Laser contact opening (LCO) of SiNx; UV pico sec
- Single side inline processing
  - Pretreat (to remove native oxide)
  - Ni LIP (contact layer and diffusion barrier)
  - Cu LIP (conducting layer)
  - Im Ag (solderable layer)
- Thermal anneal

Front side layout

- 150 finger, BB layout to keep shading similar
  - 3x 1.5mm
  - 4x 1 mm
  - 5x 0.9 mm

Material

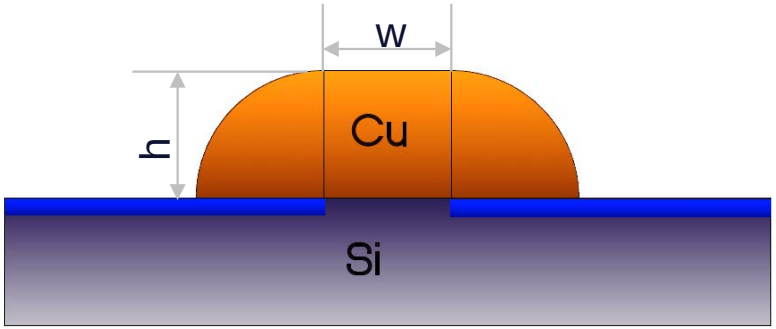
- Cz-Al BSF solar cells with 120 Ohm emitter
  - Reduced surface concentration
  - Deeper diffusion



Emitter used for these experiments processed by Trina solar

Simulation

- Gridsim[1] simulations
- Assumptions:
  - Variation just in finger length
  - All busbar parameters assumed as constant
    - width
    - height
    - conductivity
- Grid was optimized to a minimal power loss for a 3 busbar design
- $R_{s,total}$ = 0.36 Ω cm^2 fixed as goal parameter for all busbar designs
- Finger height (cross section) for 4 and 5 BB was varied to match R_s

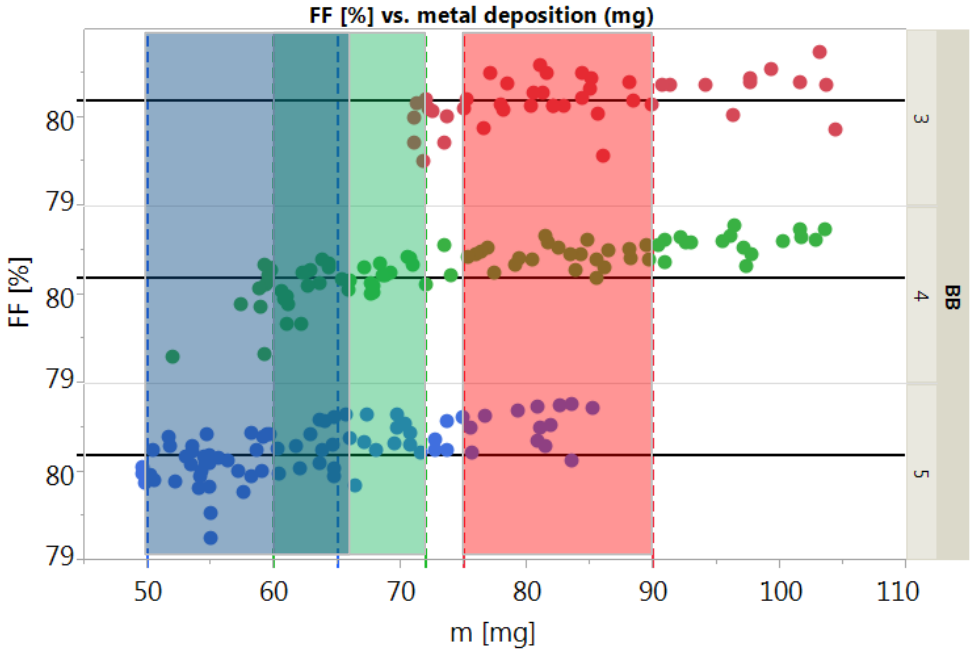


no. busbar	finger length (mm)	$R_{S\ total}$ (Ω cm^2)	finger height (µm)	finger cross section area (mm^2)
3	25	0.36	11	0.041
4	19	0.36	6	0.018
5	15	0.36	4	0.011

1) A. Mette 2007

Optimal metal mass

- A level for the FF of 80.2% is considered to be sufficiently metallised
- A 30 % metal reduction can be achieved with 5 BBs
- Results from simulation and experiment differ

