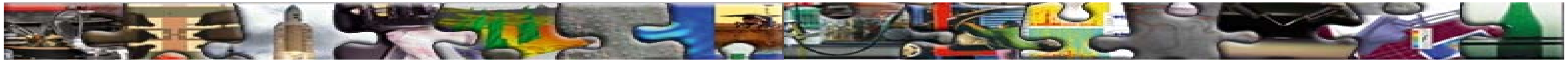
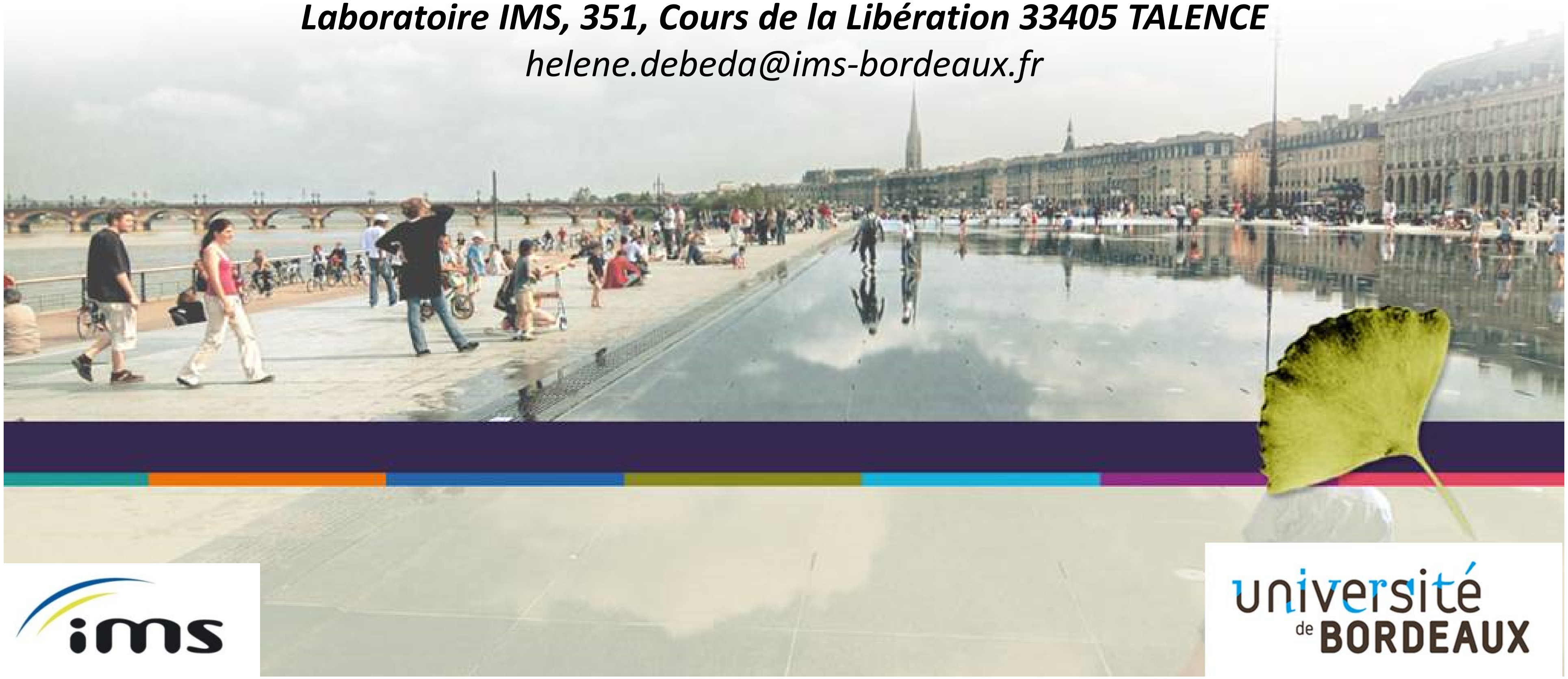


Dr. Hélène DEBEDA, Associate Professor
Université de Bordeaux – Laboratoire IMS

Laboratoire IMS, 351, Cours de la Libération 33405 TALENCE
helene.debeda@ims-bordeaux.fr



