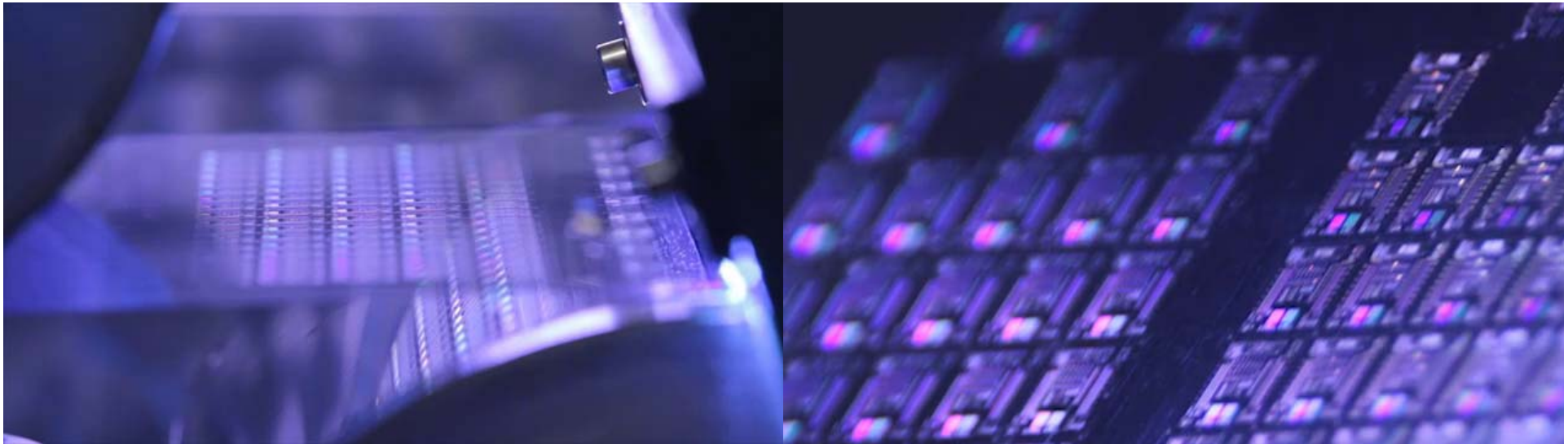


# Mikro- und Nanostrukturierung für funktionelle, interaktive Oberflächen in der großflächigen, flexiblen Elektronik

---



**Barbara Stadlober**

JOANNEUM RESEARCH

materials valley, 4. 2. 2016, Hanau

A close-up photograph of numerous water droplets of various sizes resting on a dark, finely textured surface. The droplets are clear and spherical, reflecting light. The background is a soft, out-of-focus landscape with a horizon line under a pale sky.

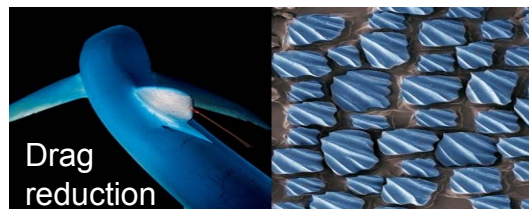
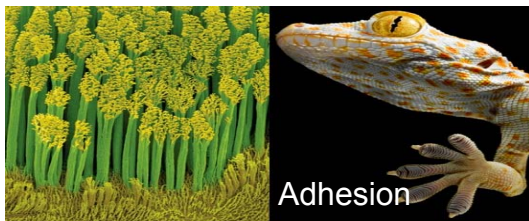
**Das Volumen** des Festkörpers  
wurde von Gott geschaffen,  
seine **Oberfläche** aber vom Teufel.

**Wolfgang Pauli**

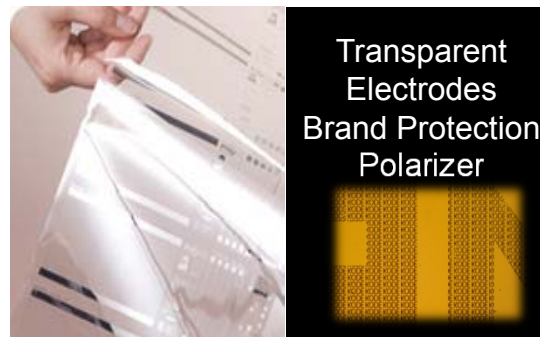


# Outline

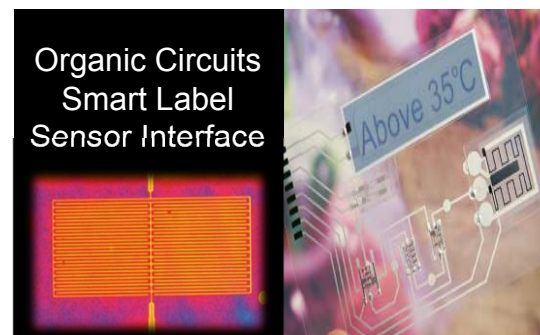
## Bionic Large-Area Surfaces



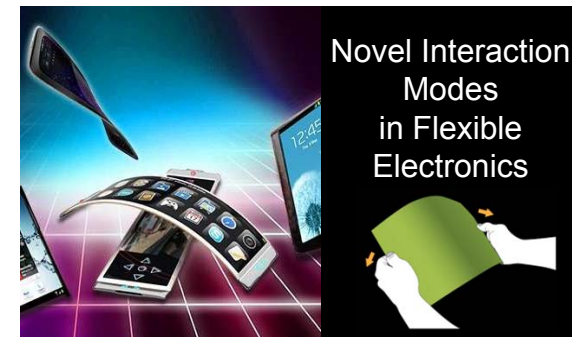
## Fine Metal Patterns on Large-Area Surfaces



Transparent Electrodes  
Brand Protection  
Polarizer

The image shows a microscopic view of a fine metal pattern, consisting of a grid of small, rectangular structures.

## Interactive Large-Area Surfaces

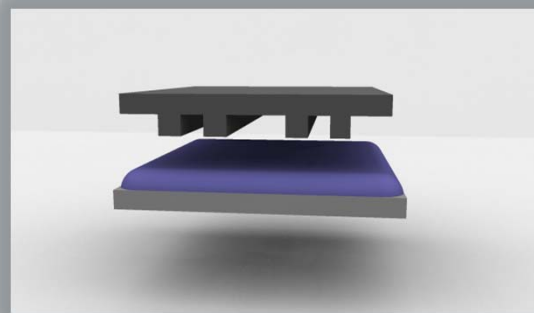


Novel Interaction  
Modes  
in Flexible  
Electronics

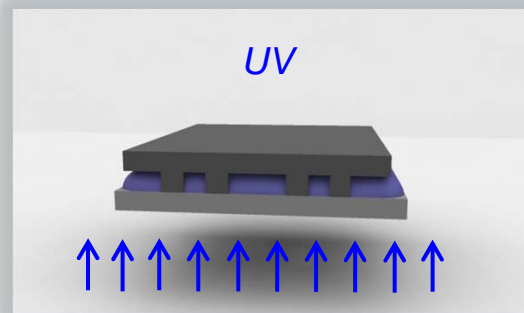


# UV-Nanoimprint Lithography

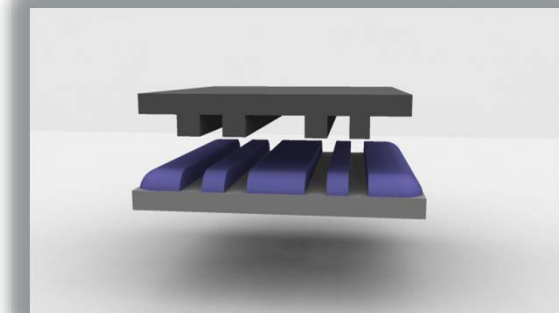
Coating & Alignment



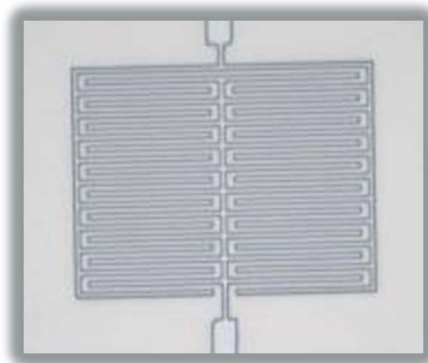
Imprinting & Hardening



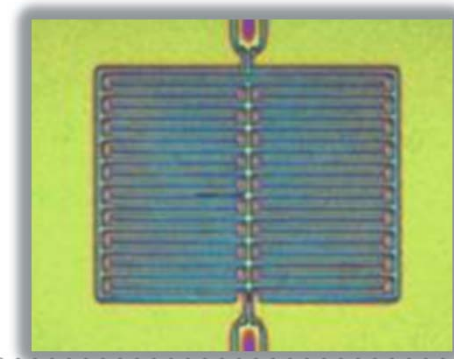
Releasing (and Etching)



*Stamp*



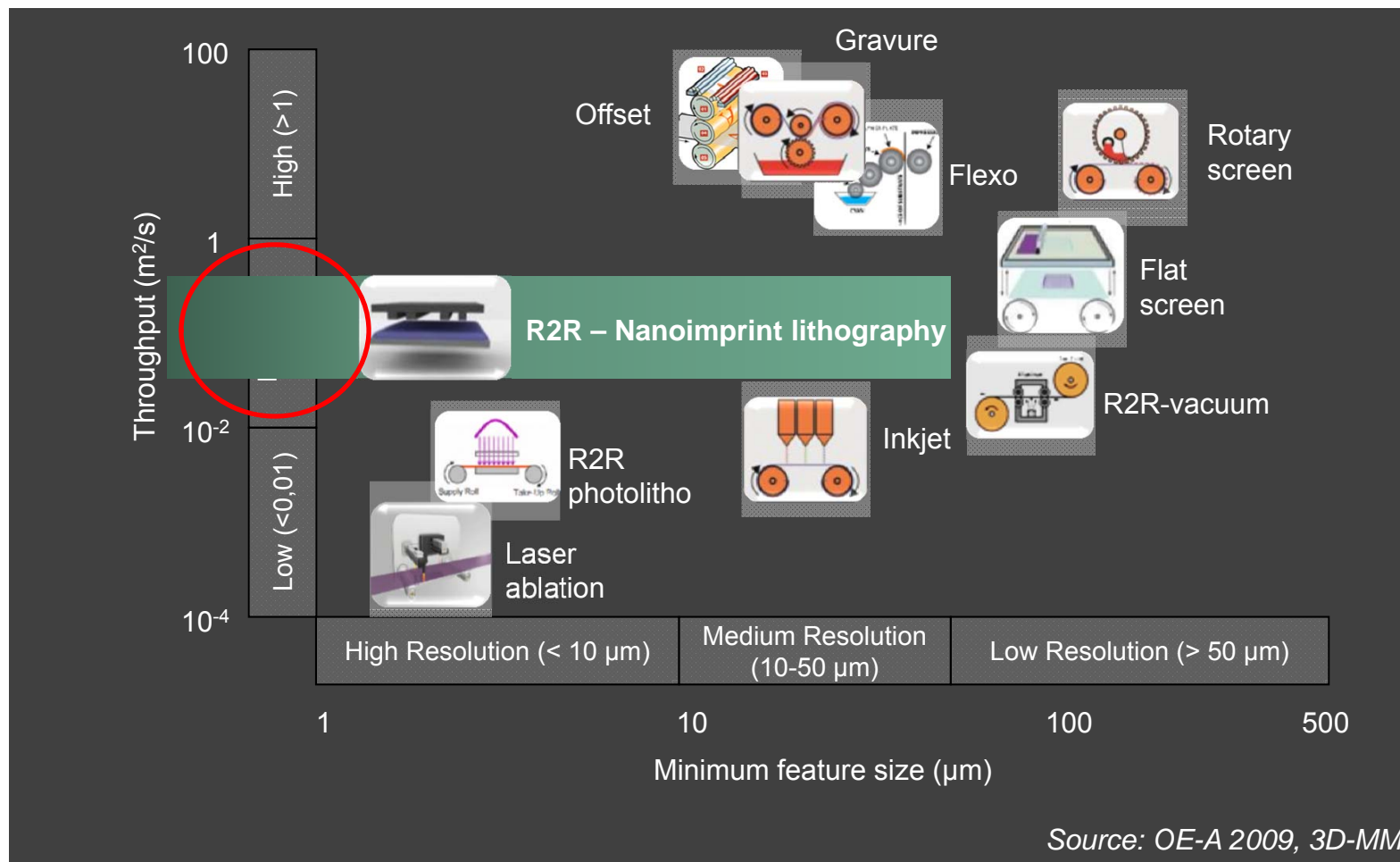
*Imprinted Resist*



- + **High Resolution (< 10 nm)**
- + **High Aspect Ratio (50:1)**
- + **Scalable**
- + **Parallel**



