

# Micro System Analyzer: Application at UCL

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PhD student

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# Louvain-la-Neuve - then (1972)



# Louvain-la-Neuve - now



# Louvain-la-Neuve - now

**Science Park**  
135+ companies  
& incubator

**City center**  
University

Artificial lake 😊

Sportive complex - Blocry  
Theatres, Cinema  
Culture center - Aula Magna

**WINFAB**  
Microelectronics  
cleanroom

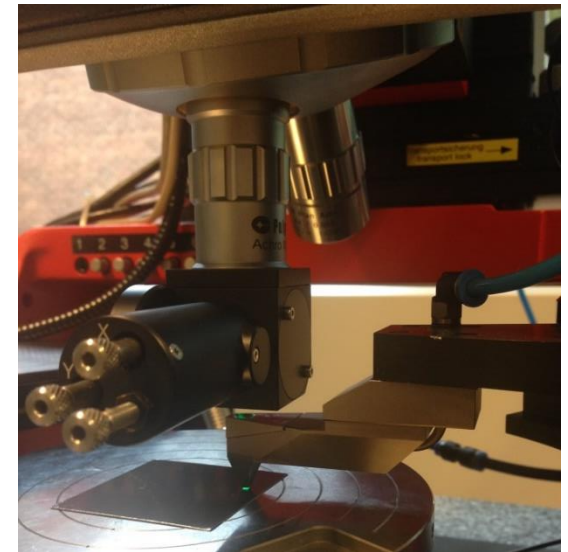
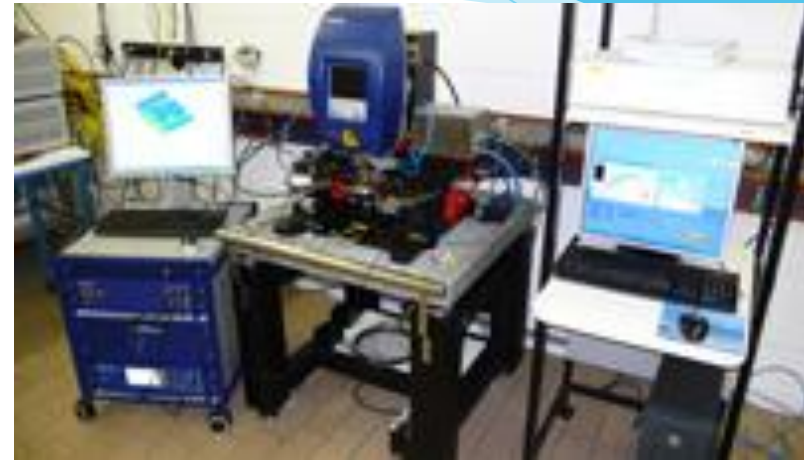
**WELCOME**  
Electrical  
measurements

**Cyclotron**



# MSA - 500

- ▶ TMS3.5 et PSV9.2 Software
- ▶ Different objectives
- ▶ Michelson set-up
- ▶ SÜSS MicroTec probe station with pressure nozzle
- ▶ Bending set-up

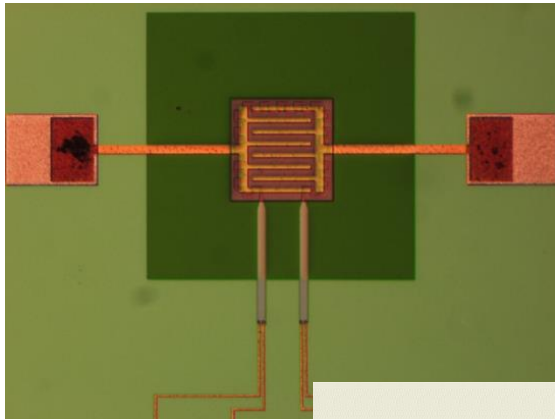


## Context:

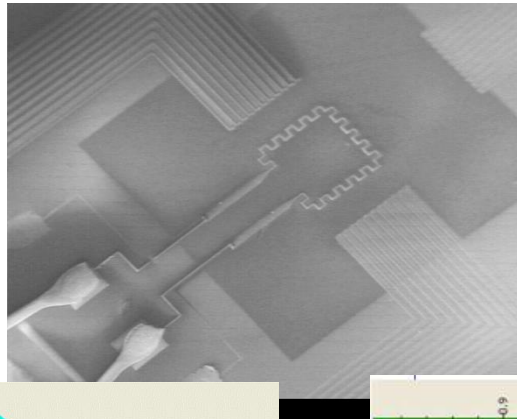
- ▶ Application for Membranes and Microelectromechanical systems (MEMS)
- ▶ Application for Ionization, Hydrogen and Strain sensors
- ▶ Application for Macro - systems (surfaces, structures, solar cells)
- ▶ Conclusion

# Membranes and MEMS applications

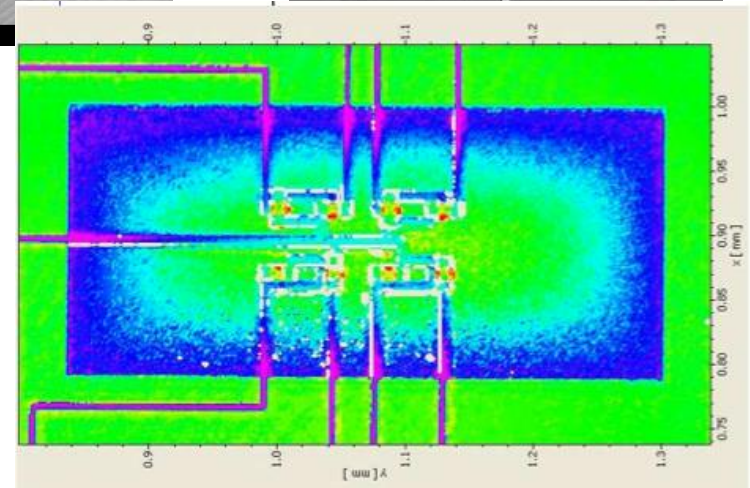
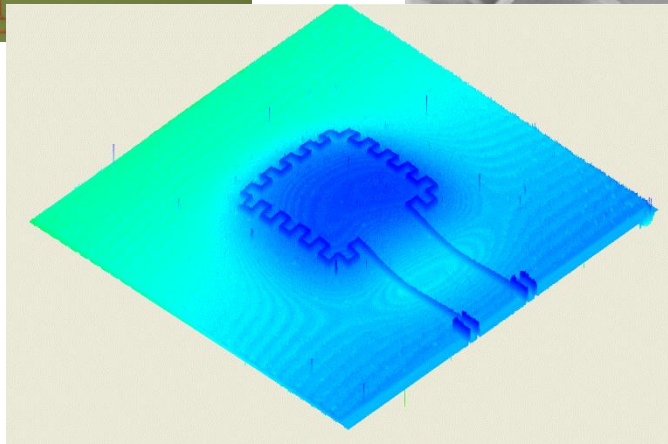
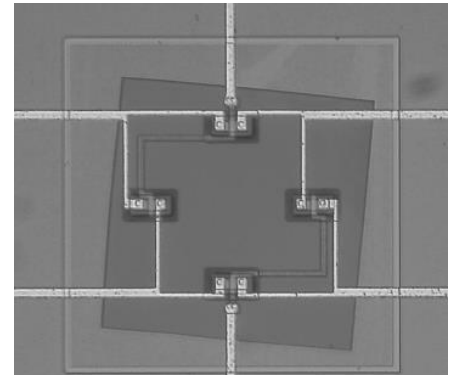
Gas sensors