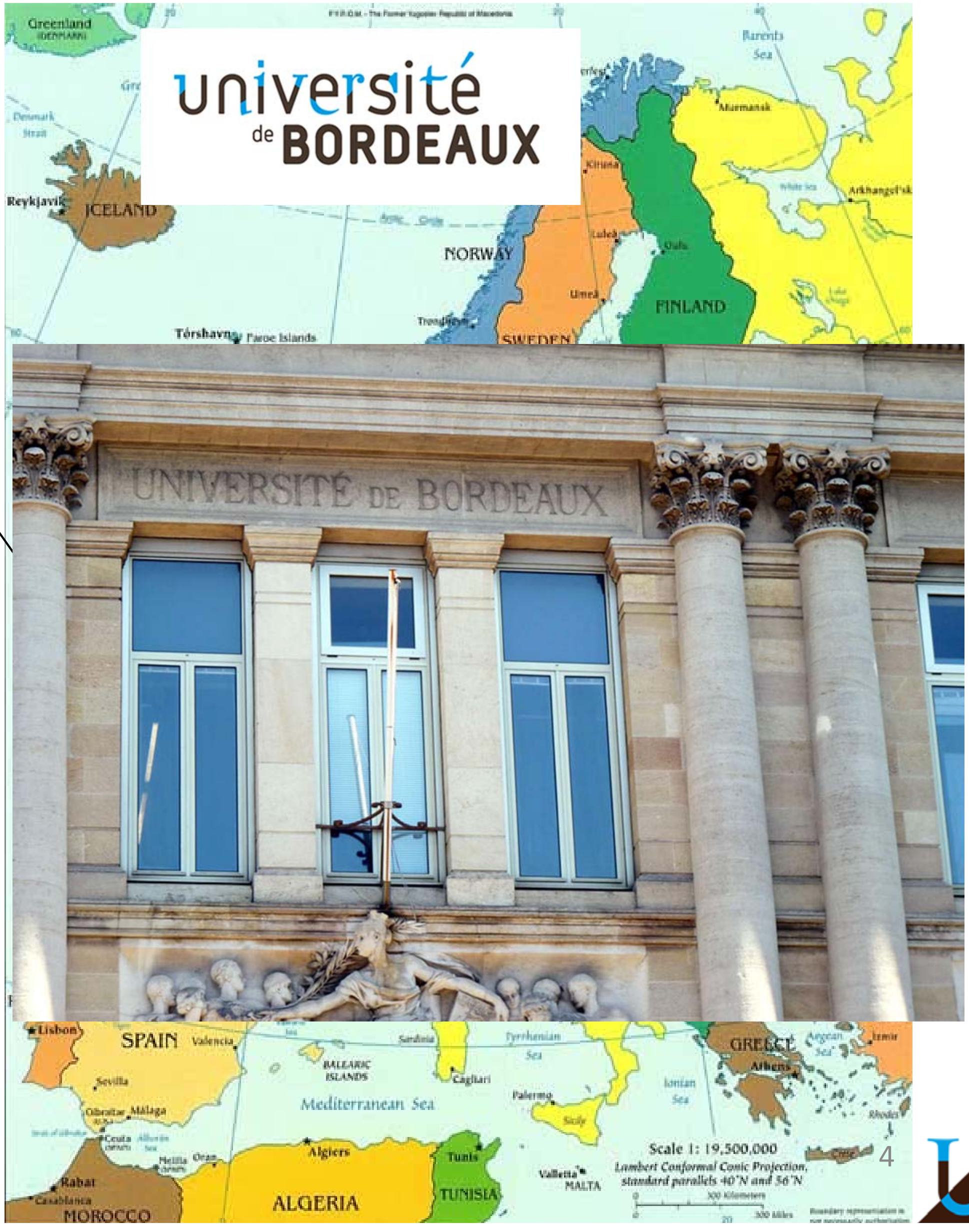
Outline

1. Bordeaux, University and IMS Laboratory
2. IMS Lab - PRIMS team activities
3. Printed technologies for electronics and MEMS
4. Screen-printed PZT MEMS
5. Printed gas sensors: toward RT detection
6. Organic MEMS

Bordeaux, University and Lab…

BORDEAUX AND ITS UNIVERSITY

~730 000 inhabitants



- **3rd rank in France**

53 000 students and 5600 employees

- **3 departments**
  - Science and technology,
  - Law, political science and economy
  - Medicine

⇓

Academic Laboratories

⇓

IMS-Bordeaux LABS

IMS-BORDEAUX LABS

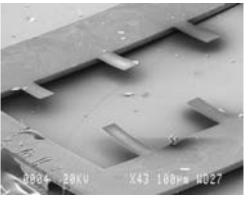
Laboratoire d'Intégration du Matériau au Système

400 people working in the field of Engineering
(material sciences, electrical engineering, biology, humanities)

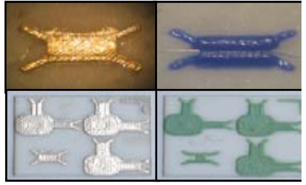
10 000 m^2: 40% dedicated to experimental facilities

IMS-BORDEAUX LABS

4 Departments	10 Groups	27 Teams		
Systems and Interactions B. Veyret	**BIOELECTRONICS** S. Renaud	**Bio-EM** I. Lagroye	**ELIBIO** N. Lew	ghi
	COGNITICS J-M André	**CIH** J-M André	**ESC** F. Daniellou	
Systems X. Moreau	**SIGNAL** Y. Berthoumieu	**MO**		
	PRODUCTION ENGINEERING Y. Ducq	**ME**		
	AUTOMATIC CONTROL A. Oustaloup	**ARI**		
Hardware Integration Y. Deval	**CIRCUIT DESIGN** J-B Bégueret	**EC2**		
	DEVICES RELIABILITY E. Woirgard	**PAC**		
	NANOELECTRONICS T. Zimmer	**LAS** D. Le	C. Maneux	N. Malbert
From Materials to Devices L. Vignau	**ORGANIC ELECTRONICS & MEMS** L. Hirsch	**ELORGA** L. Hirsch	**PRIMS** I. Dufour	
	WAVES C. Dejous	**MDA** D. Rebière	**EDMINA** L. Béchou	**MIM** V. Vigneras



PRIMS team



PRInted Microelectromechanical Systems (MEMS)

4 permanent positions and 6 PhD

420 members including 150 researchers, 160 PhDs, 15 Post-docs, 70 technical staff, 25 administrative staff

IMS Lab-PRIMS team activities

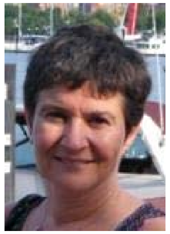
PRIMS: PRInted MEMS Team

www.ims-bordeaux.fr/fr/recherche/groupes-recherche/58-organique/prims/41-PRIMS

- 4 Permanent positions
  - 2 professors
  - 1 junior researcher
  - 1 associate professor