# Resolution and throughput of R2R-printing technologies

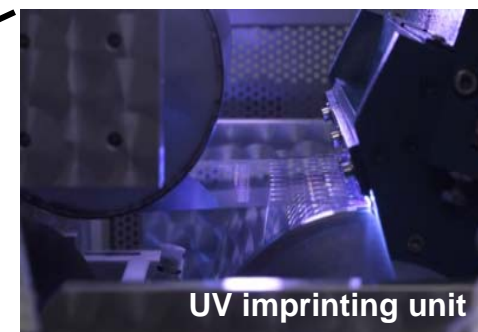
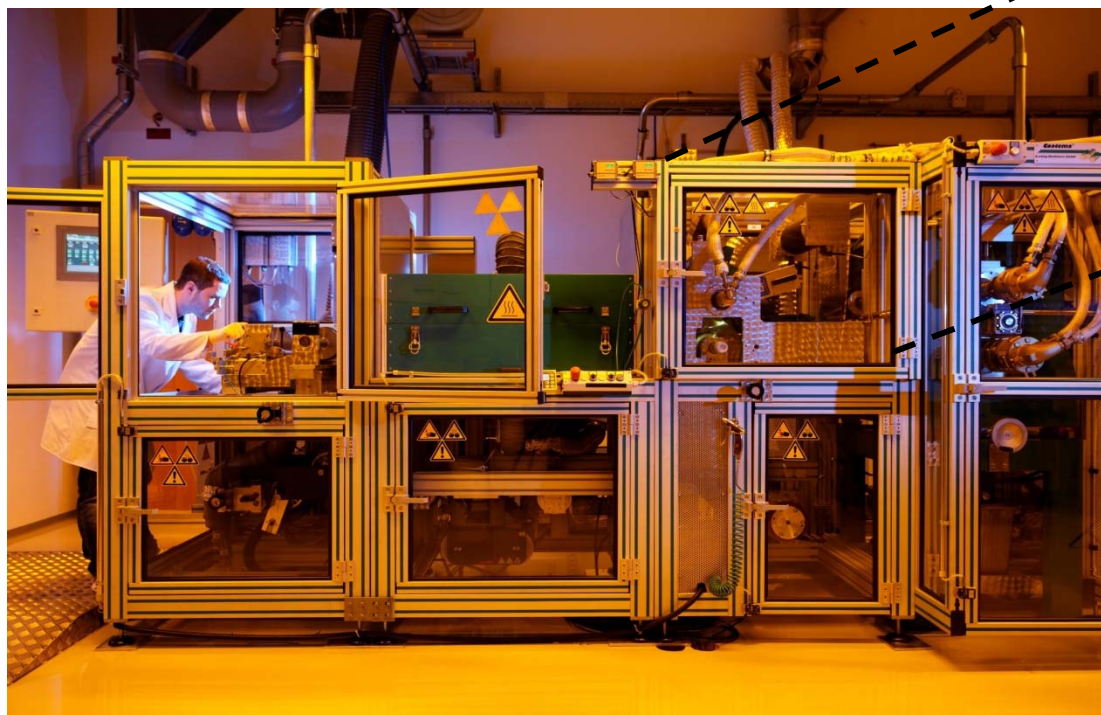


# Roll-2-Roll Imprinting





# R2R-UV-nanoimprinting @ JR



Photoresin  
(structured  
and cured)

Photoresin  
(liquid)

Shim  
on  
roller

line  
pressure

Substrate

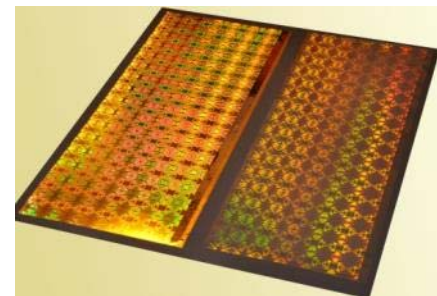
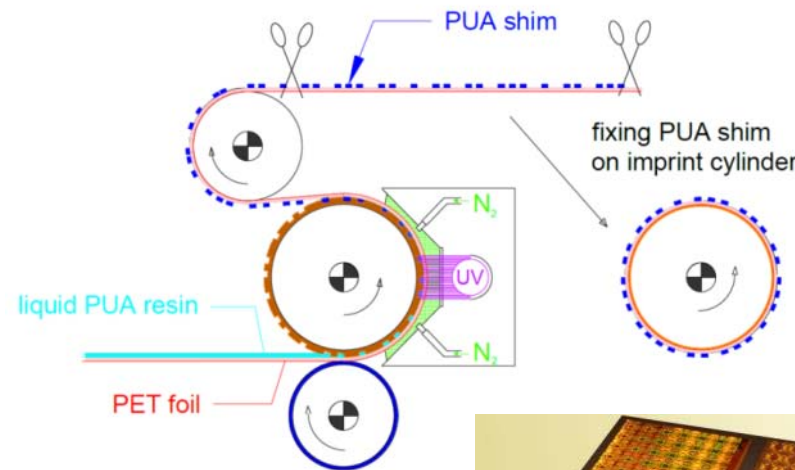


# Self-Replicability of PUA-UV-Resins

## R2R-Replication of Ni shims into polymer shims



original nickel shim  
~ 10 k€



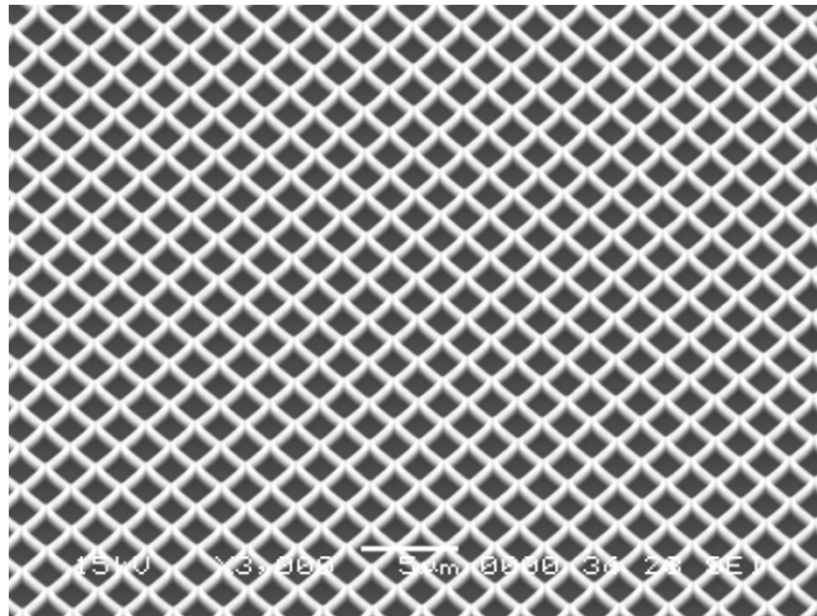
polymer shim copy  
~ 10 €



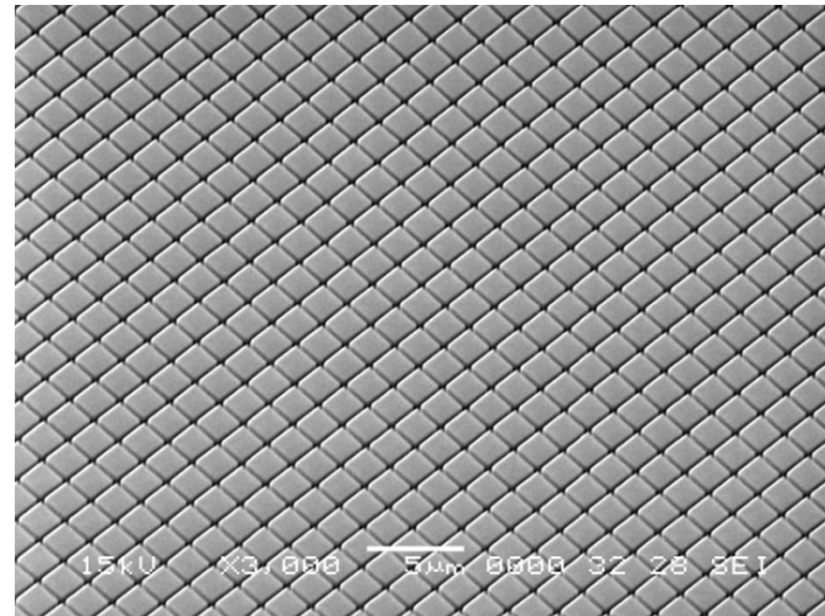
**Polymer working shims**  
→ as substitute for expensive and delicate Ni-Shims