Flow sensor

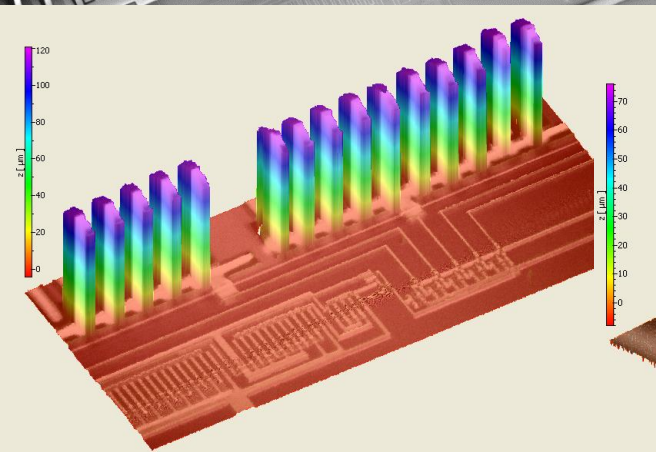
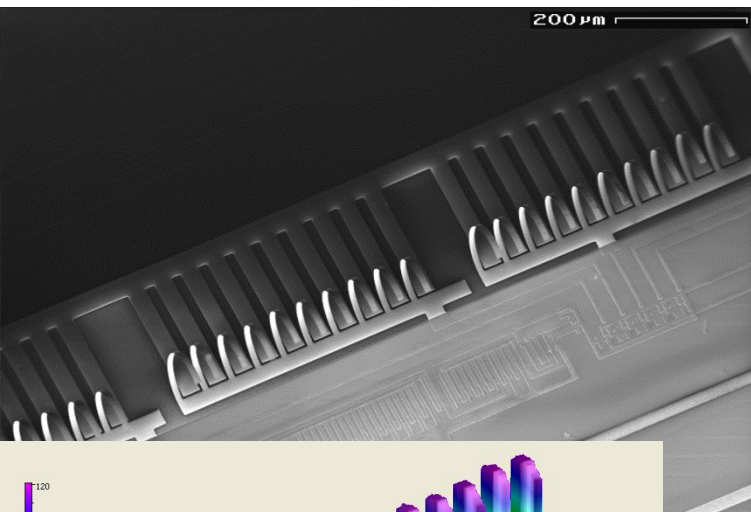


Pressure sensor

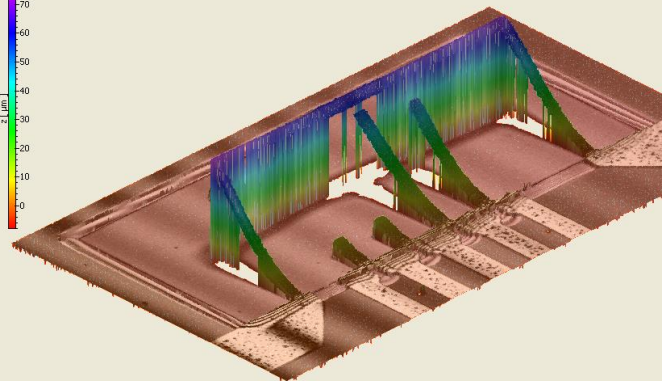
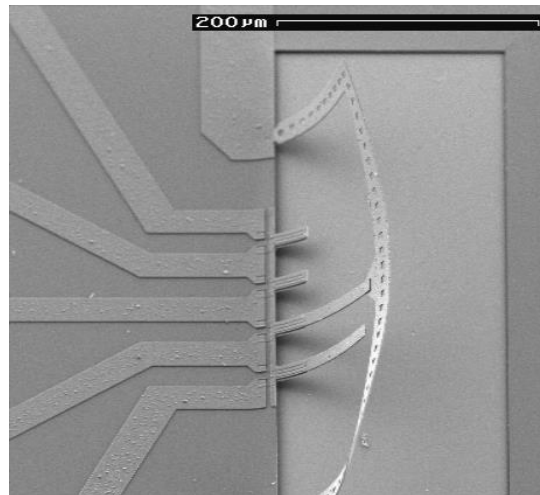


# Membranes and MEMS applications

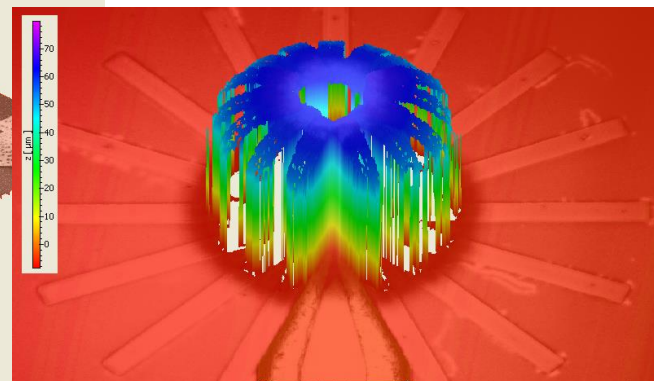
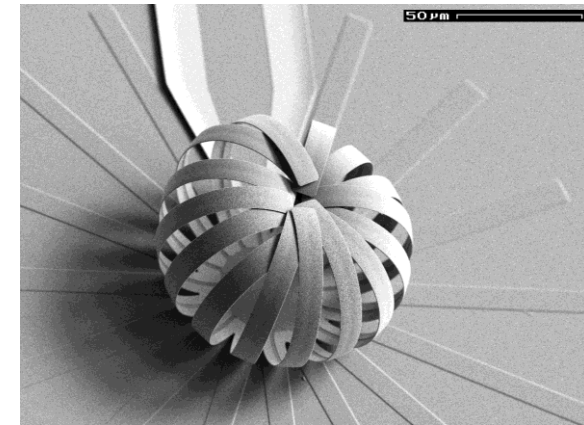
Flow/gas sensors



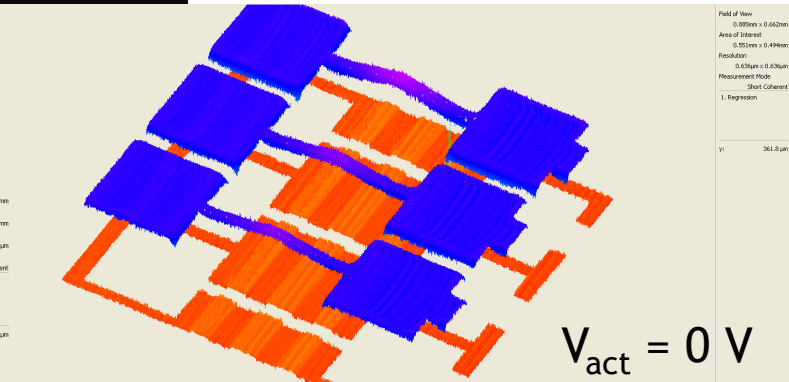
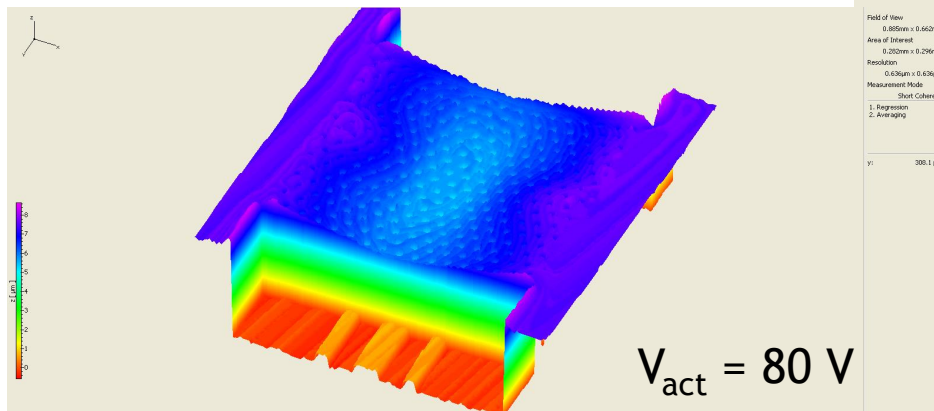
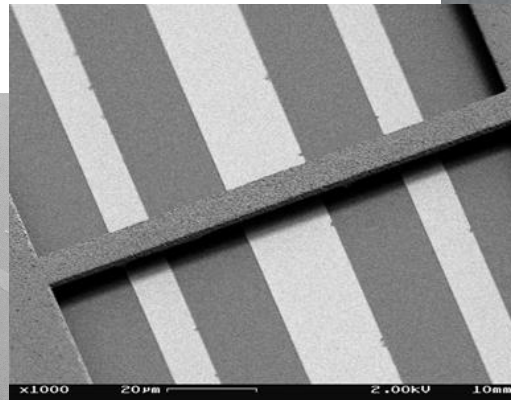
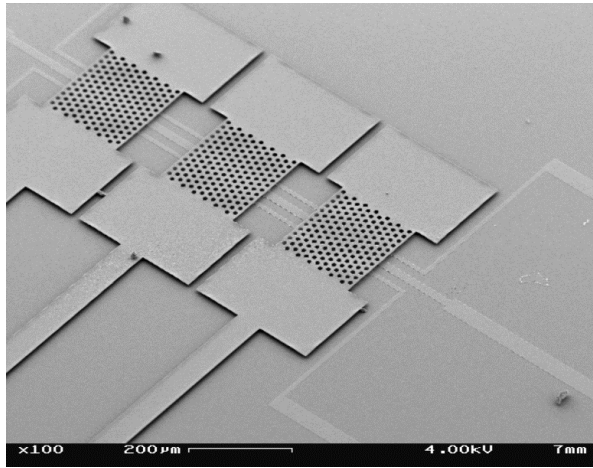
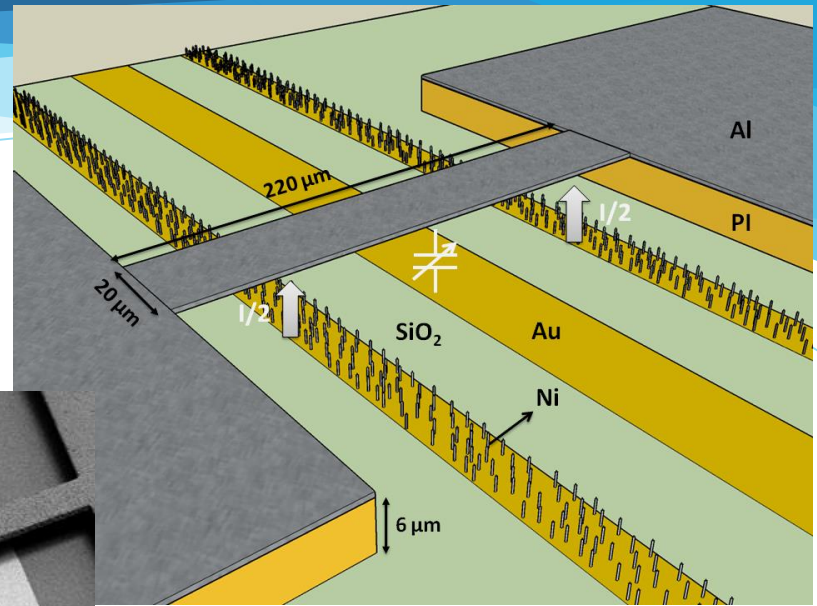
Magnetic sensors



