

# Customized texturing for advanced solar cell structures

BC Workshop, ISFH Hameln, 29.11.2023

J. Vollmer, B. Straub, Dr. A. Eljaouhari, F. Dorn, M. Passig, C. Scheiwe, Dr. A. Padiaditakis, T. Dannenberg, T. Harders, Dr. D. Brunner, Dr. H. Kuehnlein,

Katrin Krieg, Mert Isik, Dr. Martin Zimmer (Fraunhofer ISE)

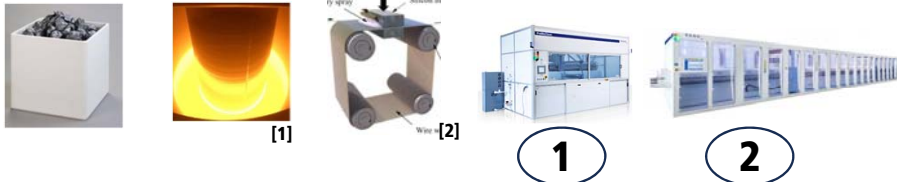
Dr. W. Favre, L. Sallaberry, Dr. A. Danel, H. Lignier



This work was funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) within the research projects TALER and TOPCon Cluster.



## Impact of wet-chemistry on cell performance and OPEX



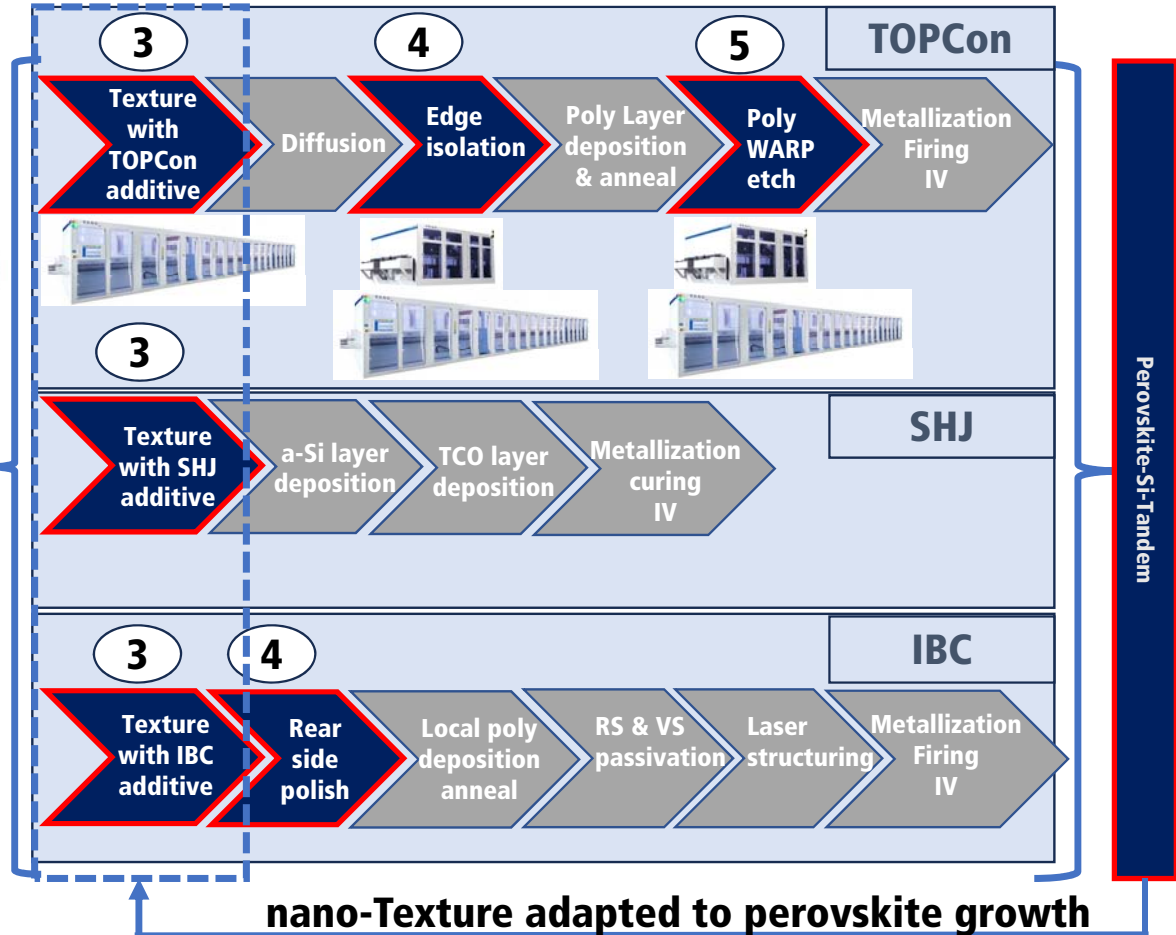
• Strong impact of wet-chemistry over process chain: 3-5 steps

• Strong interconnection

➤ 1,2 → 3 → 5 → efficiency, cost

➤ Potential for reduction of OPEX

➤ water, chemistry, energy, yield



[1] Source: PV Tech –PV Manufacturing & Technology Quarterly Report, Q4/22

[2] Source: [https://www.db-thueringen.de/servlets/MCRFileNodeServlet/dbt\\_derivate\\_00039387/ilm1-2017iwk-044.pdf](https://www.db-thueringen.de/servlets/MCRFileNodeServlet/dbt_derivate_00039387/ilm1-2017iwk-044.pdf)