Cédric
Ayela


Hélène
Debéda


Isabelle
Dufour

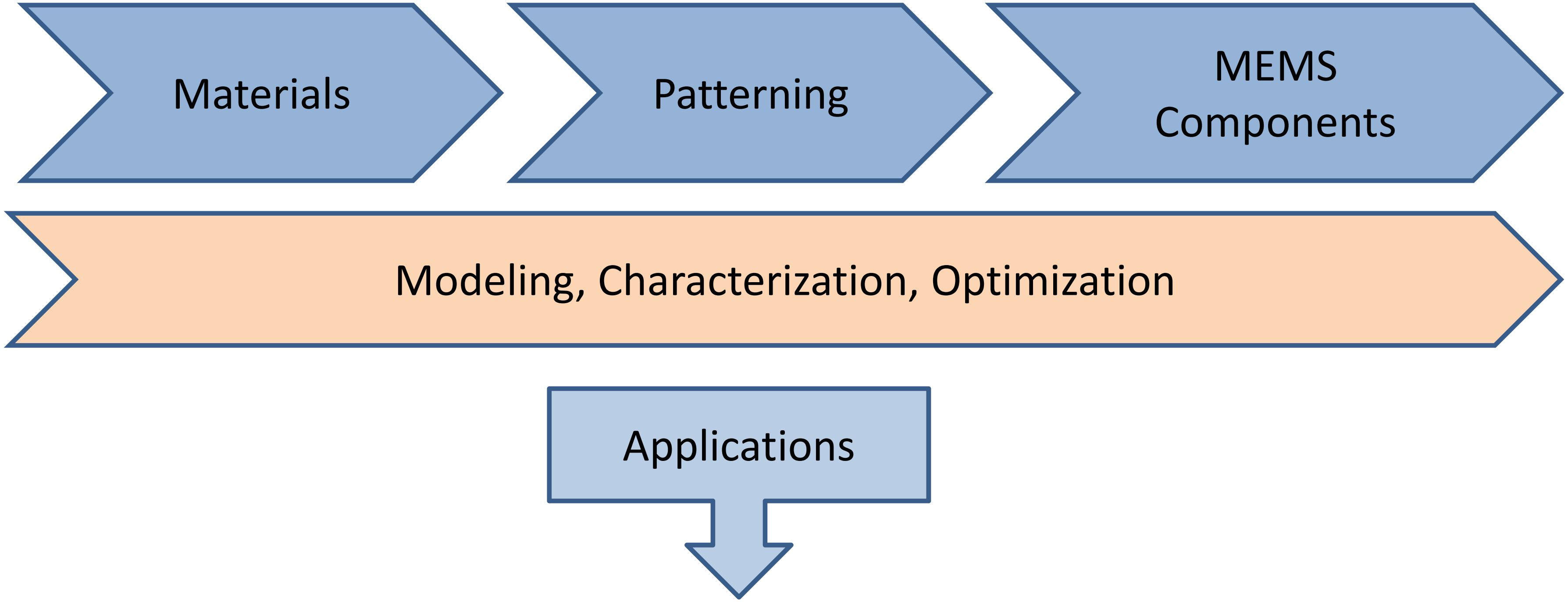

Claude
Pellet

- 6 PhD students
  - Frank Bokeloh
  - Pierre-Henri Ducrot
  - *Simon Grall*
  - Marco Pereira
  - *Maria Isabel Rua Taborda*
  - *Onuma Santawitee*

PRIMS: PRInted MEMS Team

From materials to devices … in the MEMS field

Alternative solution to all-silicon MEMS (‘home-made’ → ‘printed’)
or silicon MEMS (processed in other Labs)



Materials

Patterning

MEMS Components

Modeling, Characterization, Optimization

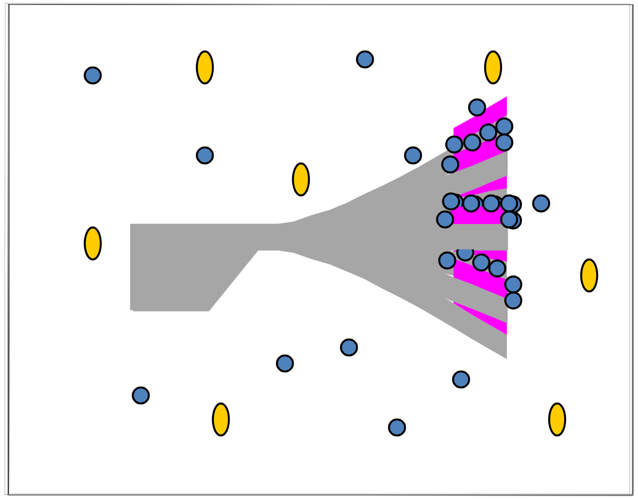
Applications

Chemical sensors, Materials characterization, Physical Sensors, Actuators, Energy Harvesting, Structural Health Monitoring, Cell Mechanics

(Chemists, Physicists, Technologists and Electronics Engineers)

