APPLICATION REQUIREMENTS FOR ELECTRICALLY CONDUCTIVE ADHESIVES AS INTERCONNECT MATERIALS FOR SHINGLED SOLAR CELLS

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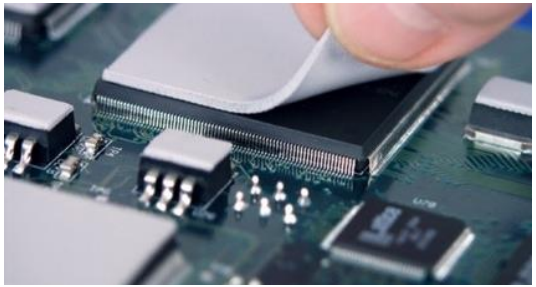
Who is Henkel?
The Largest Adhesives Supplier in the World

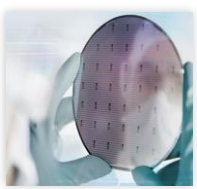
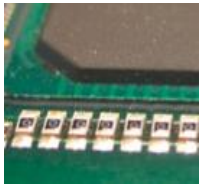
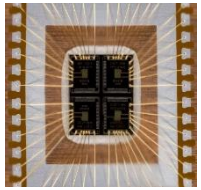
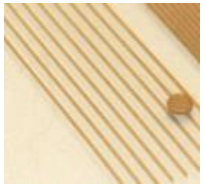
- Henkel subsidiaries working on **Electrically Conductive Adhesives** (ECA's) since the 1950's and selling them for > 10 years for photovoltaic applications
- One of the largest **low temperature conductive silver paste suppliers**
- **> €20B turnover,** 47% in Adhesives Technologies
- **170 manufacturing sites** and **21 major R&D centers** around the world

Adhesive Technologies	Beauty Care	Laundry & Home Care
		
LOCTITE, TECHNOMELT, BERGQUIST	Schwarzkopf, Dial, syoss	Persil, Purex, Pril

Electronic Adhesive Technologies

Expertise in customizing highly filled polymeric systems

Cleaners	Encapsulation	Component Assembly	Inks and Coatings	Soldering	Thermal Management	Device Assembly	Equipment

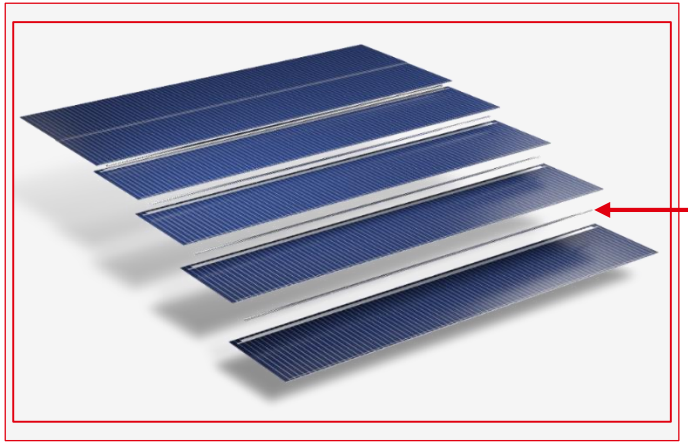


- Typically we focus on **highly customized materials** for key applications and customers
- Very broad portfolio of chemistries expertise: **Epoxy, Acrylate, Silicone, Bismaleimide** and **Hybrid.**
- Over **30% of sales come from products launched within the last 5 years.**
- **Over 500 commercial ECA's** and the largest market share globally.

Shingled Module Technology
Introduction

Optimized active area by tighter cell packing

Roadmap towards reduced overlap



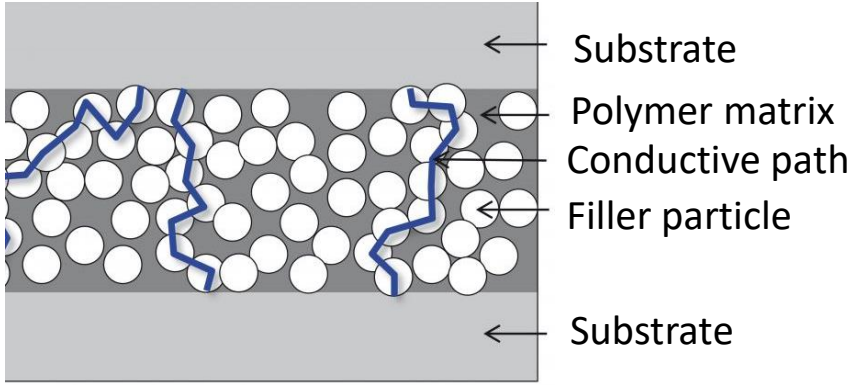
Conventional Module:

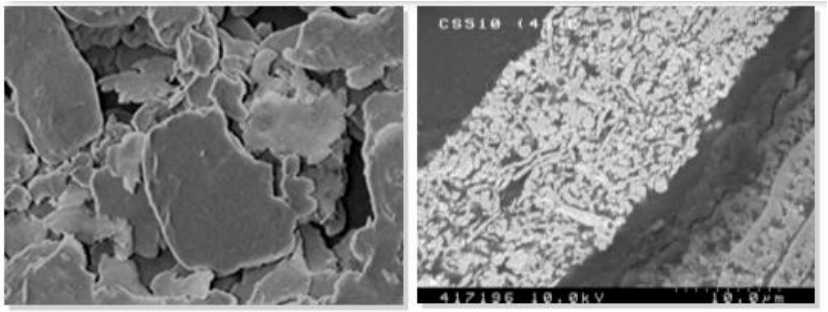
c-Si Cell interconnect in series by solder (SnPb) coated copper ribbon

Shingled Module:

c-Si cell interconnect of shingles and ribbons by **Electrically Conductive Adhesive (ECA)**

Electrically conductive adhesive (ECA)



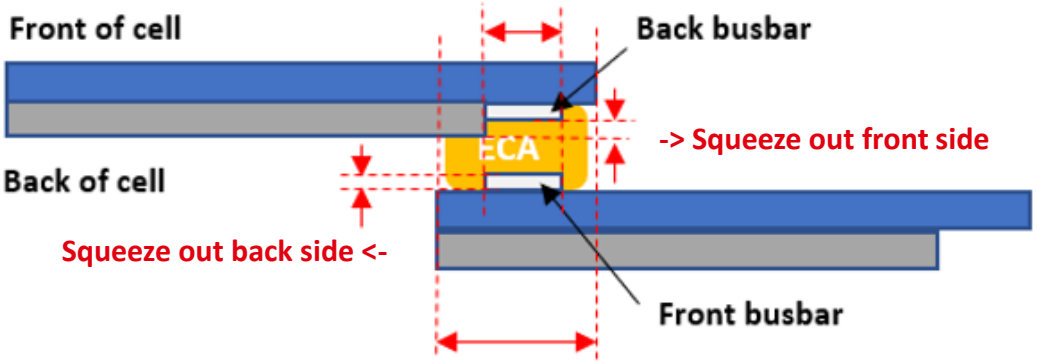


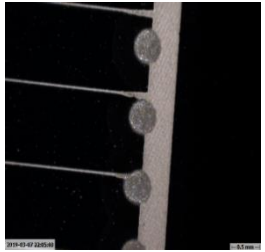
Low silver loading ECA possible

- A continuous network of particles is needed to ensure conductivity
  - High amount of contact points are needed
  - Network needs to be created before the end of cure
- Conductive filler determines viscosity/thixotropy of the material -> important for the application
- Polymer (acrylic, silicone, epoxy) determines mechanical property

Shingle overlap
Roadmap towards reduced overlap

Correct **ECA rheology**, ECA **application equipment** (ECA **position** accuracy and **dimension**) and **shingle tool** (placement accuracy) required in order to avoid ECA squeeze out both on front side and back side of cell



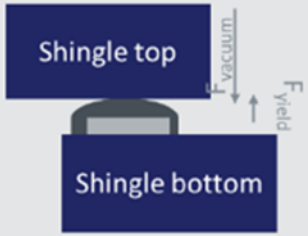
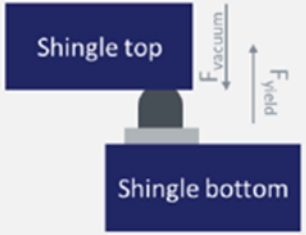