## Motivation for customized texturing

### Specification list for textures

#### PERC cells

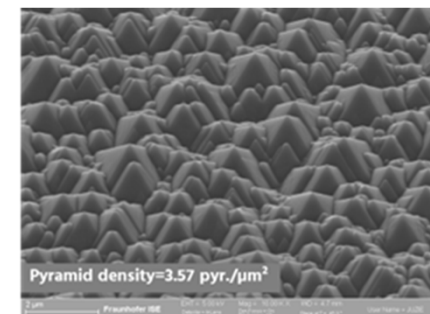
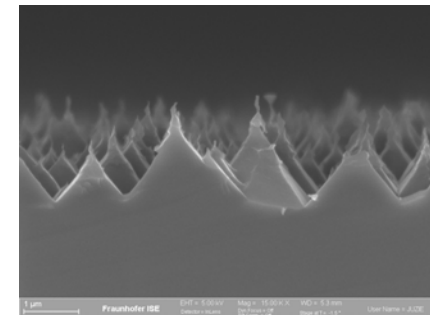
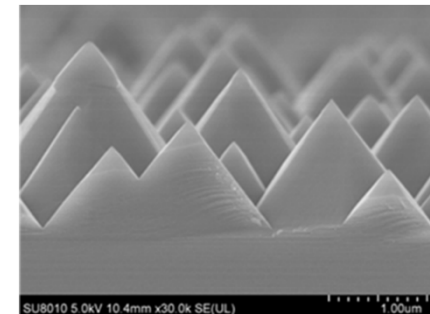
- Passivation with thin thermal  $\text{SiO}_x$  plus multi-layer  $\text{SiN}_x$
- Only conventional pyramid shape with sufficient passivation

#### TOPCon cells

- Passivation with  $\text{Al}_2\text{O}_3$  (ALD) +  $\text{SiN}_x$
- Advanced pyramid shapes can be passivated

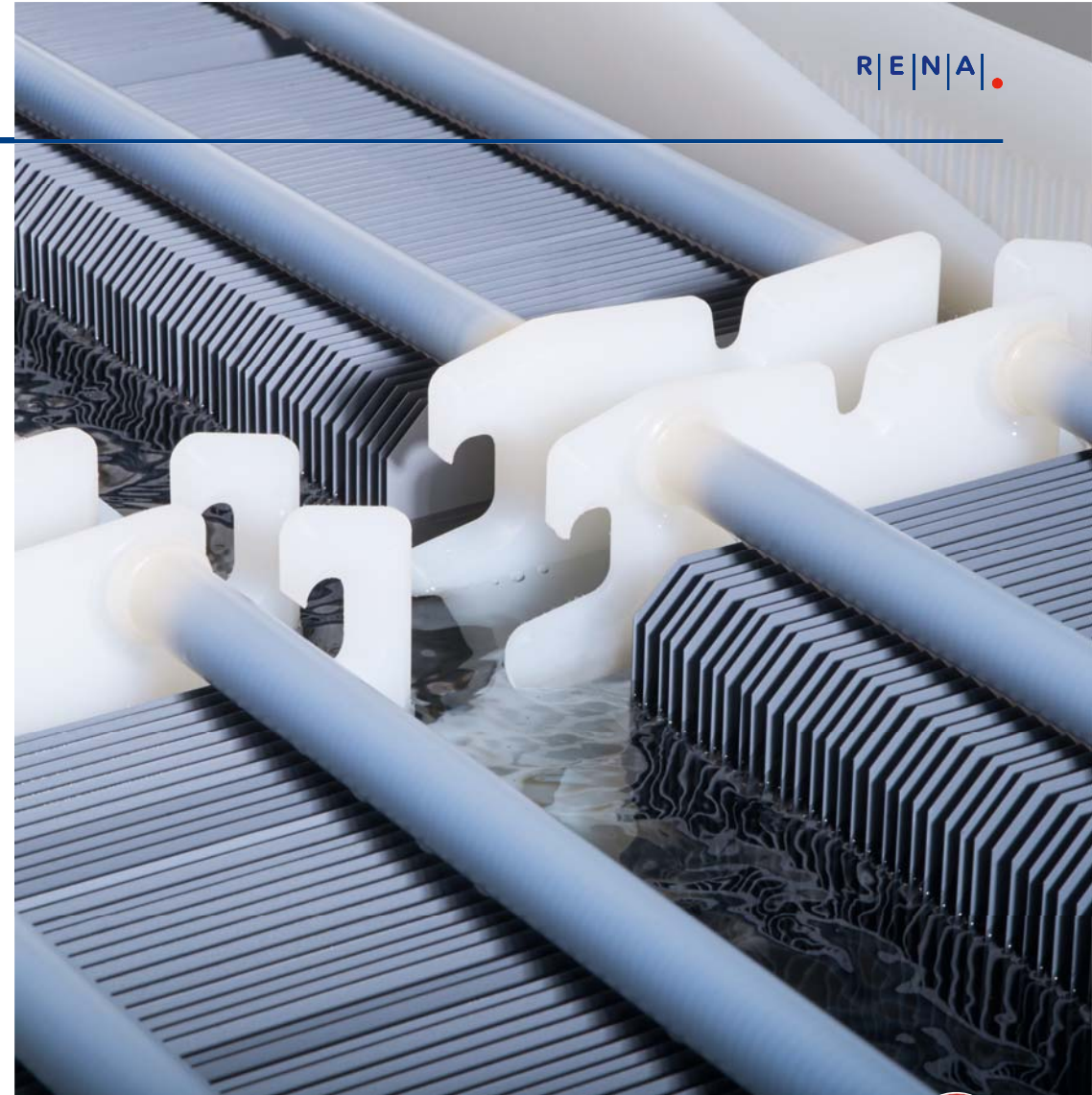
#### SHJ cells

- Small pyramids with tight distribution
- Best adaptation to sensitive and ultra thin a-Si layer stacks