Silicon cantilever: from design to gas detection

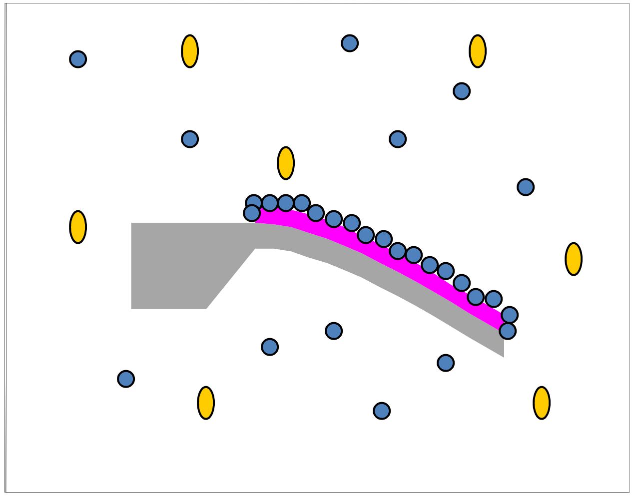
Dynamic mode



Mass modification

Variation of the resonant frequency

Static mode

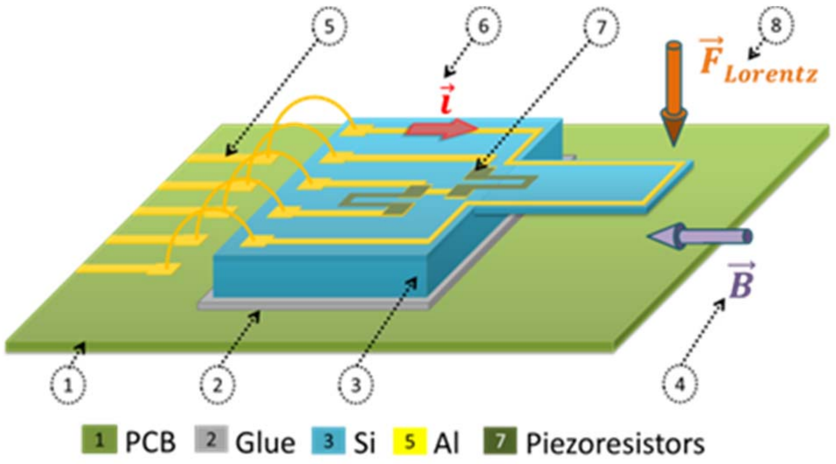


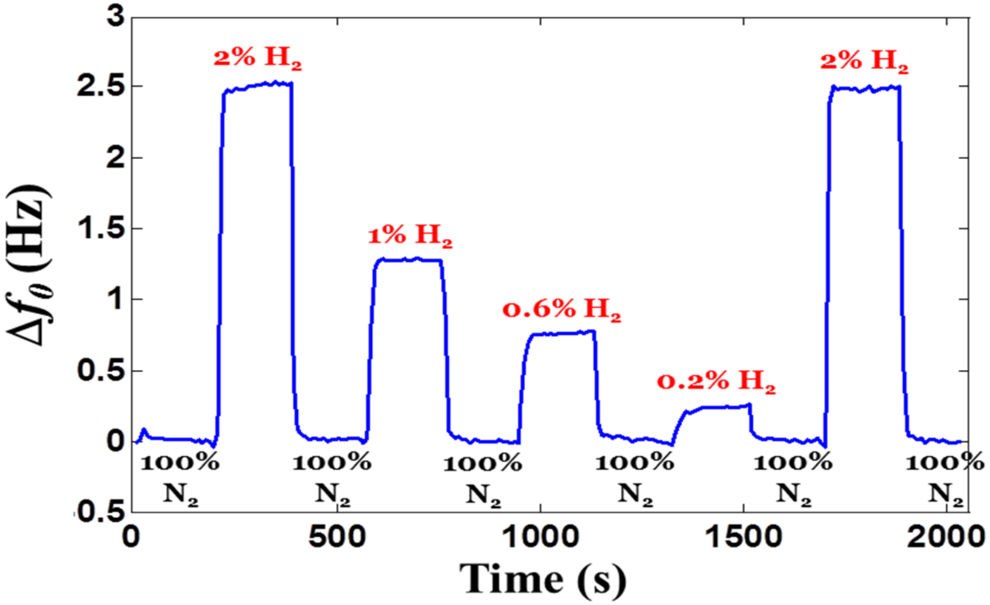
Stress/strain modification

Variation of deflection

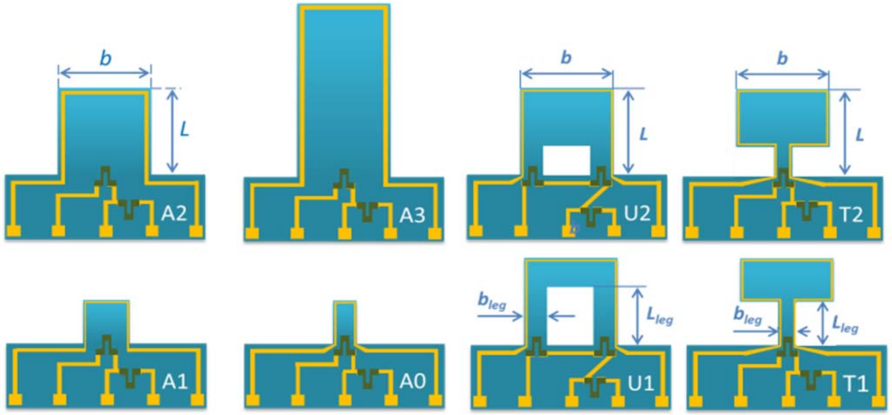
Silicon cantilever: from design to gas detection

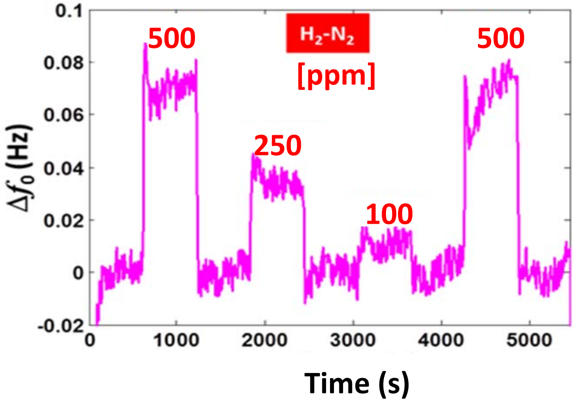
Dynamic mode: Detection with uncoated microcantilevers





L=1mm, b=1mm, h=5µm, f_0=4.5kHz

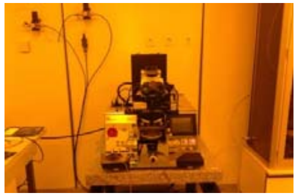




M.T Boudjiet *et al.*, **Sensors and** Actuators **B**,(2015)

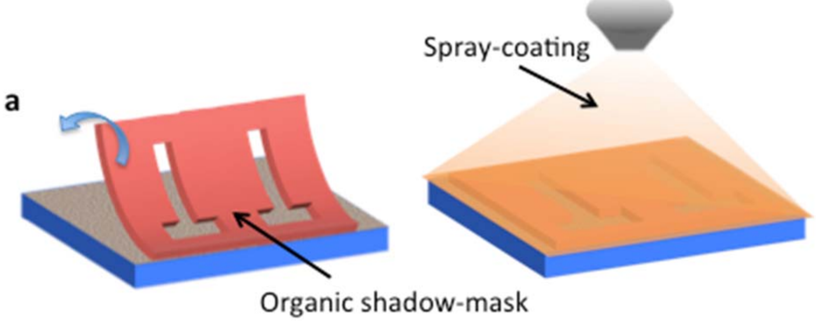
Sensors and MEMS patterning

Clean room facilities , class 10000 (TAMIS)



- Screen-printing (+ sacrificial layer)
- Spray + stencil (+ sacrificial layer)

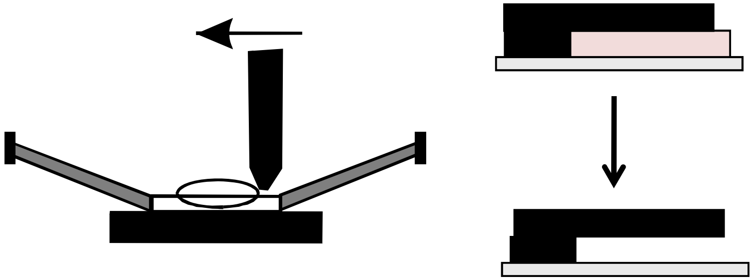
- Spin-coating + Xurography (= cutting plotter)

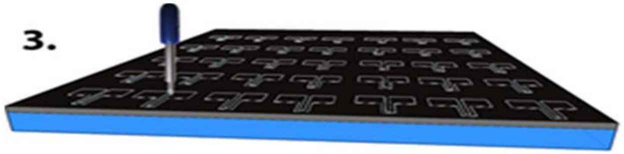


ADVANTAGES :

