METALIZATION – PLATING AND OTHER

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Metal Contact Deposition Techniques
Printing Metal Pastes

- Today's dominating technology for solar cell metallization
  - Feasibility for large scale production proven
  - Technological advances due to world-wide R&D activities
- Common high temperature approach requires glass frit for liquid phase sintering and adhesion on substrate
  - ➢ Glass layer partly covers contact area → high contact resistance
  - ➢ Glass frit usually contains Pb → Pb should be banned
- Low temperature approach for Hetero requires organic binder
  - ➢ Low conductivity → increased silver consumption
- **Silver is difficult to replace for low and high temp. approach because of its very special properties**

Metal Contact Deposition Techniques
Physical Vapor Depostion (PVD)

- Allows use of cheap materials (Ti, Al)
- Applied in micro electronics or optical disk manufacturing
- In-situ contact/silicide formation promoted by high particle energy
  - Excellent contact resistance
  - Good adhesion if chemical bonds are formed
- Extra patterning steps for grid definition on front-side necessary
- High invest and maintenance costs?

→ **Mainly interesting for rear side metallization**

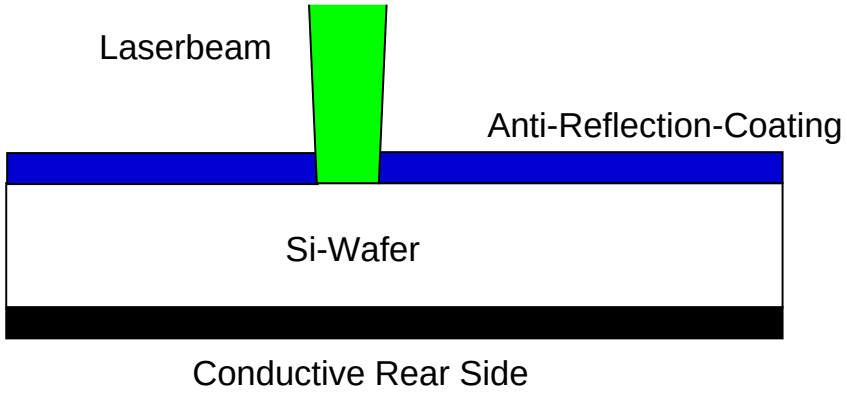
Metal Contact Deposition Techniques
Plated Contacts

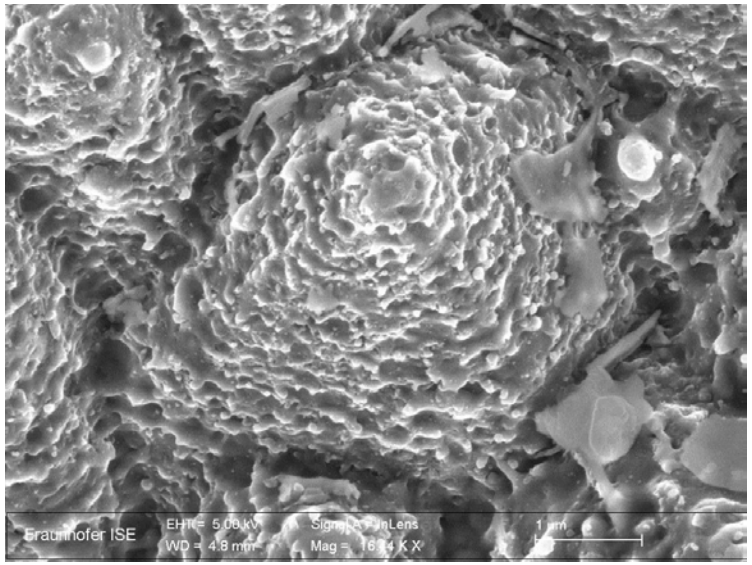
- Allows use of cheap materials (Ni, Cu, Sn)
- Low contact resistance can be reached (similar to PVD)
- But low deposition energy can hinder chemical bonding and electrical contact formation through native oxide
- Patterning steps for grid definition necessary
- Conductive layer necessary for electro-plating to spread electrical current

Plated Contacts for Al-BSF or PERC Solar Cells

Patterning

- Laser-patterned dielectric used as deposition mask
- At present UV ps-pulsed laser gives best results concerning adhesion