Reduced overlap: 1,8 mm -> **1,4/1,5 mm -> 0,9/1,0 mm** -> 0,6 mmm

TODAY

Effect of rheology of ECA

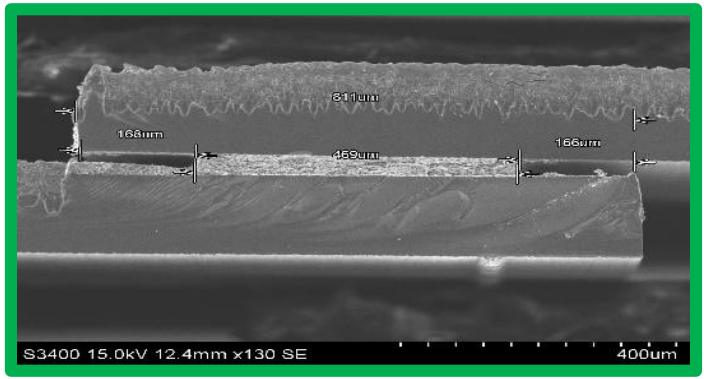
- **Viscosity and shear thinning index effect ease of application**
  - Low viscosity: ECA flows more easily
  - High shear thinning: low viscosity upon application, high viscosity at rest
- **Thixotropy** (recovery rate)
- **Yield stress** (minimum stress required to get material to flow)

	Recovery rate	Yield stress
Low	Slumping 	
High	Higher aspect ratio 	

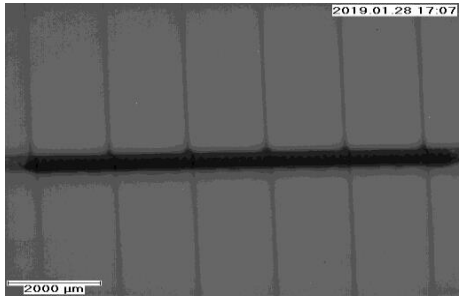
Effect of ECA deposition location

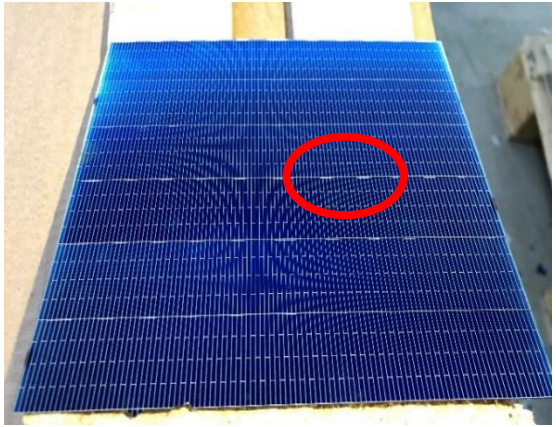
Squeeze out

No ECA squeeze out at 0,8 mm overlap



ECA squeeze out along the finger

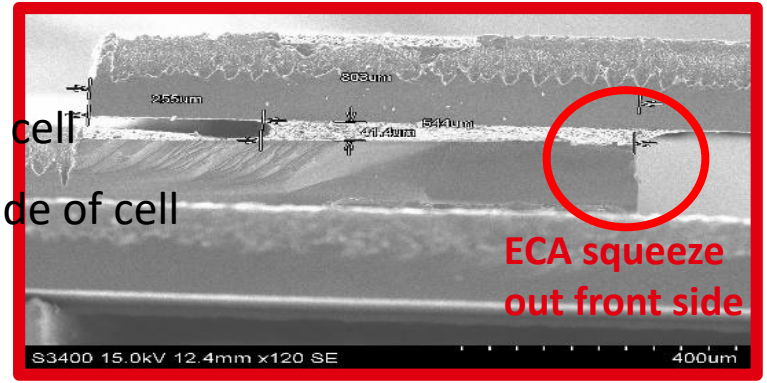




Correct print location is needed in order to avoid squeeze out of the ECA after shingling

