MECHANICAL DEFECTS AND STRENGTH OF SOLAR CELLS

Stephan Schoenfelder[1,2], Felix Kaule[1], Stephan Großer[1], Sven Thormann[3] and Ronny Lantzsch[3]

[1] Fraunhofer Center for Silicon Photovoltaics CSP
[2] Leipzig University of Applied Science
[3] Hanwha Q CELLS GmbH

PV DAYS 2017
October 24-25 | Halle (Saale)
Visit us on www.pv-days.com

OUTLINE

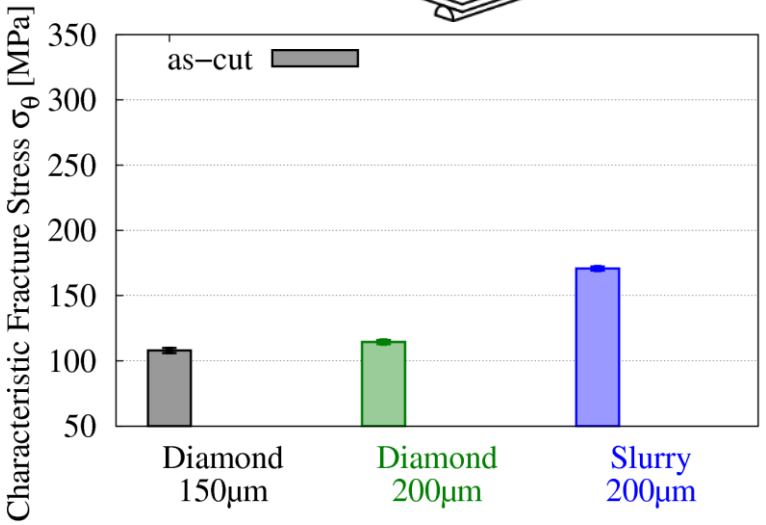
- Introduction
- Mechanical Strength of PERC Solar Cells
- Mechanical Defects in PERC Solar Cells
- Conclusions

Introduction
Breakage and Defects

As-Cut Wafer	
Type	Breakage causing defect
as-cut wafer	**cracks**

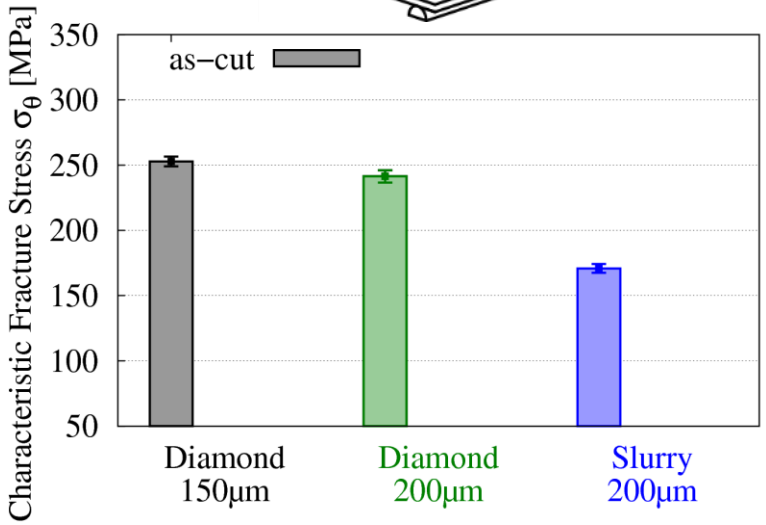
Direction of Saw Marks to Bending Rollers

parallel



- slurry >> diamond

perpendicular



- diamond >> slurry

Kaule et al., EU PVSEC, 2015

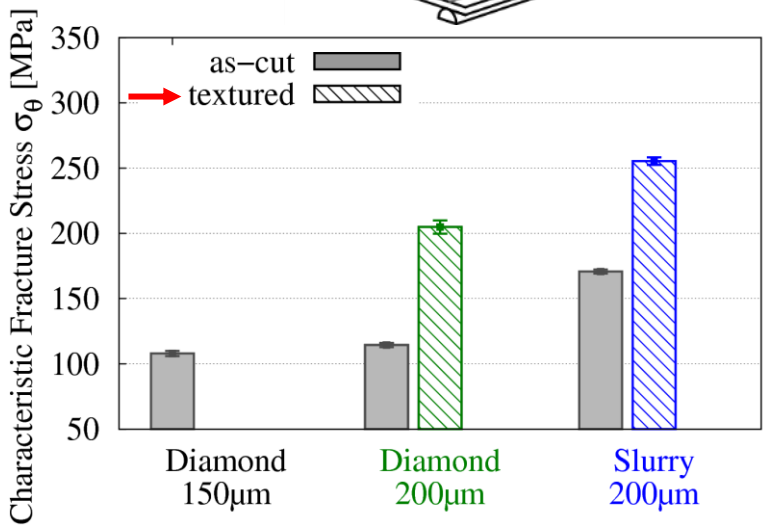
Introduction
Breakage and Defects

Textured Wafer

Type	Breakage causing defect
as-cut wafer	cracks
textured wafer	**altered cracks**

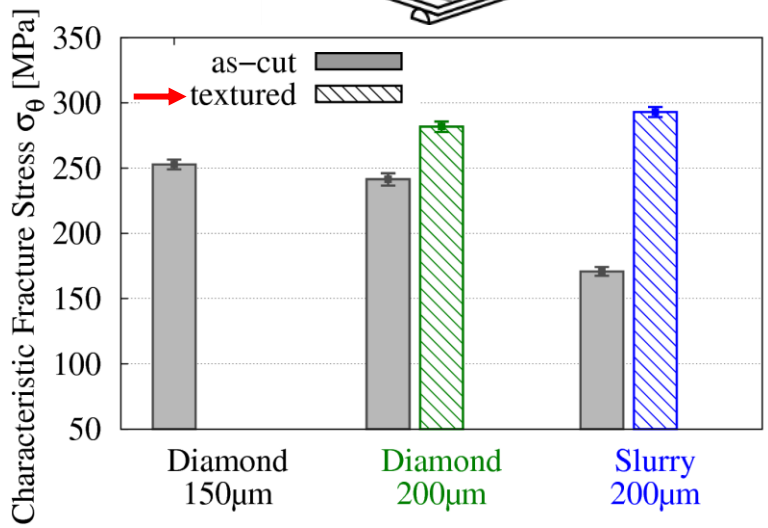
Direction of Saw Marks to Bending Rollers

parallel



- slurry > diamond

perpendicular



- diamond ≈ slurry

anisotropic strength behavior remains

texturization increases strength

Kaule et al., EU PVSEC, 2015

Introduction
Breakage and Defects

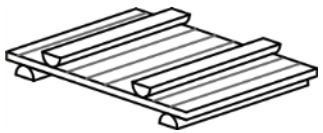
Solar Cell

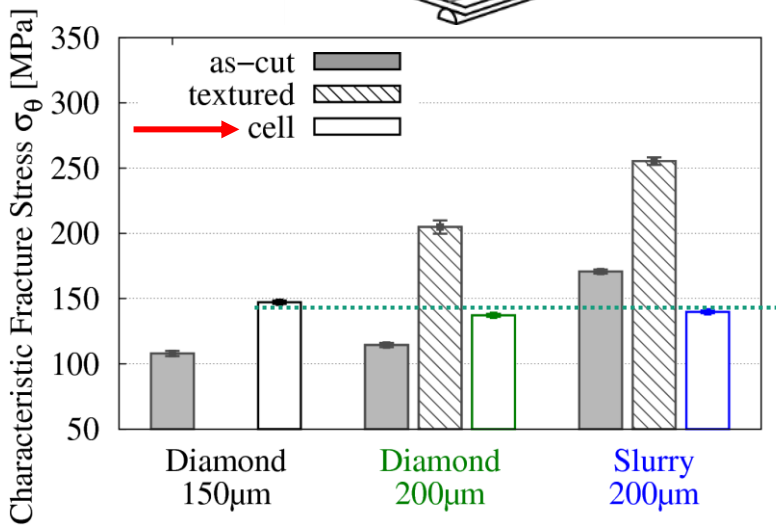
Type	Breakage causing defect
as-cut wafer	cracks
textured wafer	altered cracks
solar cell	**?**

What is the mechanical defect for solar cells?