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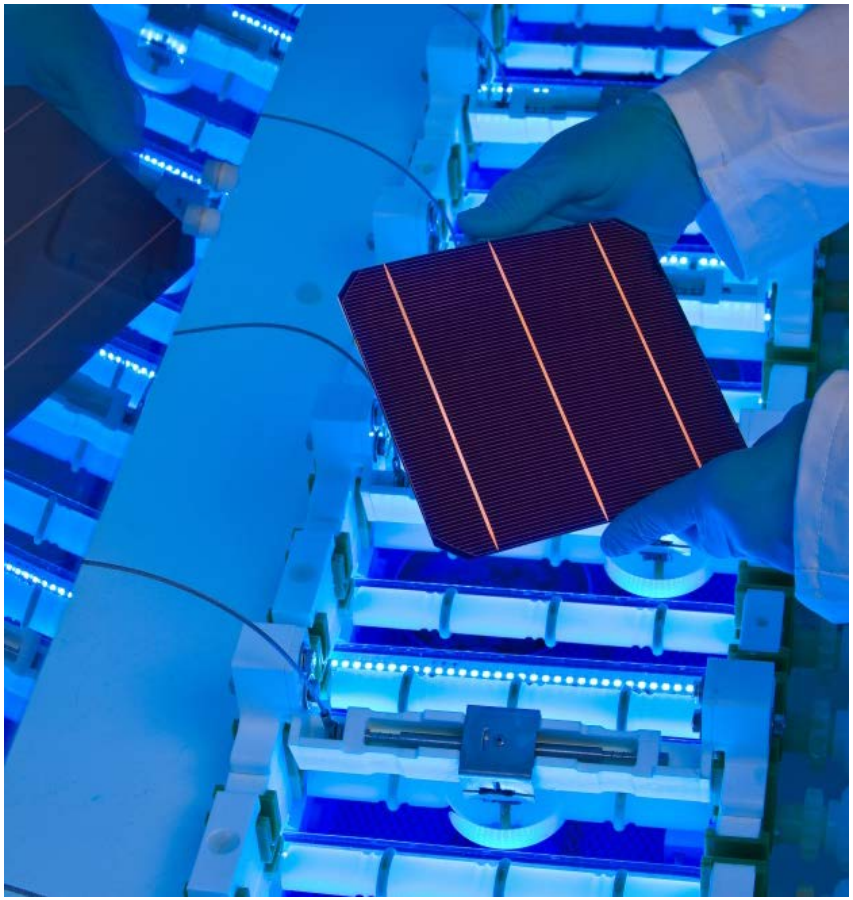
Plated Contacts for Al-BSF or PERC Solar Cells
Plating

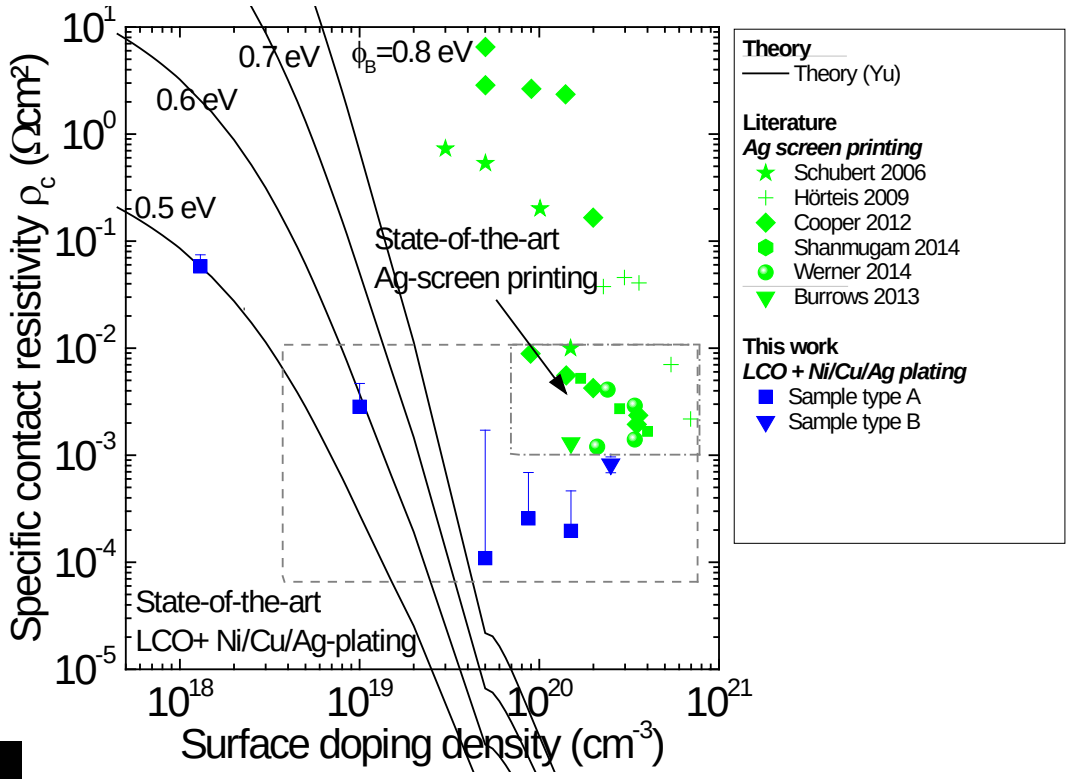
- Printed rear side used to spread current
- Light-induced plating
- Inline-tool similar to RENA-production tool
- Nickel seed layer as diffusion barrier
- Copper layer for lateral conductivity
- Silver capping layer to protect Cu from oxidation