- *low cost*
- *collective fabrication*
- *large choice of substrates and starting materials*
- *components and electronics*
- *bio-compatibility (organic)*
- *harsh environment (inorganic)*

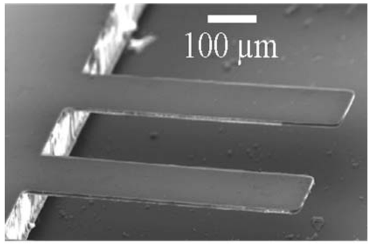
…



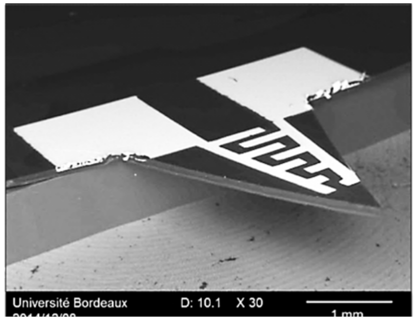


Examples of printed components

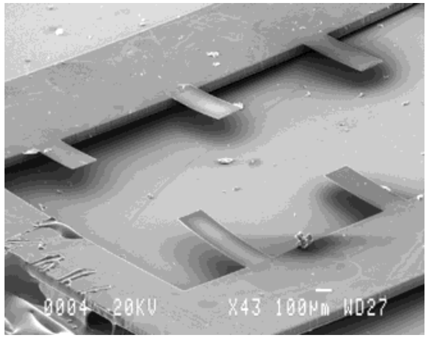
Photolithography + wafer bonding: SU8



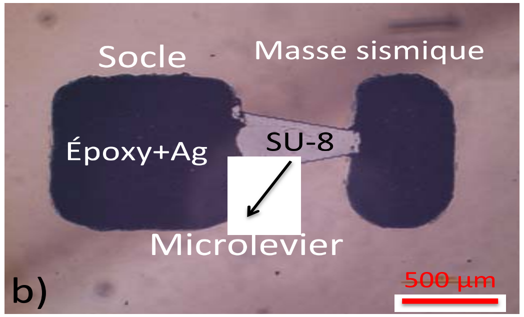
Photolithography: CNTs /SU8



Stencil + spray: MIP

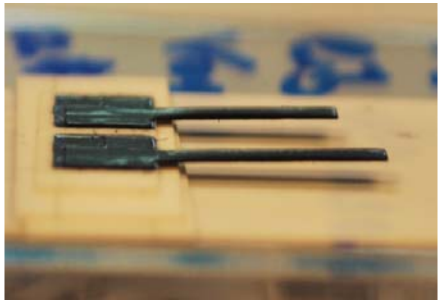


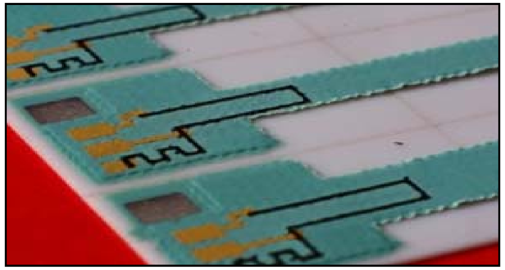
Screen-printing + Photolithography: SU8 + Ag/époxy