Micro-tweezers

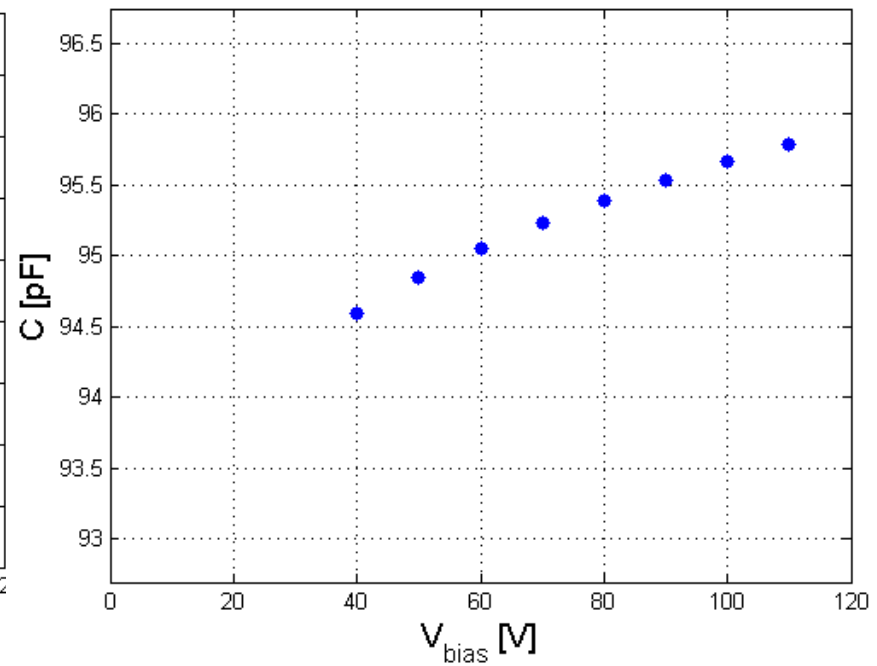
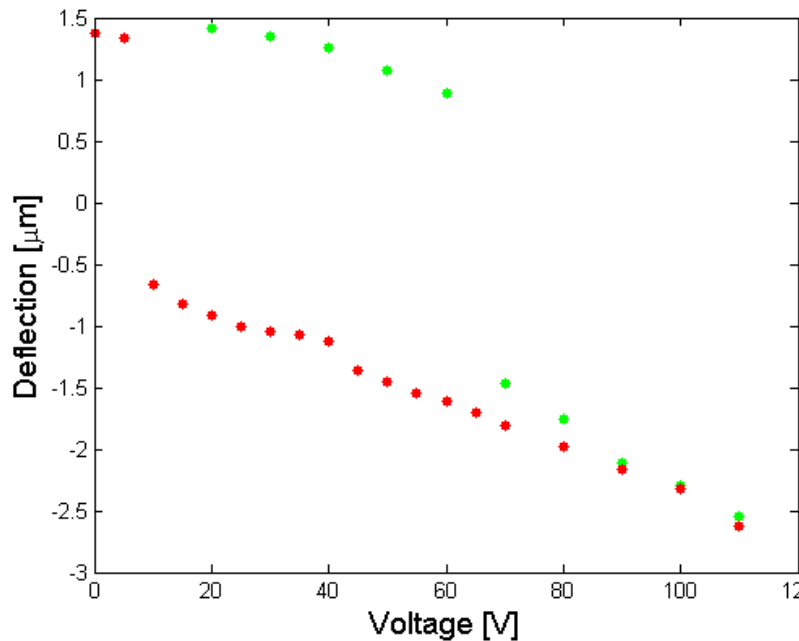


# Ionization sensor



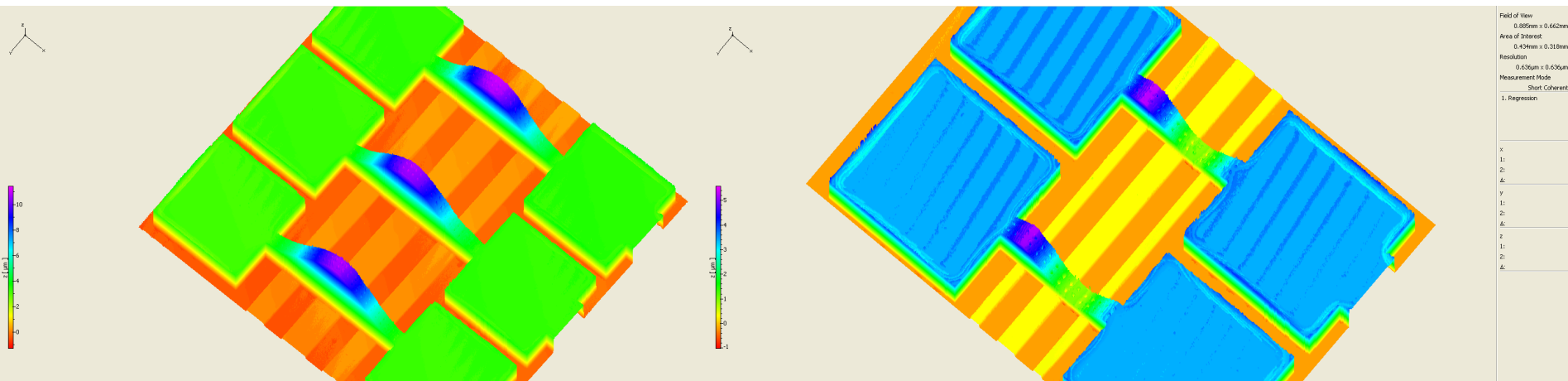
# Ionization sensor

- Mechanical characterization from deflection measurements to capacitance



# Ionization sensor

- ▶ Mechanical characterization from deflection measurements to capacitance
- ▶ Defect analysis with resonance modes



$f_1 = 189$  kHz (theoretical:  $f_1 = 169$  kHz)

$f_2 = 287$  kHz (theoretical:  $f_2 = 202$  kHz)

