

Adhesion Improvement for Solder Interconnections of Wet Chemically Coated Aluminum Substrates



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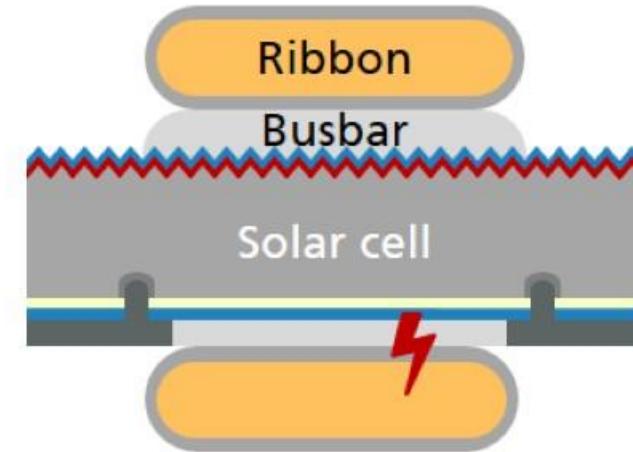
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Interconnection for Crystalline Silicon Solar Cells
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Motivation

Aluminum as Rear Electrode for Solar Cells

- All industrial p-type solar cells use **Al**
 - Back-Surface-Field (BSF) in Al-Si contact
 - Rear electrode for current collection
- Module integration requires **interconnection**
 - IR soldering of Cu ribbons with SnPb
 - Good wetting with solder ($\alpha < 60^\circ$)
 - High adhesion ($F/w > 1 \text{ N/mm}$)^[1]
 - **Al electrode not solderable** (native Al_2O_3)
- Circumventions
 - Ag pads on rear
 - Alternative: **Modification of Al surface**^[2]



Wet Chemically Coated Aluminum Substrates

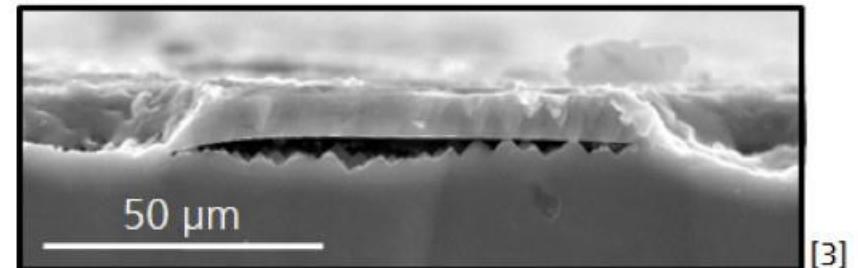
Sample Types

■ Al foil

- 200 μm thickness*
- Monolithic
- 99 %_{wt} Al
- Alloy 1200

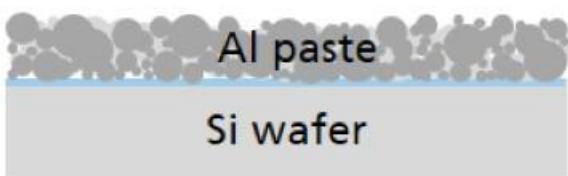


FoilMet® solar cell

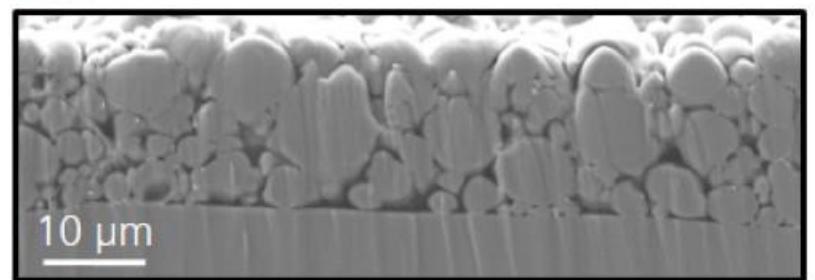


■ Al paste

- 10 μm thickness
- Screen printed on Si wafer
- 60-80 %_{wt} Al powder
- Fired



PERC w/o Ag pads

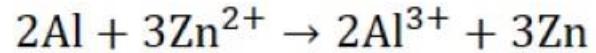


*Thickness of 200 μm is used in this study. Al foil on FoilMet® solar cell is about 10 μm thick.

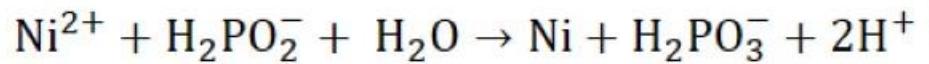
Wet Chemical Coatings for Aluminum Zincate Treatment (s-Zn) & Ni Plating