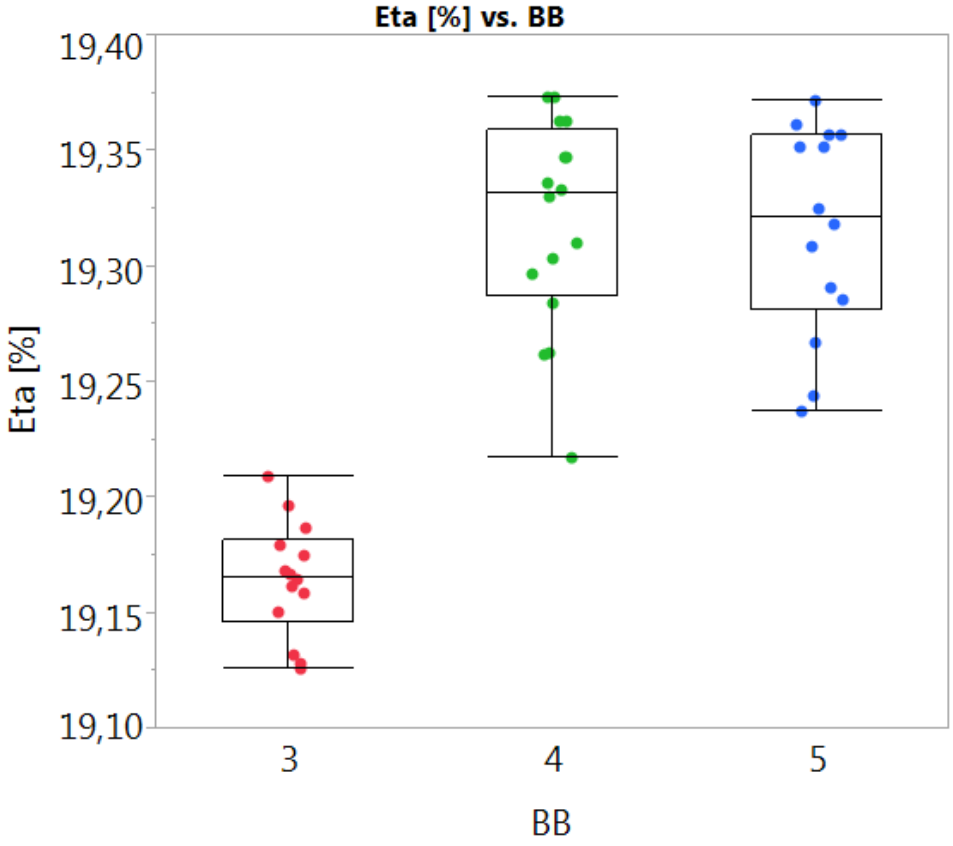


	Metal deposition /mg		Metal reduction / %	
BB	Simulation	Experimental	Simulation	Experimental
3	130	75-90	0	0
4	65	60-72	50	20
5	46	50-65	65	30