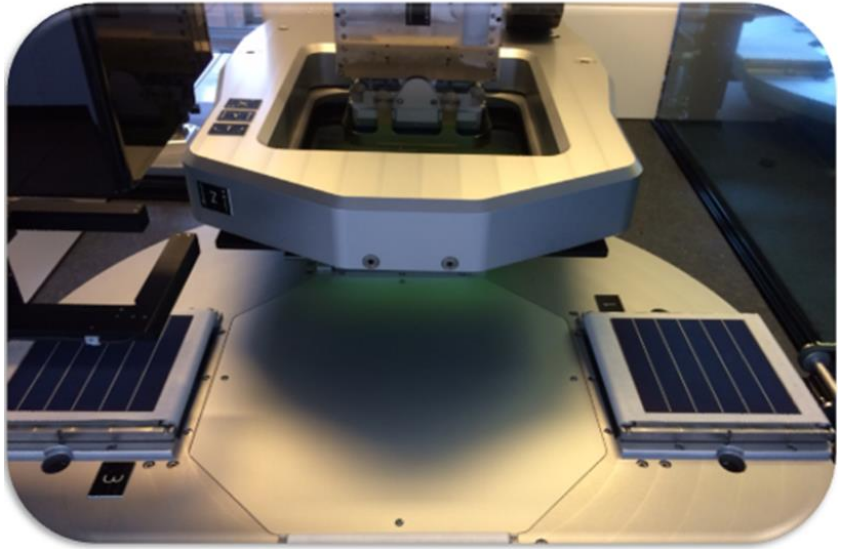
Back of cell

Front side of cell

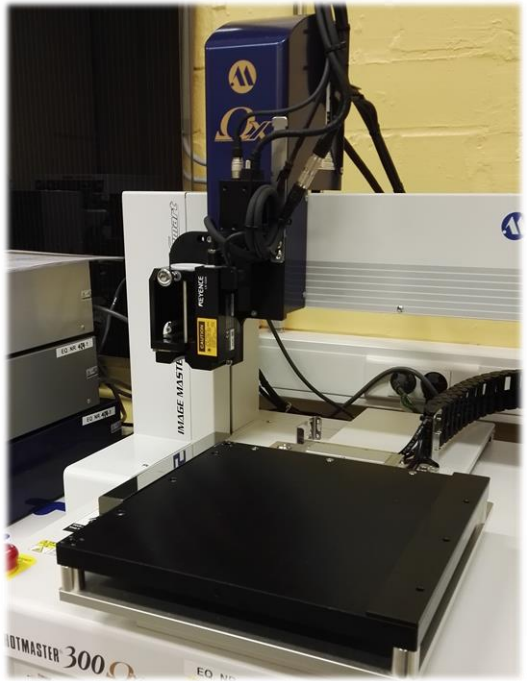


Application Techniques

Printing versus dispensing

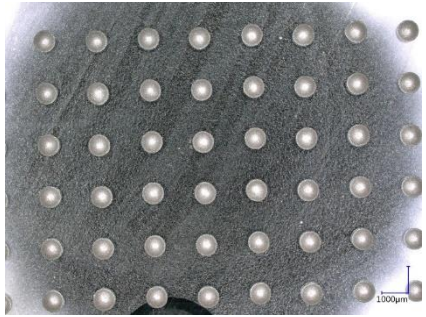


Courtesy of Applied Materials



Dispensing techniques
Jet versus time pressure dispensing

- **Jetting technology**: **fast (400 mm/sec)** – **limited line width** and requires **good maintenance of tool** for reproducible results
- **Time pressure**: **200 mm/sec possible** - demonstrated line widths of 100 microns in non-solar markets



Adhesive	ECA1	ECA2	ECA1	ECA2
Application	Time Pressure		Piezo Jet (150um)	
Line/dot width/diameter (micron)	300	300	500	400
Robot speed (mm/sec)	80	200	200	400

Too wide for 0,6 mm overlap

Vermes MDS3200A – jet dispense

Dispensing result

Items		ECA 3	ECA 1
Dispensing setting	Nozzle (Φ,mm)	0.2	0.2
	Tappet (Φ,mm)	0.15	0.15
	Pressure (MPa)	0.32	0.4
	Falling time (ms)	0.15	0.18
	Open time (ms)	2.0	2.3
	Speed (mm/s)	300	300
ECA (cure before overlap)	Width (um)	**632-663**	**700-707**
	Height (um)	149-157	127-133
	Distance between dots (um)	660-720	713-737
ECA (cure after overlap)	Width (um)	**825-940**	**959-1000**
	Height (um)	42-47	34-44