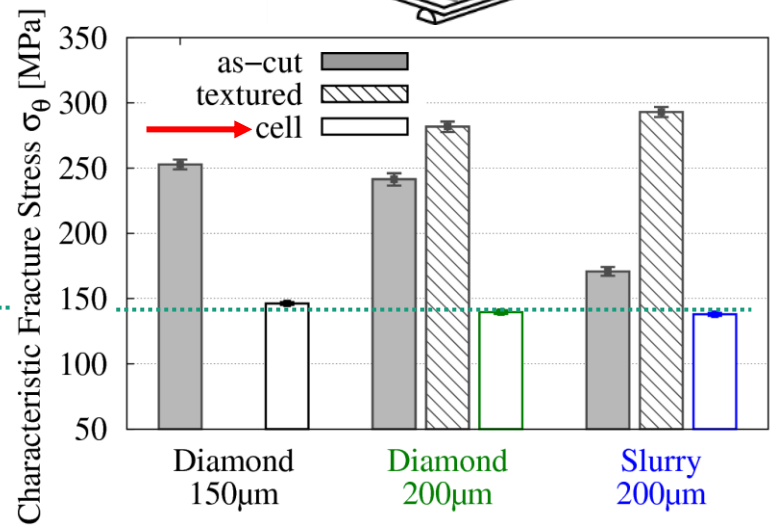
Direction of Saw Marks to Bending Rollers