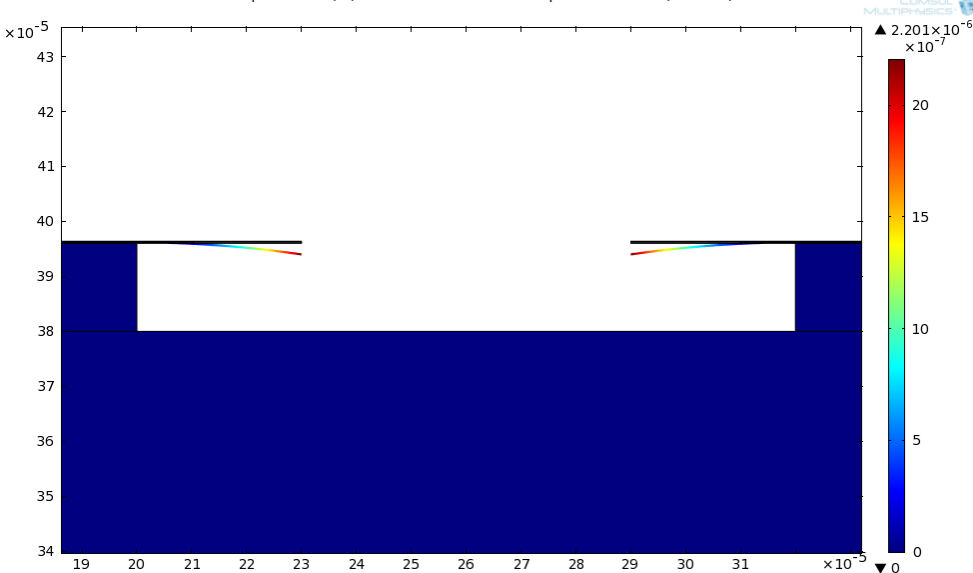
# Hydrogen sensor

- Determination of the stress due to the Pd layer

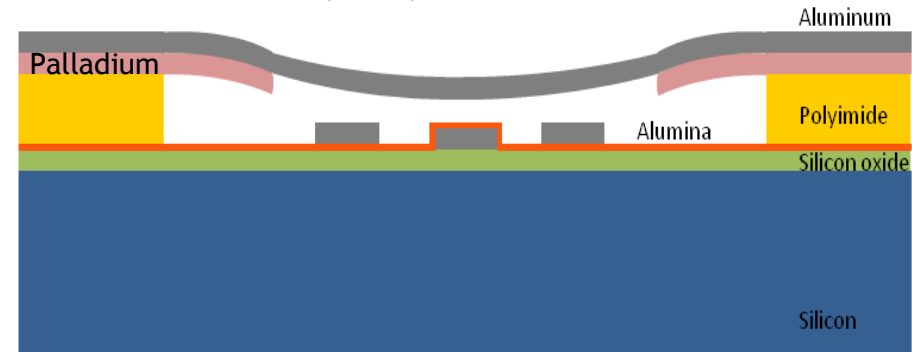
$$\sigma_{Al} = -50MPa$$

$$\sigma_{Pd} = 100MPa$$

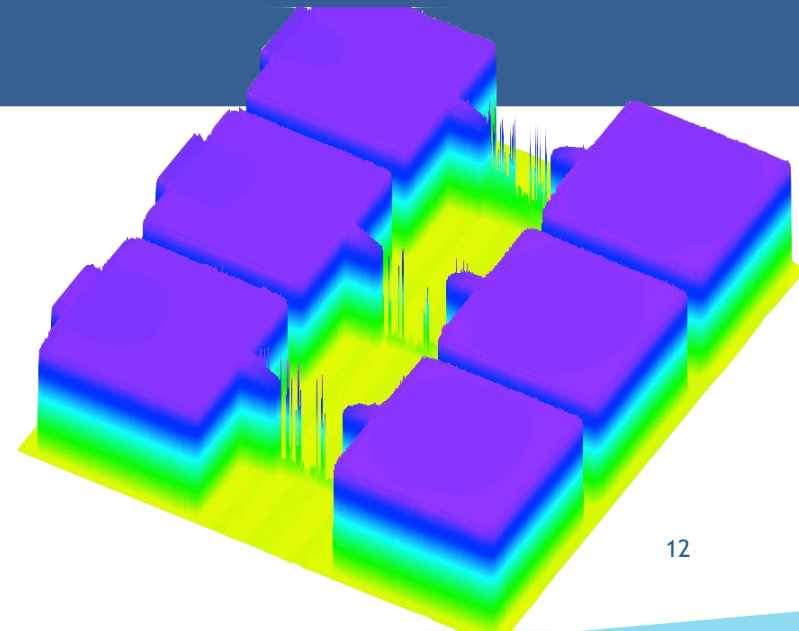
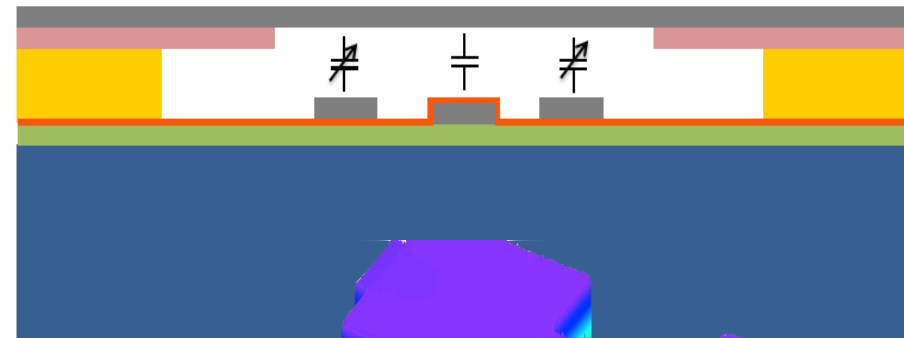
Surface: Total displacement (m) Surface Deformation: Displacement field (Material)



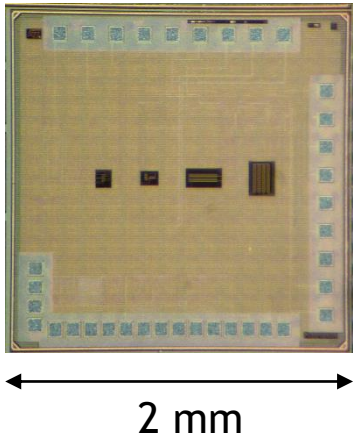
Initial: deflected cantilever by Pd deposition under stress



With H<sub>2</sub>: unbending of the cantilever



# Strain sensor



For in-situ mechanical stress measurements

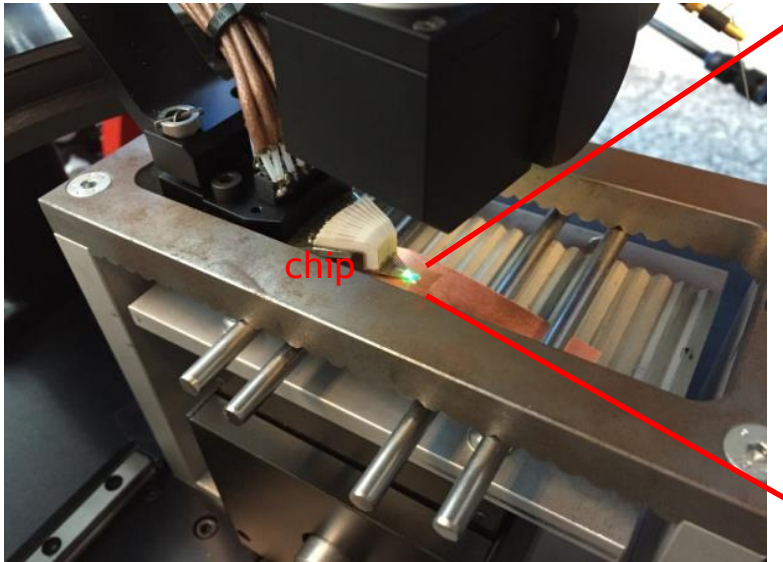
Working principle:

*Variable output frequency  $f$  as function of the strain stimulus of the silicon active layer*