# R2R-UV-NIL with Poly-Shims

**Poly-Shim**

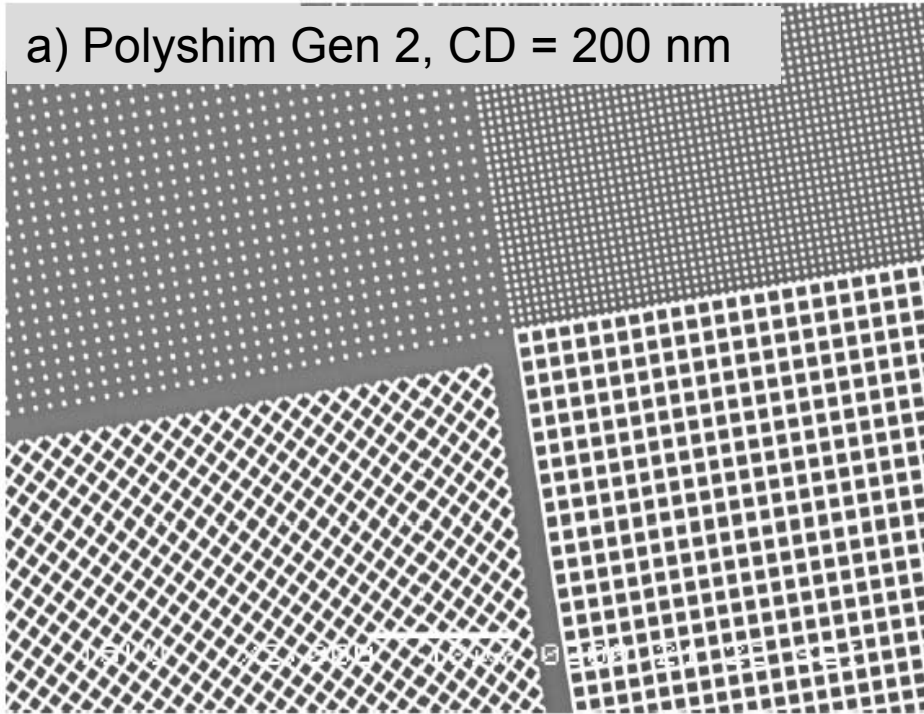


**R2R-Imprint at 0.025 m<sup>2</sup>/s**

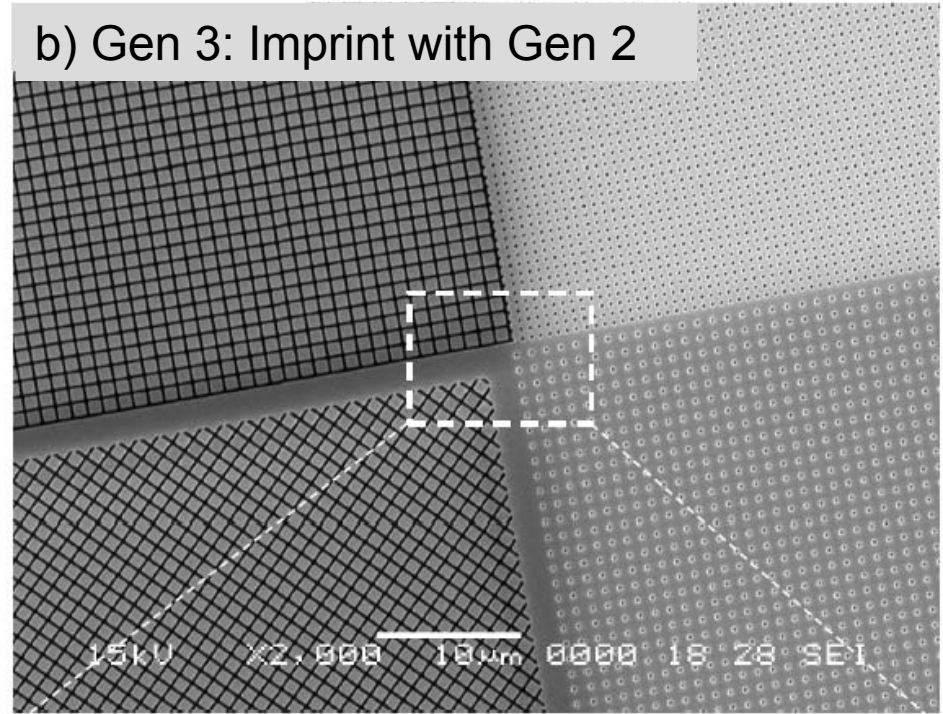


**CD = 200 nm**

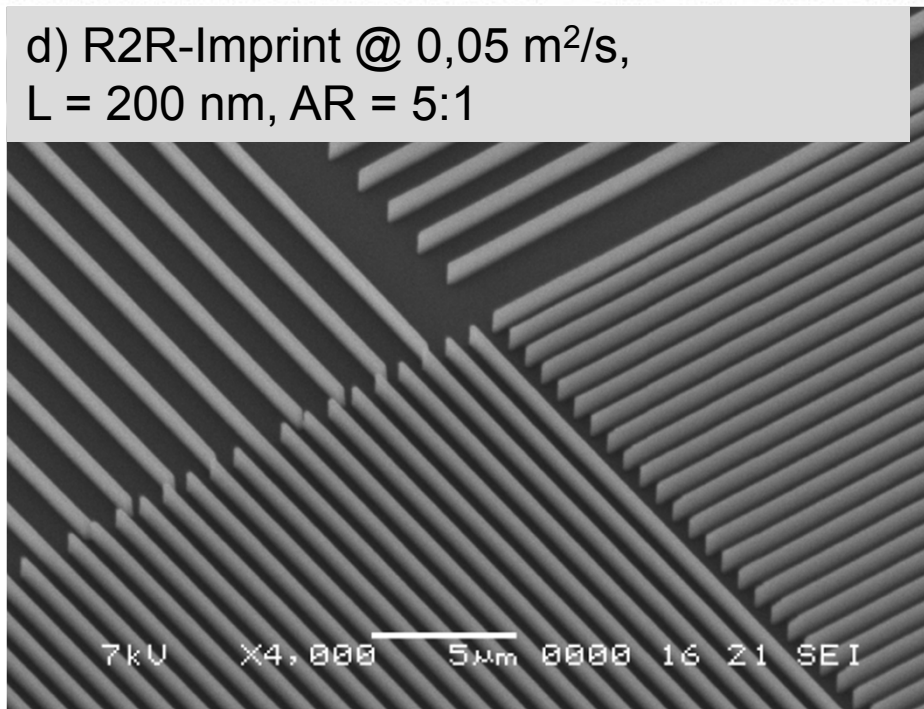
a) Polyshim Gen 2, CD = 200 nm



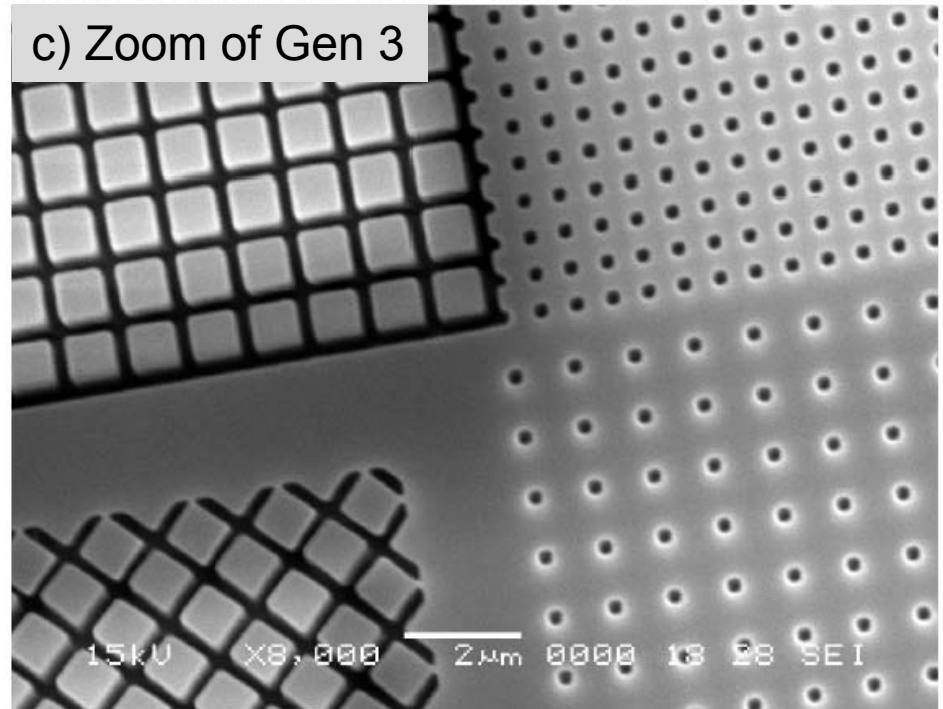
b) Gen 3: Imprint with Gen 2



d) R2R-Imprint @ 0,05 m<sup>2</sup>/s,  
L = 200 nm, AR = 5:1



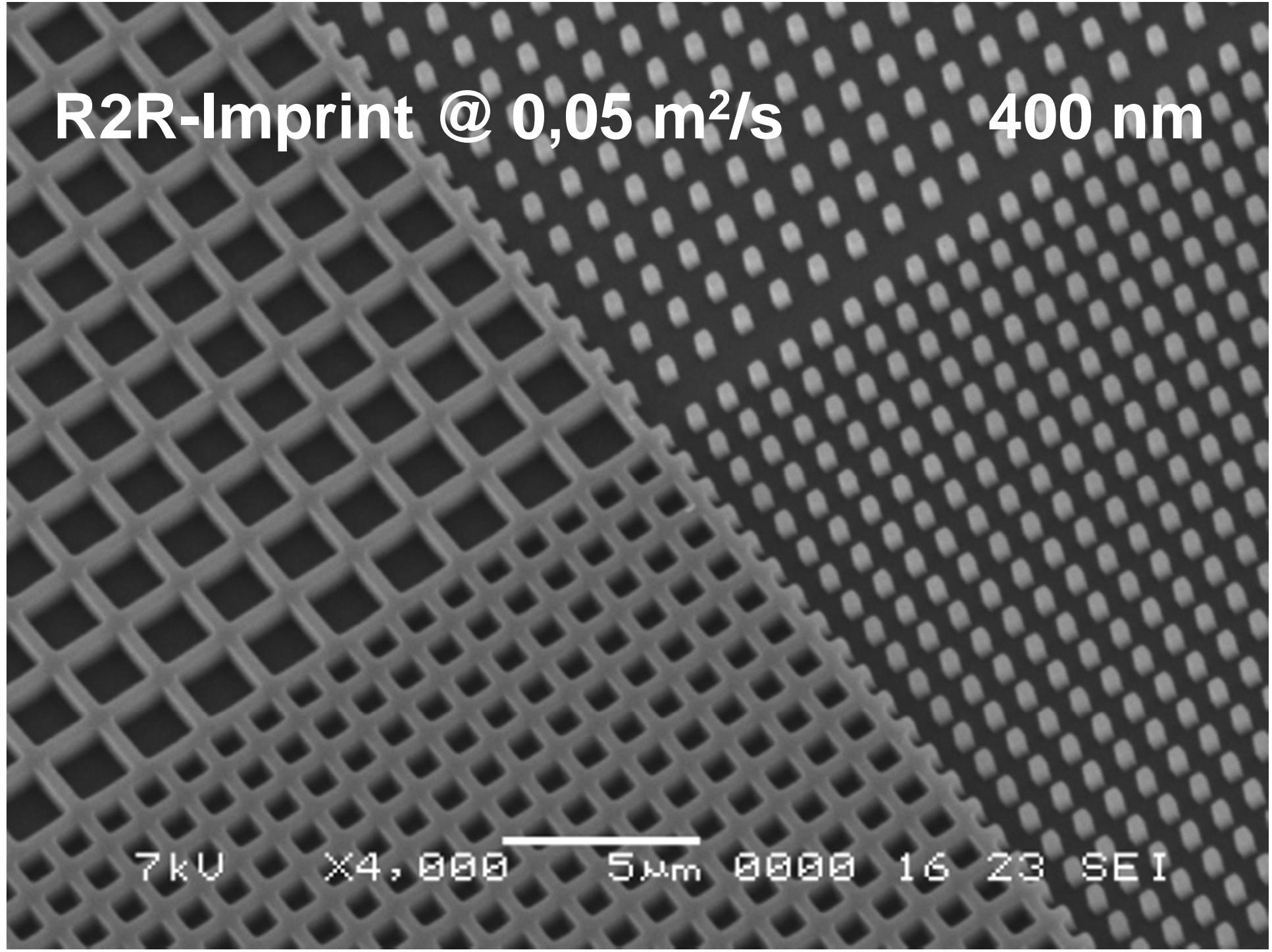
c) Zoom of Gen 3





R2R-Imprint @ 0,05 m<sup>2</sup>/s

400 nm



7kV

X4,000

5 μm

0000

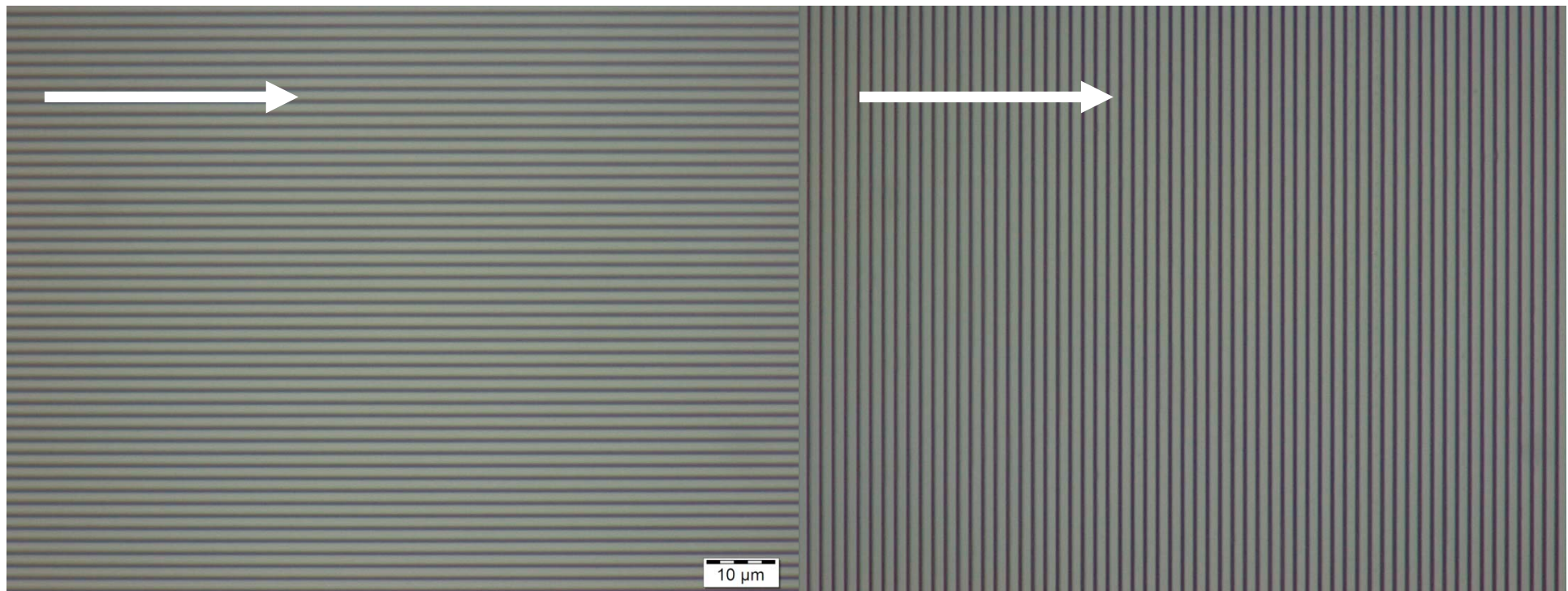
16

23

SEI

# Kilometer run

700 m @ 0.025 m<sup>2</sup>/min , 80° Flankenwinkel

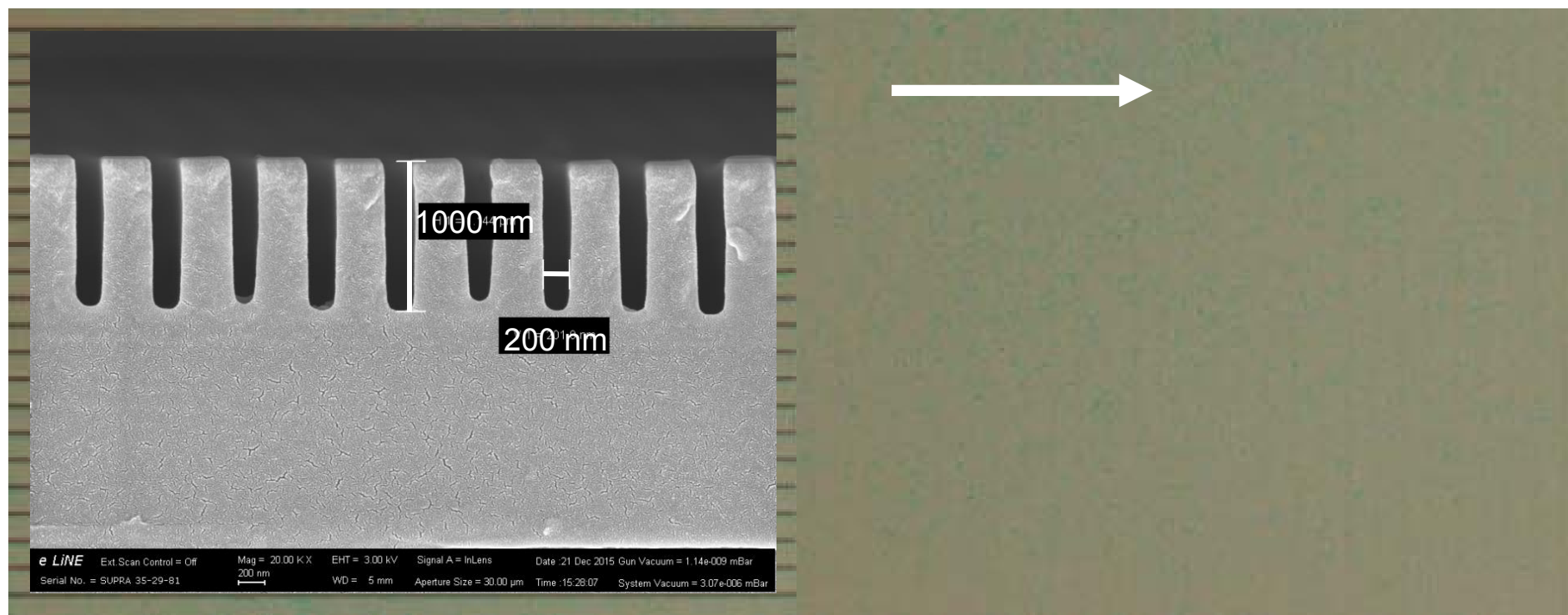


CD = 0,2 μm

AR = 5

# Kilometer run

700 m @ 0.025 m<sup>2</sup>/min , 90° Flankenwinkel

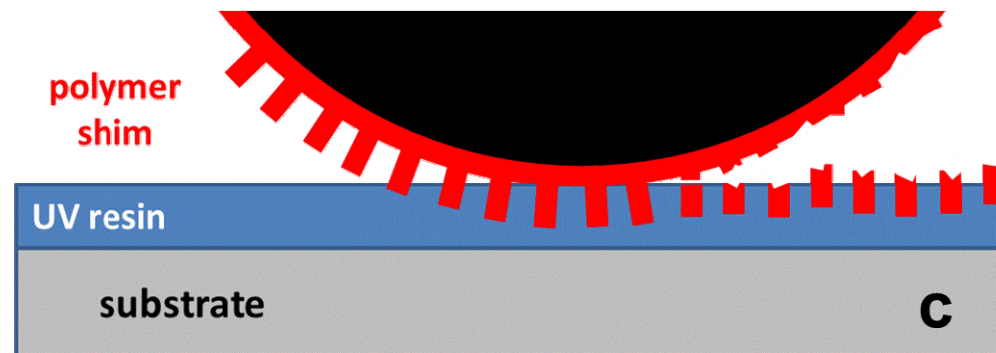
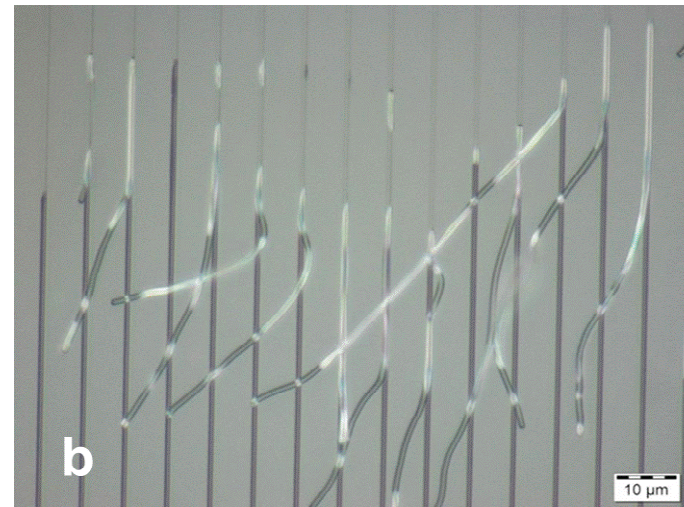
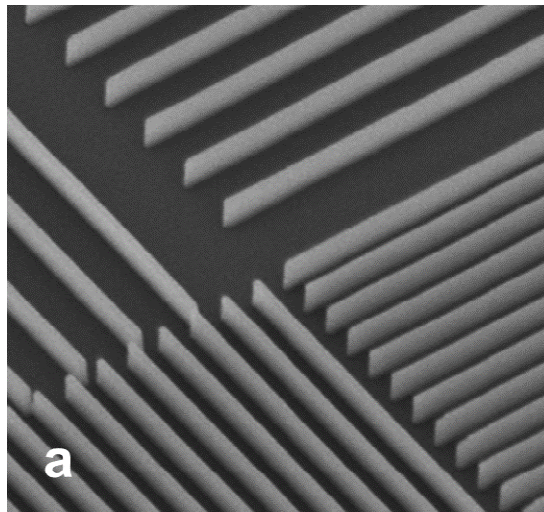