parallel





perpendicular

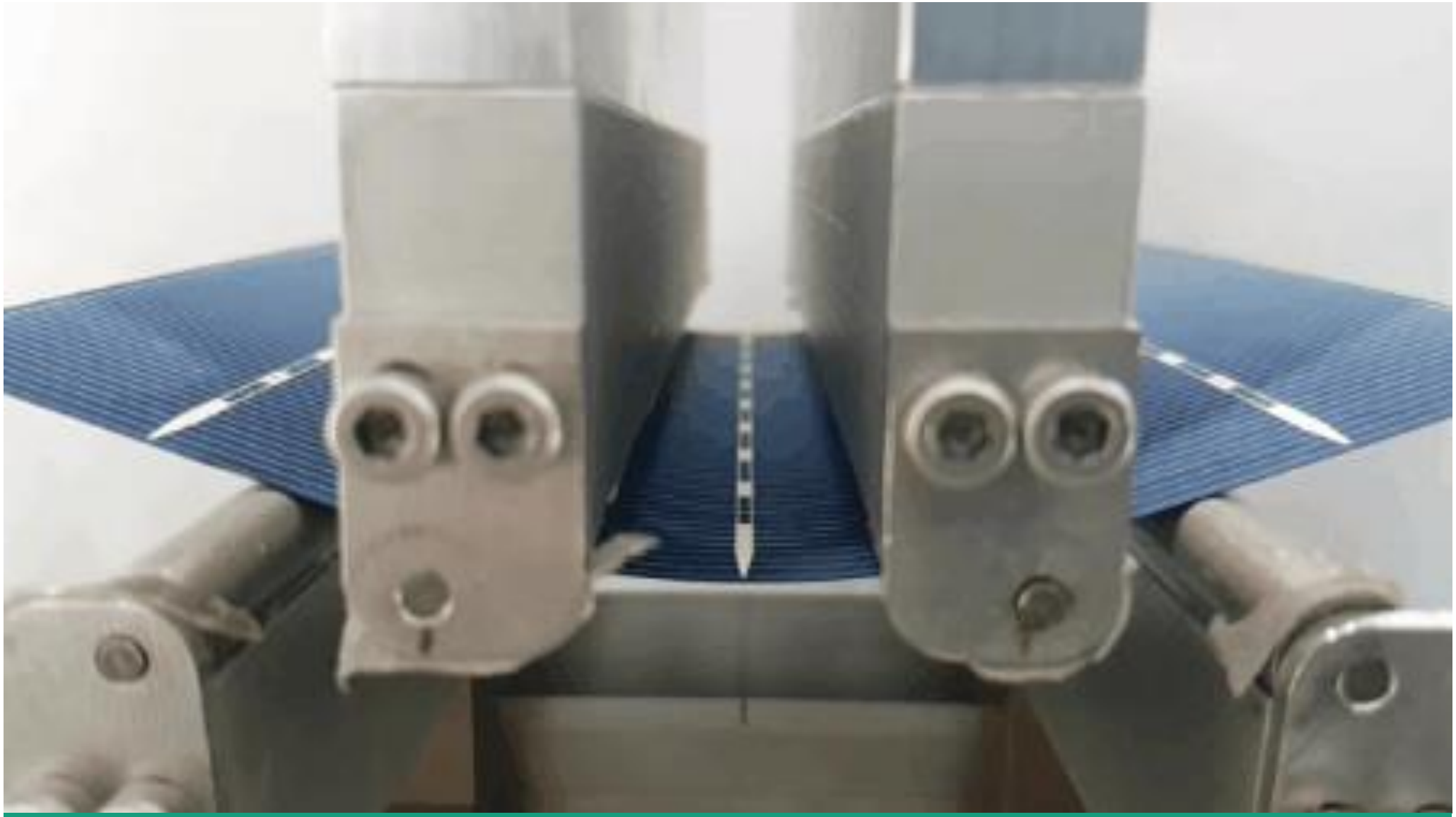


- no dependency on sawing direction
- slurry ≈ diamond

cell process decreases strength

Kaule et al., EU PVSEC, 2015

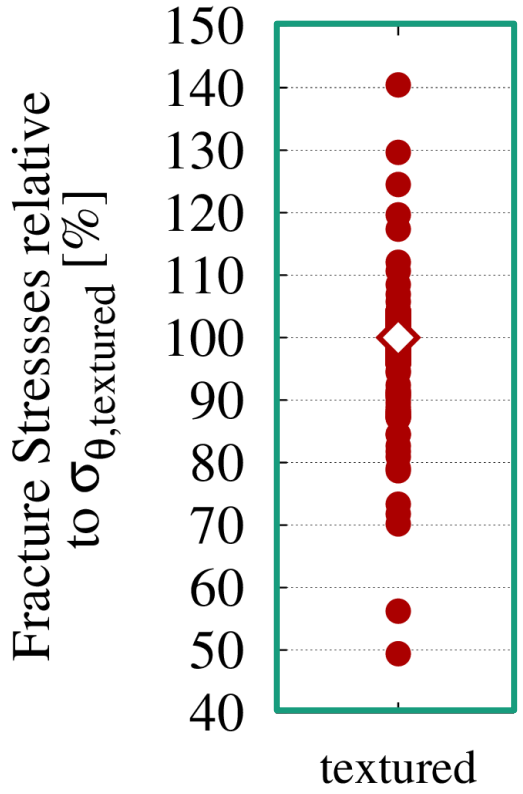
DiaCell Mech-Si Fraunhofer CSP



4-point bending setup for strength measurements

Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

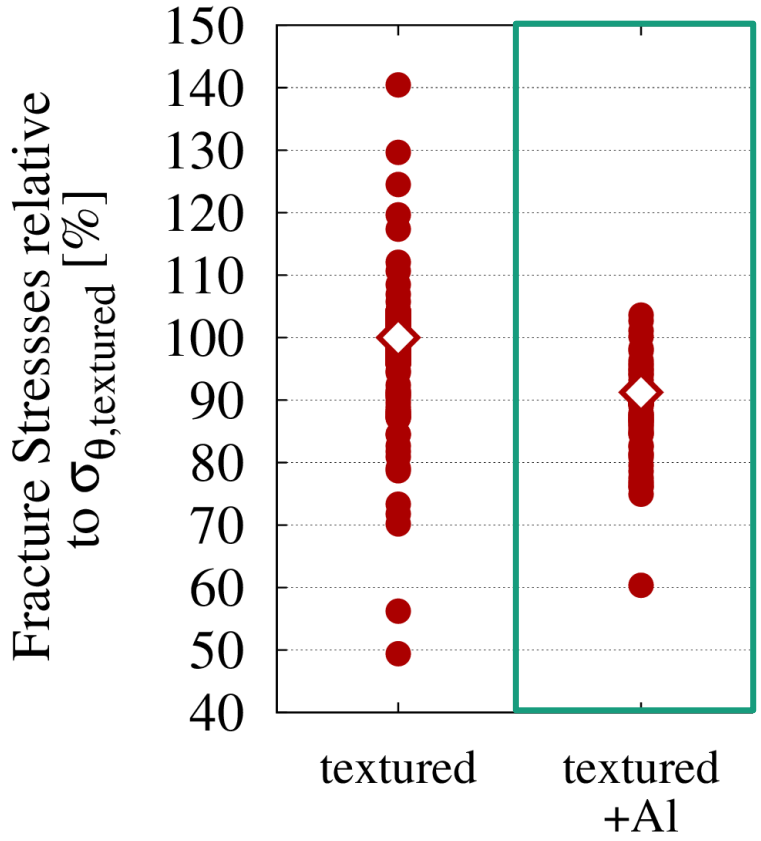
- textured wafers
- Fracture stresses relative to characteristic fracture stress σ_Θ from the textured batch (reference)



◇ Characteristic Fracture Stress σ_Θ

Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

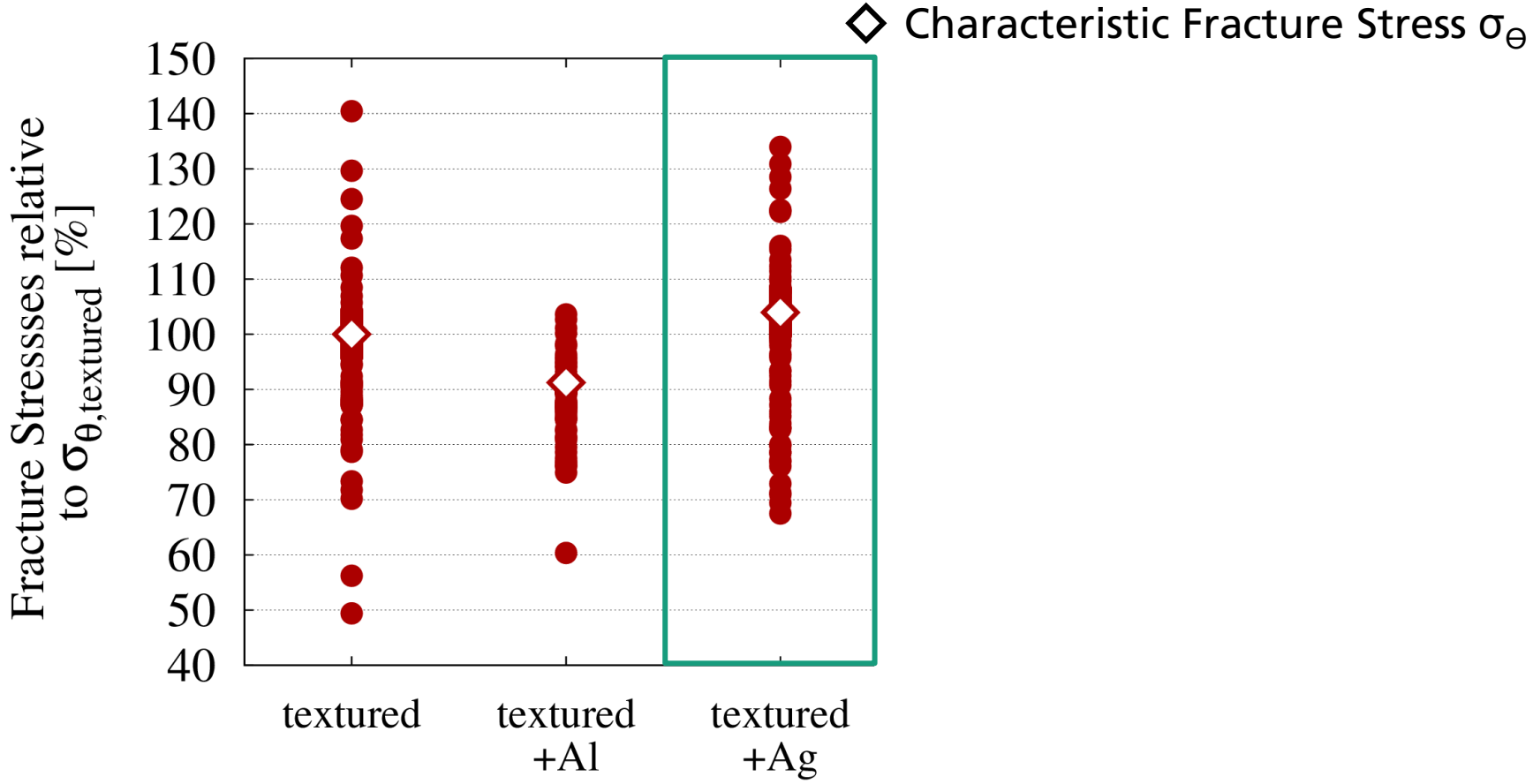
- Al only on textured wafers
- Aluminum paste reduces scattering and
- Characteristic fracture stress reduced about 9%