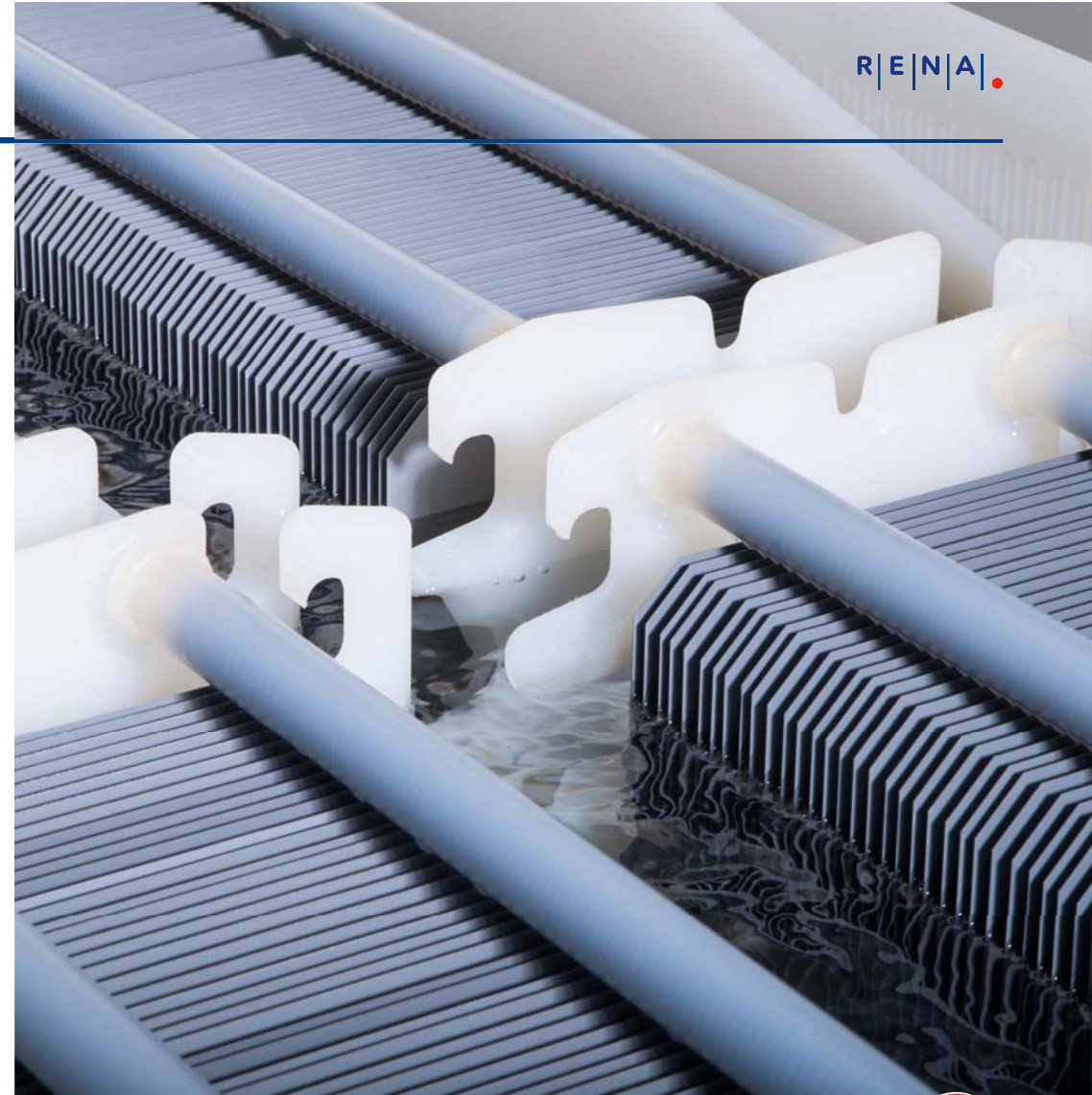
# Overview

- **Introduction BatchTex 3 N600**
- **Customized texture & clean**
  - **TOPCon**
  - **SHJ**
  - **Options for Perovskite-Si-Tandem texture**
- **Options for IBC texture**
  - **Ultra low reflection additives**
  - **Inline single-side texture**
- **Summary**



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# Wet Chemistry Step 1 | Alkaline Texturing

## BatchTex 3 N600



<https://www.youtube.com/watch?v=kf57TkCVx7I>

- 24.7 m tool length with 6 carriers / batch
- Carrier length up to 710 mm, up to 120 wfr/carrier
- Can be operated with or without SDR
- Process based on O<sub>3</sub> pre-clean & O<sub>3</sub> post-clean
- Wafer size adaption by simple carrier change possible

TP in wph	wafer size	wafer / carrier	capacity / tool / year* [MW]
12000	M10	100	780
12000	M12	100	1040
15000	M10	120	980
15000	M12	120	1300

\*Assuming 25.0% cell efficiency and 7875h of production at gross throughput per year