- ① Alkaline solution (NaOH based):
Reaction with Al_2O_3

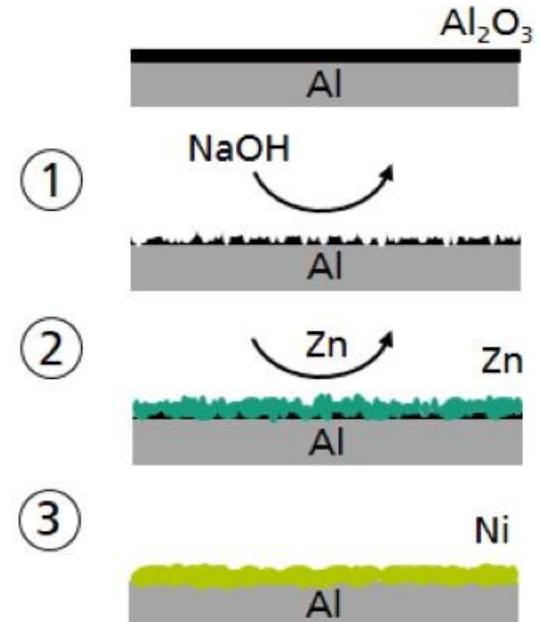
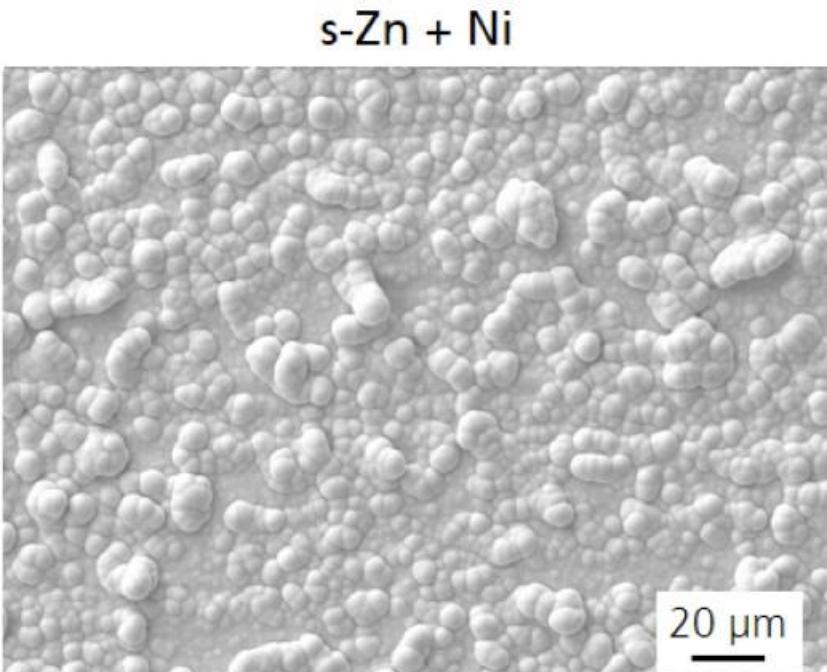
- ② Exchange reaction between Zn and Al^[4]



- ③ Electroless Ni plating^[4]



- Electrolyte with low P content (7-9 %_{wt})
- Reducing agent: sodium hypophosphite



Wet Chemical Coatings for Aluminum Zincate Treatment (d-Zn) & Ni Plating

- ① Alkaline solution (NaOH based):
Reaction with Al_2O_3

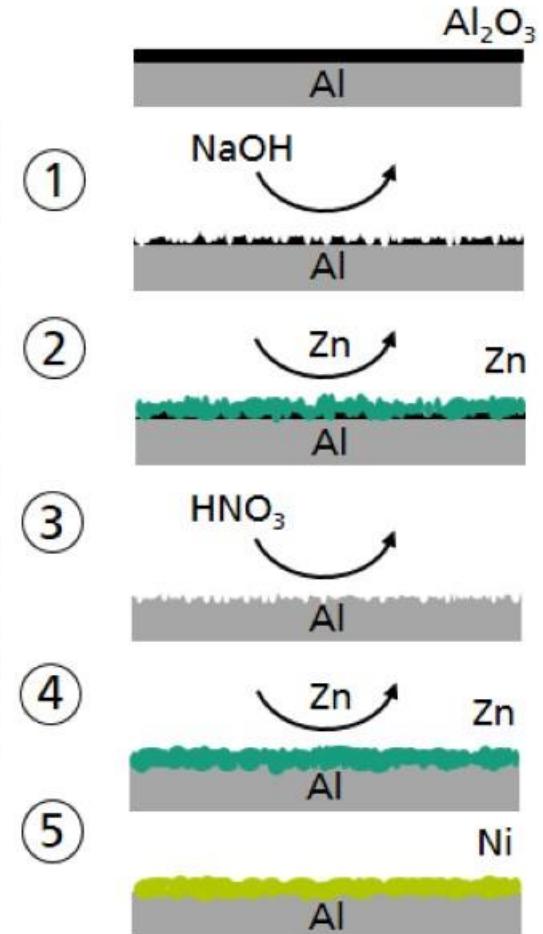
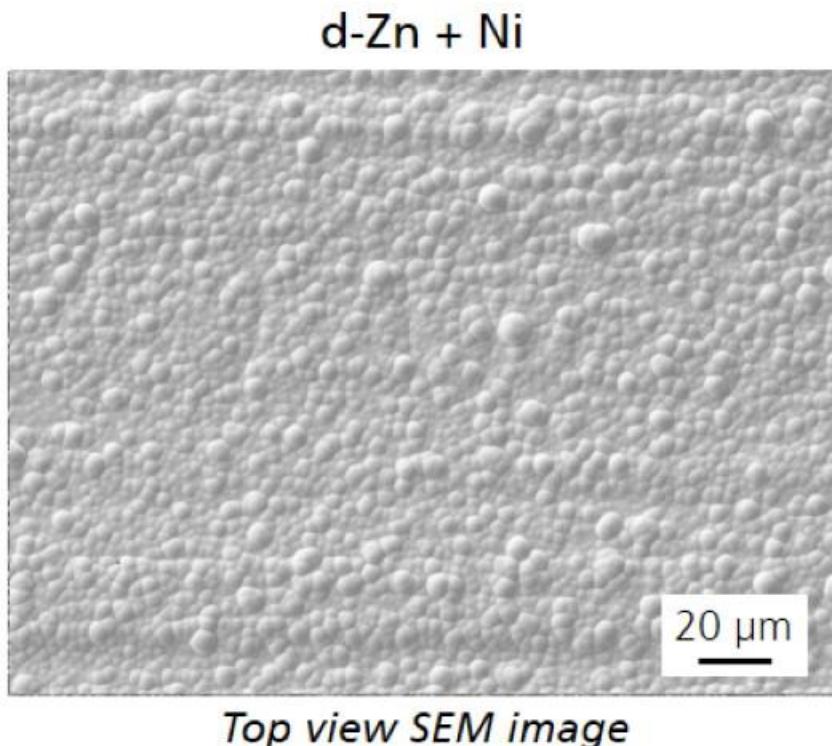
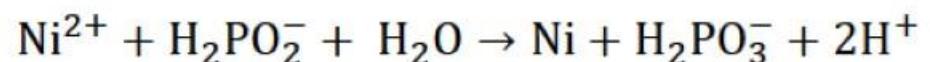
- ② Exchange reaction between Zn and Al^[4]