◇ Characteristic Fracture Stress σ_Θ

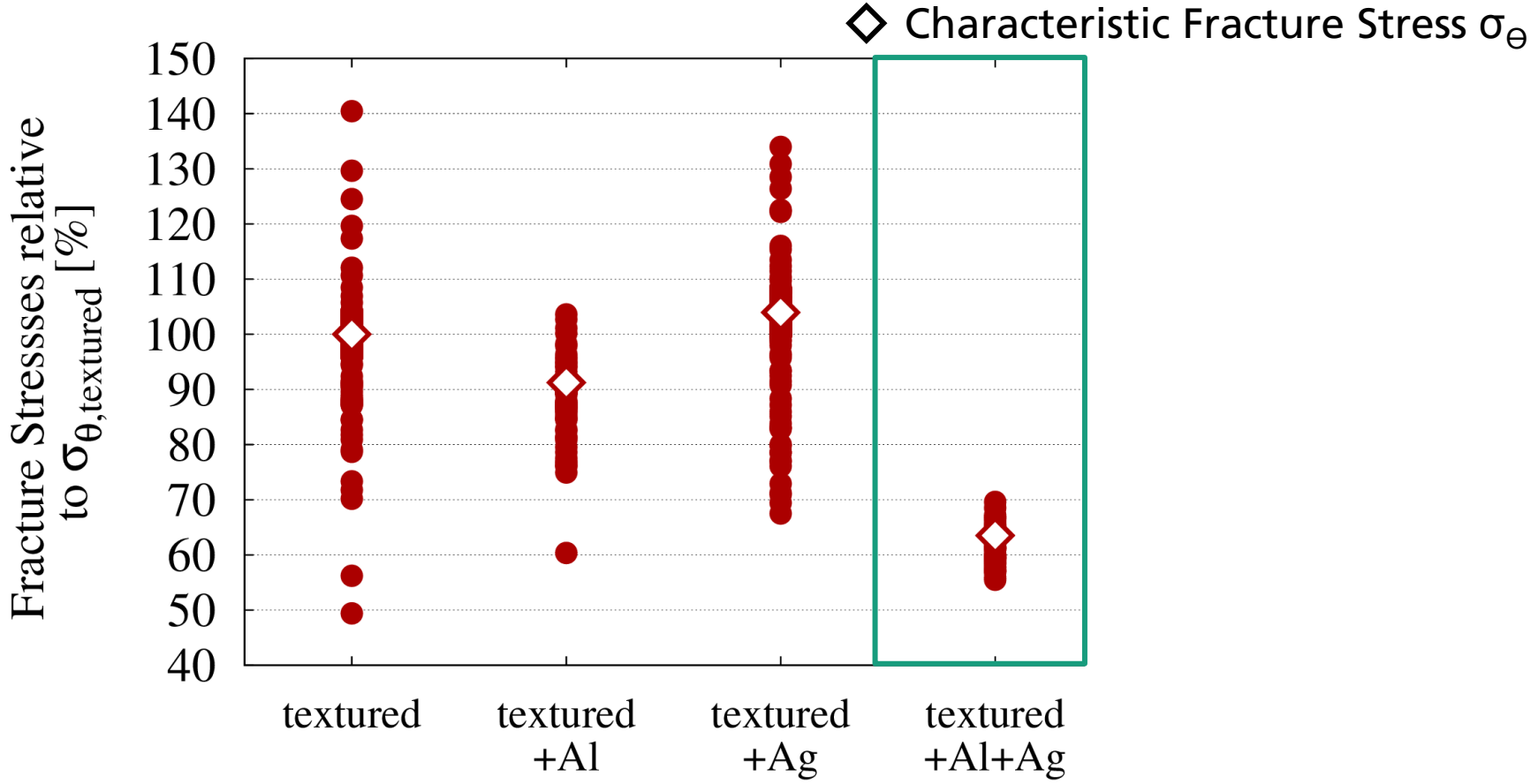
Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

- Ag only on textured wafers
- Silver paste as pads has no significant influence



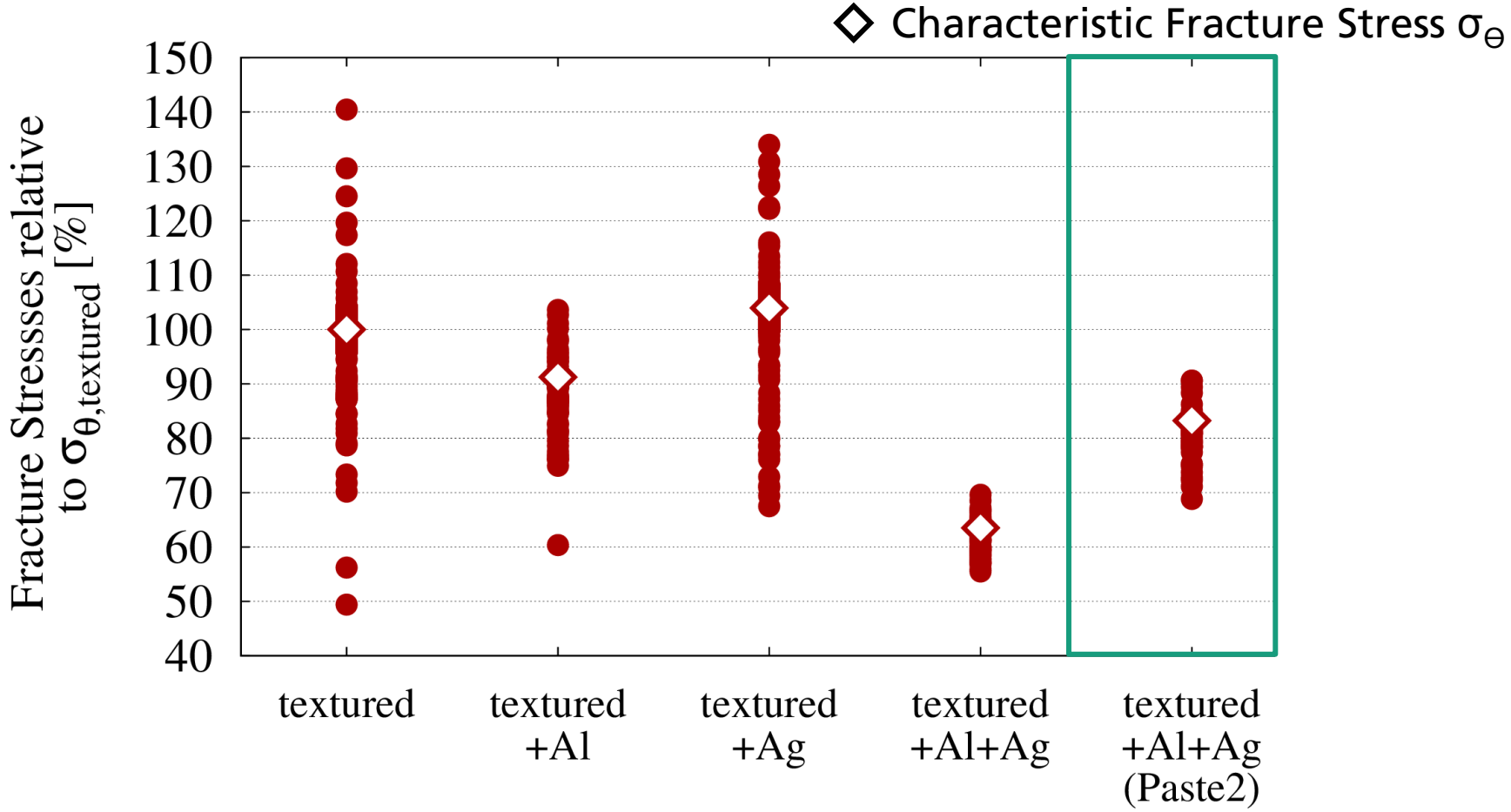
Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