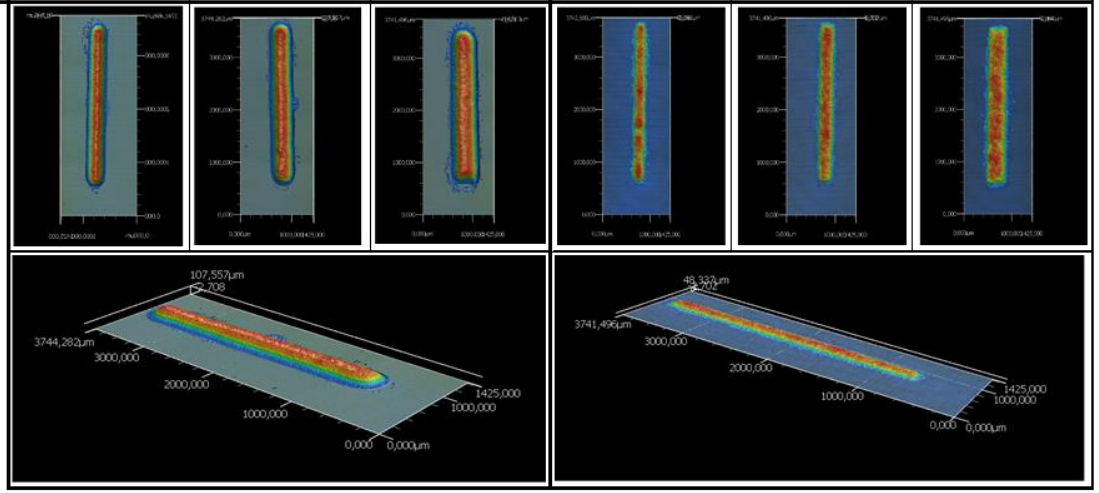
High jet speeds of 300 mm/s possible with nozzle diameter of 200 micron to enable a 1,4 mm shingle overlap

Printing techniques
Screen versus stencil printing

- **Stencil printing**: contact method, well known for electrically conductive adhesives

- **Screen printing**: contact less method, well established into the solar market (cell metallization paste)

	stencil			screen		
	200 µm	300 µm	400 µm	200 µm	300 µm	400 µm
width (µm)	375	441	526	300	408	519
heigth (µm)	81	90	98	50	62	64

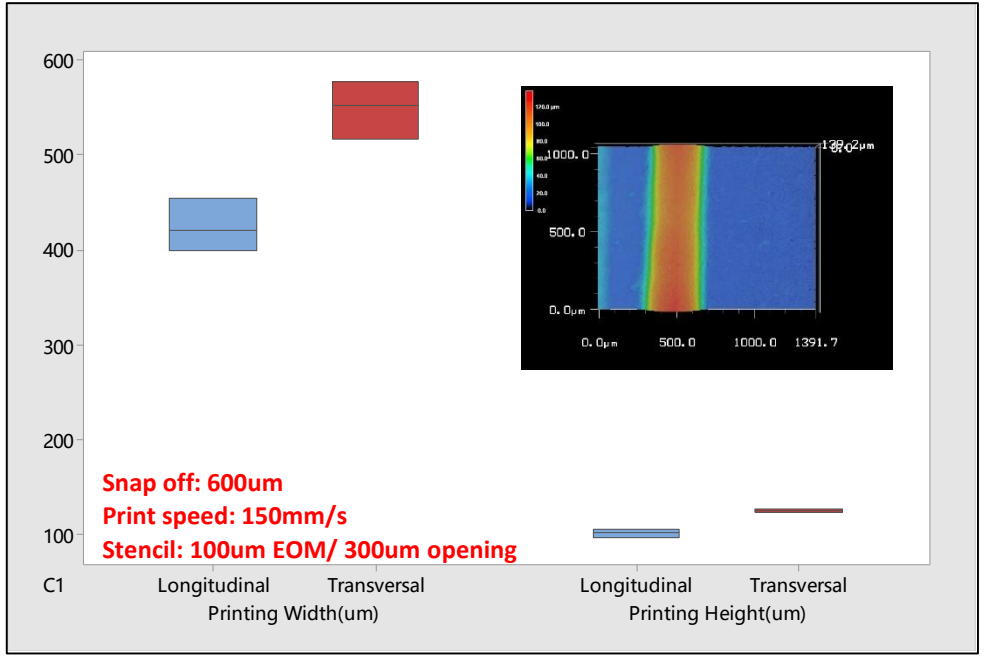


stencil printing: 100 µm thick, electrocut stencil - print speed: 200 mm/s - pressure: 50N - snap off: 0 mm
screen printing: stainless steel 200/40, 20 EOM, 25 N screen - print speed: 200 mm/s - pressure: 125 N - snap off: 1,5 mm