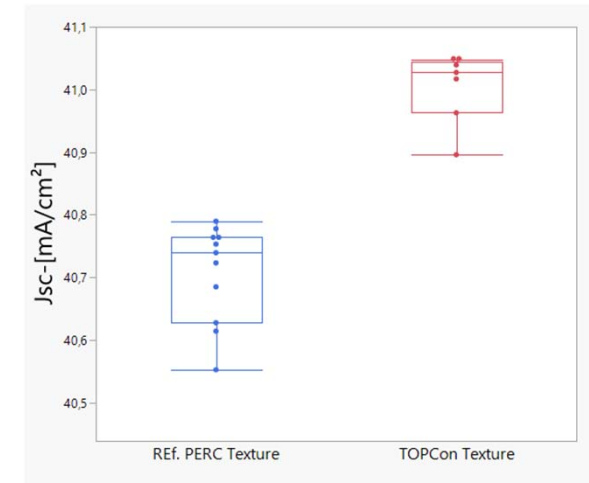
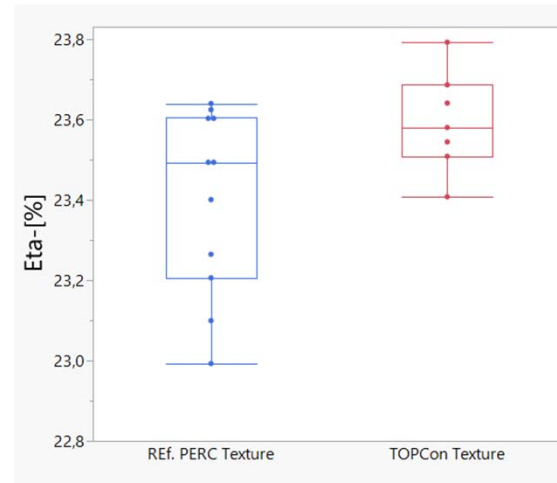
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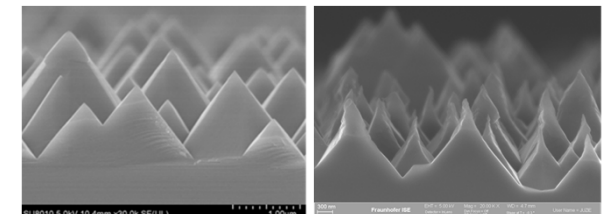


# Advanced Texture applied to TOPCon Cells

- **Proof that advanced textures can be integrated into TOPCon cells (ALD  $\text{Al}_2\text{O}_3$ )**
- **Significant gain in  $J_{sc}$  of about  $0.3 \text{ mA/cm}^2$  observed**
- **First small increase in efficiency of  $0.05 \%$  visible**
- **Outlook: more aggressive texture  $R < 9 \%$**



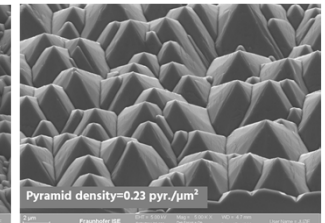
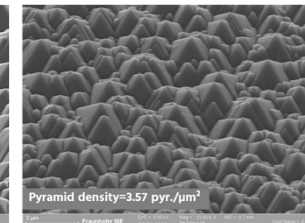
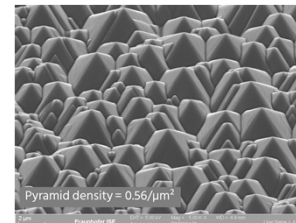
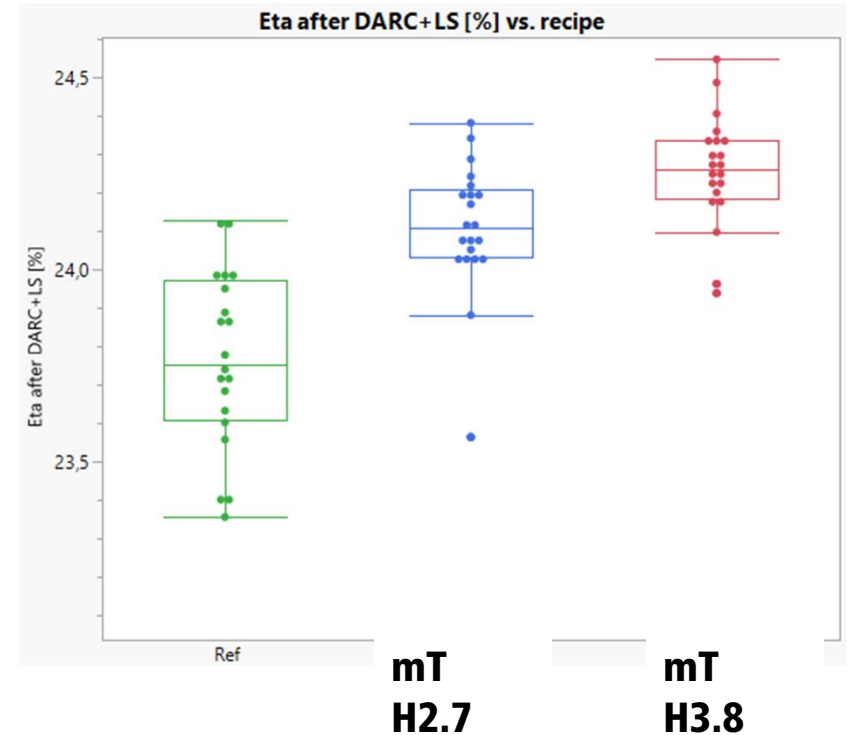
Texture	Reflection @ 600 nm [%]
New TOPCon texture	9.24
old "PERC" texture	11.10





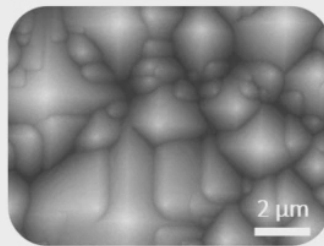
## Silicon Heterojunction

- SHJ texture comparison of different RENA SHJ additives with competitors
- $R_{600\text{ nm}} = 10\text{-}11\%$
- Efficiency gain up to 0.3% and 0.4%
- $V_{OC}$  and  $J_{SC}$  on same level
- Efficiency gain through better FF and decrease in  $R_s$
- Effect still under investigation