- solar cell (w/ Al-Ag-overlap):
  Ag-paste 1
  geometry 1
- Combination of aluminum and silver paste leads to strong reduction of σ_Θ by about 36%
- Scattering reduced significantly



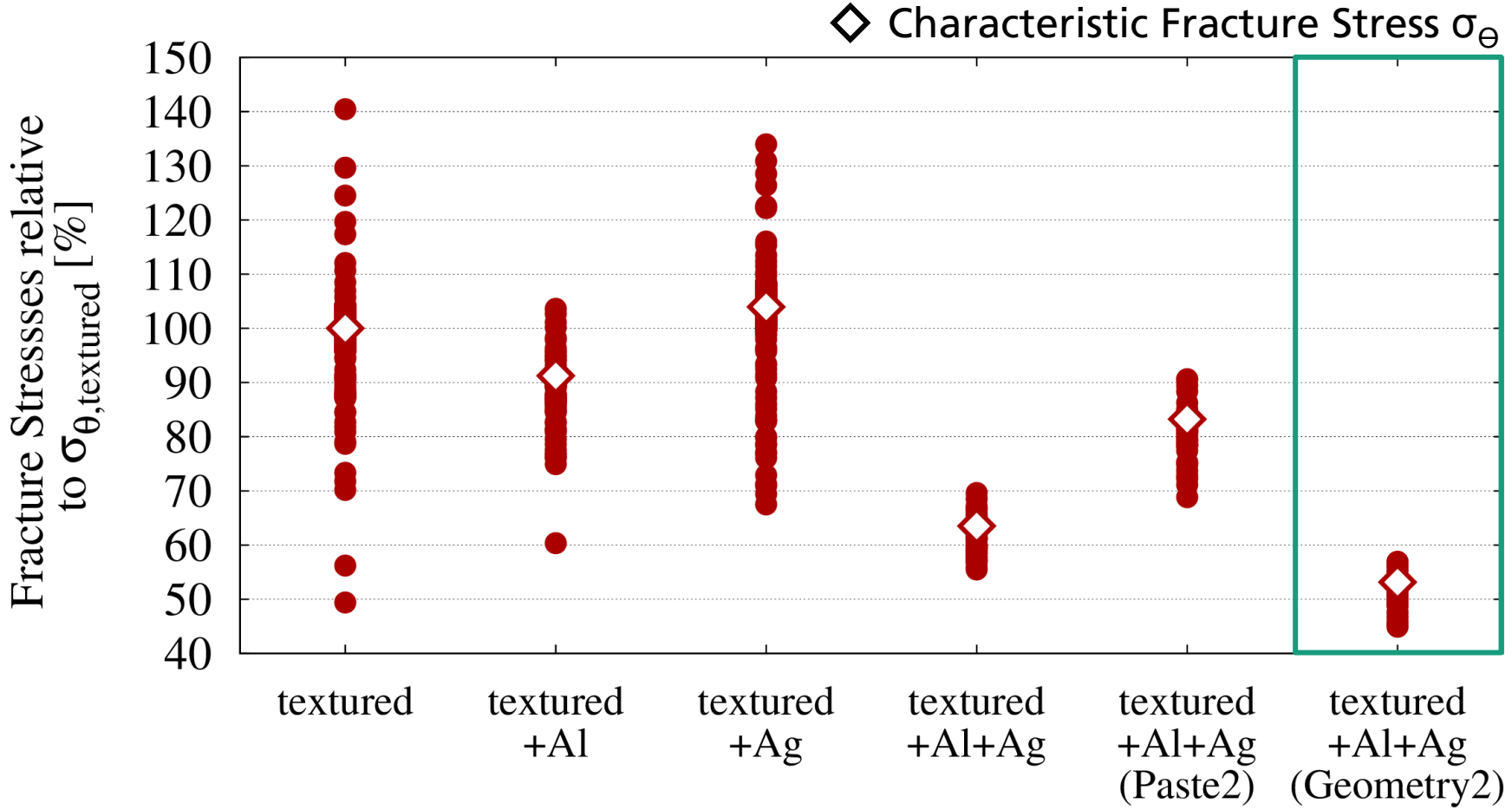
Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

- solar cell (w/ Al-Ag-overlap):
  Ag-paste 2
  geometry 1
- Aluminum and another silver paste reduces σ_Θ only by about 17%
- Scattering reduced significantly



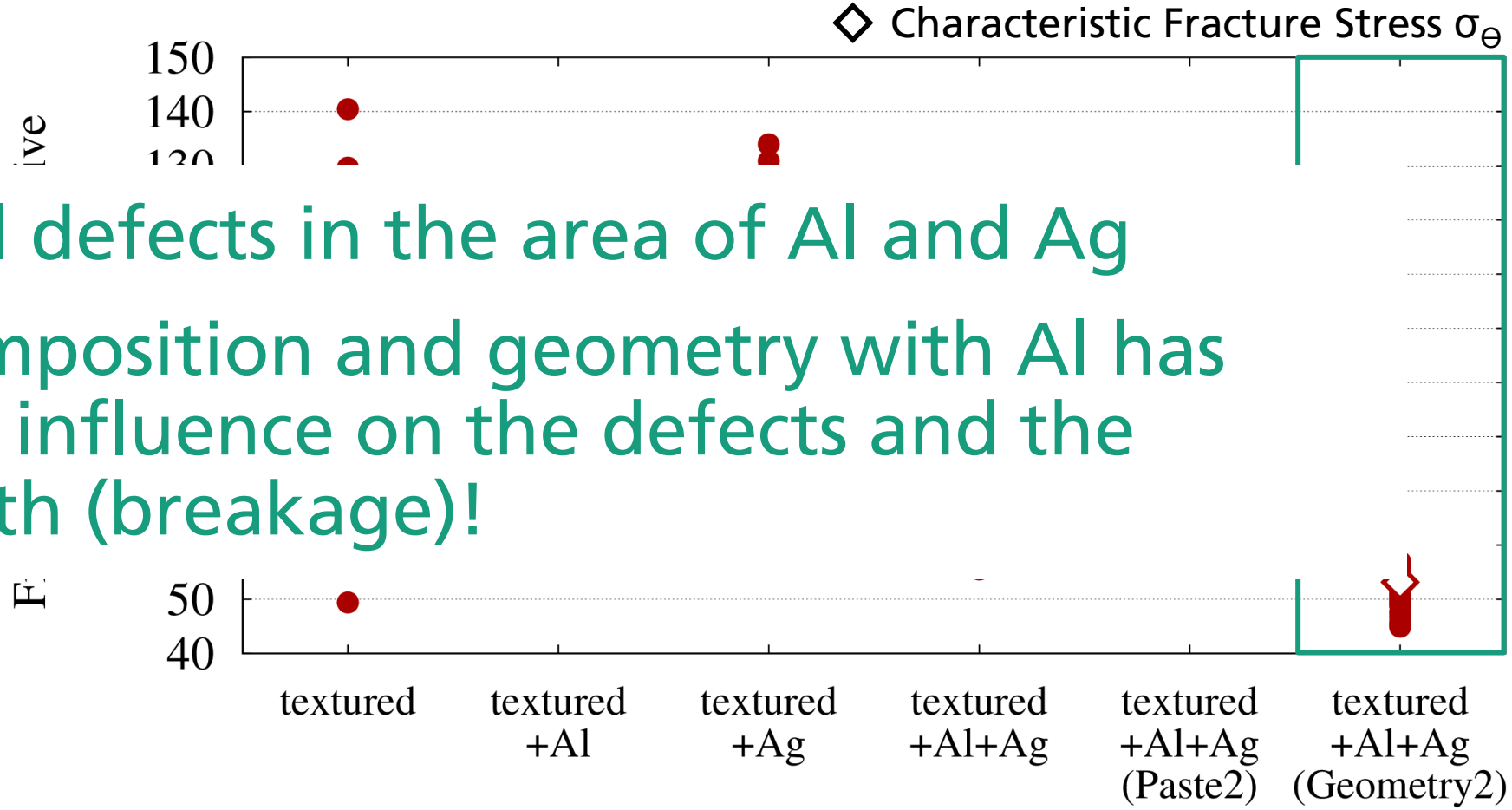
Mechanical Strength of PERC Solar Cells
Investigation of Cells Processing