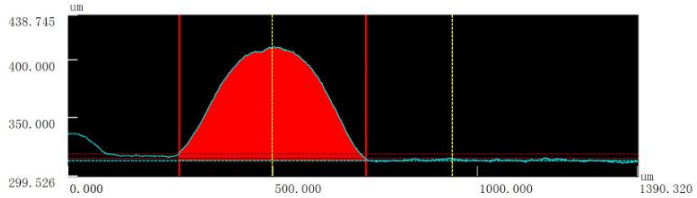
Higher aspect ratio and volume of ECA applied with stencil

Stencil print – 100 um thick stencil – 300 um opening

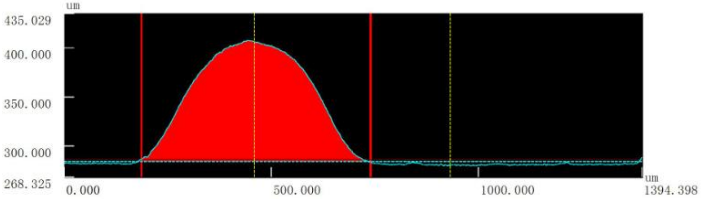
Height and width of ECA with different printing direction



Longitudinal (direction of BB)



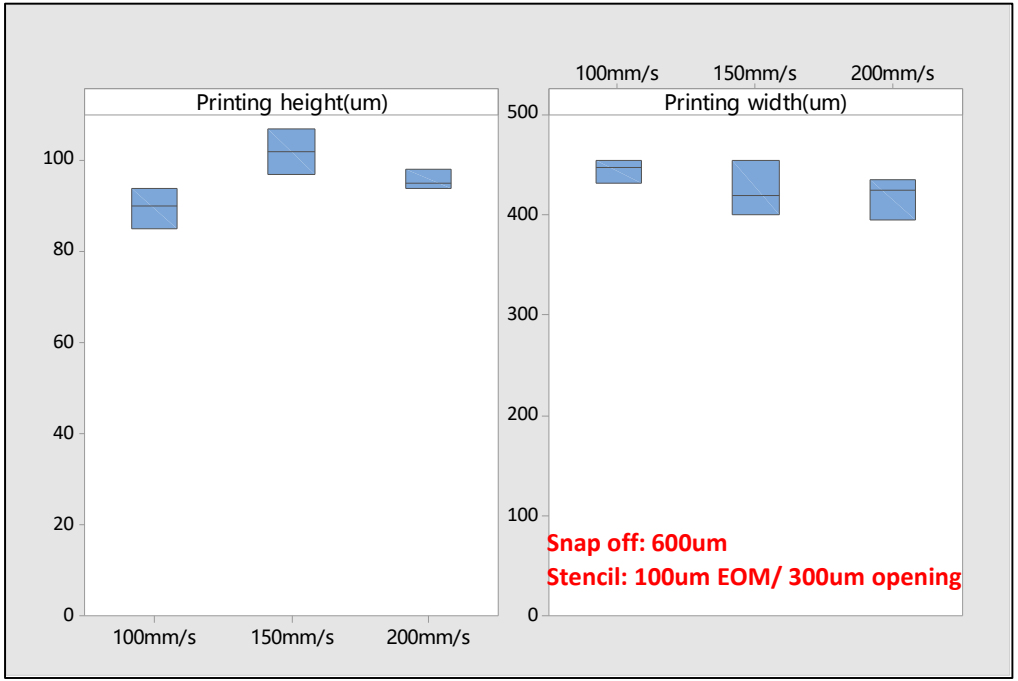
Transversal (perpendicular to BB)