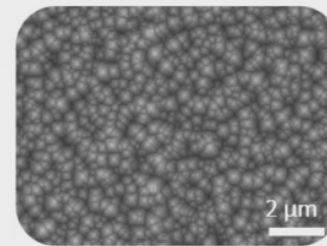


# MOTIVATION

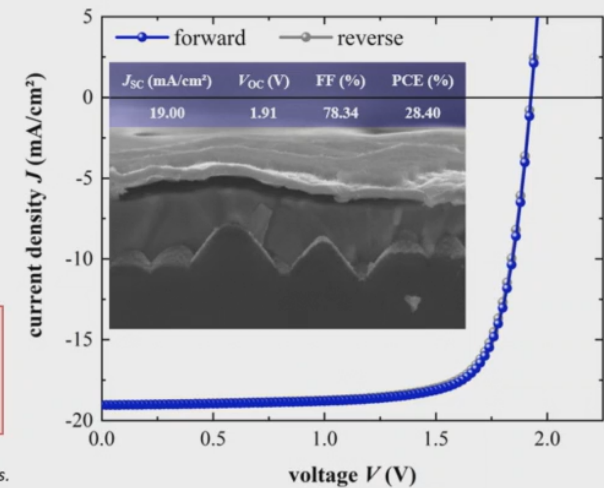
## ALKALINE NANO-TEXTURING OF THE BOTTOM CELL



- reduced size
- narrow height distribution



### Si/perovskite tandem solar cell

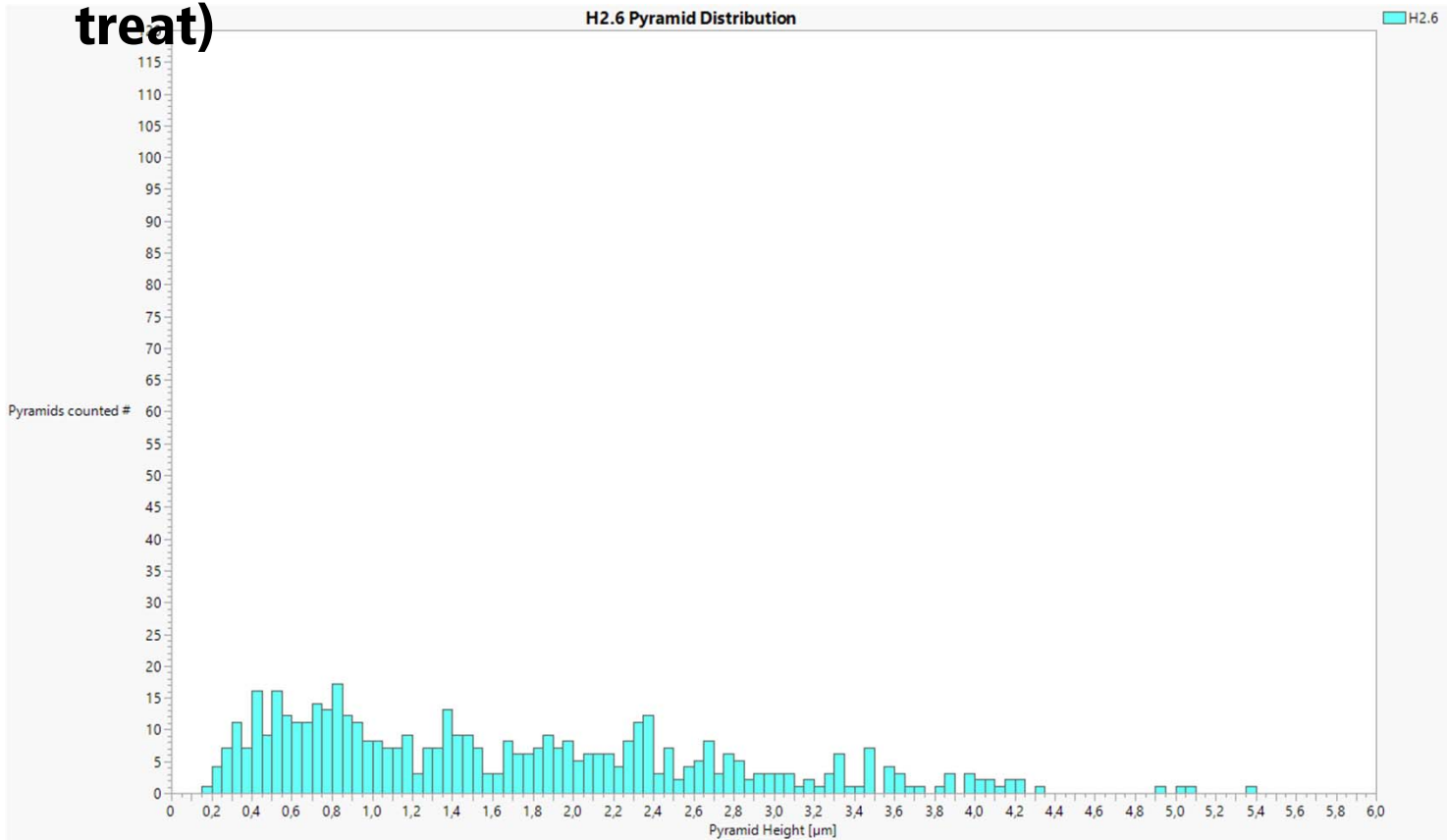


Nano-texturing<sup>[2]</sup> enables solution processing and upscaling with industry compatible processing for tandems.

[2] Harter, A. et al (2023). *Progress in Photovoltaics: Research and Applications*.