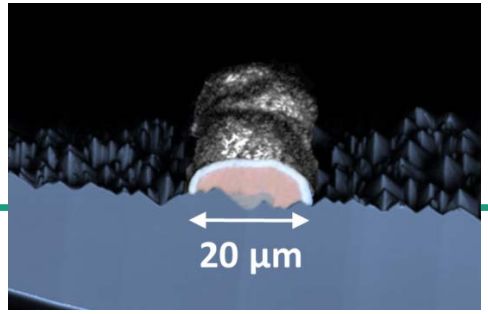


Plated Contacts for Al-BSF or PERC Solar Cells

Results

- Finger width down to 20 µm demonstrated
- Excellent contact resistance for lightly doped emitters
- Sufficient adhesion and long term stability to pass related IEC-Tests
- Suitable for next generation PERC with η > 22%





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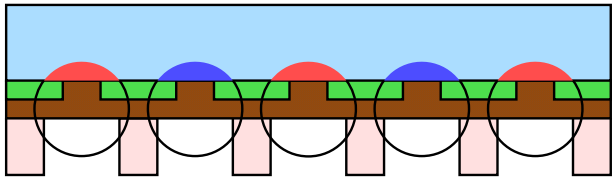
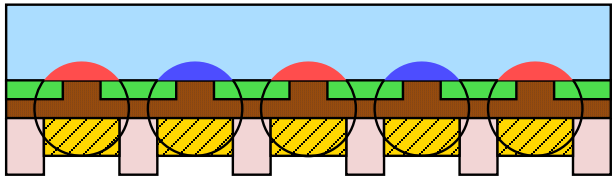
Plated Contacts for IBC Solar Cells

Standard Process Flow

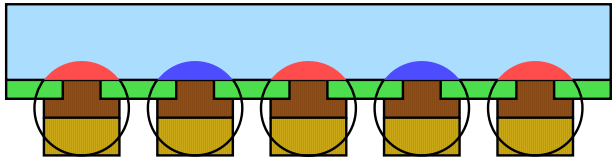
- PVD of seed-layer stack
- Printing of plating mask