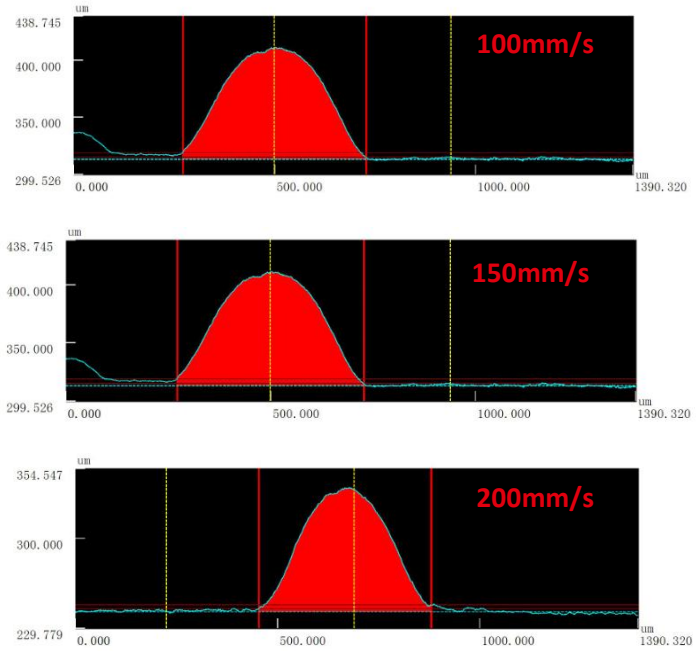


- Higher height and wider width when using transversal printing direction.

Stencil print – 100 um thick stencil – 300 um opening

Height and width of ECA with different printing speed



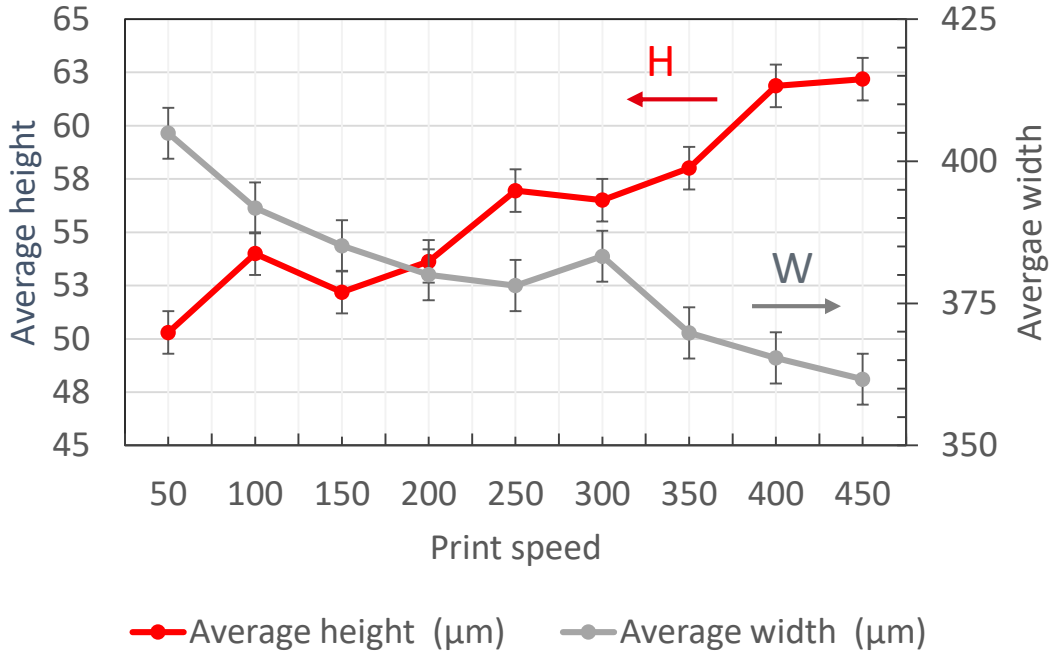


- Narrow printing width of ECA when increasing the printing speed

Screen print – 200/40 SS, 18 µm EOM

Height and width of ECA with different printing speed

- Print evaluation: Very fast speeds are possible
- Printed weight remains constant for all tested print speeds



Conclusions

- Shingle based modules have promising future for different cell technologies and modules produced with Henkel ECA shown good reliability passing IEC standards

- Henkel offers ECAs based on different chemistries (epoxy, acrylate, silicone based) with high application speeds (> 200 mm/sec) for both print and dispense methods

- In order to enable a small shingle overlap it's important to have correct:
  - **ECA rheology** (viscosity, shear thinning, thixotropy, yield stress)
  - **ECA application method** (type, accuracy)
  - **Shingle tool**

- **Shingled solar modules with 0,8 mm overlap** were assembled by printing Henkel ECA without squeeze out after application optimization

Thank you!