- ③ Etch-back with HNO_3

- ④ Second Zn treatment

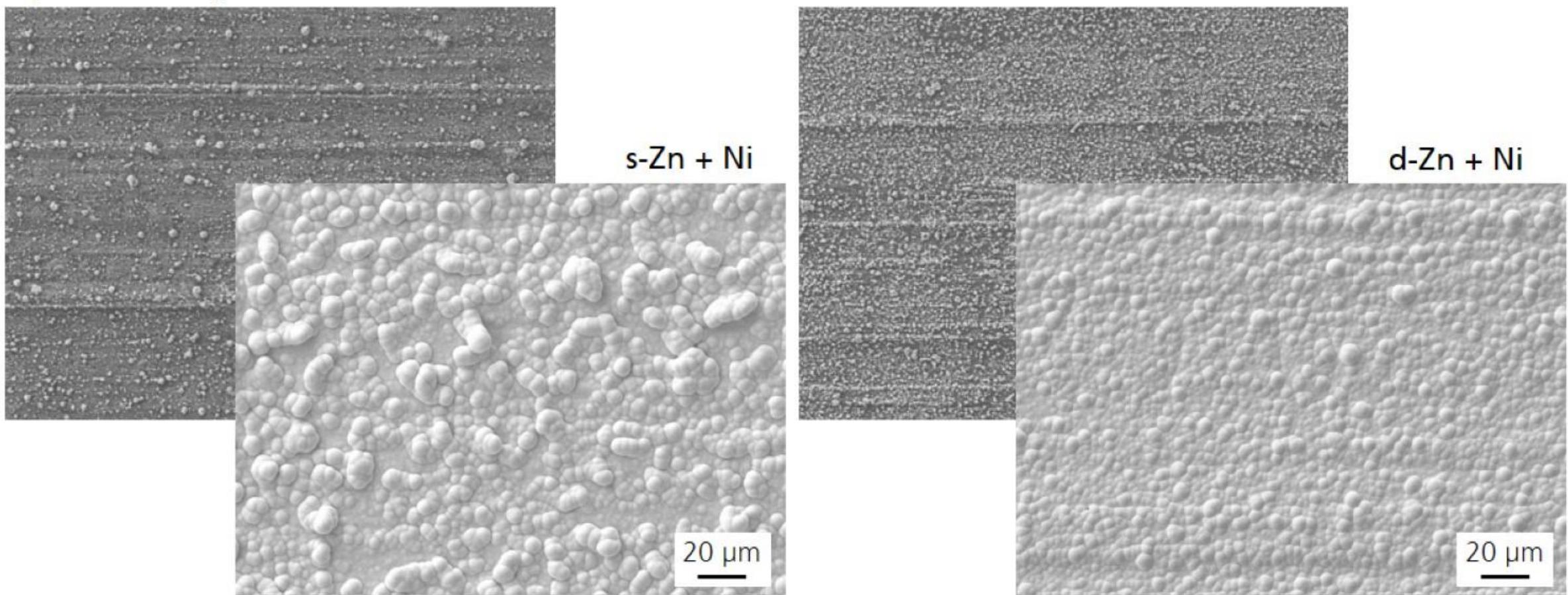
- ⑤ Electroless Ni plating^[4]