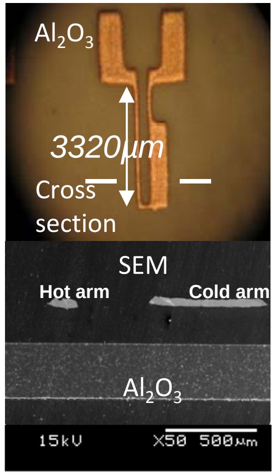


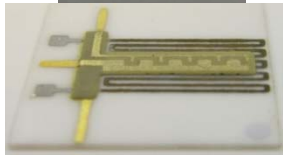
Xurography: CNTs/SU8

Screen-printing: Cu, Pt, vitroceramic, PZT, epoxy/C





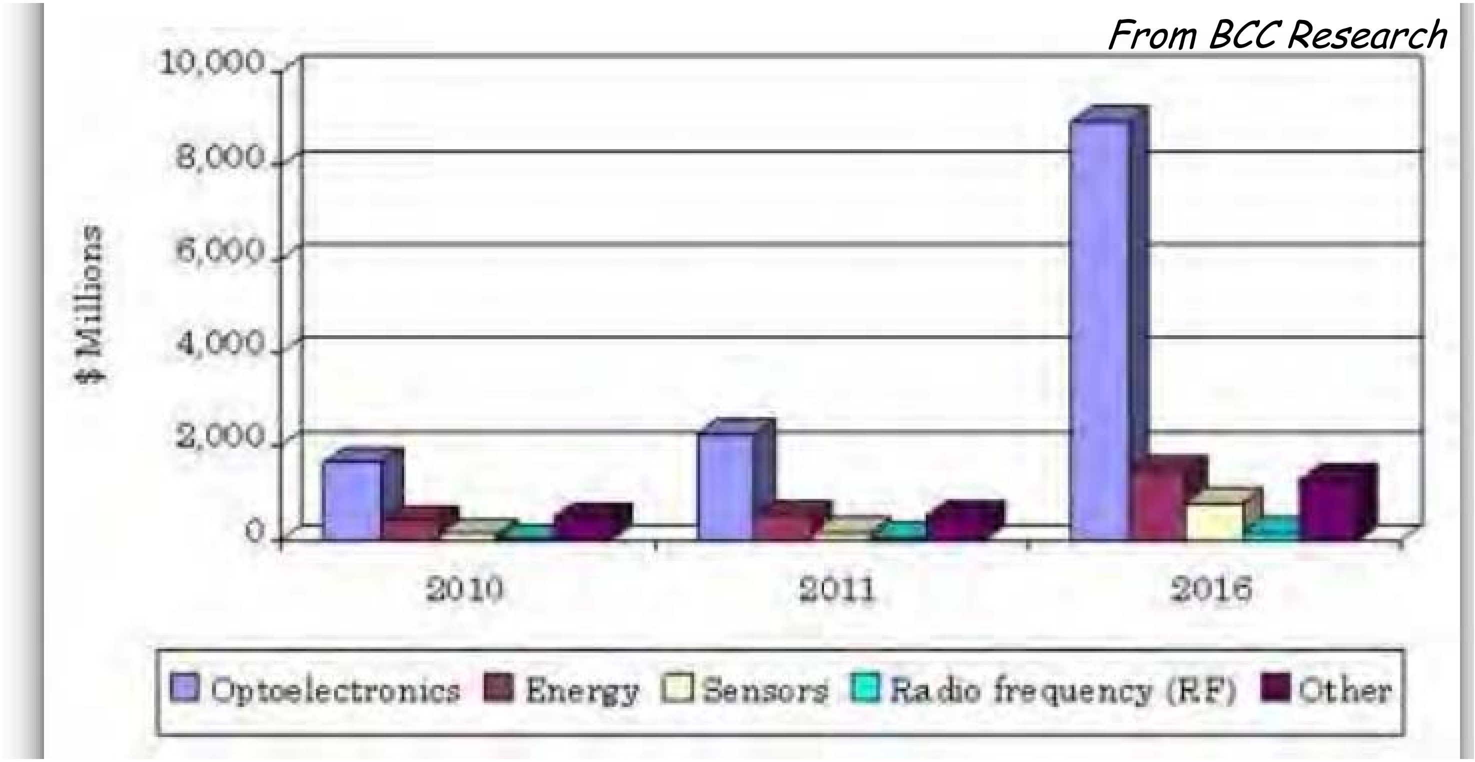




Printed technologies for Electronics and MEMS

Printed technologies →

growing demand of the electronic market



From BCC Research

- ✓ **Low cost:** additive process, fast/high volume, low capital investment
- ✓ **Good enough quality**: repeatable, good resolution
- ✓ **Capabilities:** printed layers, substrates, form factors, temperature process

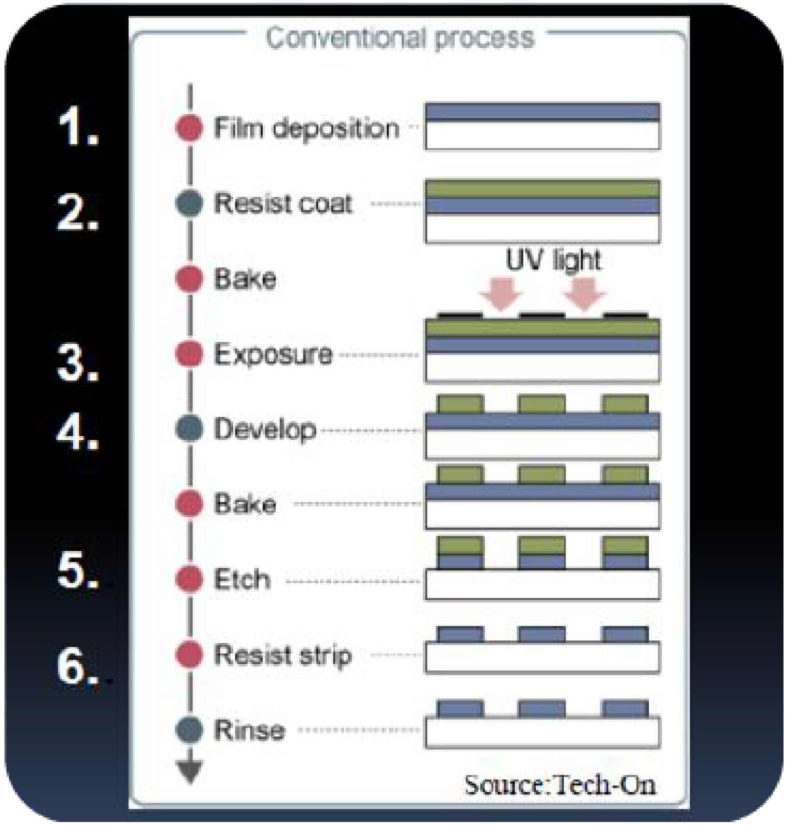
Printed technologies →

Additive process (≠ substractive process)

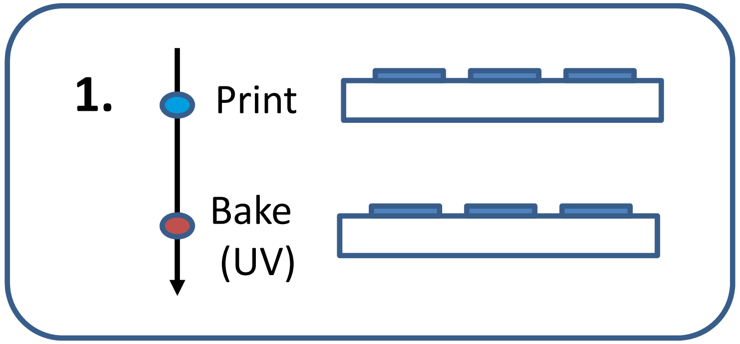
Conventional layer application:
6 steps

Simpler

Printing layer application:
« 1 » step



Source:Tech-On



1. Print

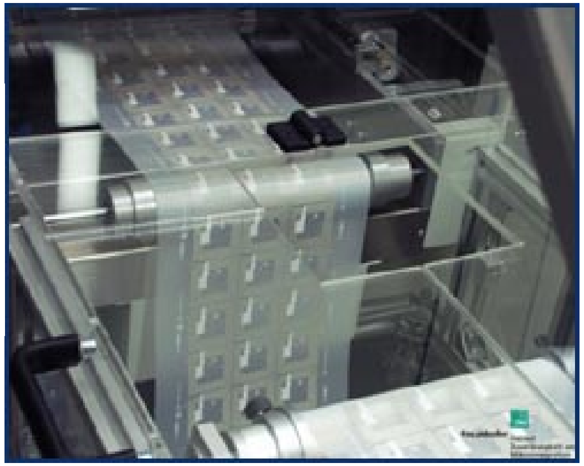
Bake (UV)

High speed printing

- ❑ **High speed printing ⇨ Low cost**

⇩

R2R
(Roll to roll,
Reel to Reel
printing processes)