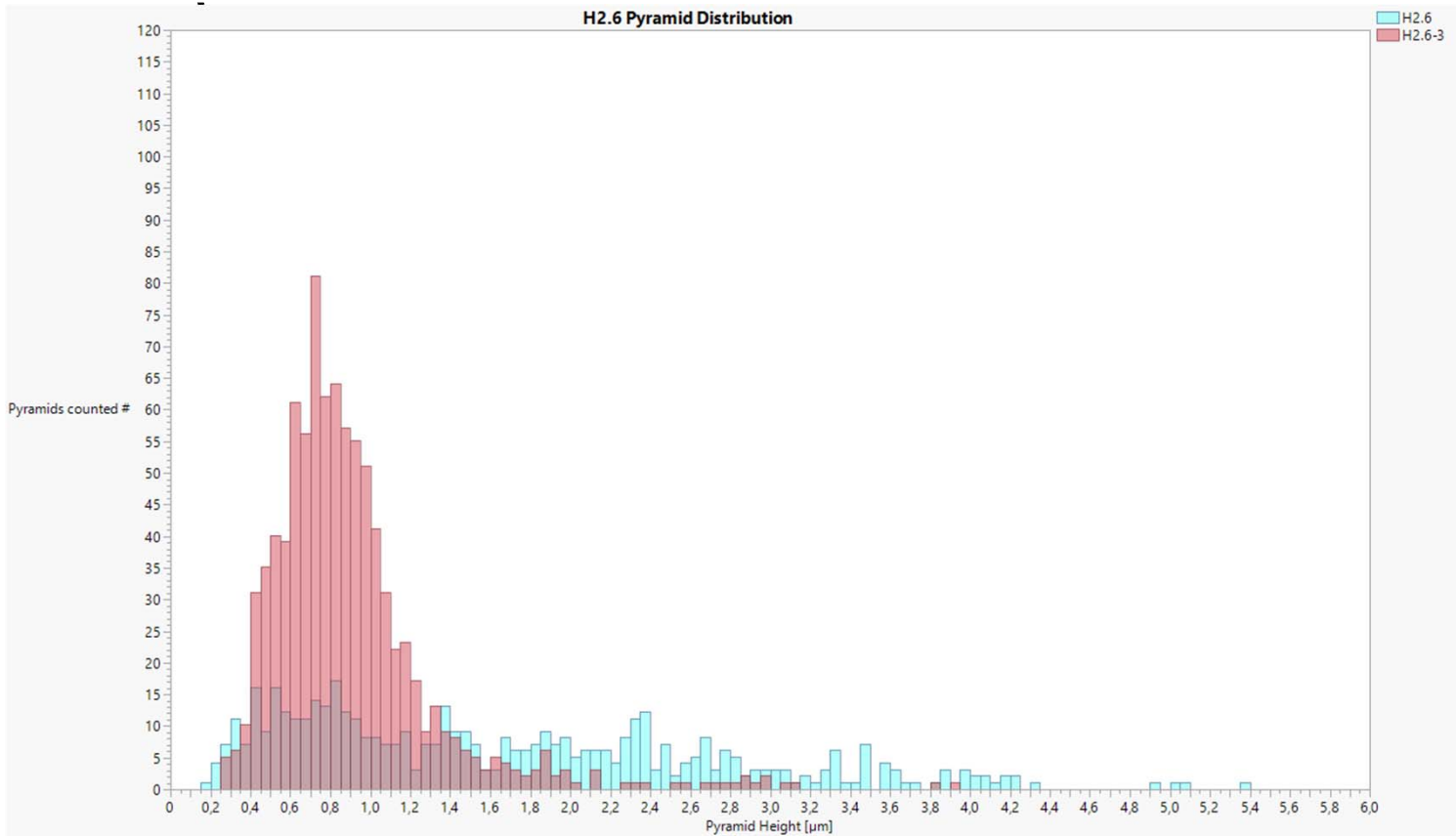
# RENA Additive H2.6 Evolution to H2.7 (incl. Pero Pre-treat)



- H2.6:**
- Old PERC Standard
- With SDR  $\rightarrow$  4  $\mu\text{m}$
- Pyramid height = 1.14-1.47  $\mu\text{m}$
- Pyr. per sq.  $\mu\text{m}^2$  = 0.18 pyr/ $\mu\text{m}^2$