- solar cell (w/ Al-Ag-overlap):
  Ag-paste 1
  geometry 2
- Aluminum and silver paste with changed geometry reduces σ_Θ by 45%
- Scattering reduced significantly



Mechanical Strength of PERC Solar Cells

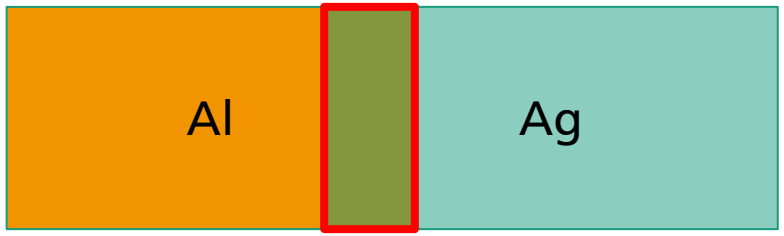
Investigation of Cells Processing



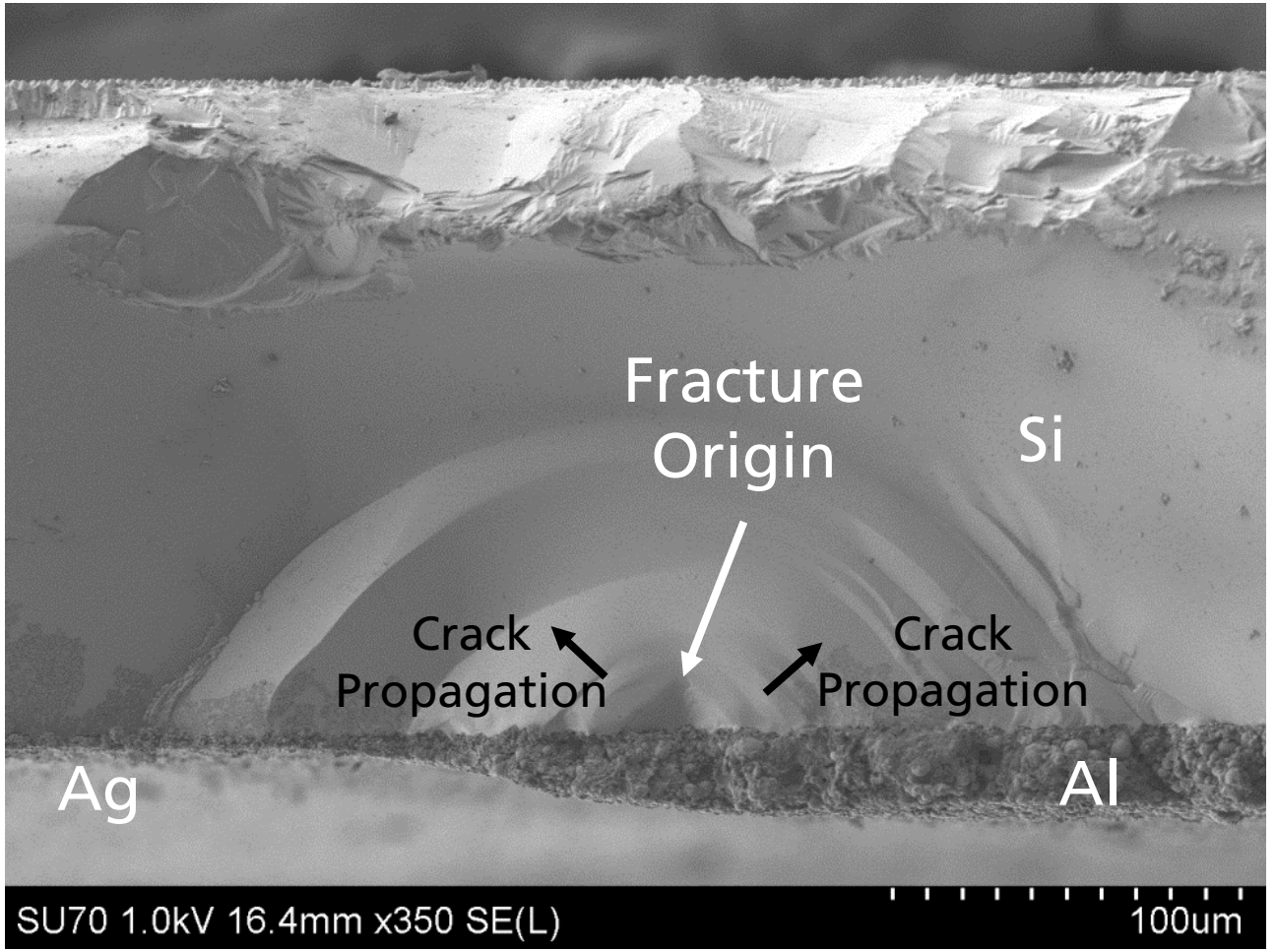
- Critical defects in the area of Al and Ag
- Ag composition and geometry with Al has strong influence on the defects and the strength (breakage)!

Mechanical Defects in PERC Solar Cells
Fractography

- Fractography of broken solar cells
  => identify root cause for breakage
- Fracture origin was found in the overlap area of Al and Ag