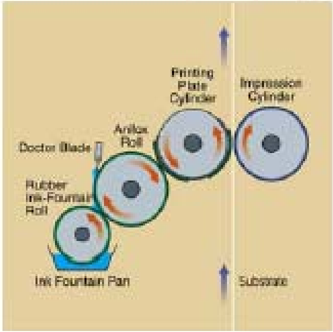
IZM Fraunhofer, R2R screen-printing

RFID cost per tag

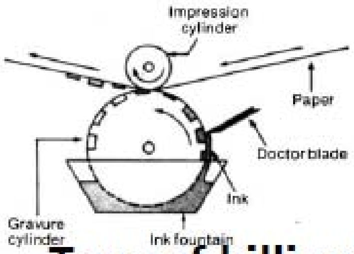
Flat-bed screen

Rotary screen

Flexography



Gravure



50m/min

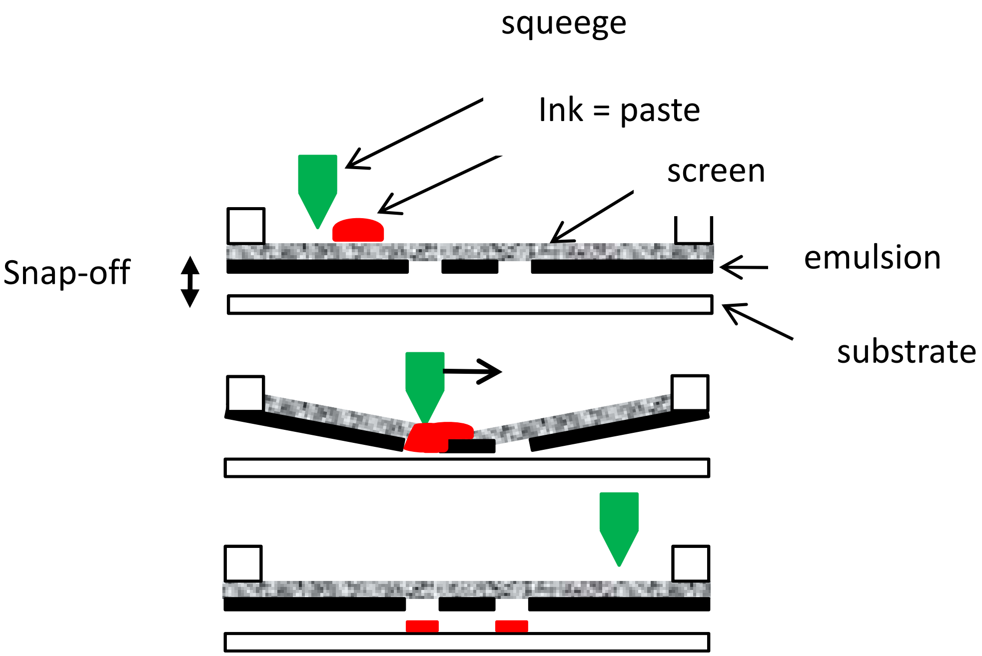
100's million

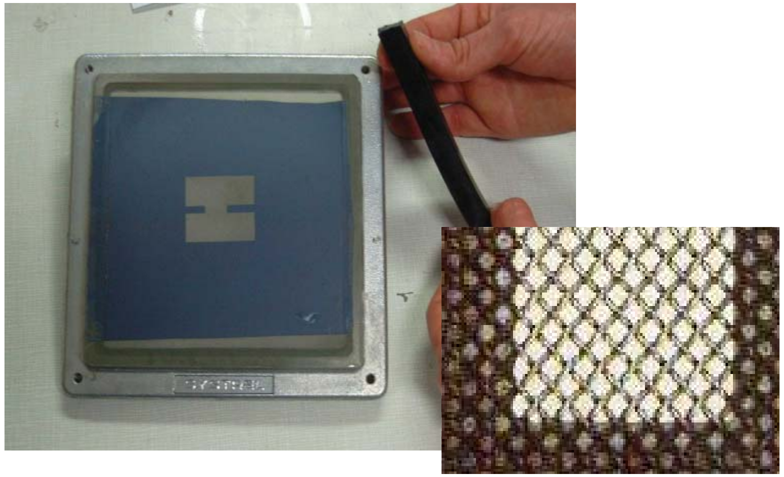
Tens of billions

Print Speed

Screen-printing

- ❑ **Most simple, flexible and cheap**



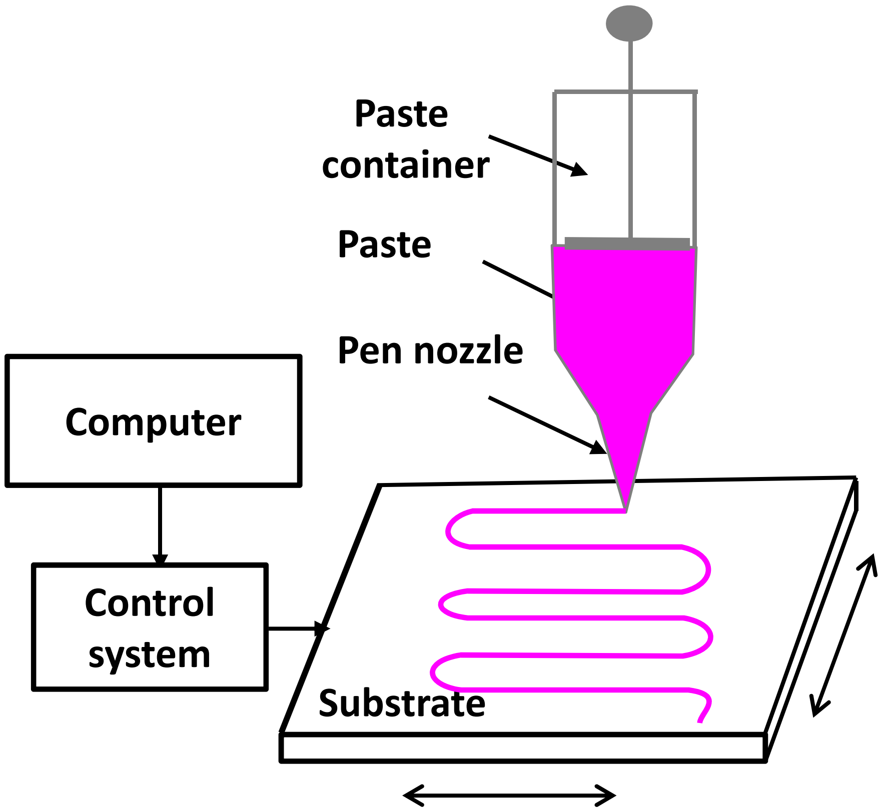


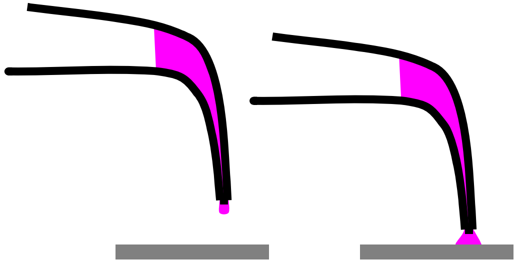
1. Patterning of a screen by photo-lithography