Efficiency

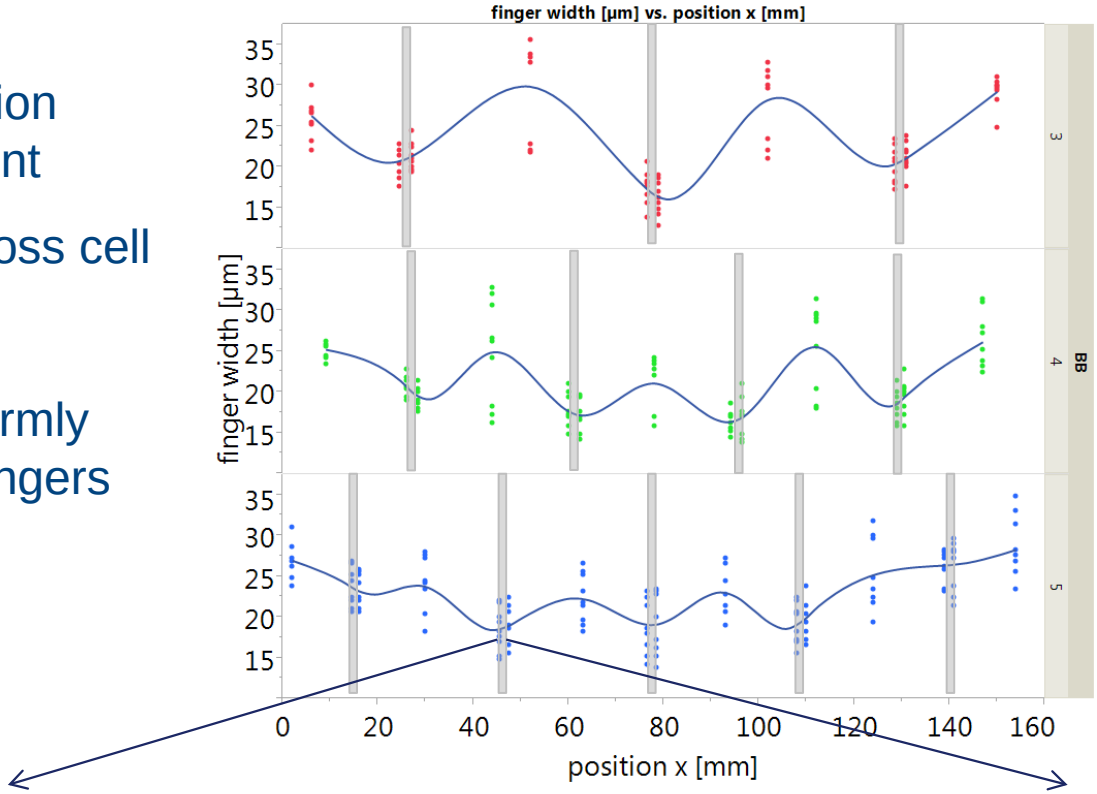
- Lower metal mass
- Above 0.15% efficiency gain is achieved with more busbars
- 4 busbar cells have a reduced shaded area compared to 3,5 busbar cells

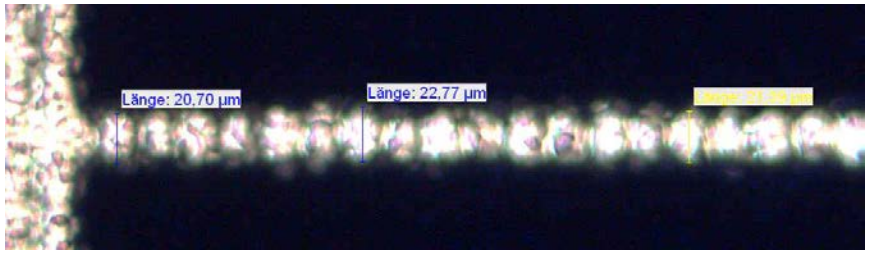
- Best cells Eta = 19.5%



Comparison of simulation and experimental results

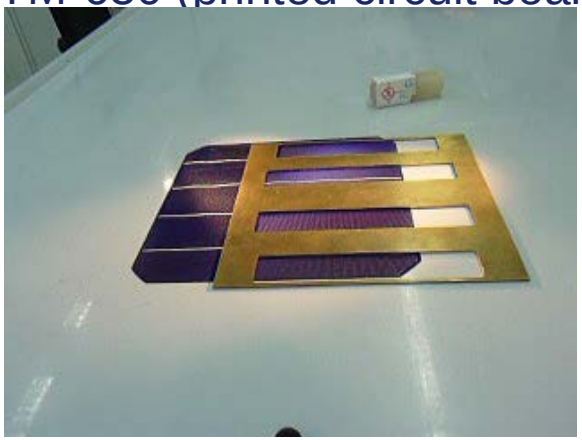
- There is a significant deviation from simulation to experiment
  - Finger width varies across cell
  - Finger roughness
  - Metal mass is not uniformly deposited on BB and fingers