Top View

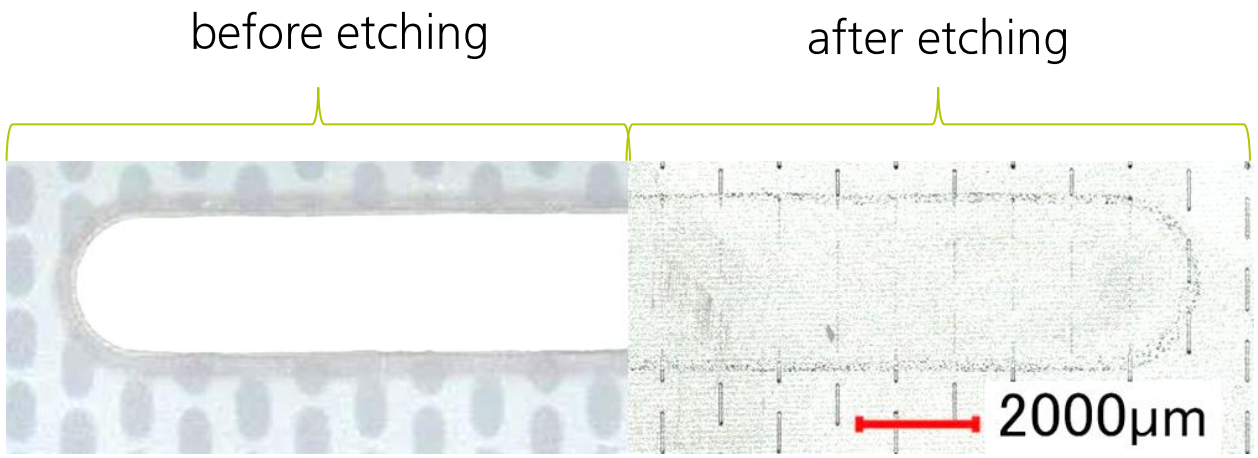


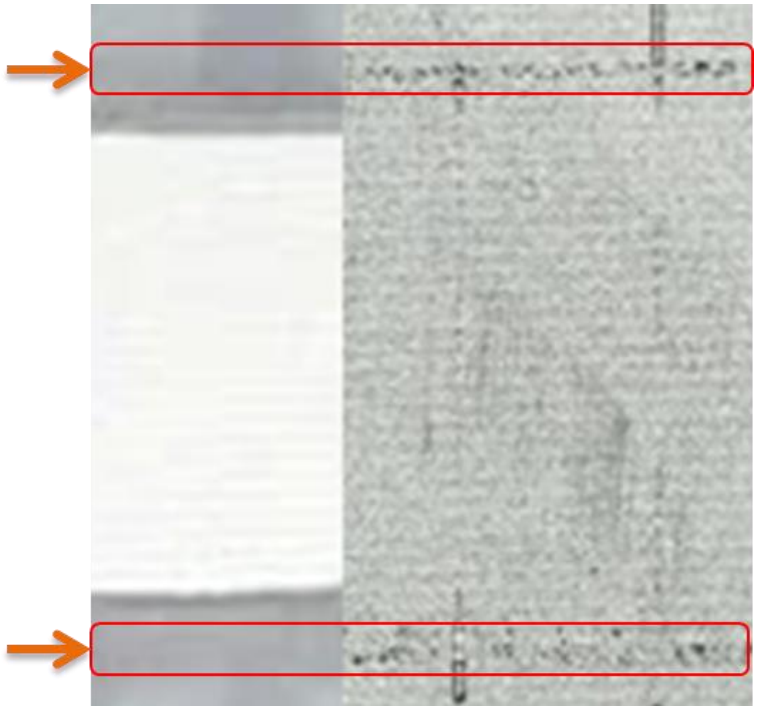
Side View

Fracture Plane

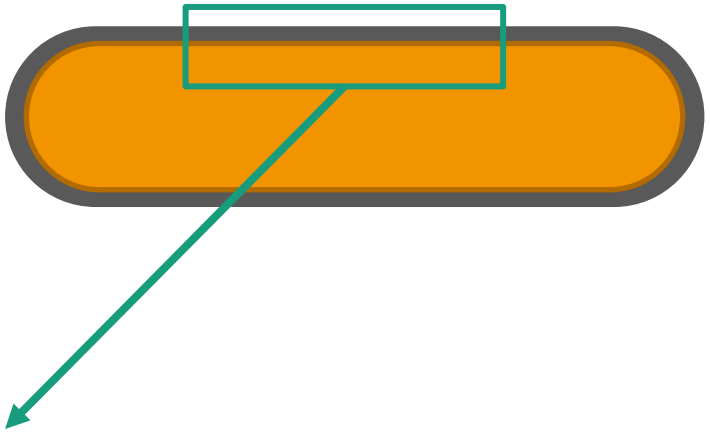
Mechanical Defects in PERC Solar Cells
Microstructure

- Defects were found in the overlap area of Al/Ag layers
  - → Visible as inverse pyramids within the silicon