- Plating metals stack for lateral conductivity



- Stripping of plating mask
- Etching of seed layer stack



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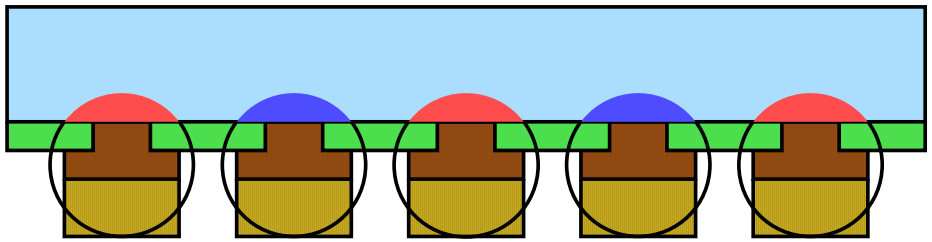
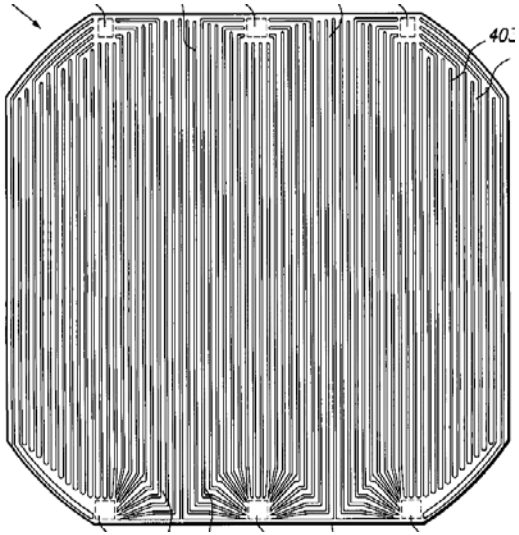
Plated Contacts for IBC Solar Cells

Standard Process Flow

- Process applied in mass production (~ 1 GW/a by SunPower)
- Lead free, no or low Ag consumption
- Excellent contact properties with PVD Al
- But rather expensive process steps