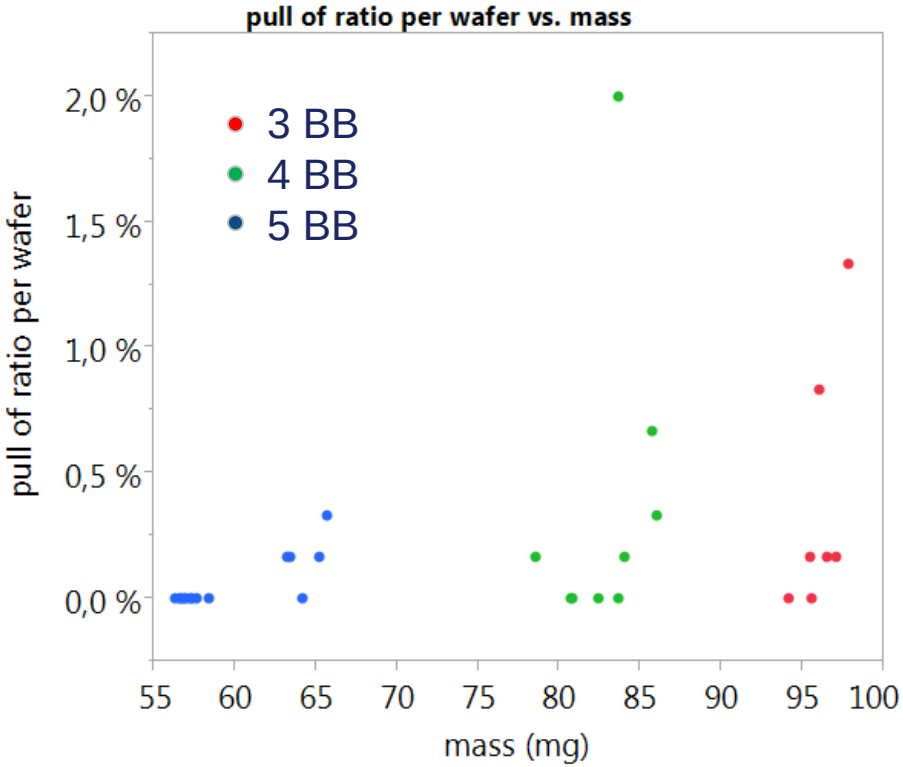




Finger adhesion

- Finger adhesion is tested with a tape test that is close to IPC-TM-650 (printed circuit boards)