CD = 0,4 μm

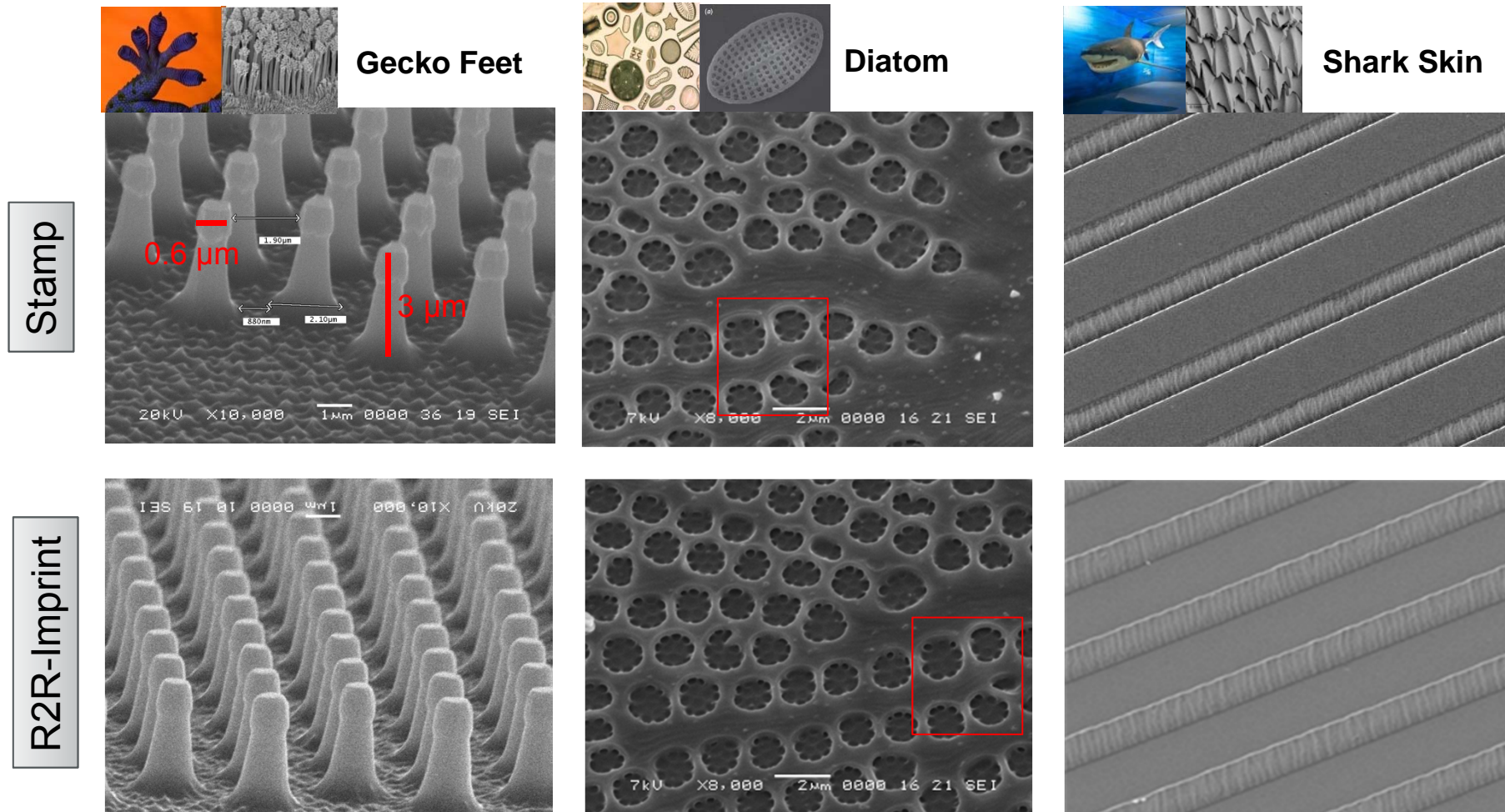
AR = 5



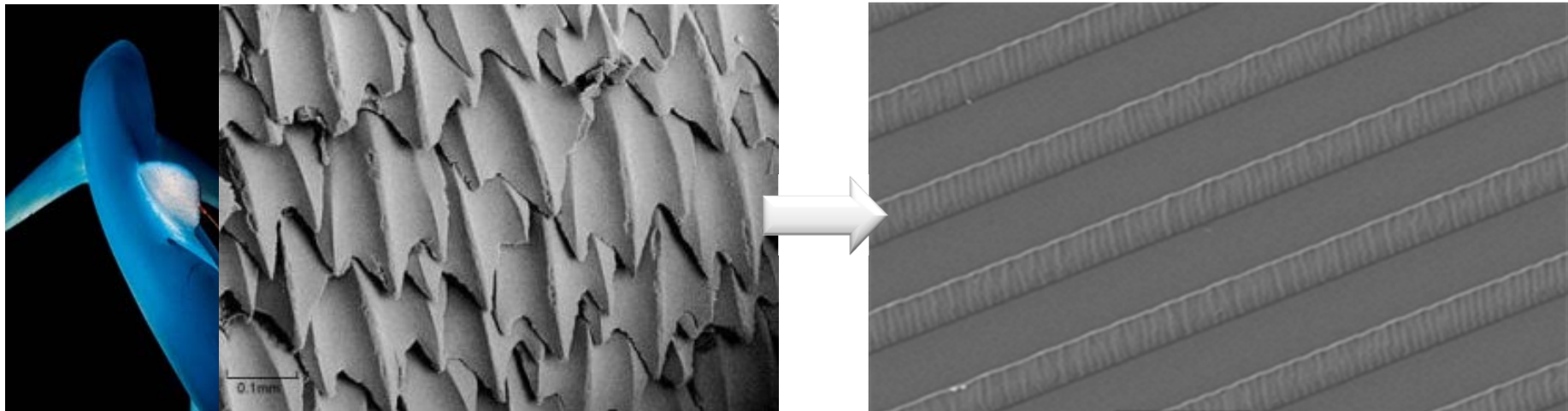
# Degradation of Poly-Shim



# R2R-fabricated hierarchical bionic structures



# Application 1: Large-area drag reducing surfaces



Shark skin

R2R- fabricated riblets





## Application 2: Superhydrophobic riblet foil

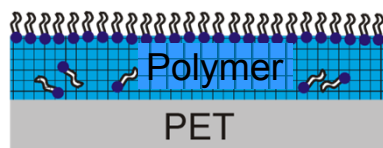
19



Structure

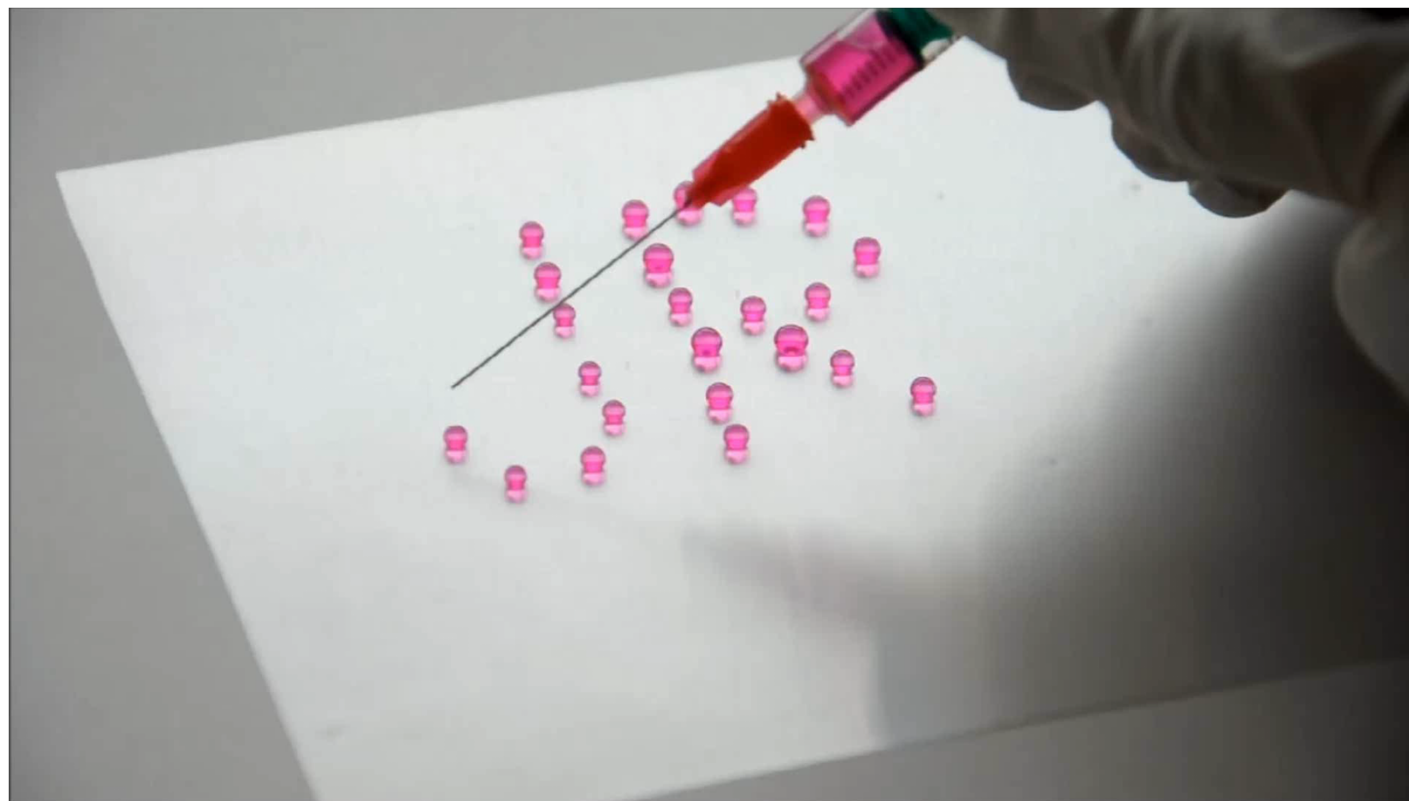
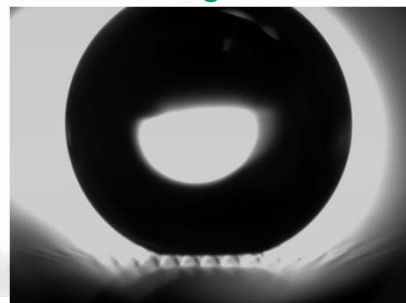
+

Material



=

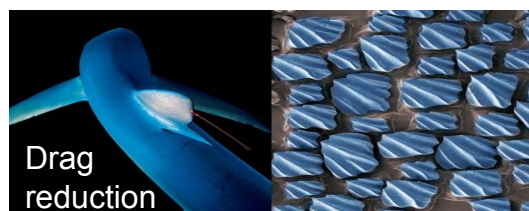
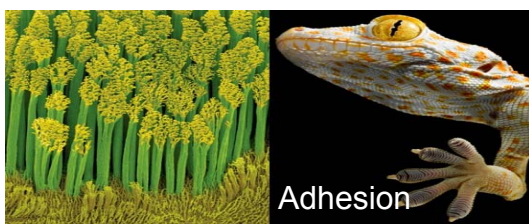
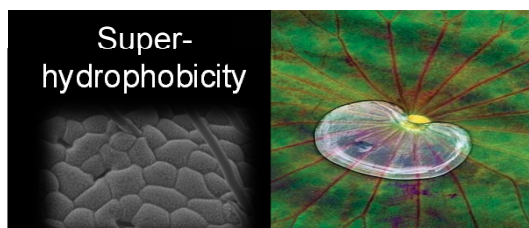
Wetting State



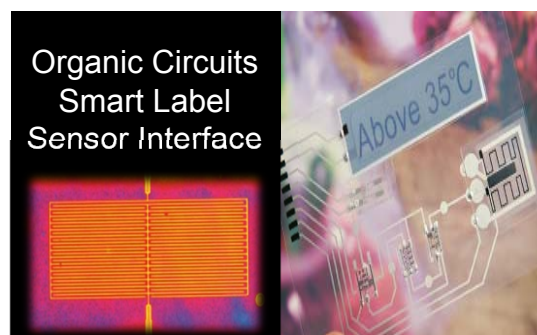
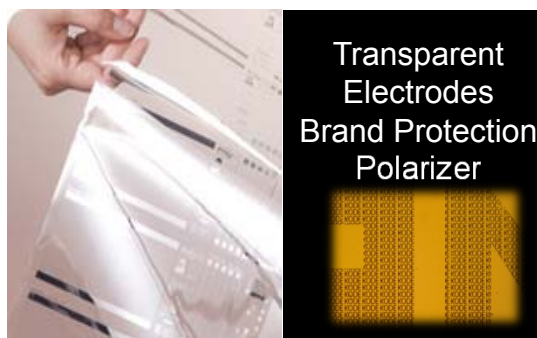
Riblets in hydrophobic surface → Superhydrophobicity