Wet Chemical Coatings for Aluminum

Zincate Treatments (s-Zn, d-Zn) & Ni Plating

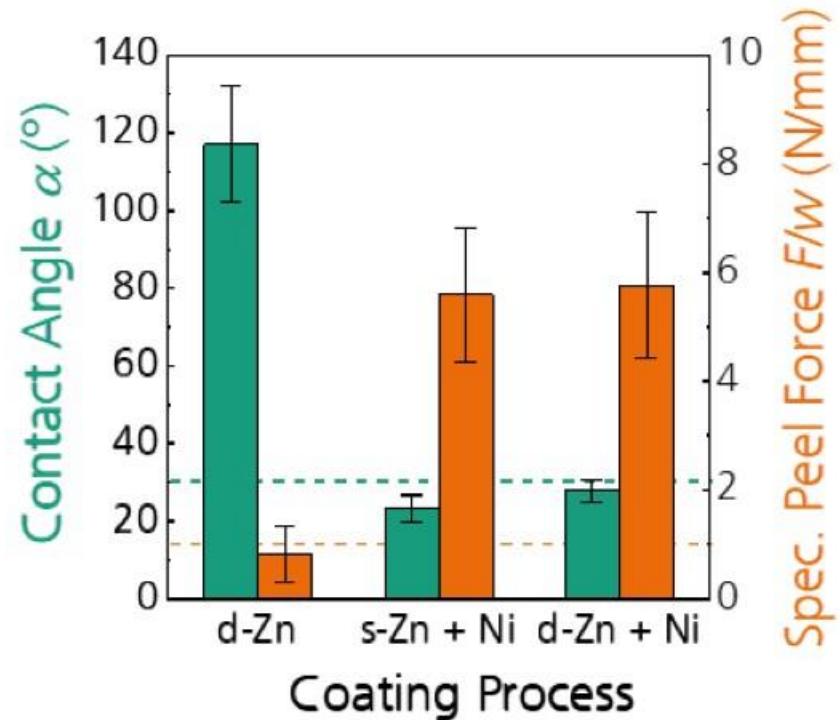
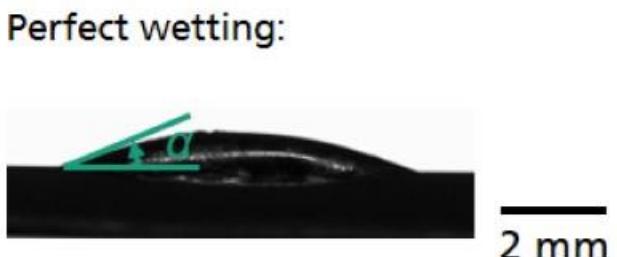
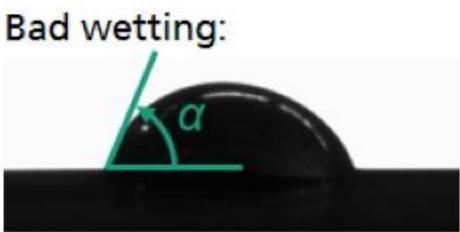
Top view SEM images



Characterization

Al Foils: Wetting and Adhesion

- Contact angle measurements
 - SnPb 60/40, 250 °C hotplate temperature
 - **Perfect wetting** for Ni-coated Al foils*
- 90° peel tests of soldered ribbons
 - SnPbAg 62/36/2, no-clean flux
 - **Very high peel forces** approaching 6 N/mm for solder joints on Ni-coated Al foil