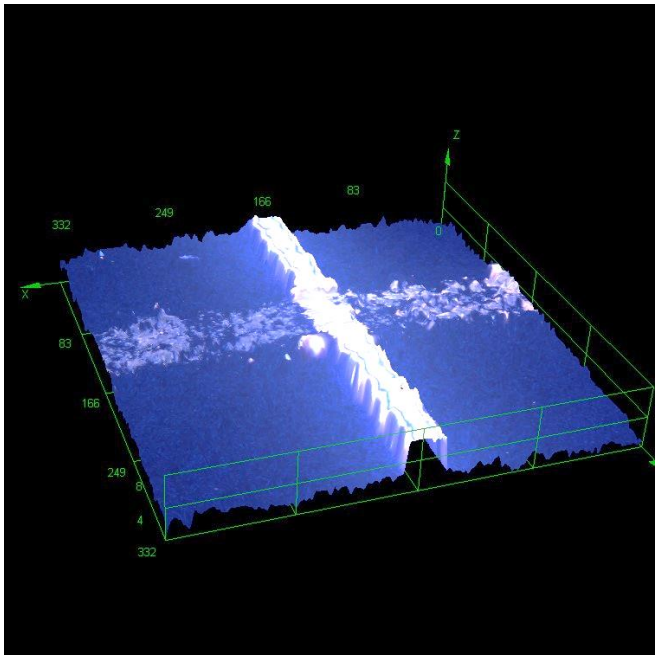


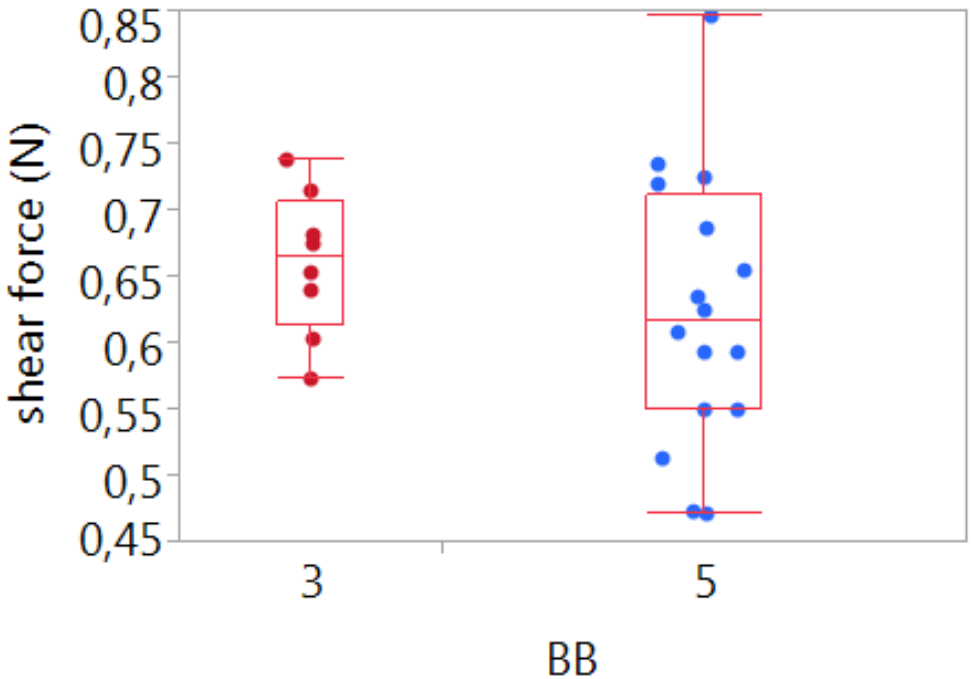


- Finger adhesion seems to be influenced by metal mass
- This could be related to mechanical stress in the metal stack
- Or geometric, broader fingers have more surface for the adhesive tape to attach to

Finger adhesion

Shear test



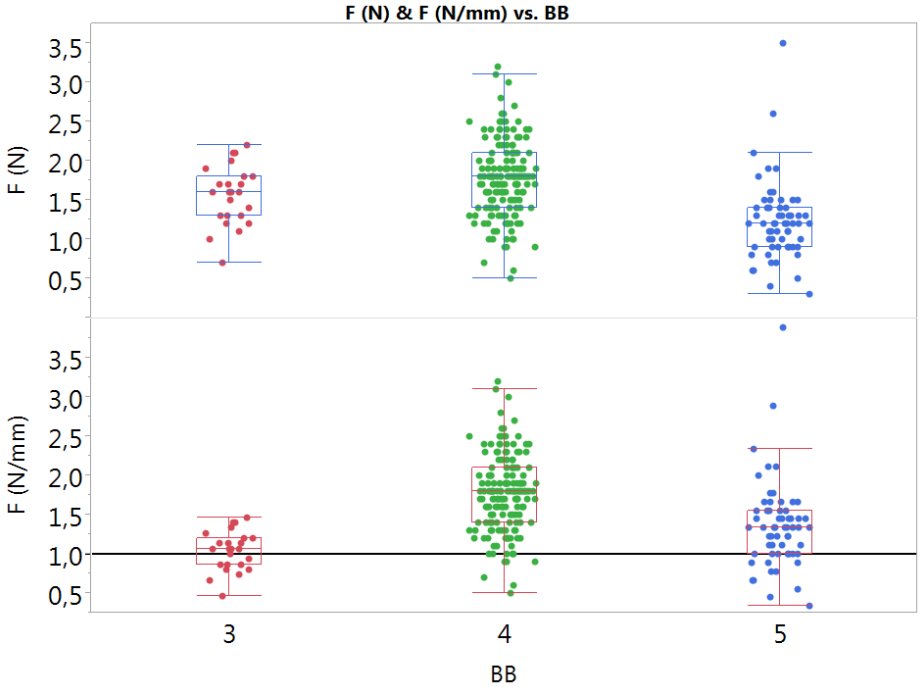


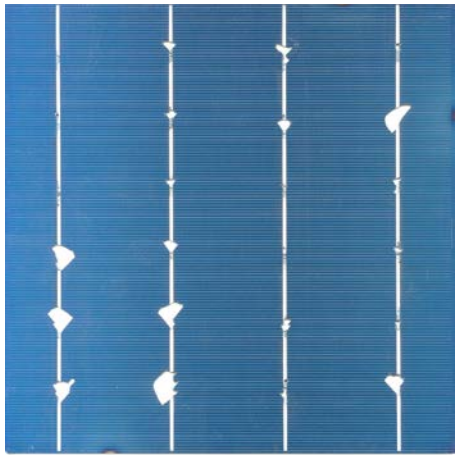
- No difference between the groups
- More investigation necessary

- Pragmatic approach: finger adhesion is on a good level and having narrower fingers is certainly not a disadvantage

Solder adhesion

- 90° peel test
- Force per busbar area is approximately the same
- Peel forces are mostly above 1 N/mm
- Low values can partly be explained by manual assembly
- Adhesion is good enough to cause wafer fracture in peel test