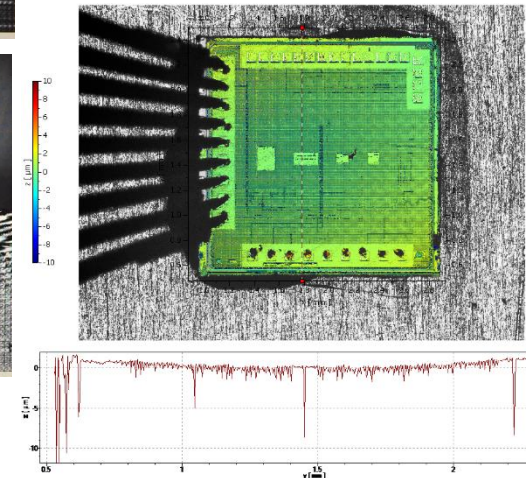
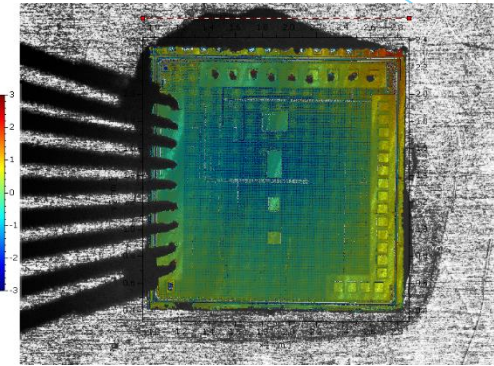
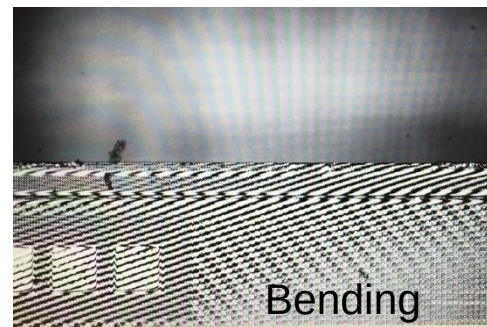
Challenge: How to control the deformation of a small chip?

Issues: footprint, strain transfer through the glue, access for the probes tips

# Solution: local strain measurements



A four-point bending machine

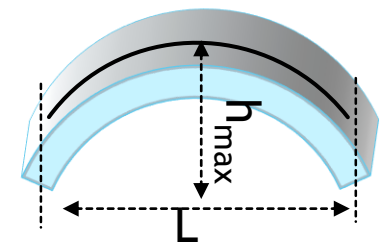
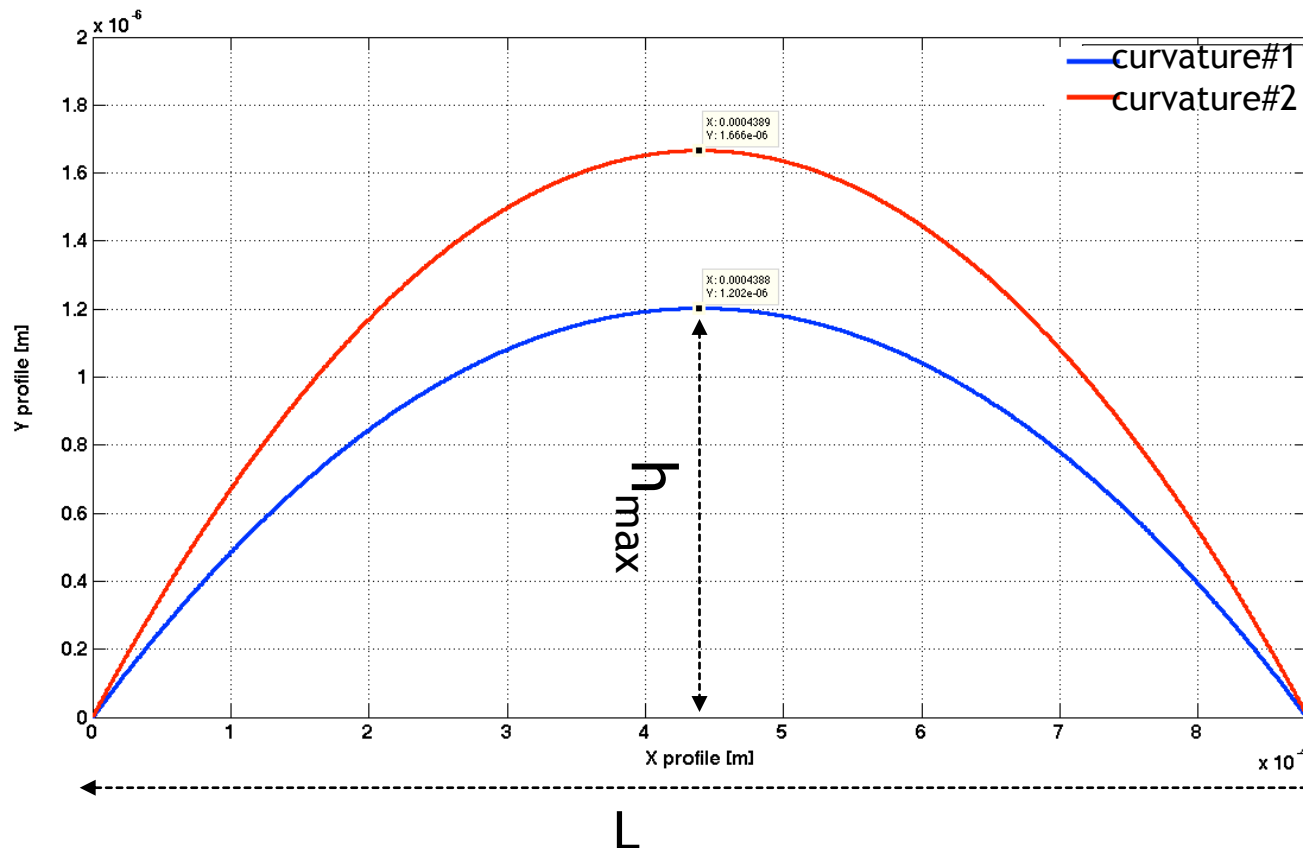


N. André *et al.*, "Ultra-low-power 130nm SOI CMOS smart sensor for in-situ mechanical stress in SiP and SoC applications", IRSP 2016, Germany

Work supported by STARflo PLUS project funded by the Walloon Region

# Results: Stress extraction from $h_{\max}$

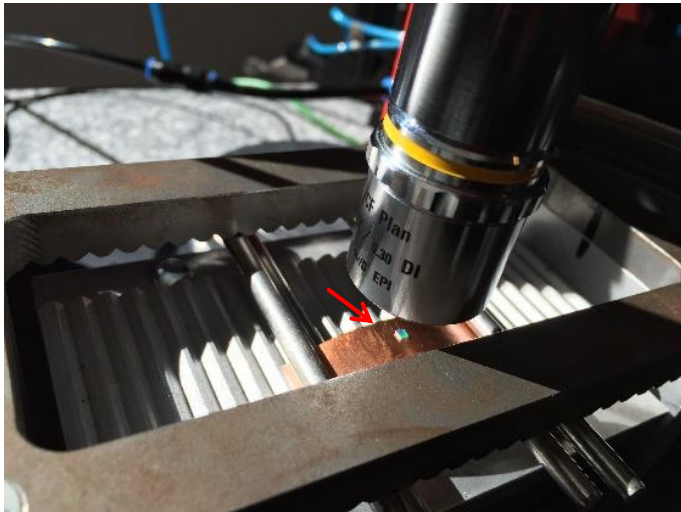
$h_{\max}$  is measured directly on the chip



97 MPa  
 $f_{\text{circuit}} = 247$  kHz

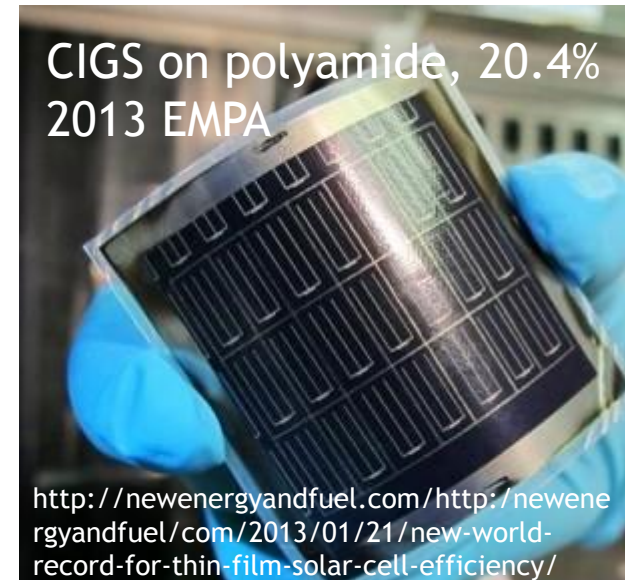
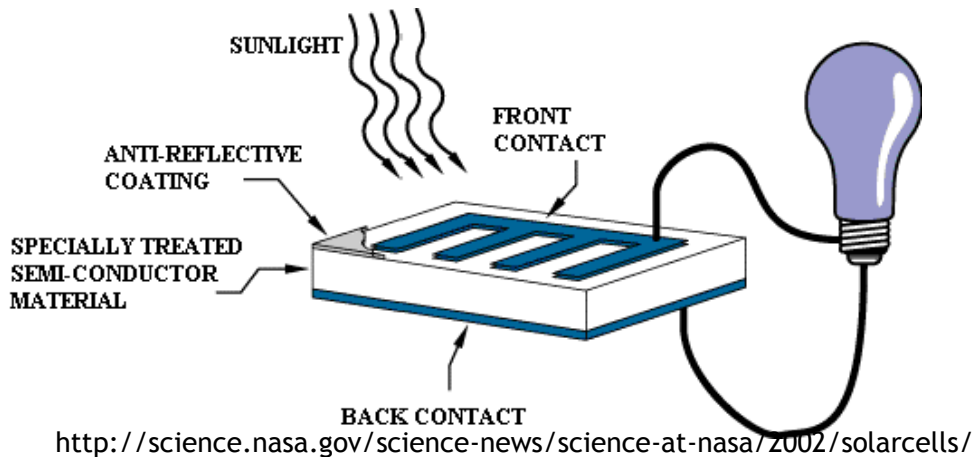
134 MPa  
 $f_{\text{circuit}} = 270$  kHz