# Outline

## Functional Large-Area Surfaces



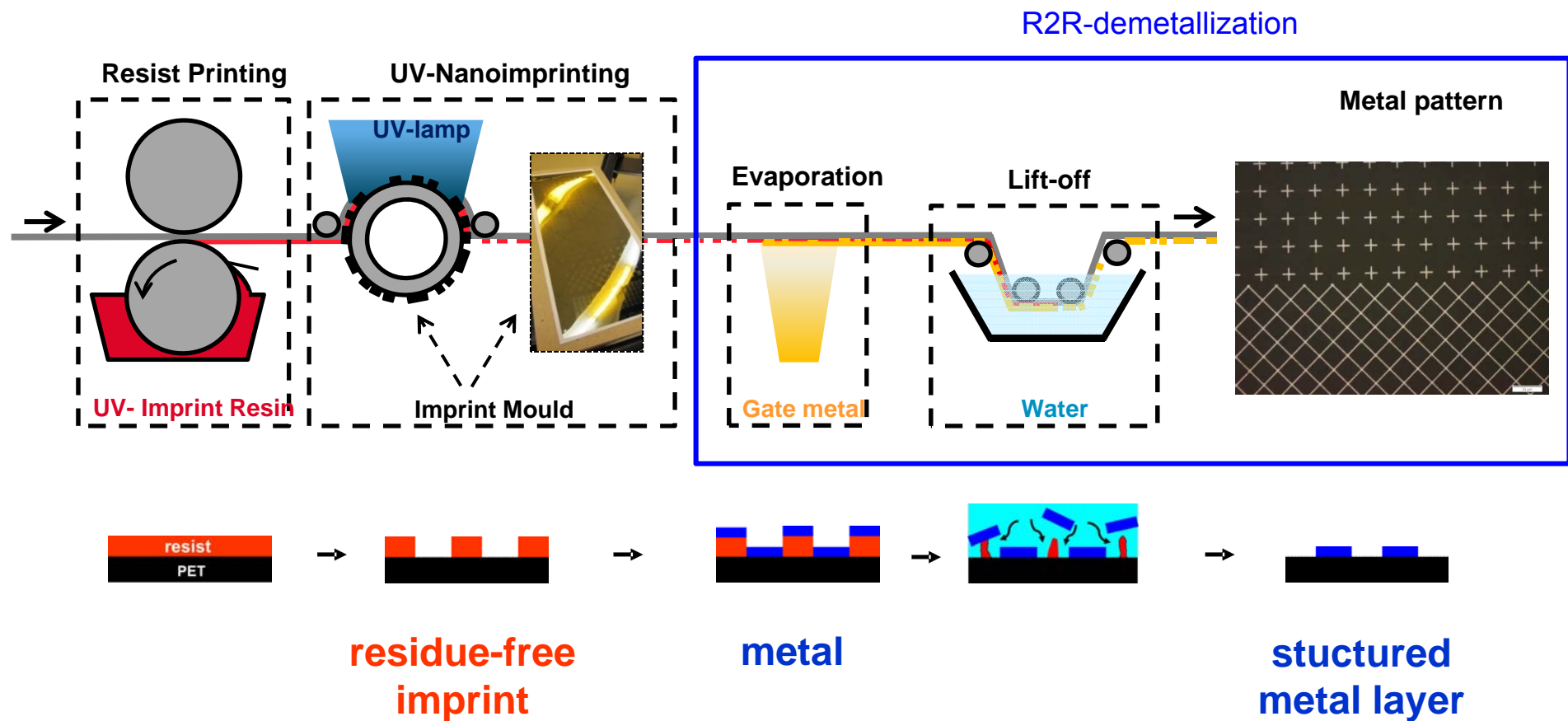
## Fine Metal Patterns for OTFTs & Circuits



## Interactive Large-Area Surfaces



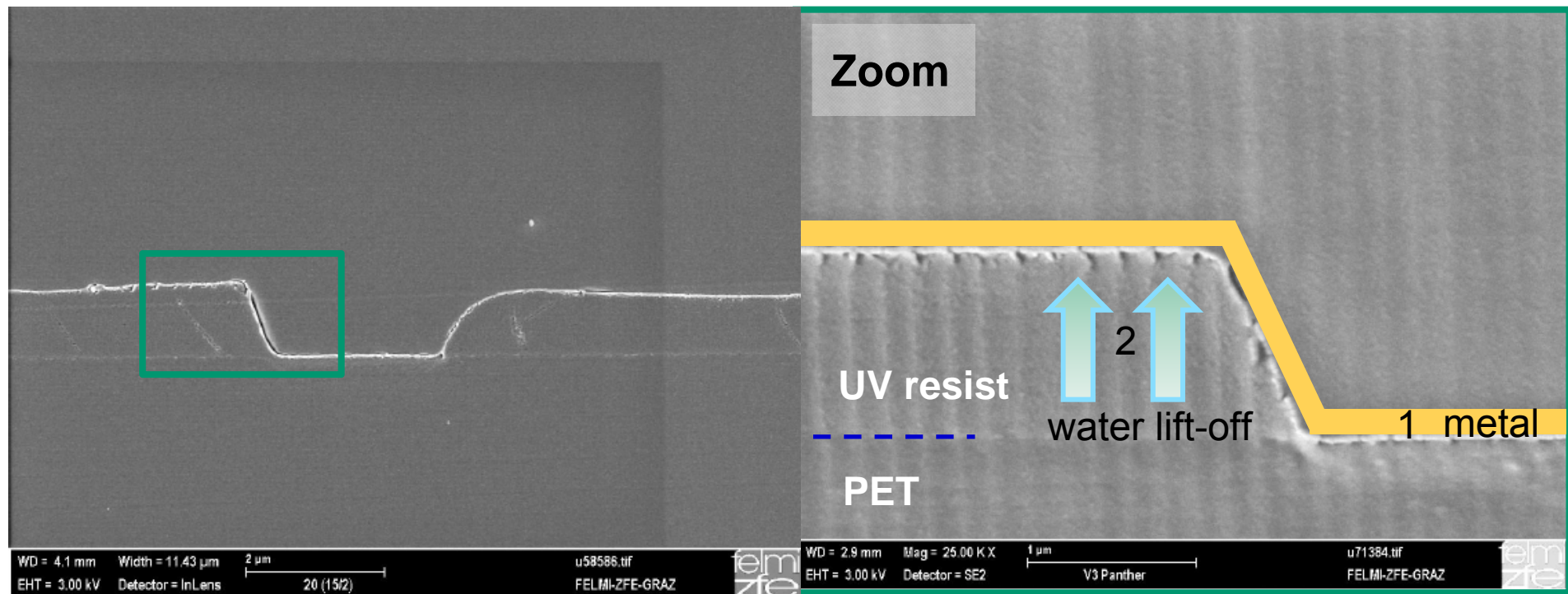
# R2R-Demetalization



# Residue-free R2R-UV-NIL

Resist: Monoacrylate with polar rest group

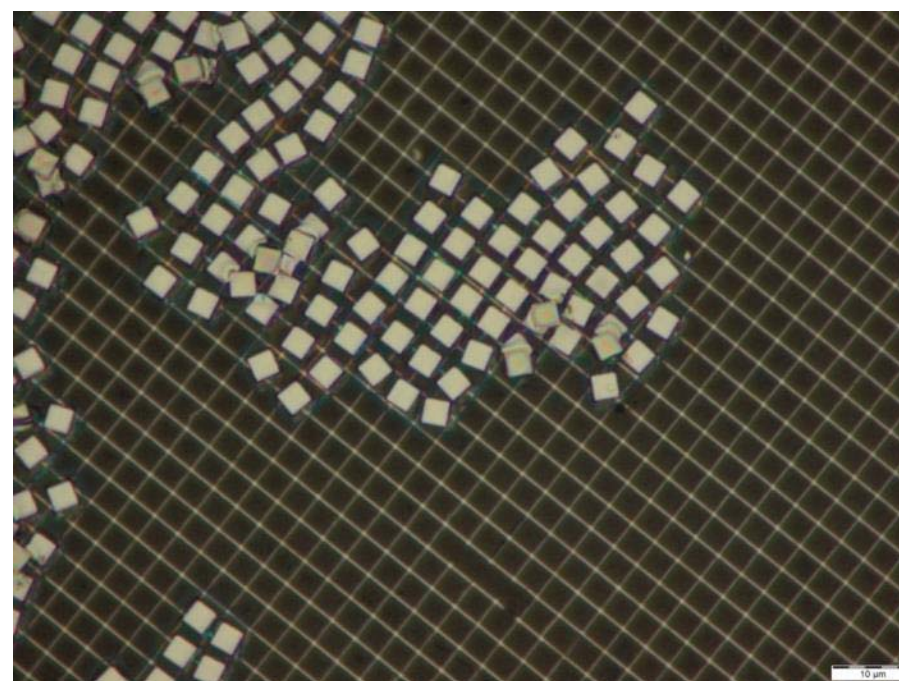
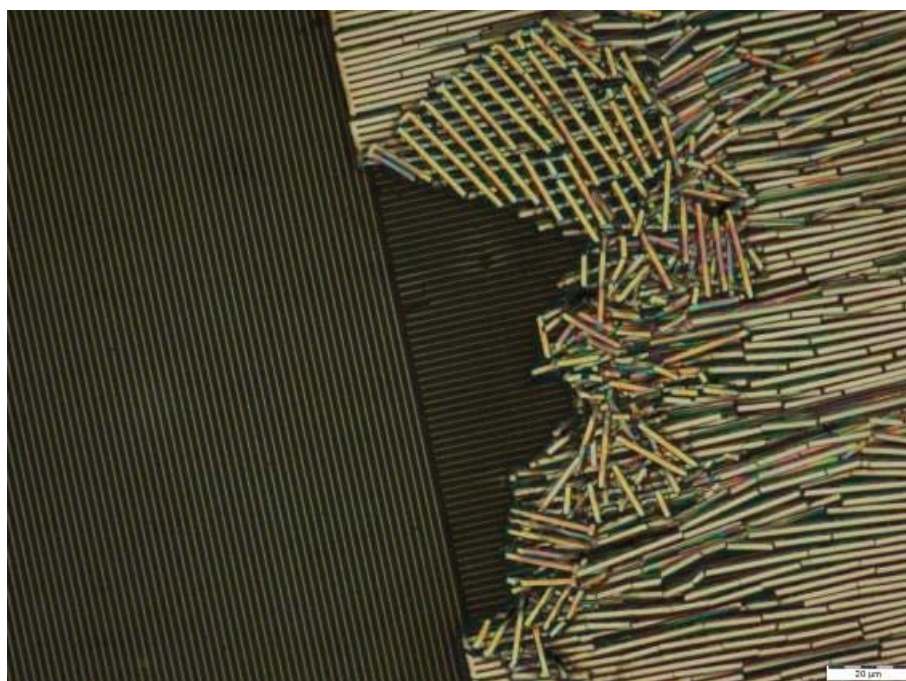
SEM -cross section of imprinted resist edge (10m/min)





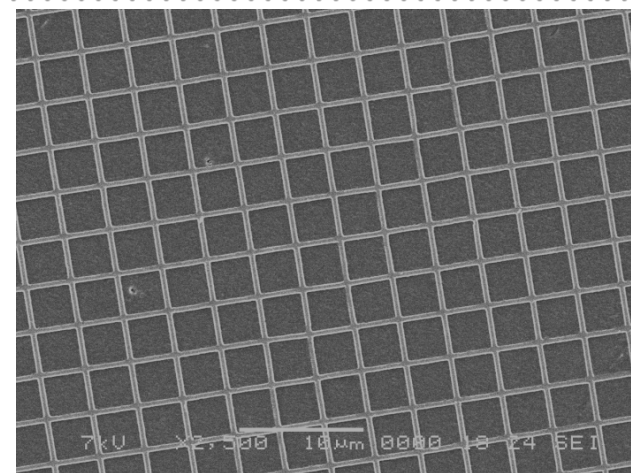
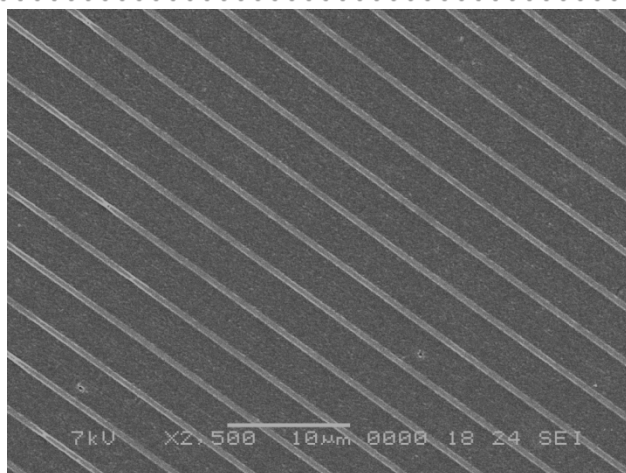
# Metal lift-off in progress

Metal = 3 nm Cr + 30 nm Al

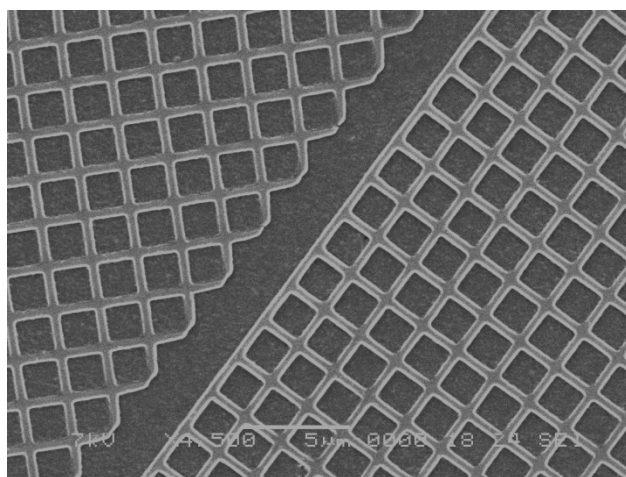


CD = 400 nm

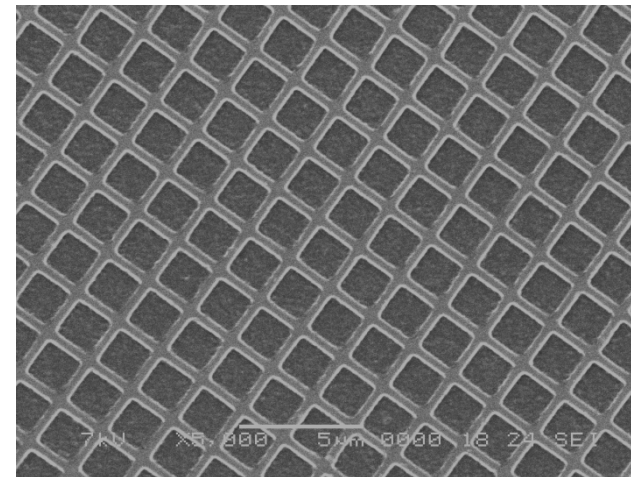
# Al-lines @ 0.05m<sup>2</sup>/s; CD = 400nm