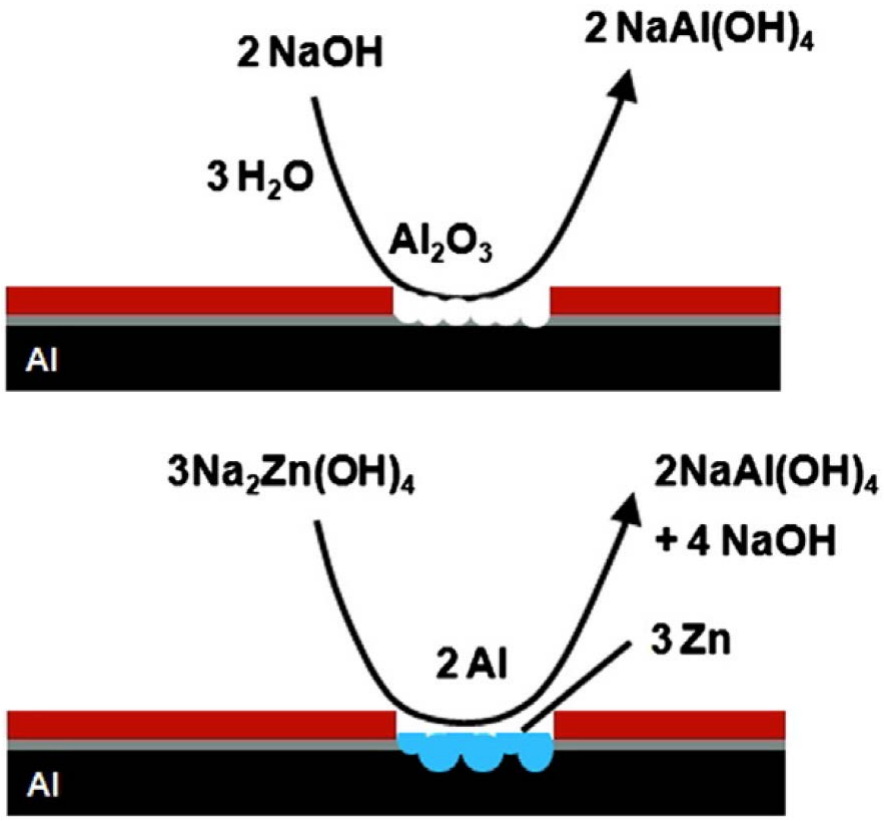
Sketch from De Ceuster Patent, 2010

Plated Contacts for IBC Solar Cells

Zincate Process

- Cost for PVD-layers higher than for wet-chemical deposition

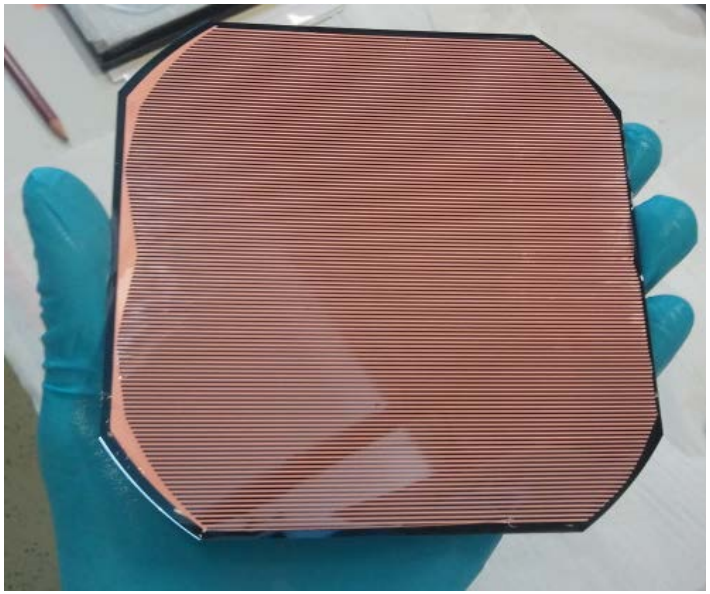
- PVD of only Al seed layer
- Chemical conditioning for plating via zincate process
  - NaOH etches native Oxide
  - Al-Atoms replaced by Zn-Atoms
- Plating of Ni, Cu and Sn with standard electrolytes

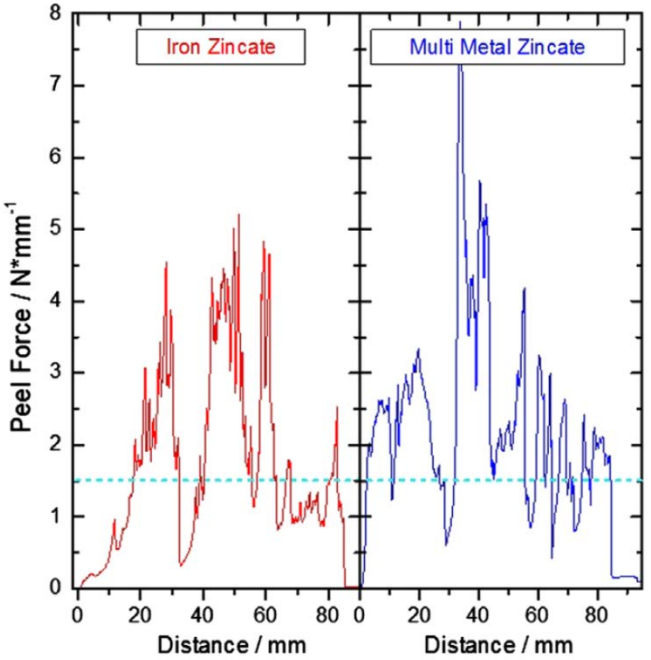


Kamp et al, Solar Energy Materials & Solar Cells, 2014

Plated Contacts for IBC Solar Cells
Zincate Process

- Process demonstrated on large area
- Peel force of up to 7 N/mm reached → exceeds requirements of IEC





Kamp et al, Solar Energy Materials & Solar Cells, 2014

Plated Contacts for IBC Solar Cells
Electrochemical Patterning

- Stripping of organic plating resist causes high costs for waste-water treatment

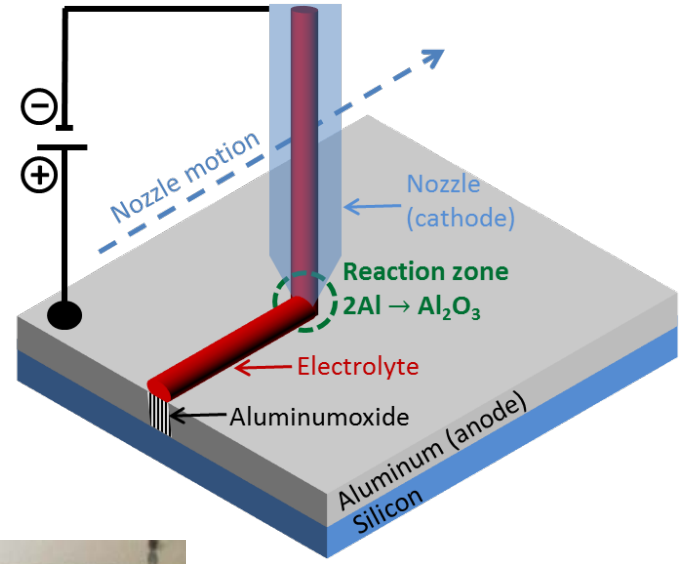
- Electrochemical patterning of Al-surface by local anodization