Total cost of ownership Three busbars

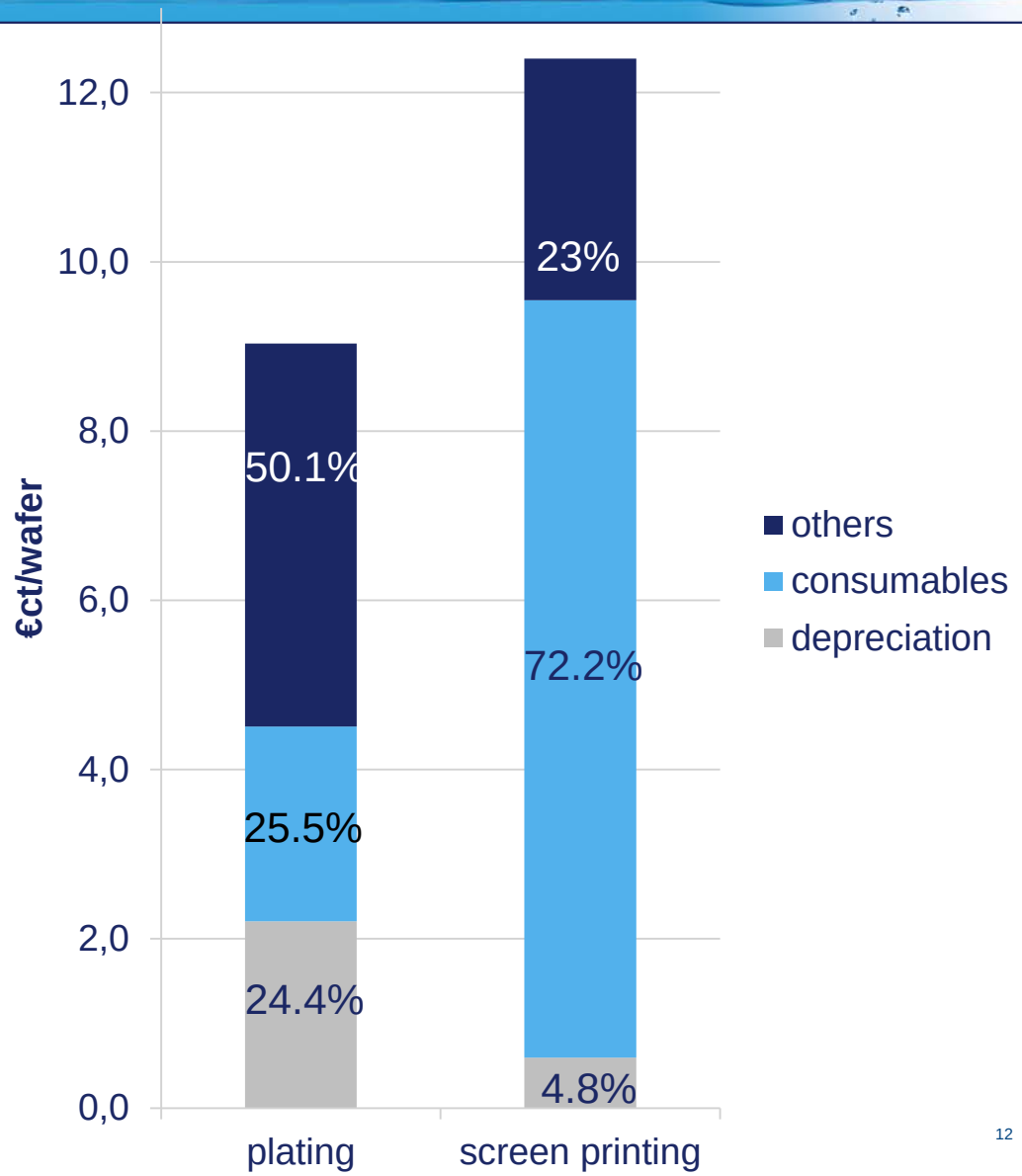
Plating

- Lower consumable costs
- Higher tool costs
- TCoO=9.0 €ct/wafer

Screen printing

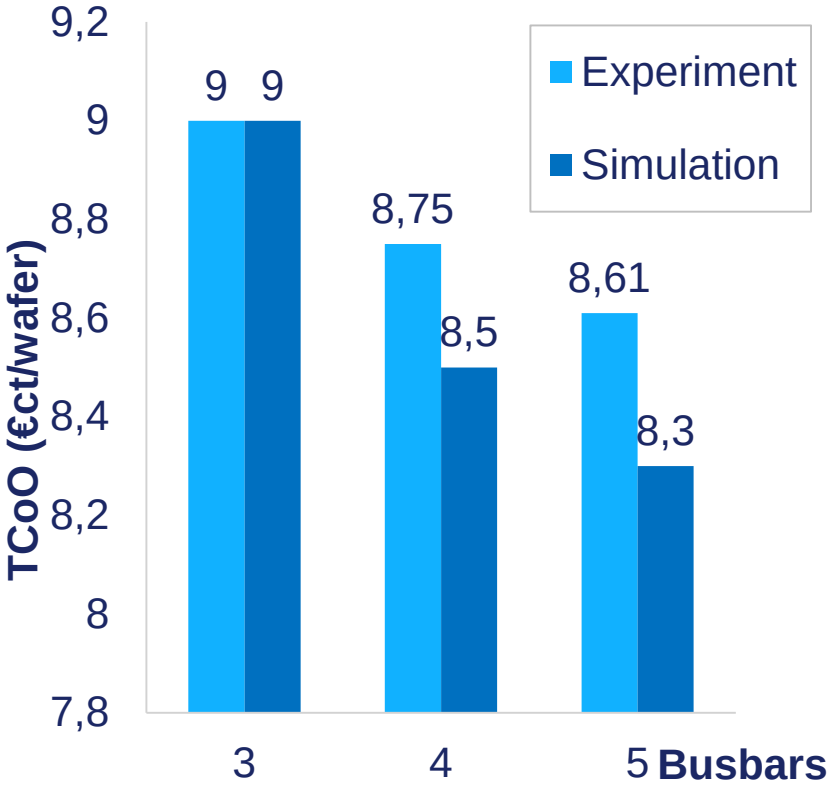
- Ag price 480 €/kg (March 2016)
- Double print 90mg paste
- Lower tool costs
- TCoO=12.4 €ct/wafer

Others: labour, facility, waste treatment, etc.



Savings in TCoO for plating

- Transition from 3 to 5 BB:
  - Cost reduction consumables ~ 75%
  - Shorter plating bath ~25%
- equals ~35 mg Ag paste deposition
- Efficiency gain not accounted for