SEM

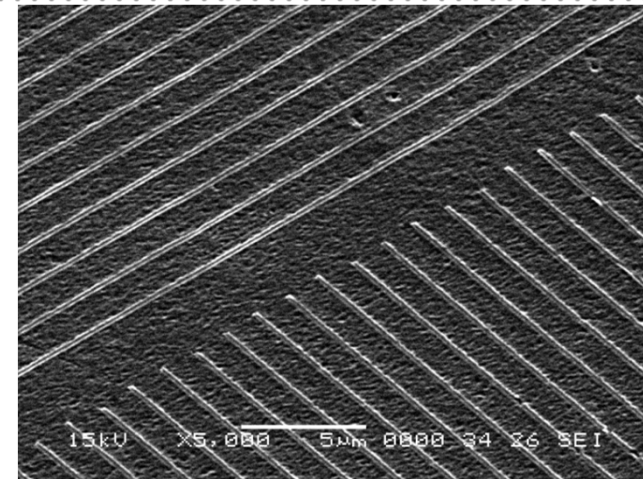
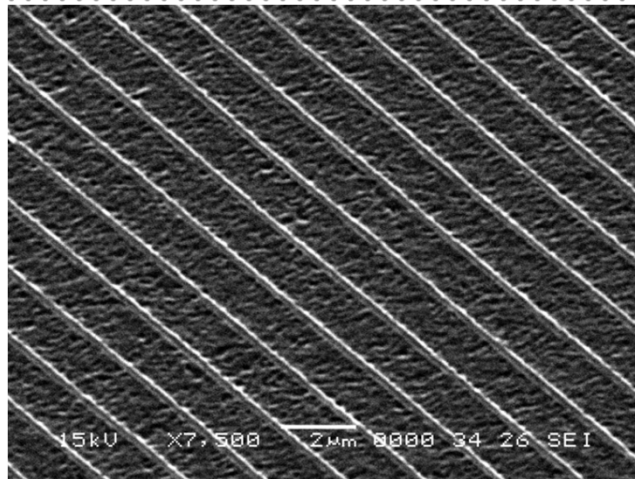


3nm Cr  
+  
30nm Al

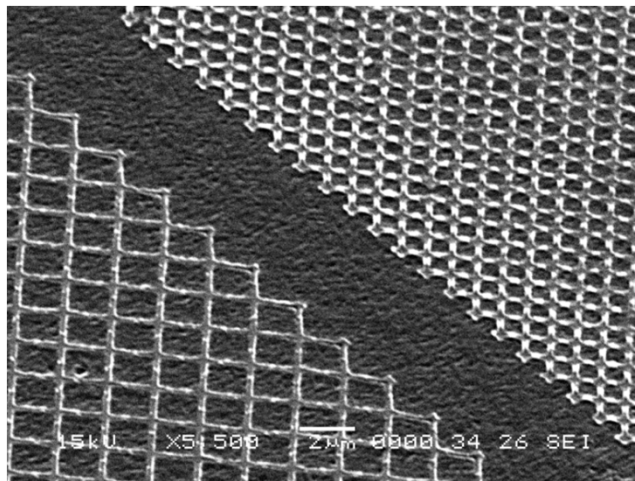




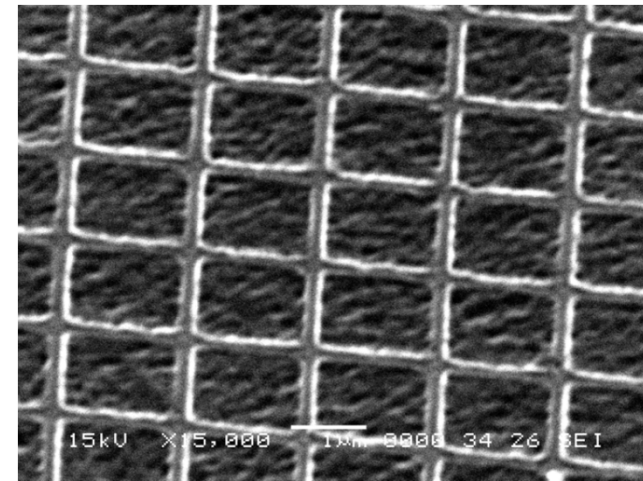
# Al-lines @ 0.05m<sup>2</sup>/s; CD = 200nm



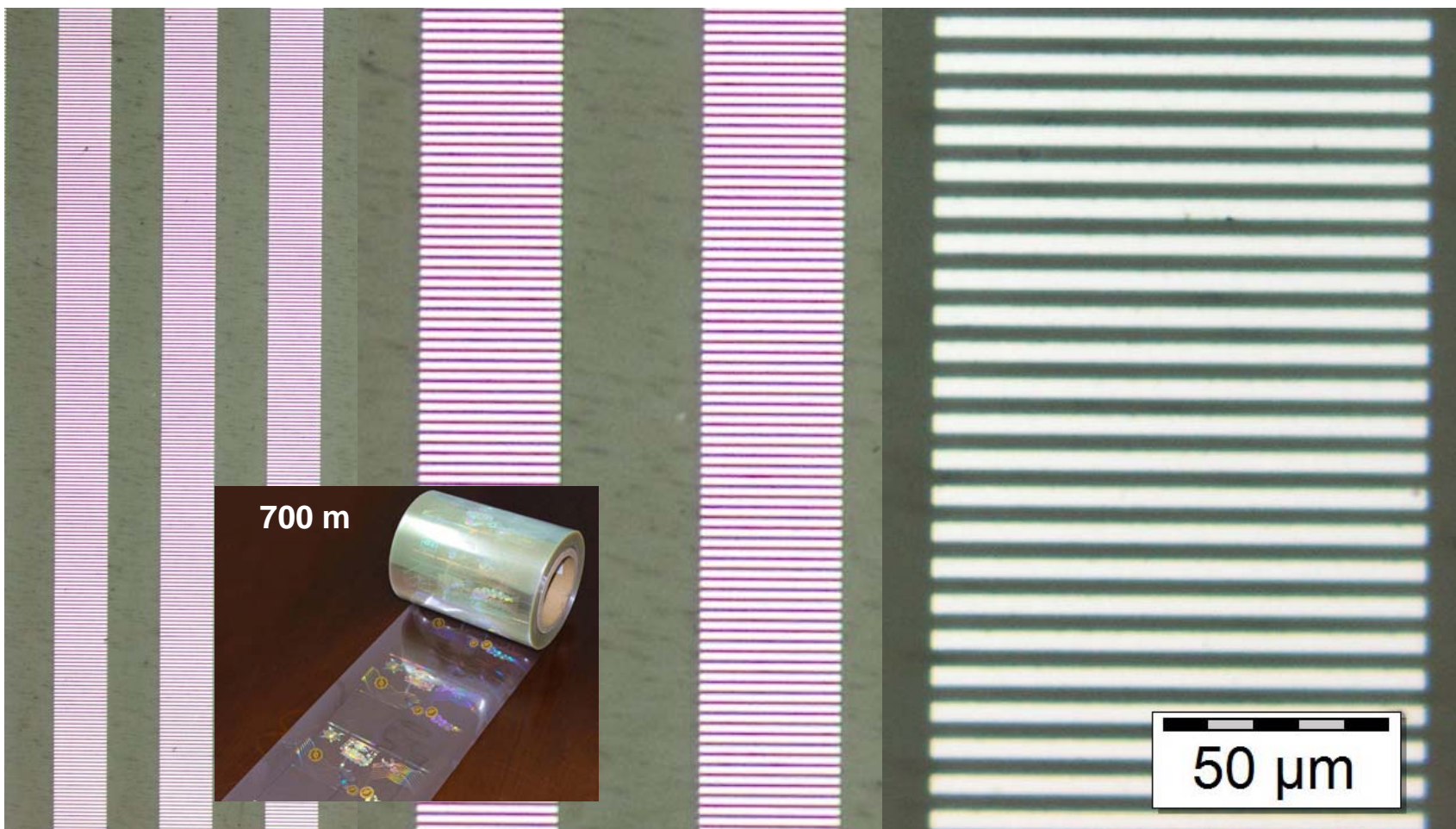
SEM



3nm Cr  
+  
30nm Al

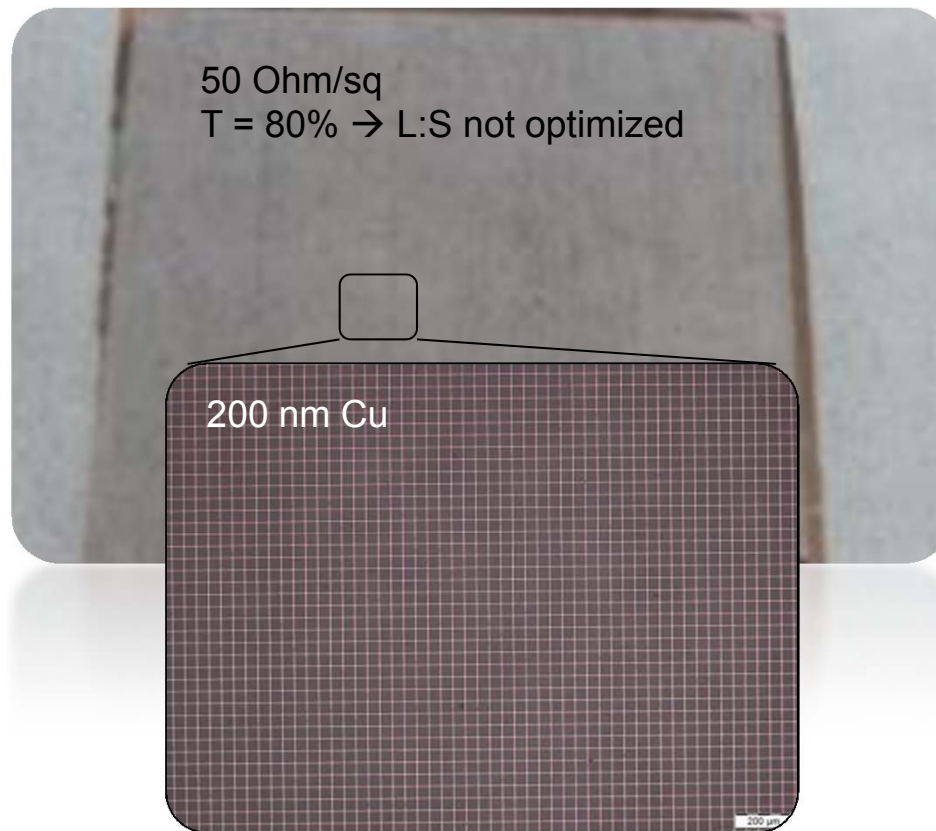


# Application “micro”: Patterns for product ID





# Application “nano”: Metal grids for transparent conductive foils

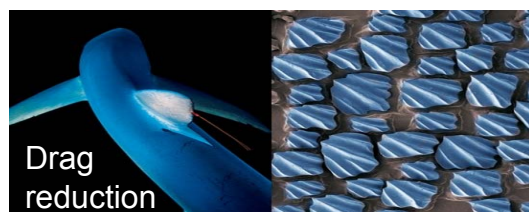
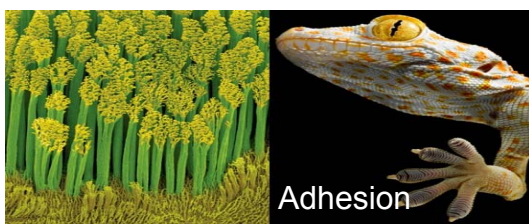
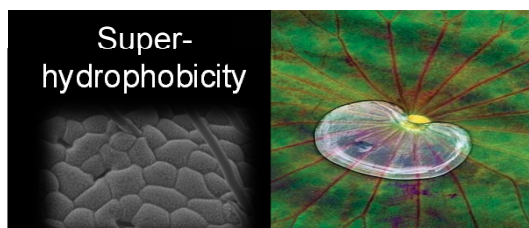


Source: Samsung

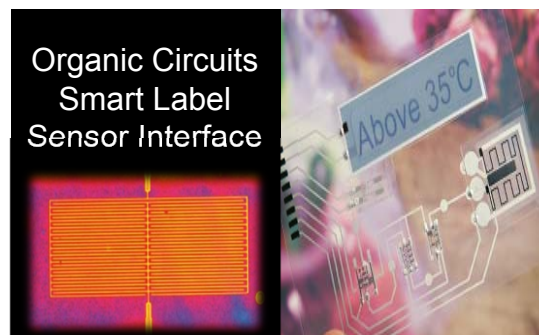
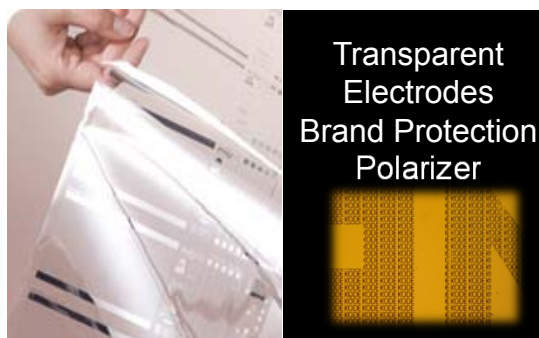
**Flexible displays, touch panels, sensor surfaces, shielding foils,...**

# Outline

## Functional Large-Area Surfaces



## Fine Metal Patterns for OTFTs & Circuits



## Interactive Large-Area Surfaces





The image shows a hand holding a flexible, transparent device with a grid pattern. The device is curved and has a grid of lines on its surface. The PyzoFlex logo is in the top left corner. A list of features is in the bottom left corner.