# Results: agreement between simulations and measurements



- Ultra-low power = 10  $\mu$ W for the sensing circuit
- Sensitivity of 2400 ppm/MPa amongst the best results of the literature
- Agreement simu/meas. with less than 3% difference

# Thin film Solar Cells on flexible substrates

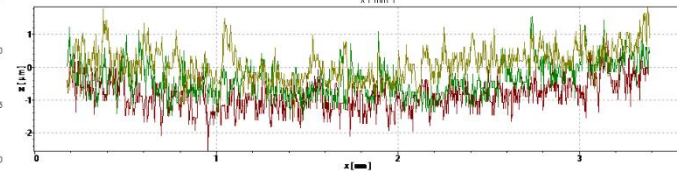
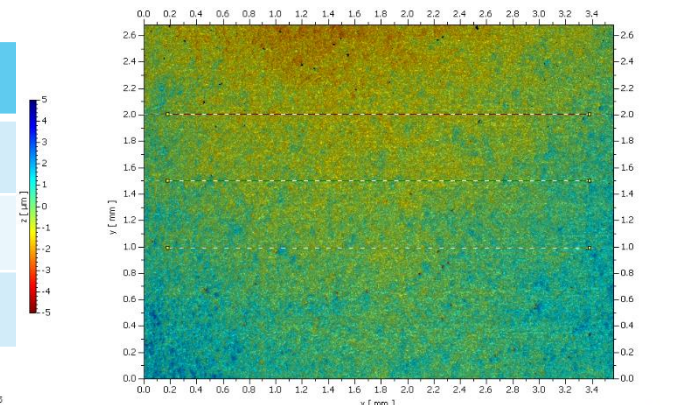
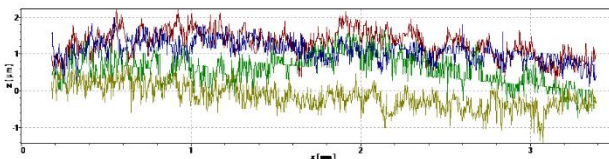
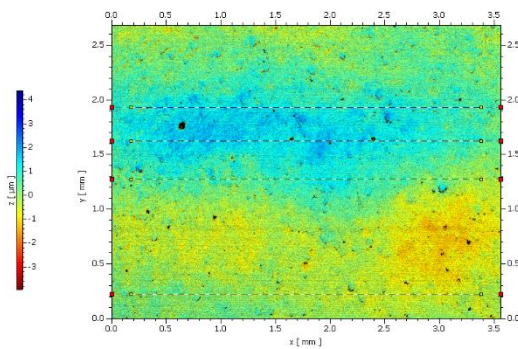
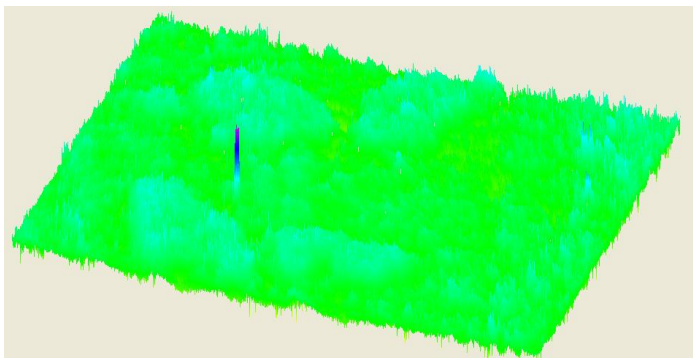


- ▶ *Flexible substrate (steel)*
- ▶ *Barrier layer to provide diffusion barrier and electrical insulation*
- ▶ Molybdenum back contact
- ▶ Copper-Zinc-Tin-Sulfide (CZTS) based absorber
- ▶ Interface Mo/CZTS

# Barrier layer characterization

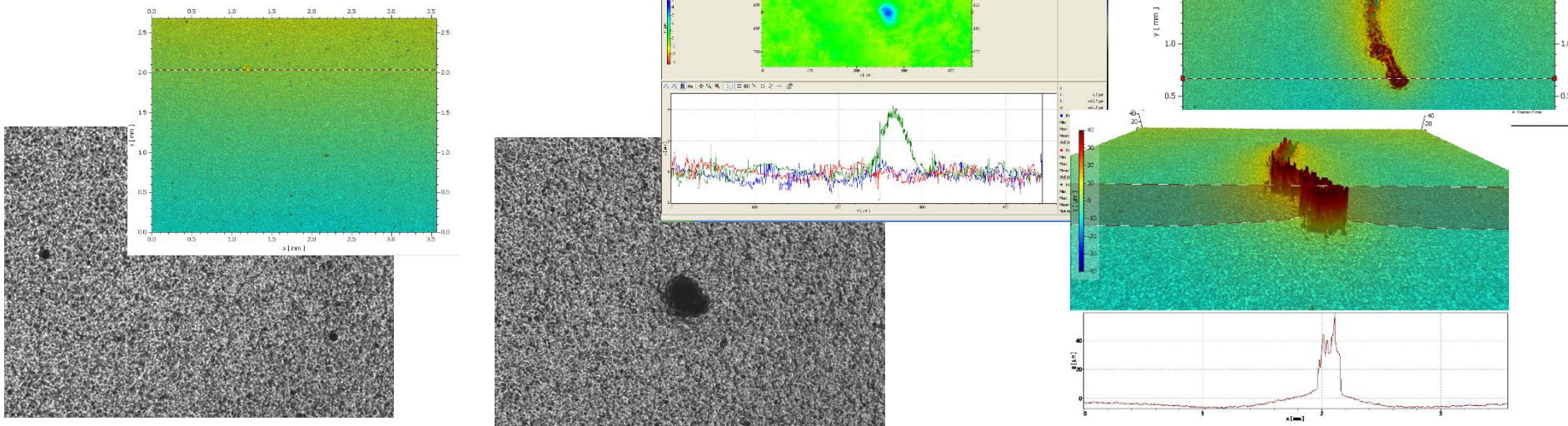
- Roughness for different substrates for solar cells (Glass, Insulated steel barrier layer)

|                 | Ra, $\mu\text{m}$ | Rz, $\mu\text{m}$ |
|-----------------|-------------------|-------------------|
| Barrier layer 1 | 0.26 - 0.28       | 2.3 - 2.7         |
| Barrier layer 2 | 0.22 - 0.27       | 1.5 - 1.8         |
| Barrier layer 3 | 0.13 - 0.15       | 1.0 - 1.2         |



# Barrier layer characterization

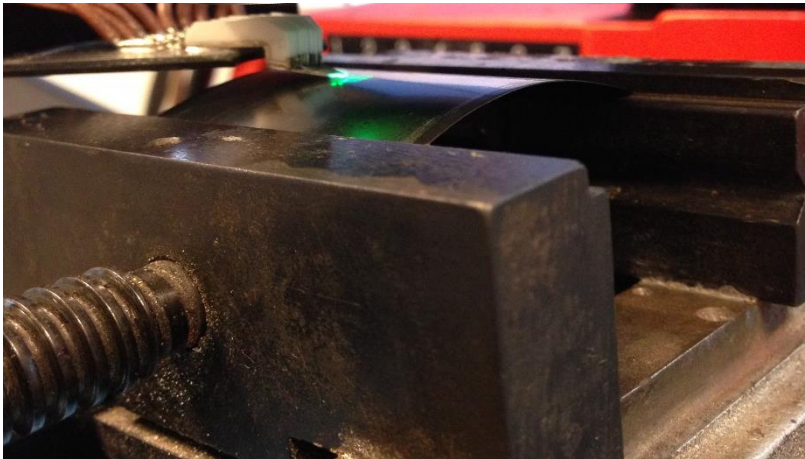
- ▶ Roughness for different substrates for solar cells (Glass, Insulated steel barrier layer)
- ▶ Defects classification