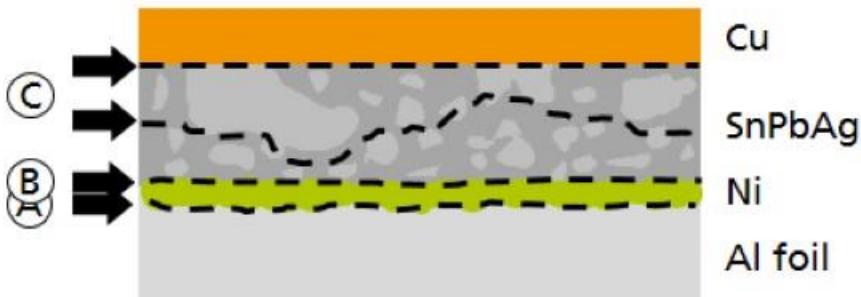
Characterization

Al Foils: Fracture Pattern

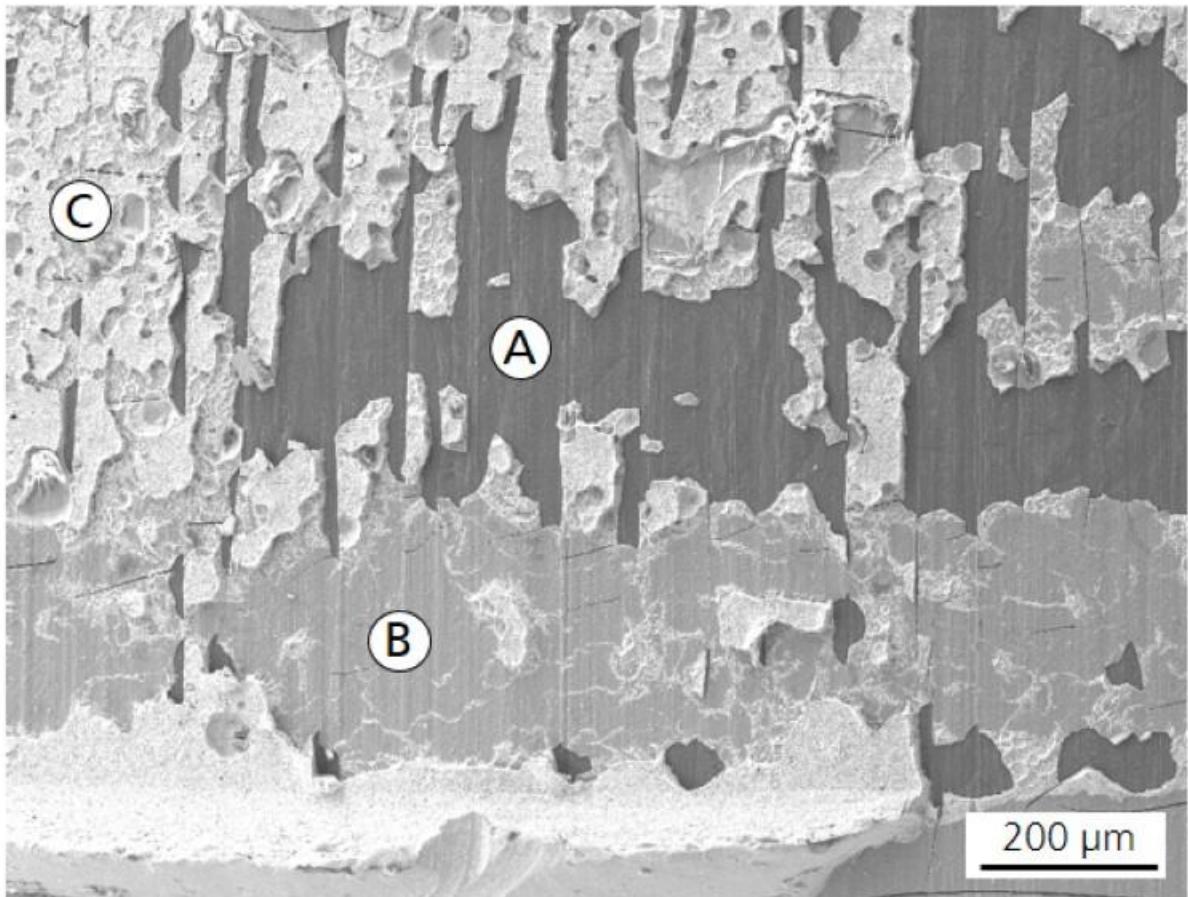
- s-Zn + Ni and d-Zn + Ni both show:
Mixed fracture pattern

- (A) Adhesive between Al and Ni
- (B) Adhesive between Ni and solder
- (C) Cohesive within solder
- (C) Adhesive between solder and Cu ribbon