**PyzoFlex<sup>®</sup>**

- **Intuitive 3D interaction**
- **Flexible**
- **Scalable**
- **Energy-efficient**
- **Low cost**



# PyzoFlex<sup>®</sup>

## Properties

Pyroelectric



Piezoelectric



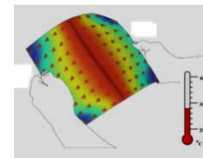
Flexible



# PyzoFlex<sup>®</sup>

## Properties

Pyroelectric



TEMPERATURE  
CHANGES

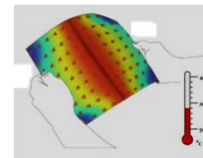


# PyzoFlex<sup>®</sup>

## Properties

Pyroelectric

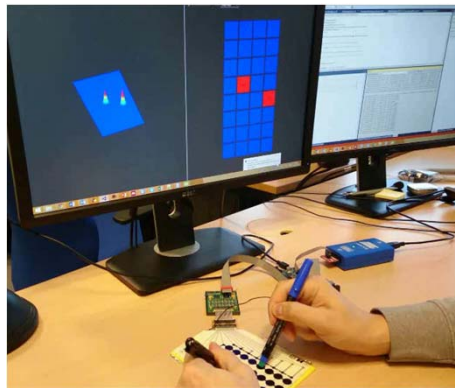
Piezoelectric



TEMPERATURE  
CHANGES



TOUCH/  
PRESSURE





# PyzoFlex<sup>®</sup>

## Properties

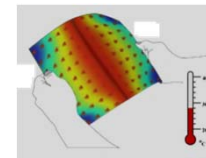
Pyroelectric



Piezoelectric



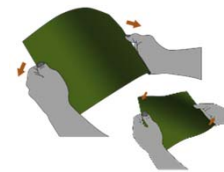
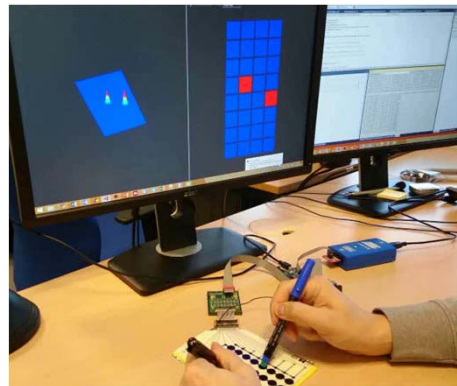
Flexible



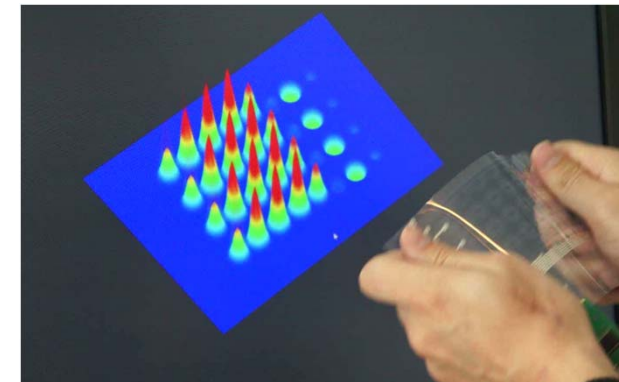
TEMPERATURE  
CHANGES



TOUCH/  
PRESSURE

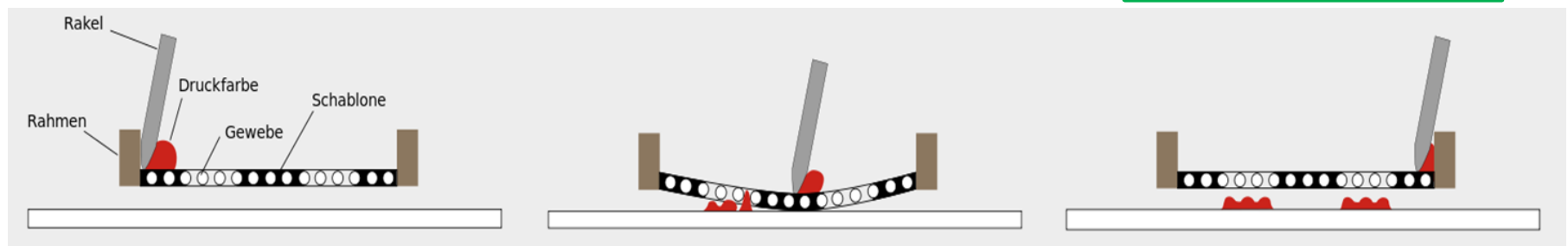
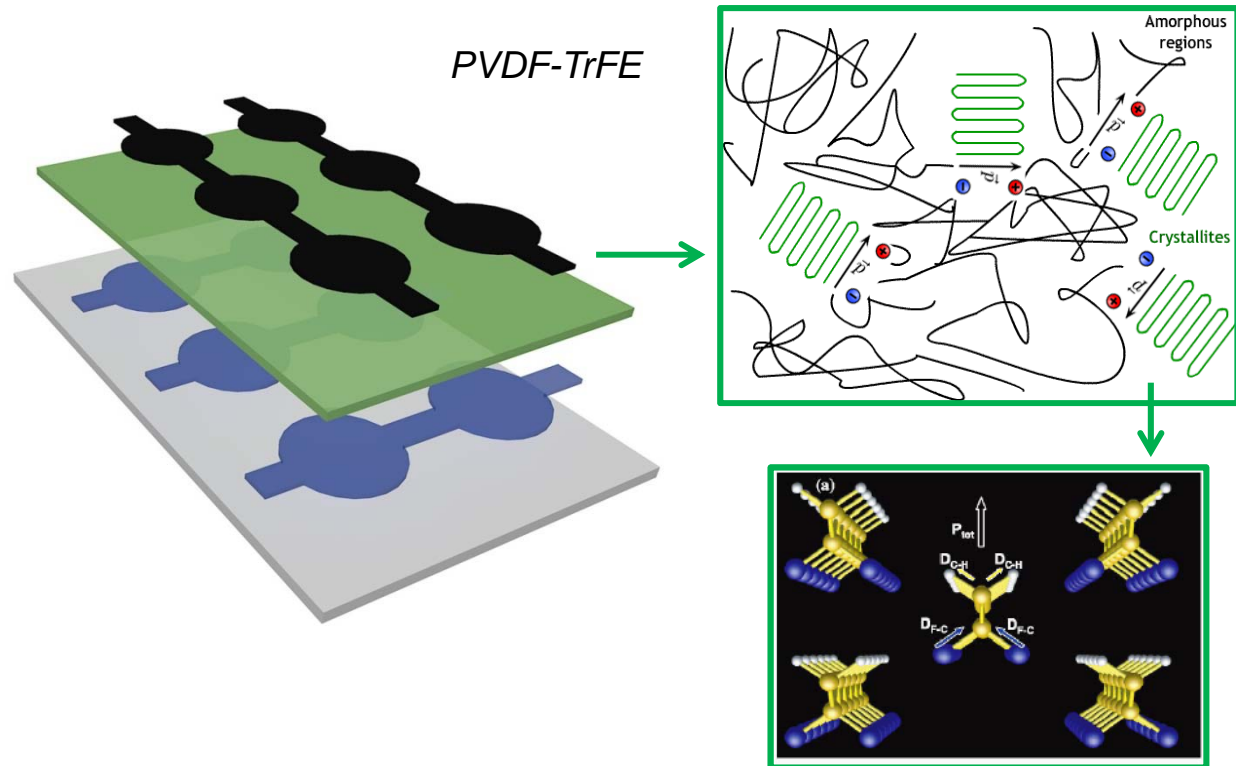


BENDING/  
TWISTING



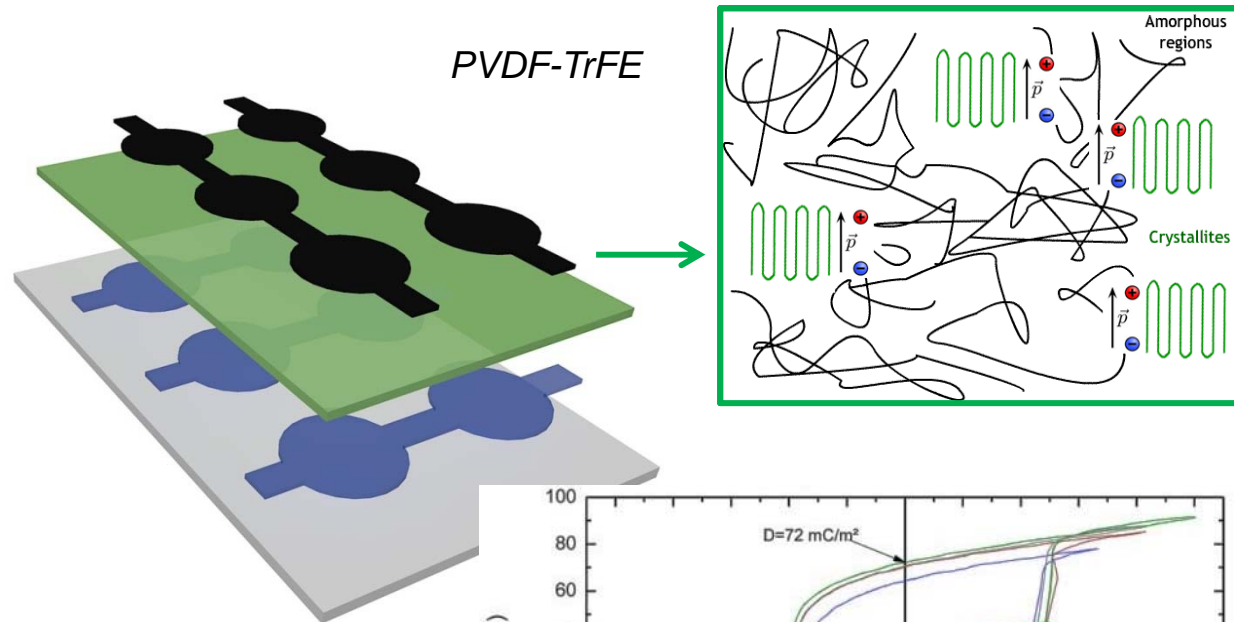
## Fabrication by Screen Printing

- **Substrate:**
  - PET
- **Bottom electrode:**
  - PEDOT:PSS
  - 100° C for ≥ 3 minutes
- **Active Sensor Material:**
  - PVDF:TrFE: own synthesis
  - 100° C for ≥ 5 Minutes
- **Top electrode:**
  - PEDOT:PSS
  - Carbon
  - 100° C for ≥ 3 minutes

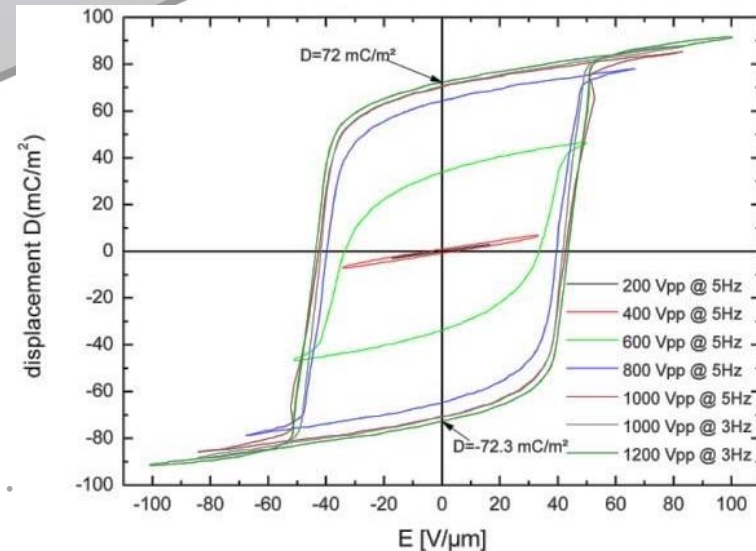


## Poling

- **Substrate:**
  - PET
- **Bottom electrode:**
  - PEDOT:PSS
  - 100° C for ≥ 3 minutes
- **Active Sensor Material:**
  - PVDF:TrFE: own synthesis
  - 100° C for ≥ 5 Minutes
- **Top electrode:**
  - PEDOT:PSS
  - Carbon
  - 100° C for ≥ 3 minutes