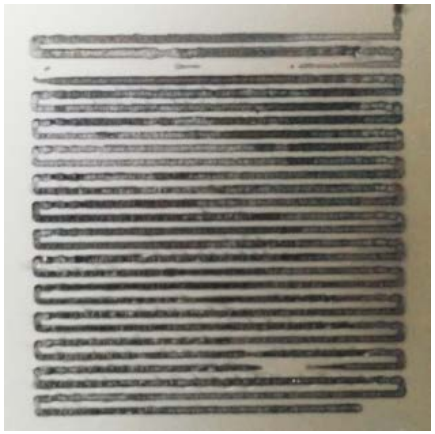
Kamp et al, Solar Energy Materials & Solar Cells, 2014

Plated Contacts for IBC Solar Cells
Electrochemical Patterning

- Dispensing system for pattering
- Adapted electrolyte as ink
- Voltage applied between nozzle and substrate

➢ Thick Al_2O_3-layer is formed, that is not removed in zincate process

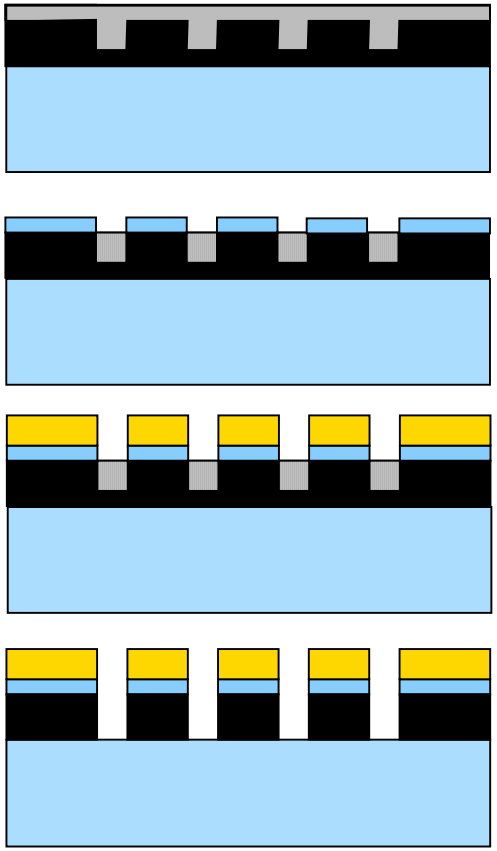




Plated Contacts for IBC Solar Cells

Simplified Metallization Process

- Electrochemical patterning of Al-layer
- Surface treatment with zincate process
- Plating for lateral conductivity
- Etching of residual Al for contact separation



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Plated Contacts for Silicon Hetero-Junction Solar Cells
Negative Masking

- ITO is a good diffusion barrier for Cu
- Ni and Cu plate on ITO

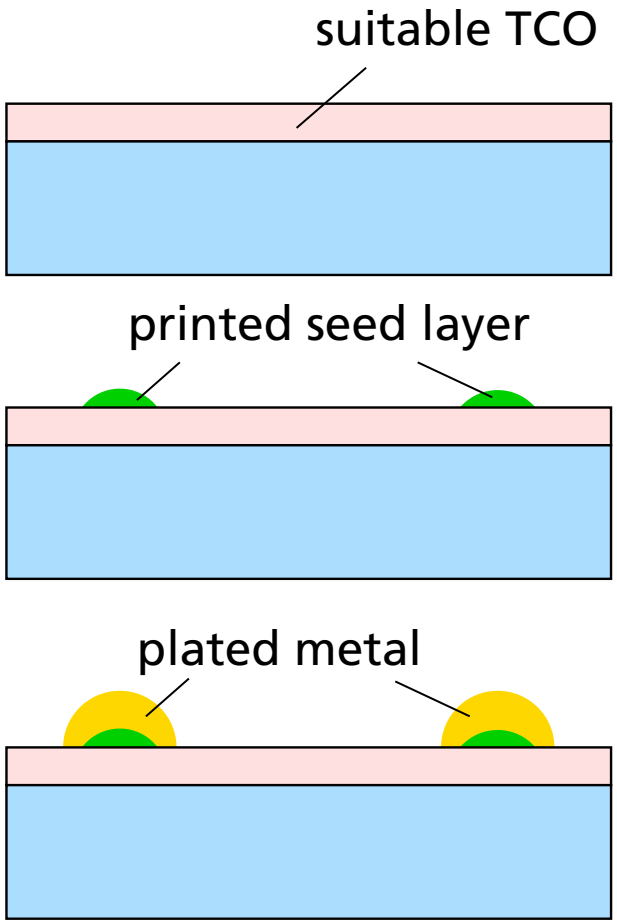
- Patterning techniques for grid deposition by applying negative mask
  - Photo lithography (CSEM)
  - Inkjet-printed resist (OTB)
  - Laser patterned resist (SERIS/ISE)
  - …
- Silevo/SolarCity claims to start mass production (1 GW/a) with such process
- Concerns about costs!