- No dominant failure

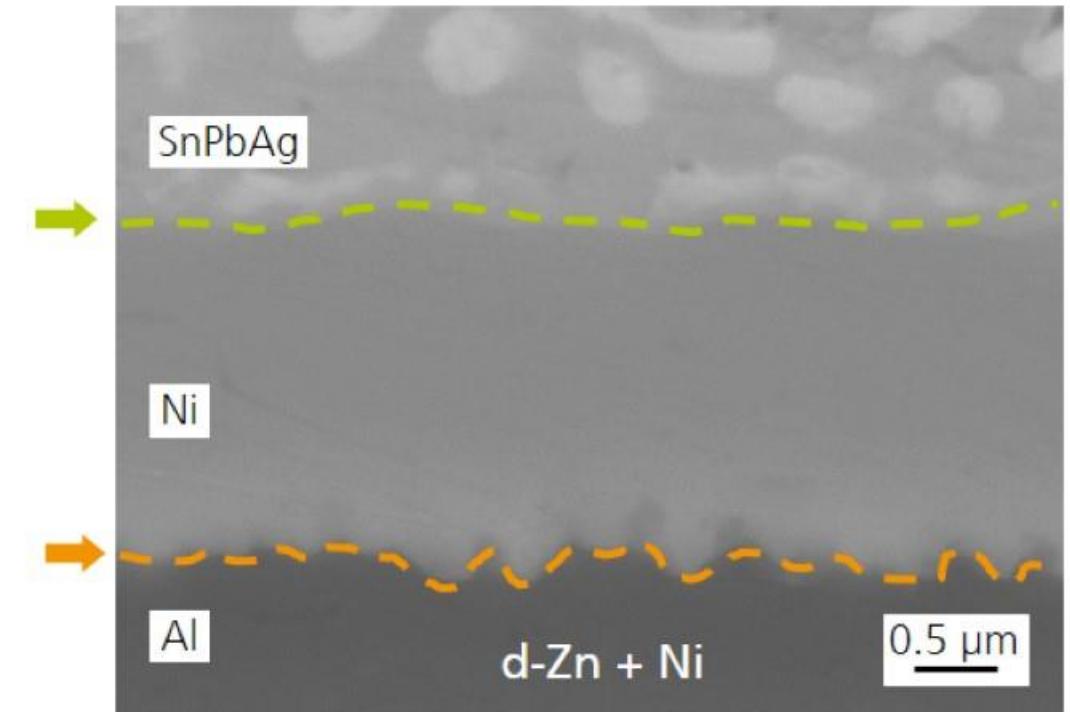
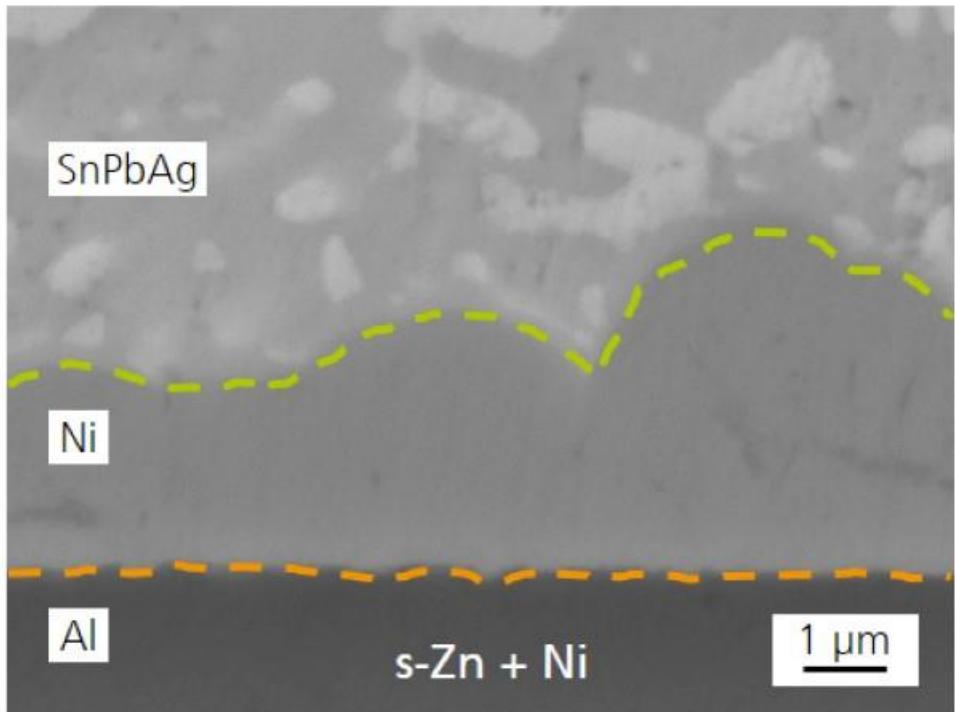