# RENA Additive H2.6 Evolution to H2.7 (incl. Pero Pre-



**H2.6:**

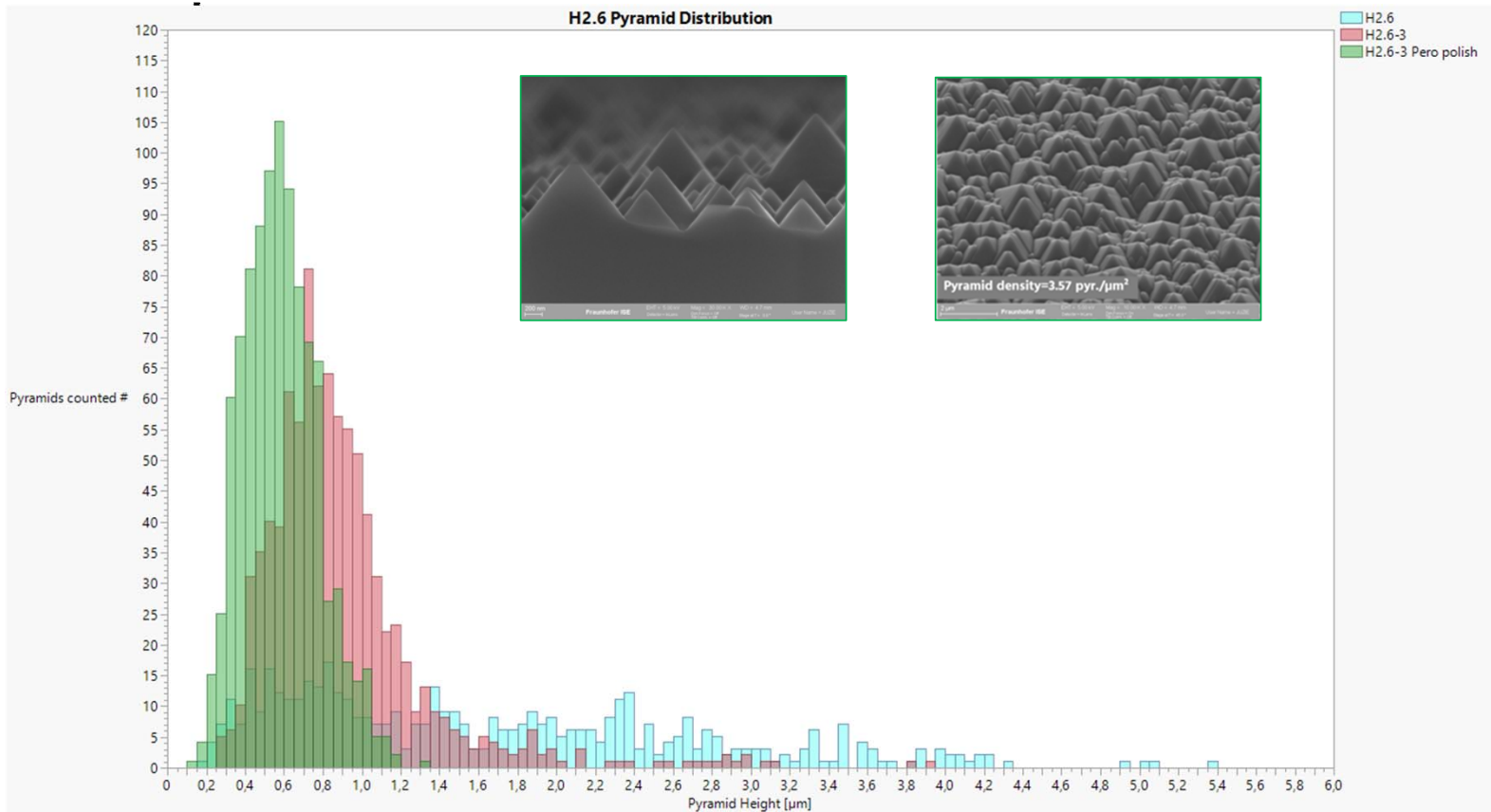
- Old PERC Standard
- With SDR → 4 µm
- Pyramid height = 1.14-1.47 µm
- Pyr. per sqr.µm = 0.18 pyr/µm<sup>2</sup>

**H2.7:**

- New variant
- With and without SDR
- Pyramid height = 0.8-0.9 µm
- Pyr. per sqr.µm = 1.04 pyr/µm<sup>2</sup>



# RENA Additive H2.6 Evolution to H2.7 (incl. Pero Pre-



**H2.6:**

- Old PERC Standard
- With SDR  $\rightarrow$  4  $\mu\text{m}$
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- Pyr. per sqr. $\mu\text{m}$  = 0.18 pyr/ $\mu\text{m}^2$

**H2.7:**

- New variant
- With and without SDR
- Pyramid height = 0.8-0.9  $\mu\text{m}$
- Pyr. per sqr. $\mu\text{m}$  = 1.04 pyr/ $\mu\text{m}^2$

**H2.7 (incl. Pero Pre-treat):**

- In development for Pero
- Adapted pre-treat
- Pyramid height = 0.5-0.6  $\mu\text{m}$
- Pyr. per sqr. $\mu\text{m}$  = 3.2 pyr/ $\mu\text{m}^2$

**Cell data is on the way**



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R|E|N|A|.

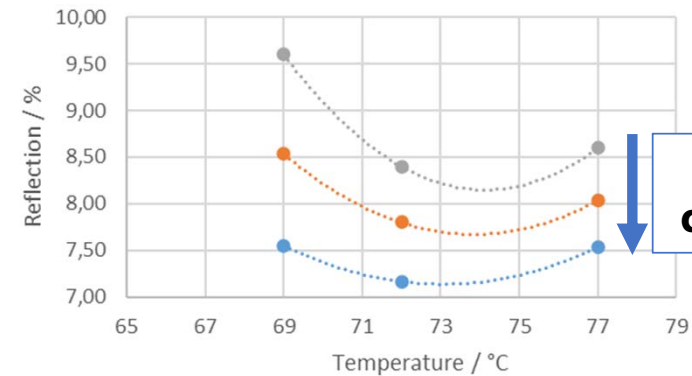


# Options for IBC Texture

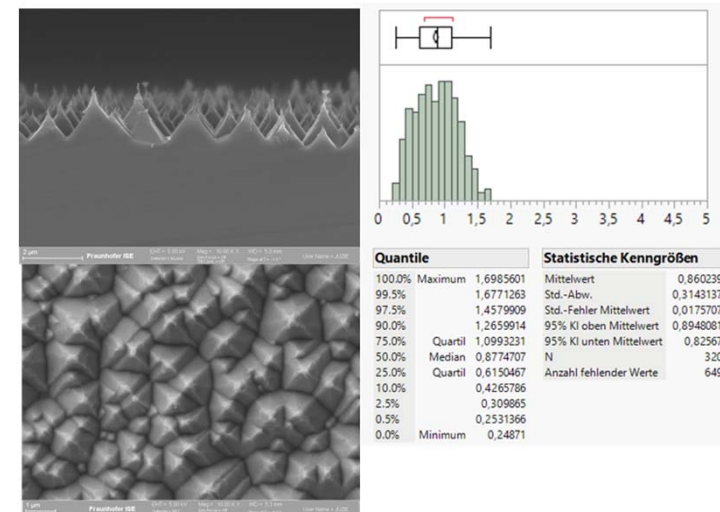
## Ultra low reflection additive

- Additive allows reflectivity values below 7 % at 600 nm
- Direction of black silicon
- Open question of suitable passivation
- BC could allow a wider range of passivation options
- Open for sampling / collaborations