Plated Contacts for Silicon Hetero-Junction Solar Cells

Positive Masking

- No plating on certain TCOs or or even metals observed
- Theses TCOs or metals can be electrically contacted by printed seed layer

➢ Grid can be defined by printed seed layer on suitable TCO layer

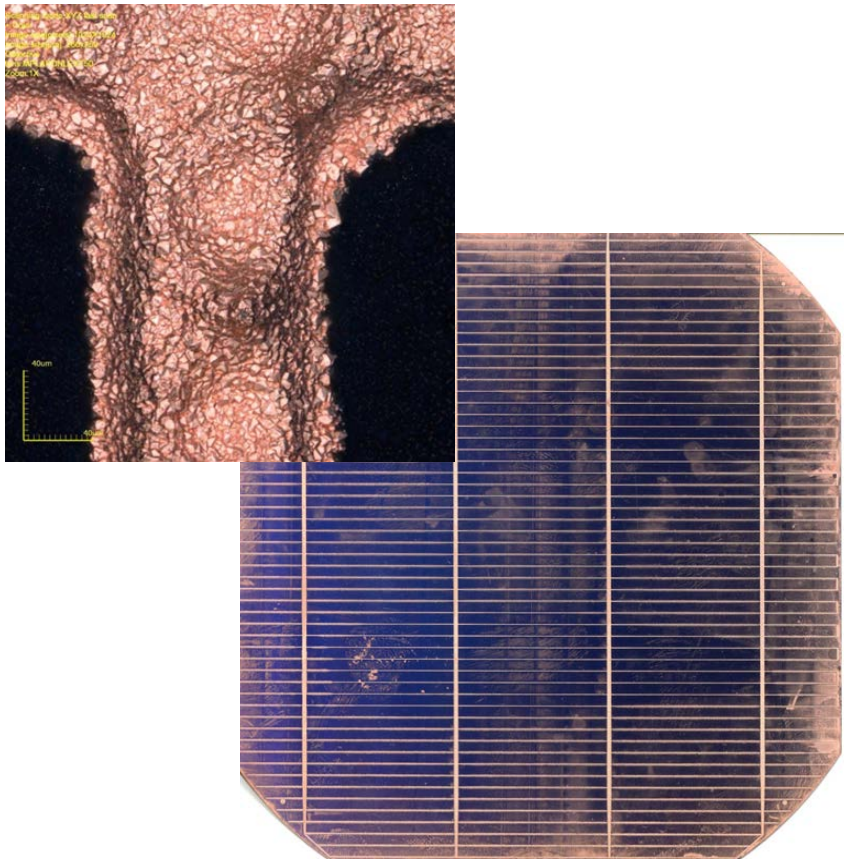


Plated Contacts for Silicon Hetero-Junction Solar Cells
Positive Masking

- Proof of principle given on standard ITO with printed silver seed layer (CSEM solar cells)

ToDo:

- Mechanism for selectivity of plating process need to be investigated
  - Avoid parasitic plating
  - Increase plating speed
- Tailor ITO properties
- Use of different TCOs
- Check edge isolation



Conclusion

- Plating on Al-BSF or PERC solar cells mature to start integration into production
- Plated front side highly promising for next generation PERC with >22% without use of Ag or Pb

- Plating already applied in industrial IBC solar cell production
- Cost reduction potential by simplified process sequence

- Plating on silicon hetero-junction solar cells very interesting
- Best masking technology not identified yet