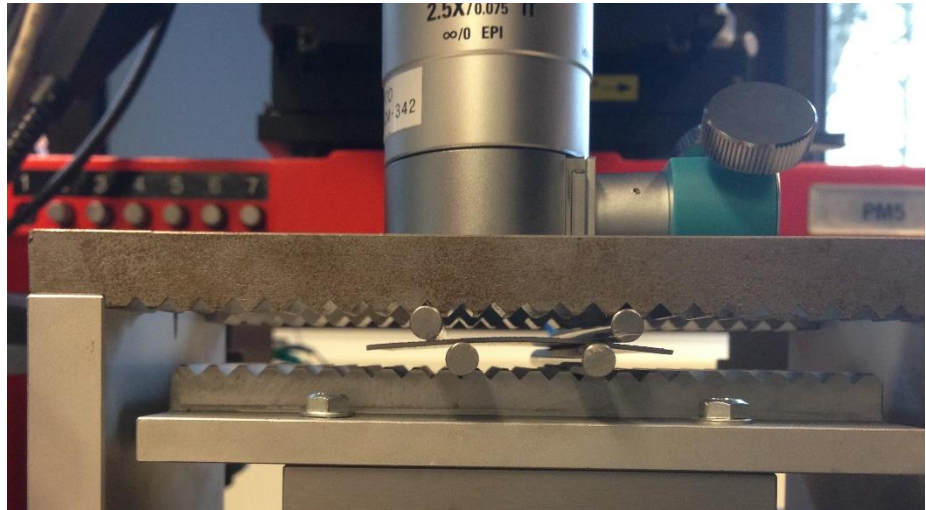
| Height <1μm                  | Height: 2-5μm              | Height >5μm                |
|------------------------------|----------------------------|----------------------------|
| 20-50 over 15mm <sup>2</sup> | 7-8 over 15mm <sup>2</sup> | 1-2 over 18cm <sup>2</sup> |

# Electrical characterization under bending

- ▶ Four point probe measuring for Mo back contact characterization under bending



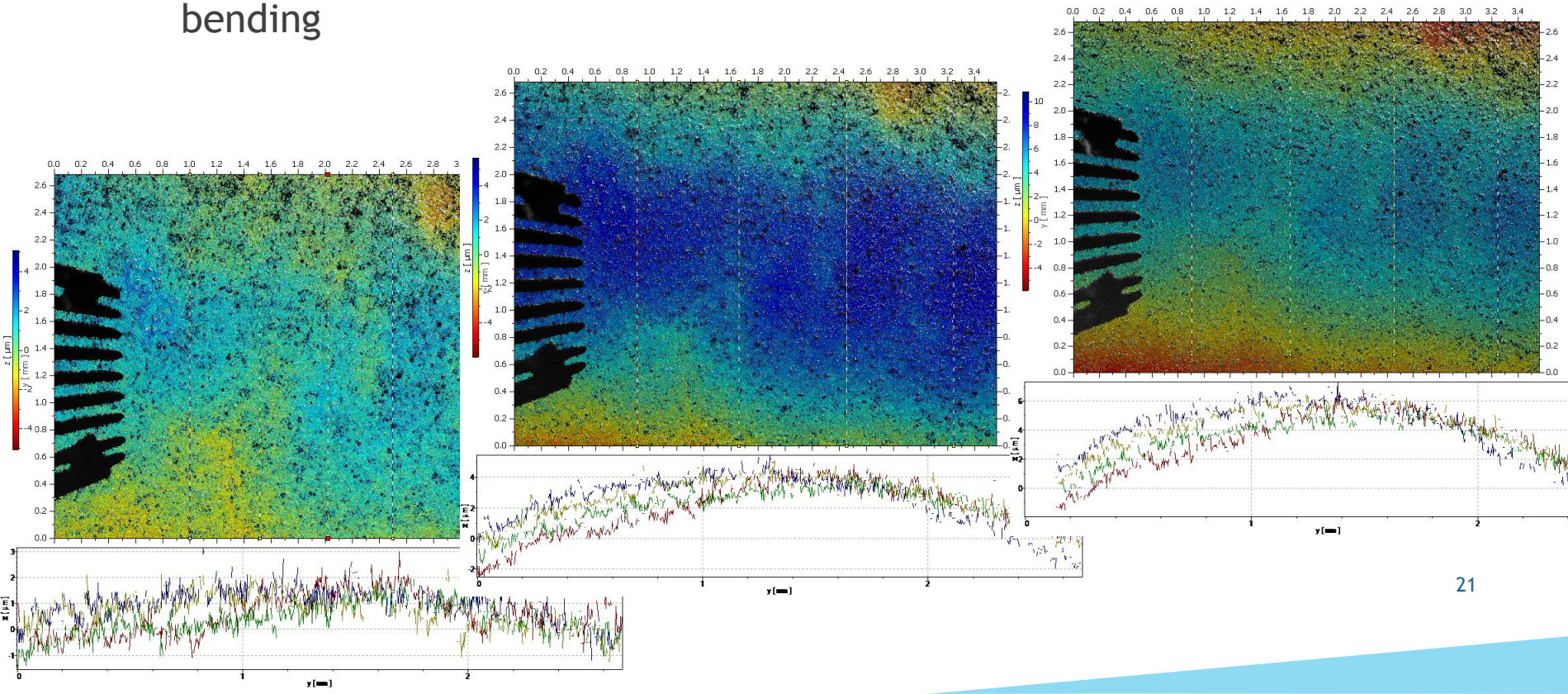
A two-point bending



A four-point bending

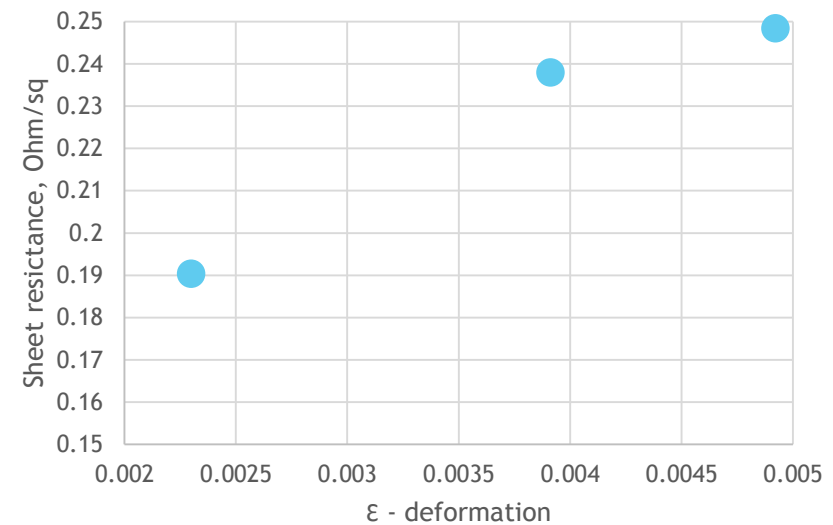
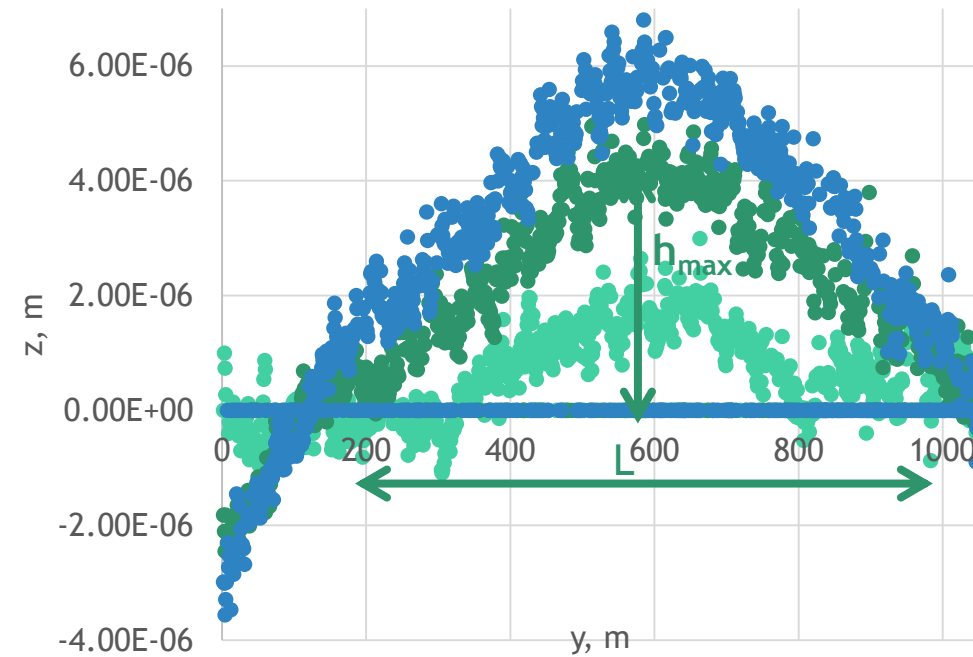
# Electrical characterization under bending