Top view SEM image of **d-Zn+Ni** coated Al foil after peel test



Characterization

Al Foils: Micro Structure Analysis



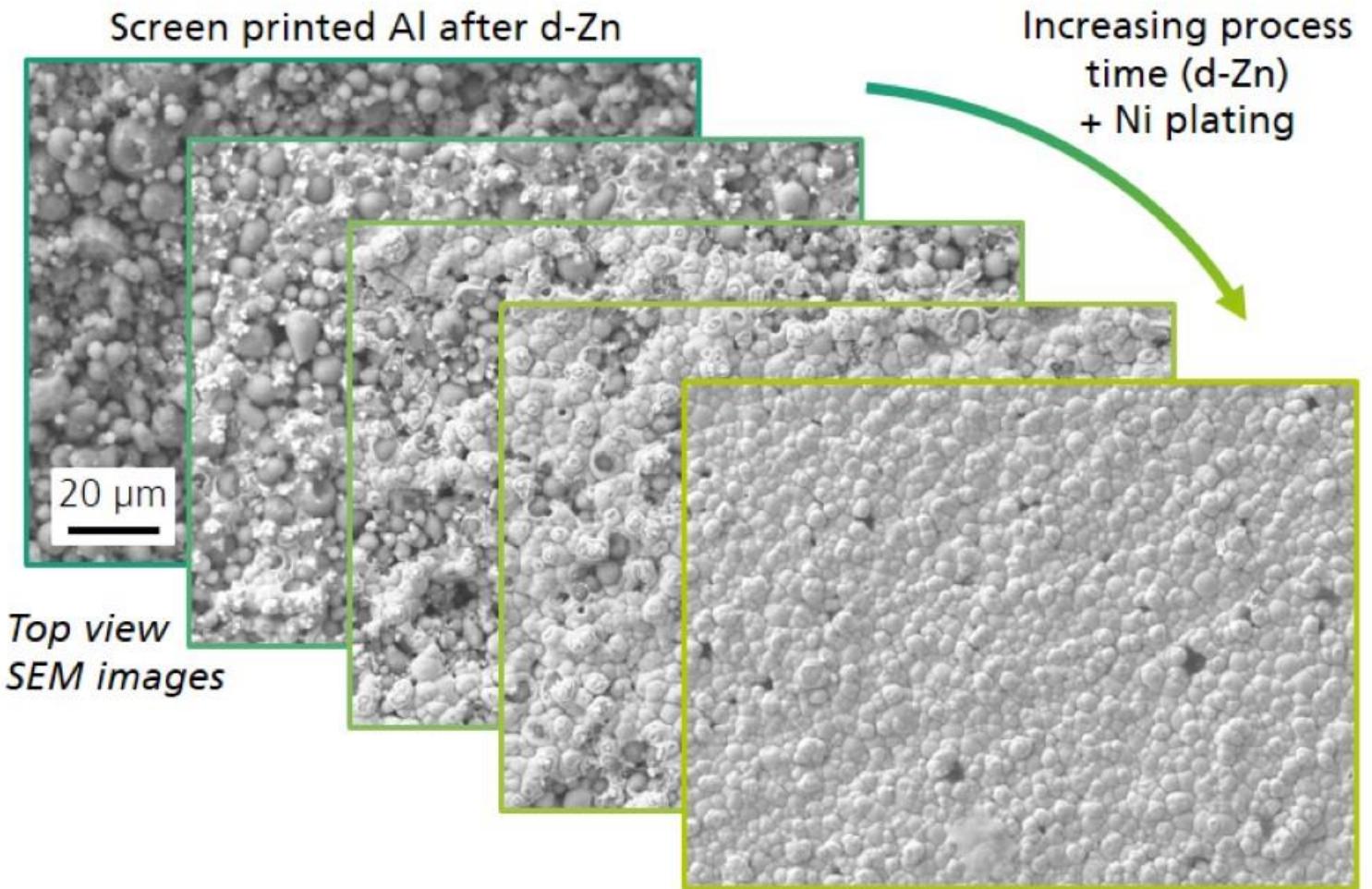
Cross section SEM images

- d-Zn + Ni: smooth **Ni surface**, rougher **Al surface** after d-Zn
- Void-free solder joints for both processes

Characterization

Screen Printed Al: Surface Analysis

- No sufficient Ni coverage with d-Zn + Ni process used for Al foil
- Increasing process time for d-Zn improves Ni deposition
- Good wetting on homogeneous Ni layer allows for soldering



Characterization

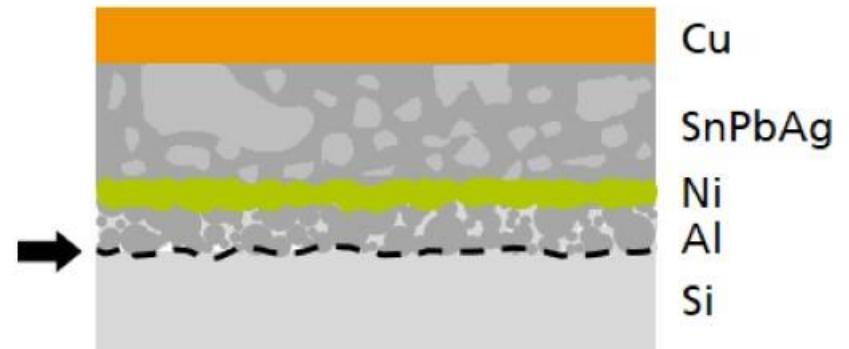
Screen Printed Al: Solder Interconnection

- Soldering of SnPbAg-coated ribbons
 - Cell pieces form a bow during cooling
 - Ribbons peel-off partly
- No reasonable peel test possible ($\approx 0.1 \text{ N/mm}$)

Photo of soldered cell piece



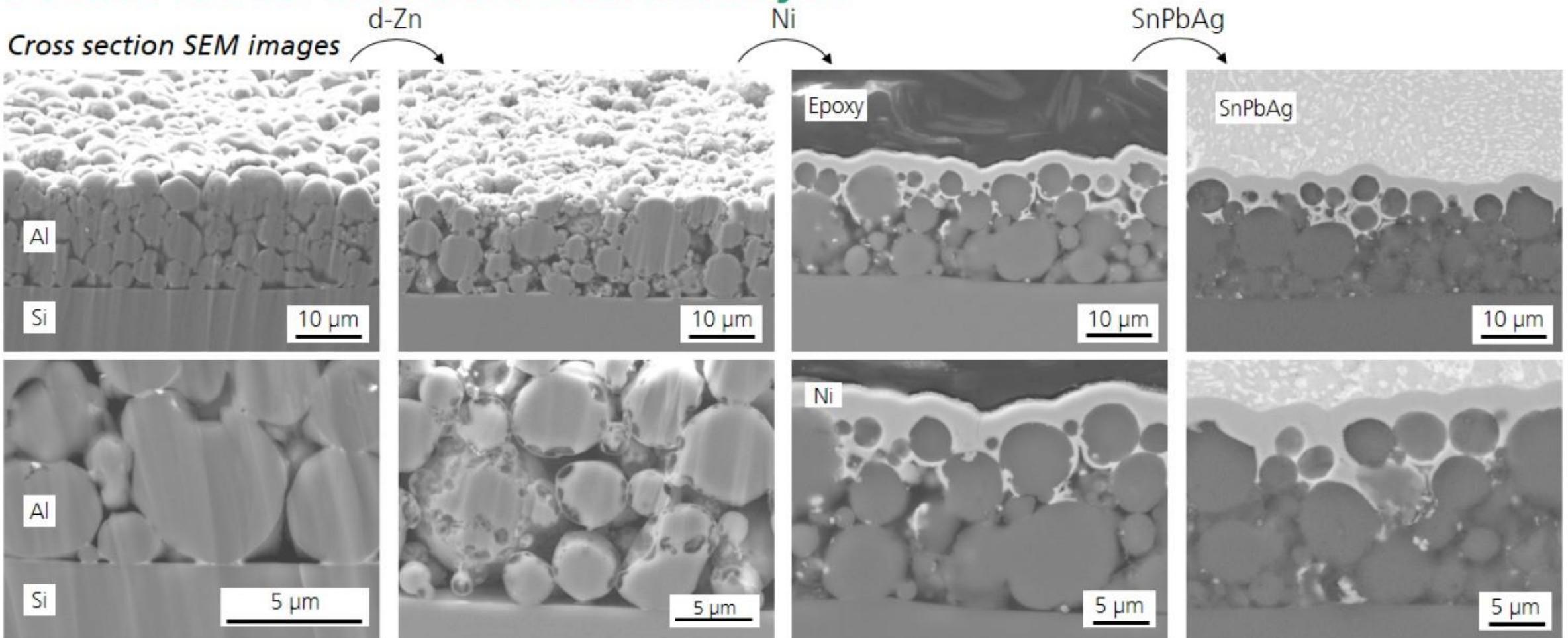
- **Failure at interface of screen printed Al to Si wafer**
 - SEM analysis of cross sections