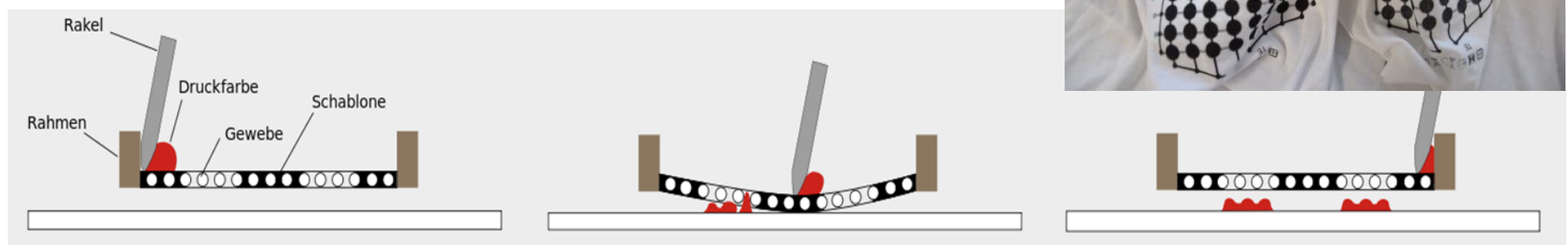
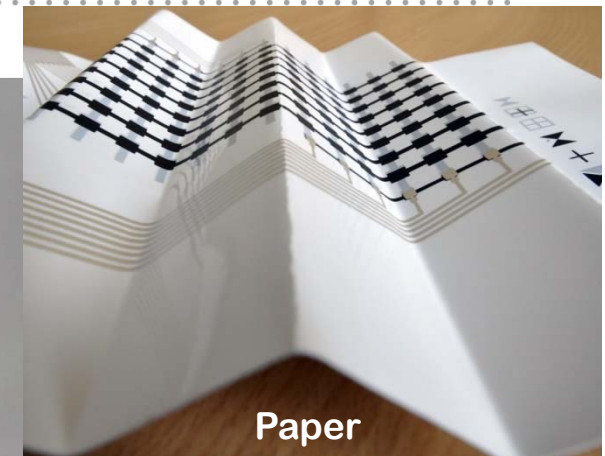
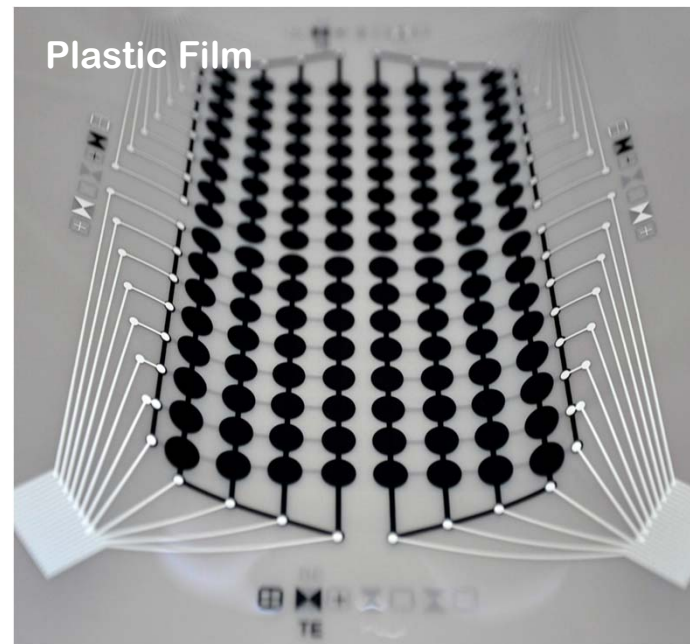


*Remanent polarization: 70-80 mC/m<sup>2</sup>*  
*Coercive field strength: 50 V/μm*  
*Poling field strength: 100-200V/μm*



## Substrates

- **Substrate:**
  - PET
- **Bottom electrode:**
  - PEDOT:PSS
  - 100°C for ≥ 3 minutes
- **Active Sensor Material:**
  - PVDF:TrFE: own synthesis
  - 100°C for ≥ 5 Minutes
- **Top electrode:**
  - PEDOT:PSS
  - Carbon
  - 100°C for ≥ 3 minutes
- **Connection lines:**
  - Ag





# Novel Enhanced User Interfaces

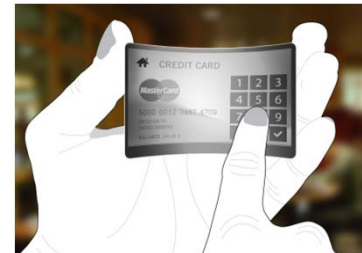
powered by **PyzoFlex**

**PyzoFlex-Cover**



UIST 2014

**PyzoFlex-Card**

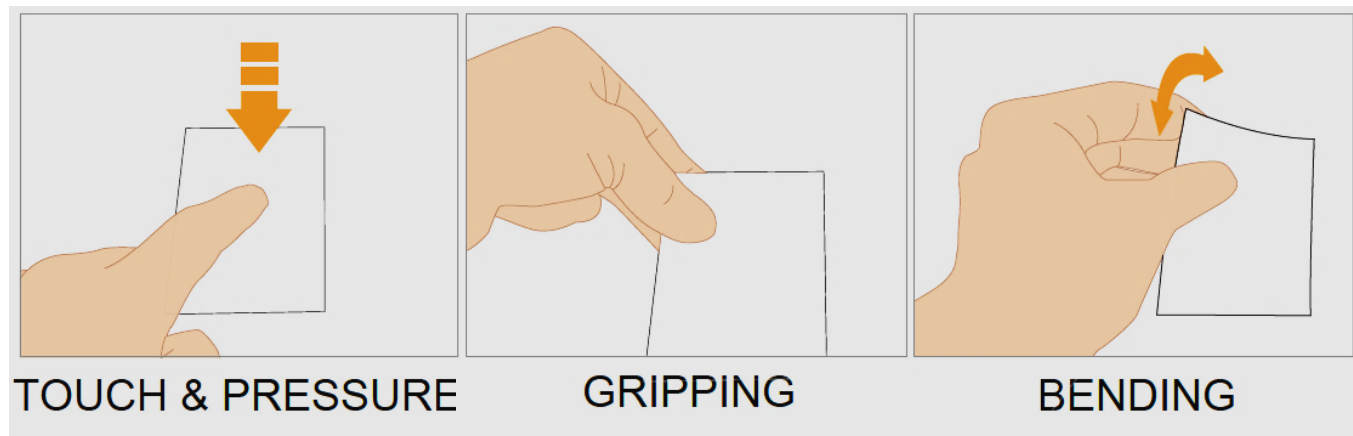


**PyzoFlex-Case**



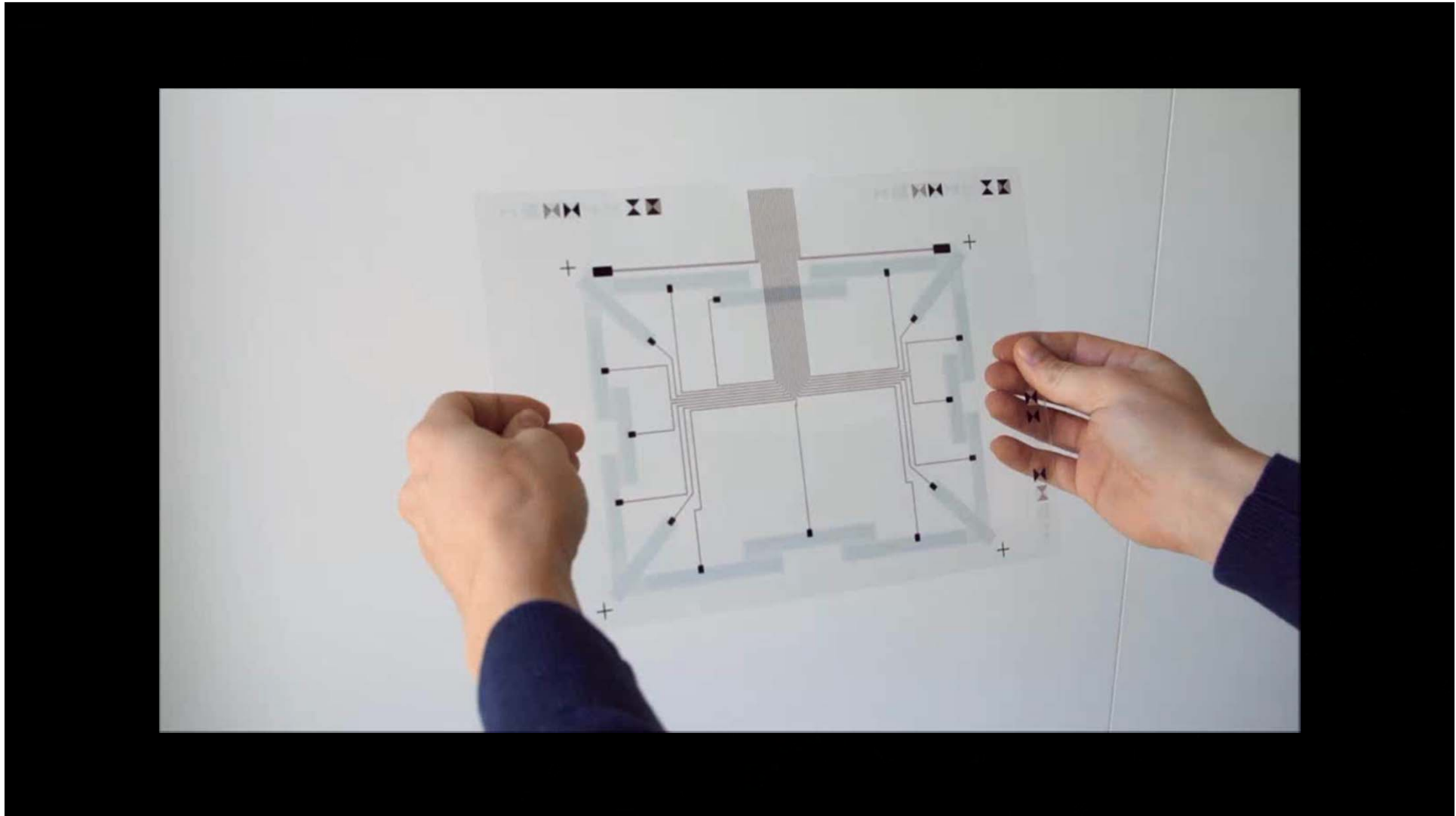
Chi 2015

## Novel gestures



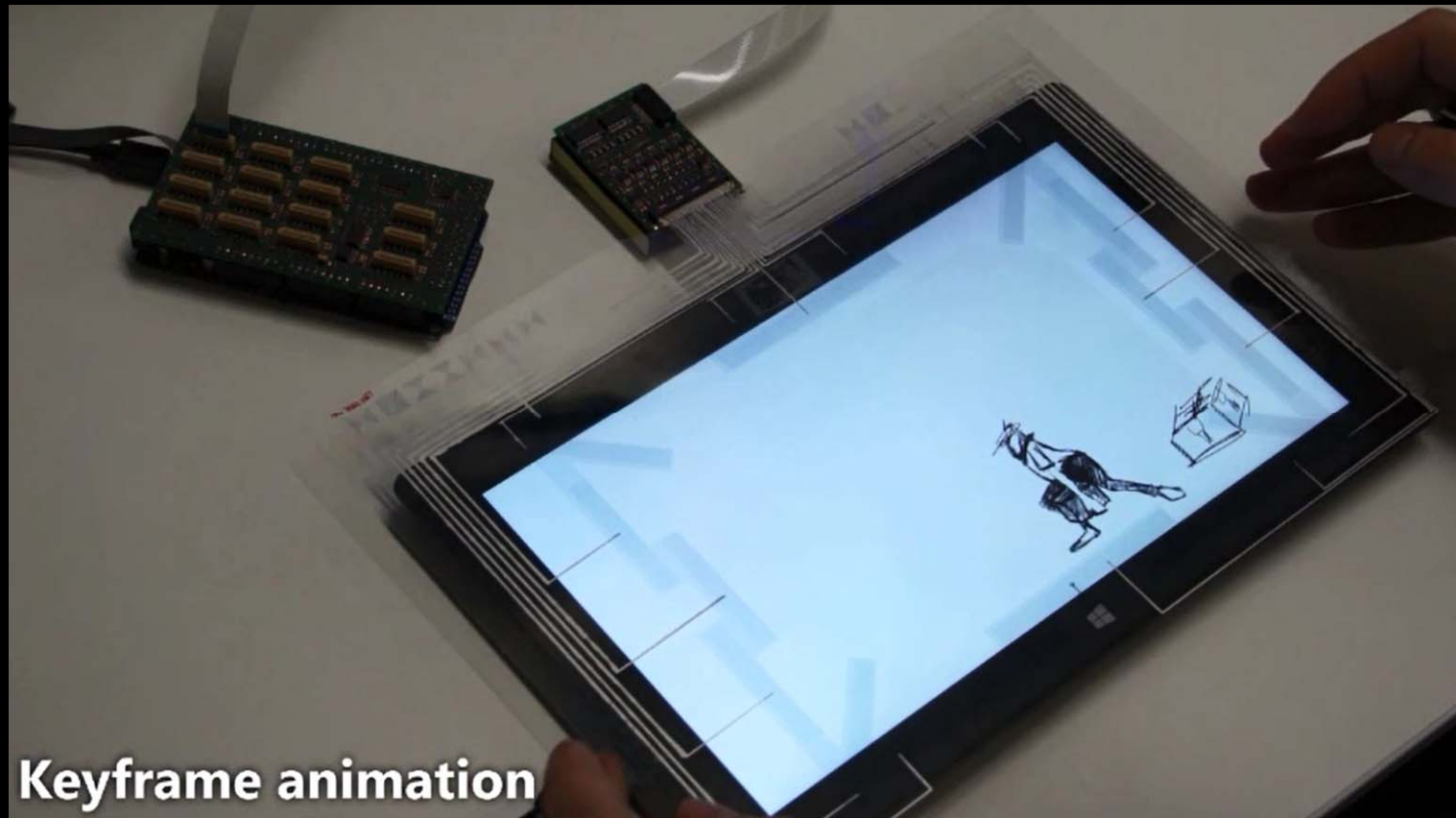
# PyzoFlex-Cover

<https://www.youtube.com/watch?v=3Jo9ww9cLzg>



Rendl, C., Greindl, P., Haller, M., Zirkl, M., Stadlober, B., & Hartmann, P. (2012). *PyzoFlex*. *Proceedings of the 25th annual ACM symposium on User interface software and technology - UIST '12* (pp. 509–518). New York, New York, USA: ACM Press.

# PyzoFlex-Cover







# PyzoFlexCase

41





# Acknowledgements



Dieter  
Nees



Johannes  
Götz



Stephan  
Ruttloff



Ursula  
Palfinger



Markus  
Leitgeb



Maria  
Belegatis



Philipp  
Schäffner



Lazo  
Kuna



Martin  
Zirkel



Gregor  
Scheipl



Andreas  
Tschepp



Thomas  
Rothländer



Philipp  
Hütter



# Summary

43

- R2R-UV-nanoimprinting of features down to 200 nm size, 3D shape, high aspect ratio (5:1) at 5 -15 m/min
- R2R nanoimprinting over 700m = 200 m<sup>2</sup> plastic film
- R2R-fabrication of m<sup>2</sup> of multifunctional riblet foils with superhydrophoby and drag reduction
- R2R-production of fine metallic patterns with CD < 1μm at 15 m/min
- Large-area (A3) screen printing of ferroelectric polymer sensors
- Pressure-sensitive foils for intuitive user interfaces in flexible electronic devices

Thank you for your attention !