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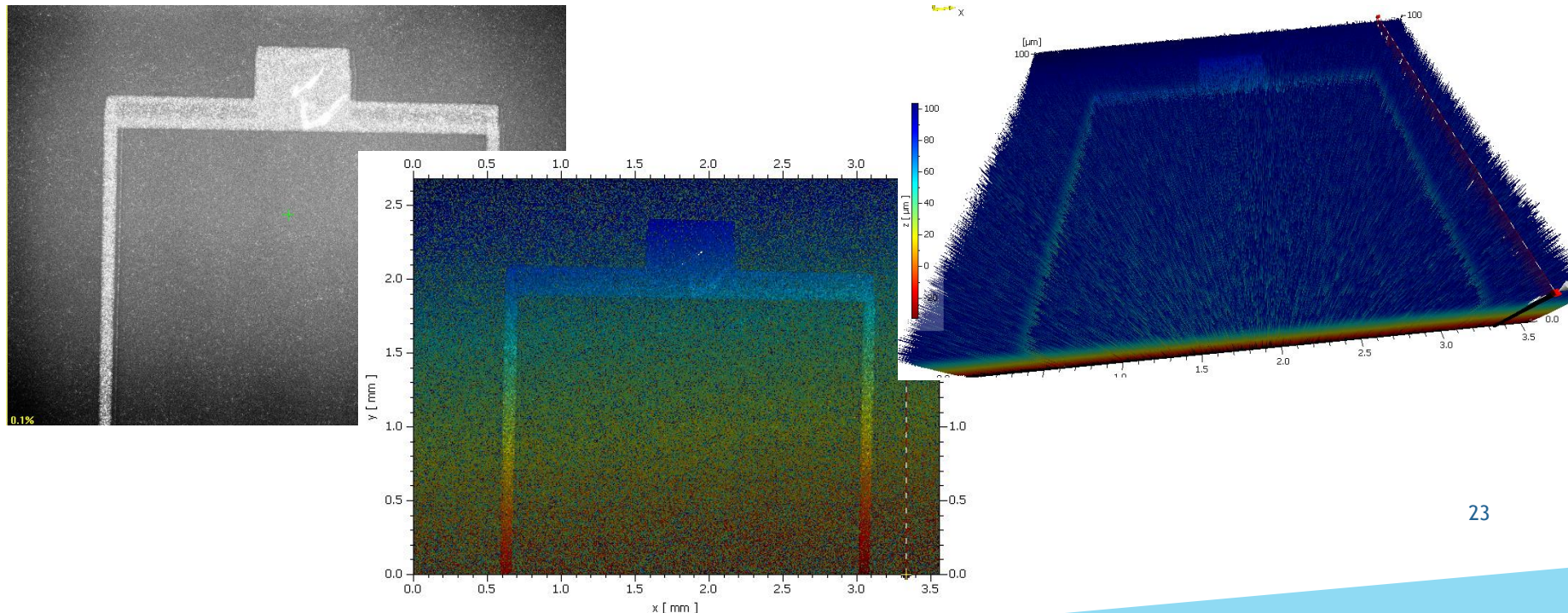
# Electrical characterization under bending

- Four point probe measuring for Mo back contact characterization under bending



# Electrical characterization under bending

- ▶ Four point probe measuring for back contact characterization
- ▶ IV curve under bending condition for solar cell on flexible substrates



# Conclusion

- ▶ Interest for characterization of MEMS at both research and pre-industrial for:
  - ▶ Fabrication process development: in release tests, material characterization (yield stress, Young modulus, etc.)
  - ▶ Test and reliability of foundry-manufactured MEMS devices
- ▶ Surface characterization (roughness and defects)
- ▶ Interest for thin layer characterization (internal stress or stress under deformation)

# Acknowledgements

- ▶ Institute of Information and Communication Technologies, Electronics and Applied Mathematics



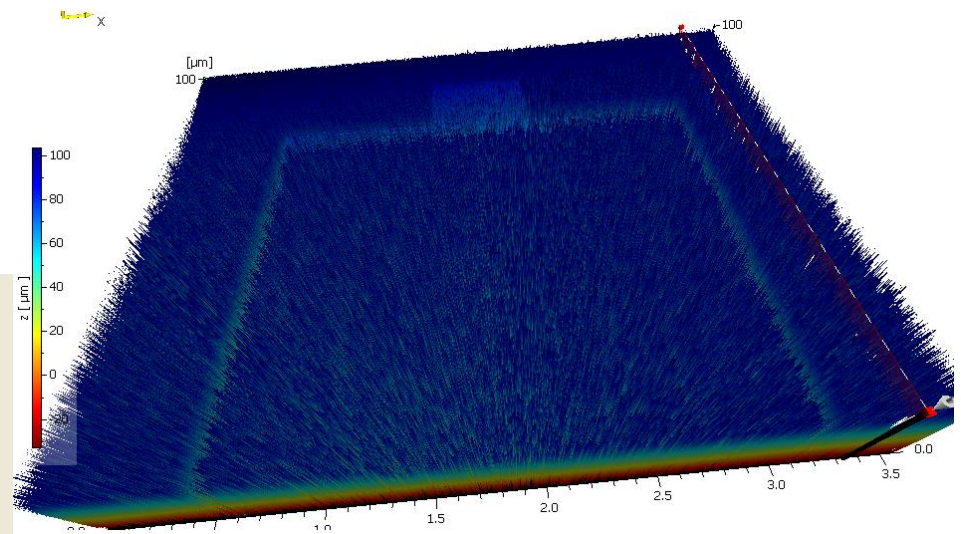
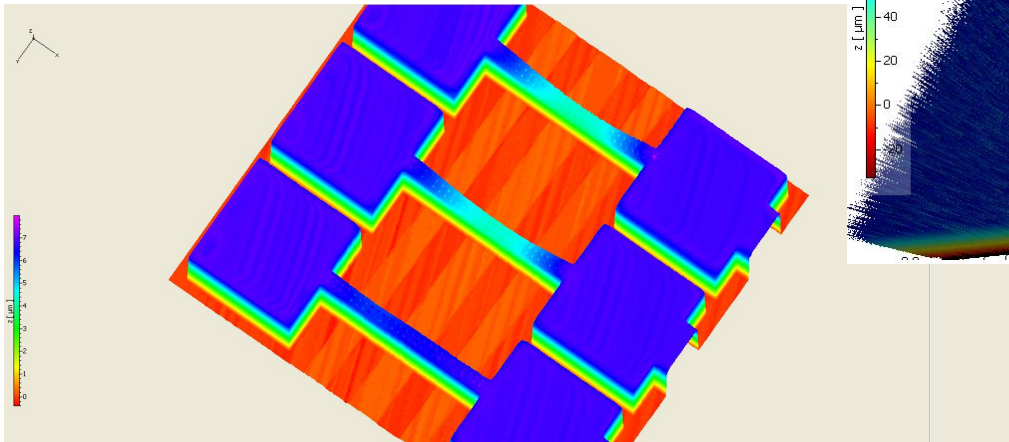
- ▶ Wallonia Infrastructure Nano FABrication



- ▶ Wallonia **E**lectronics and **C**ommunication **M**Easurement



# Thank you for your attention!



# Interface Mo/CZTS