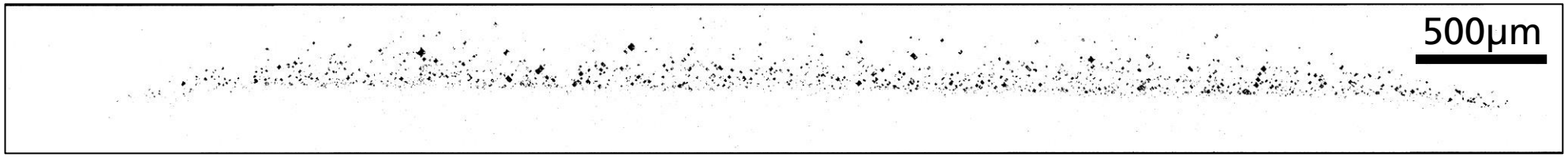


Mechanical Defects in PERC Solar Cells
Microstructure

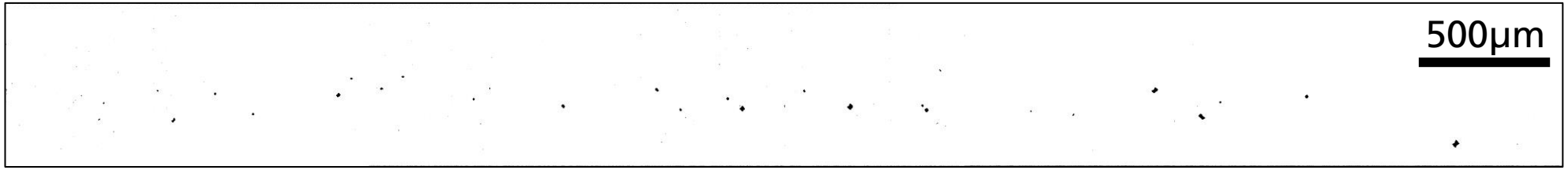


- Defects were found in the overlap area
  - → Strongly depends on the Ag-paste

Top view of the silicon surface after etching



Ag-Paste 1: approx. 880 defects



Ag-Paste 2: approx. 32 defects

Mechanical Defects in PERC Solar Cells
Microstructure

- AgAl-spiking was found in the area of the overlap

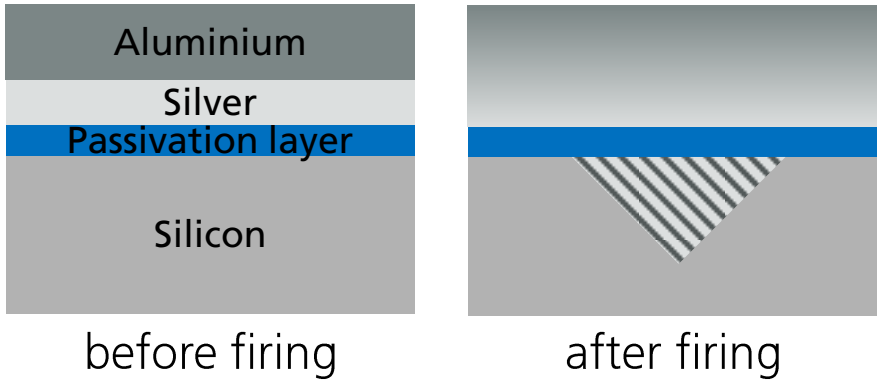
→ Inverse pyramid within the silicon

→ Silicon is diffused into the paste

→ Al and Ag diffuse into the silicon

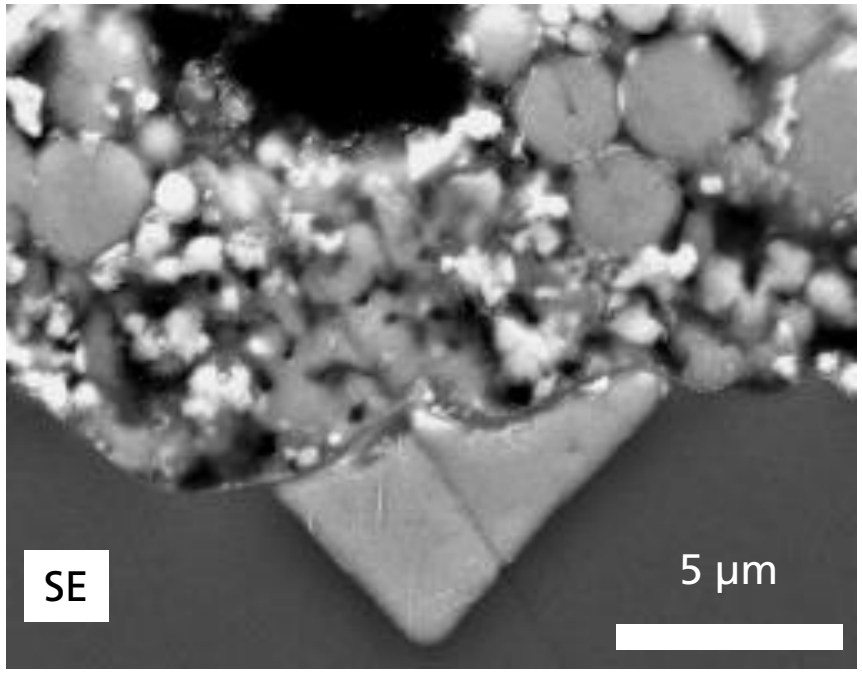
→ Mechanical acting defect – sharp notch!

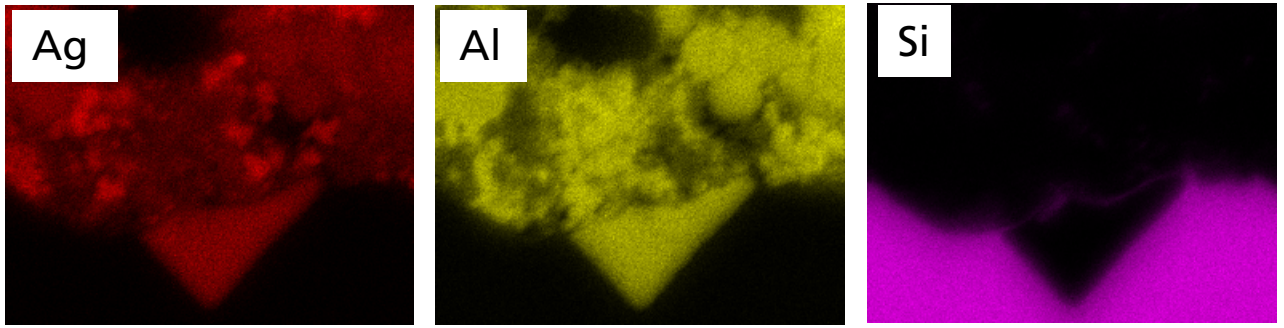
→ Breakage of solar cell



before firing | after firing

EL images of the cross section



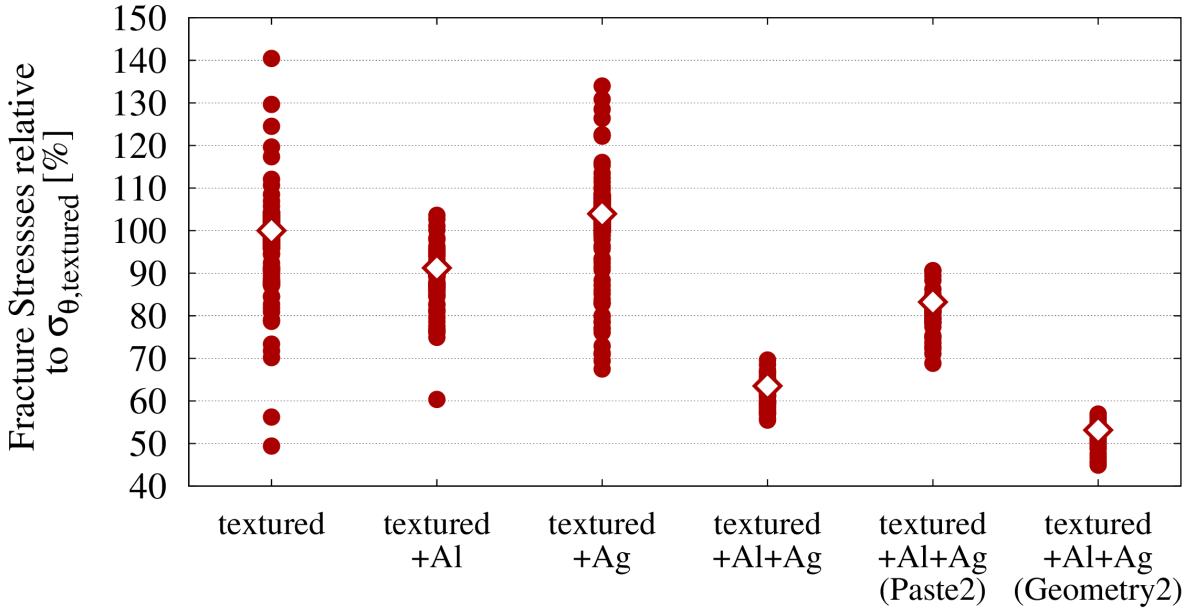


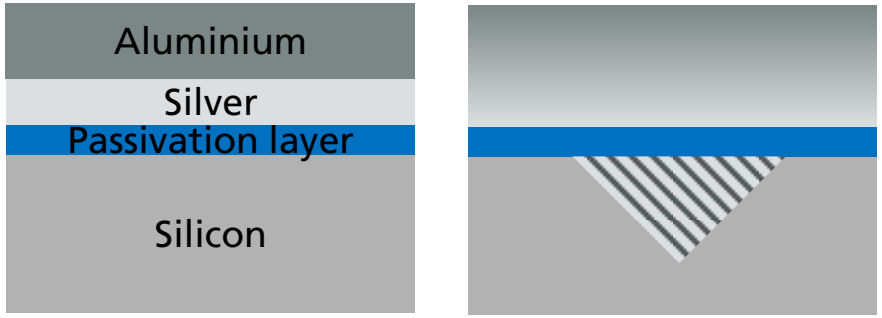
Conclusions

- Strength of PERC cells can be reduced by 17% to 45% regarding textured wafer strength
- In the overlap area between aluminum and silver AgAl-spiking was found
  - induced sharp notches within the silicon in shape of inverse pyramids (mechanical defect)

⇒ The composition of the Ag paste and the pad geometry strongly influence on the strength and breakage of solar cells

⇒ detailed analysis of strength and microstructure can be used for optimization of paste and pad geometry





Acknowledgement

- This work was funded by the Federal Ministry of Education and Research in the Innoprofile initiatives „DiaCell“ (contract no. 03IPT607A) and „MechSi“ (contract no. 03IPT607X)