Characterization

Screen Printed Al: Microstructural Analysis

Cross section SEM images

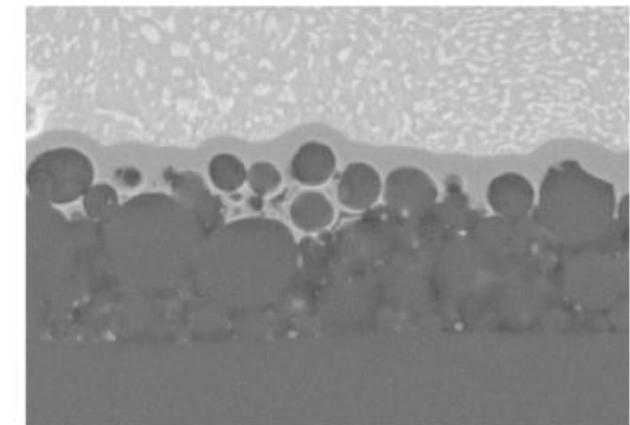
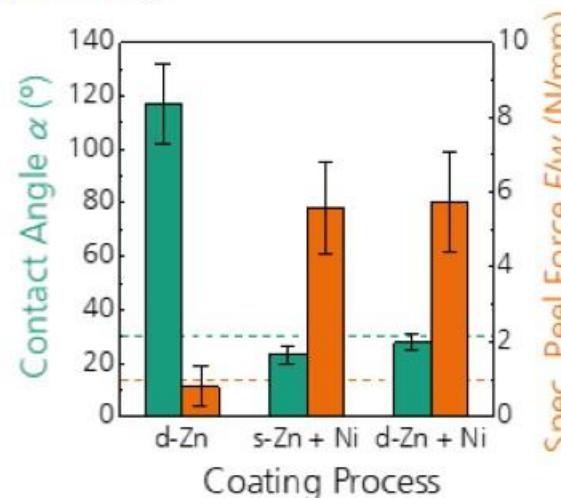


- Successful coating (Zn and Ni) and void-free solder joint formation

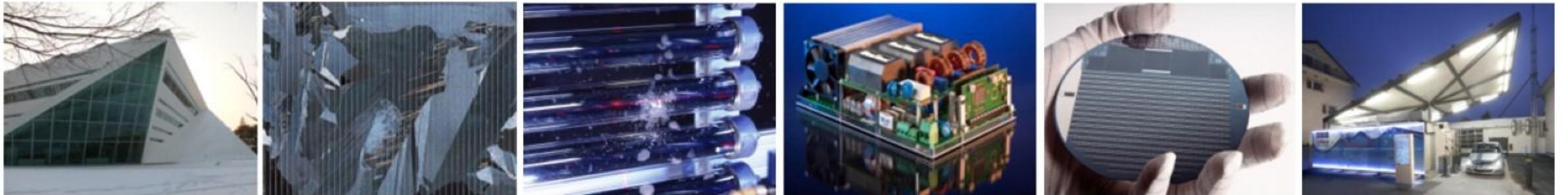
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Conclusion

- Modification of Al substrates by zincate and Ni plating
 - Perfect wetting of solder ($\alpha < 30^\circ$)
 - Very high adhesion ($F/w \approx 6 \text{ N/mm}$)
 - Mixed fracture pattern
 - Industrial process conditions
- Transfer to PERC solar cells
 - Monolithic foils: FoilMet® approach possible
 - Screen printed and fired Al rear pastes
 - Coating and soldering successful
 - Paste adhesion to Si wafer not optimized



Thank you for your Attention!



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