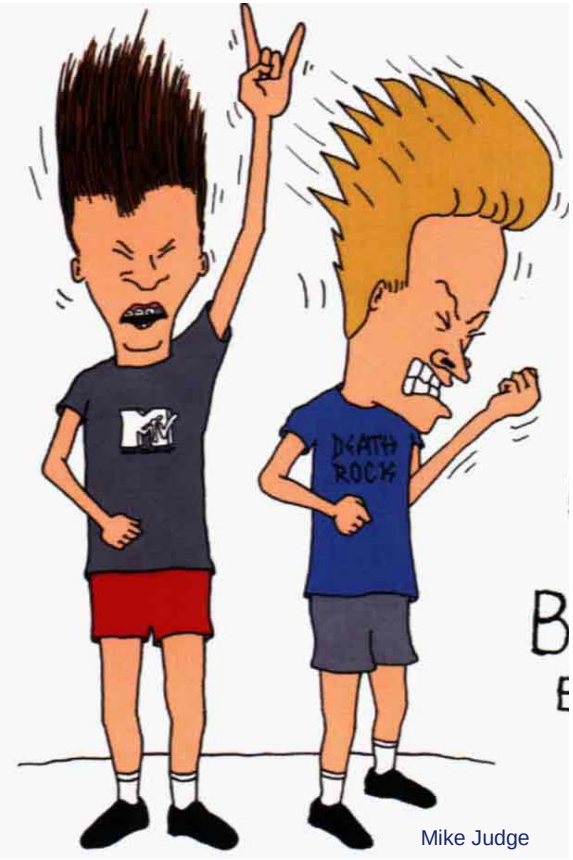
Potential saving		
BB	Simulation	Experimental
3 to 4	6 %	3 %
3 to 5	8 %	4 %

Conclusion

- Transition from 3 to 4 or 5 busbars is on its way
- 4, 5 BB cells were processed with electroplated NiCuAg grid that
  - Need less metal deposit
  - Show better finger adhesion
  - Comparable solder adhesion

  to 3 BB cells
- CoO for plated cells is improved by
  - Lower consumption
  - Smaller production tool

Thank you for your attention



Mike Judge

Although not everyone will agree that having less metal is a good thing