Reflection @ 600nm vs Temperature

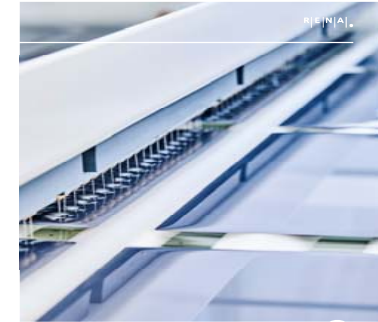
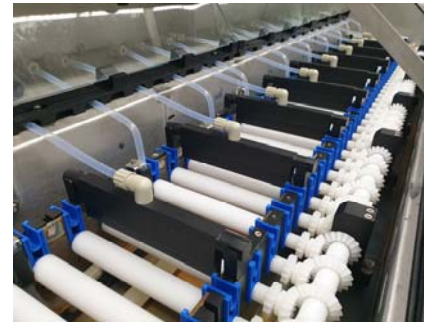


additive composition



## Inline single-side texture

- **Reduced invest on machinery compared to process flow with capping layer or polishing after double side texture**
- **Combination of three RENA solutions**
  - Texturing, Additive, Inline
- **No need for protective layer on rear side**
- **Maximum process time for Inline processes < 3 min**
- **New additive leads to inline process time roughly to about 3 min**
- ✓ **Single side quality and reflectivity value below 10 % are proven**
- **Work in progress: Demo of same lifetime as batch reference texture**





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## Customized texturing for advanced solar cell structures

- PERC & TOPCon
- SHJ
- Perovskite Si-Tandem
- IBC



Additives & cell types	Year	Reflectivity (@600 nm)	SEM pictures		Pyramide distribution	Pyramide rounding (etch back)
			45 ° Top view	0 ° cross-section		
monoTex H2.6 (PERC, HJT)	2015-2020	10.6 %			 • pyramid height = 1.14-1.47 μm • pyr. per sq.μm = 0.18 pyr/μm <sup>2</sup>	
monoTex H3.7 (PERC, TOPCon)	2021 - on going	8-9 %			 • pyramid height = 0.84-1.06 μm • pyr. per sq.μm = 0.84 pyr/μm <sup>2</sup>	 9% Refl. 9.5% Refl.
monoTex H2.7 (TOPCon, HJT)	2023 (New development)	8-9 %			 • pyramid height = 0.8-0.9 μm • pyr. per sq.μm = 1.04 pyr/μm <sup>2</sup>	under investigation
monoTex fast MT (HJT, IBC)	2023 (New development)	7-8 %			 • pyramid height = 0.56-0.7 μm • pyr. per sq.μm = 1.49 pyr/μm <sup>2</sup>	under investigation

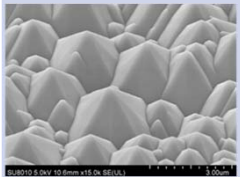
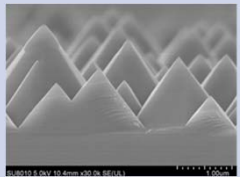
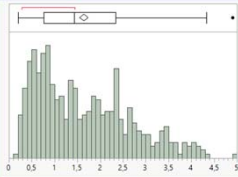
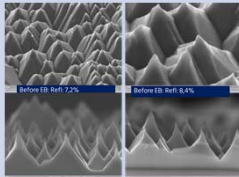
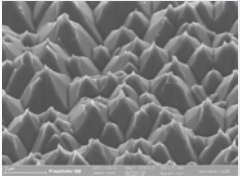
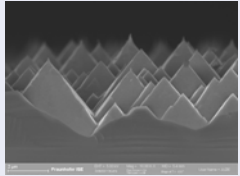
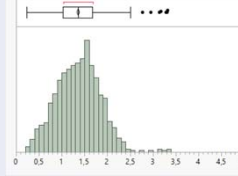
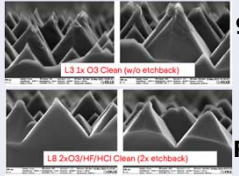
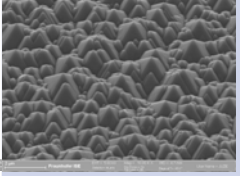
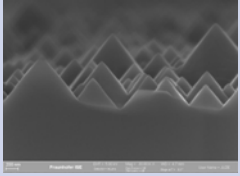
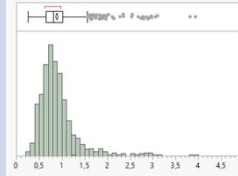
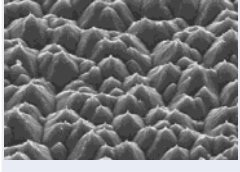
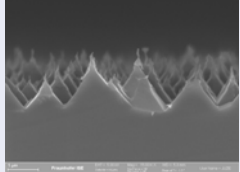
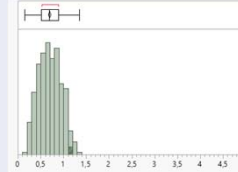


Thank you for your attention

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R | E | N | A | ●

The art of wet processing.

Additives & cell types	Year	Reflectivity (@600 nm)	SEM pictures		Pyramide distribution	Pyramide rounding (etch back)
			45 ° Top view	0 ° cross-section		
<b>monoTex H2.6</b>  (PERC, HJT)	2015-2020	10.6 %			 <ul style="list-style-type: none"> <li>pyramid height = 1.14-1.47 <math>\mu\text{m}</math></li> <li>pyr. per sq. <math>\mu\text{m}^2</math> = 0.18 <math>\text{pyr}/\mu\text{m}^2</math></li> </ul>	
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