2. Paste transfer onto a substrate through the screen by a squeege

Direct printing techniques

- ❑ **Filament microdispensing systems (Micropen®)**





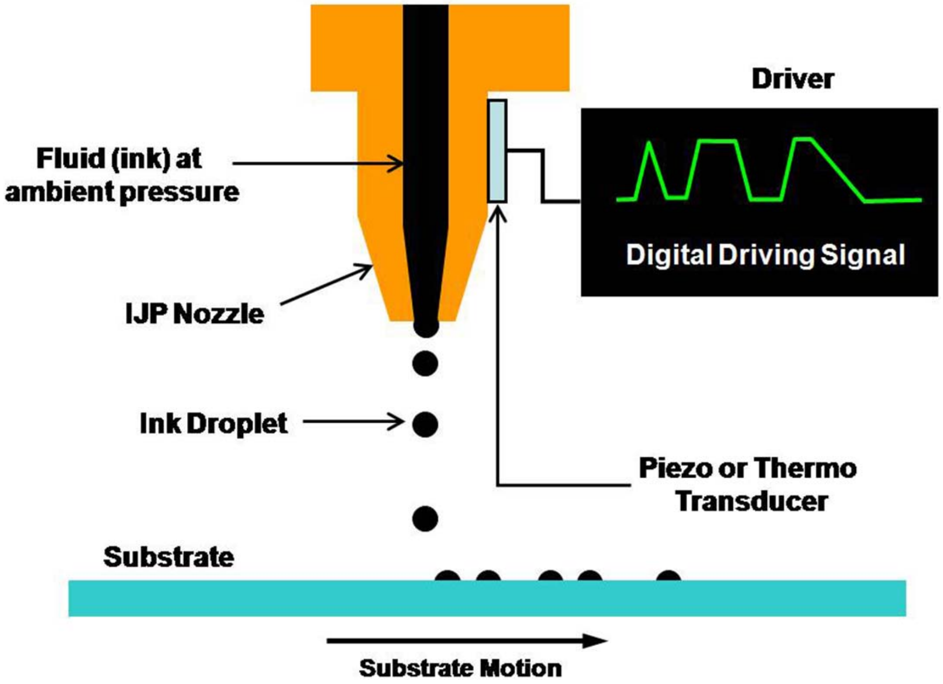
1. Printing pattern created on software

2. Printing via capillarity action

3. Ink loaded in a syringe, compressed and squeezed out into the writing head by controlled pressure

Direct printing techniques

- **Inkjet technology (DOD Drop On Demand *)**



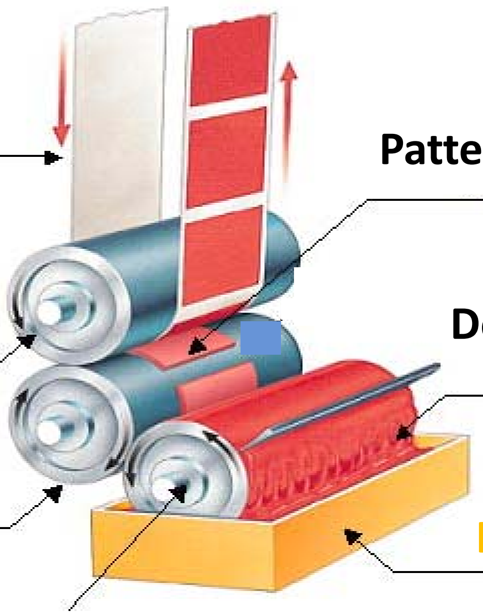
http://spie.org/x18497.xml?ArticleID=x18497

Direct projection of drops (∅15-200μm) on localized area

* CIJ continuous inkjet exists

Reel to reel printing techniques (R2R)

❑ Flexography printing (flexo)



Flexible or rigid substrate

Pattern

Hard Impression cylinder

Doctor blade

Ink

Elastic printing plate
(rubber or polymer)

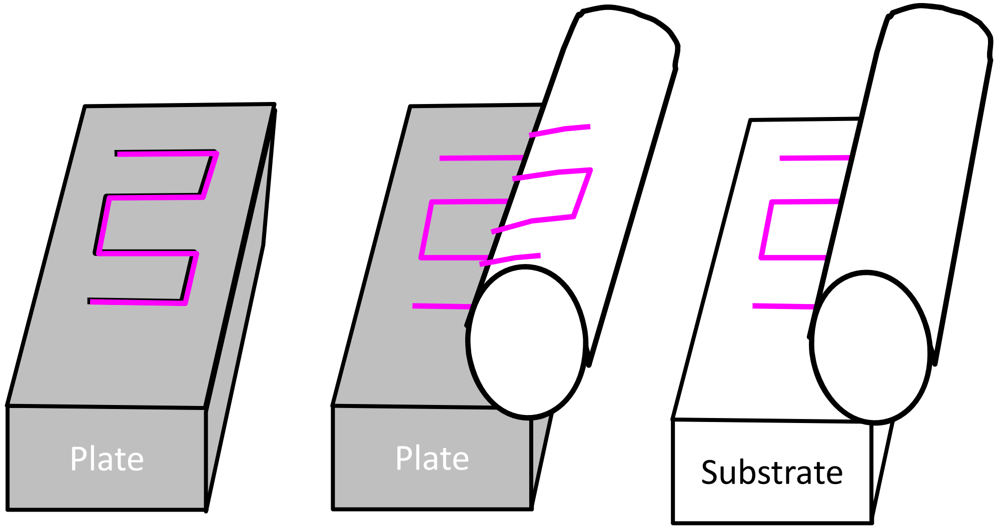
Ink reservoir

Ceramic roller ('anilox')
with cells of regular size and shape according to thickness and resolution needed

1. Pattern engraved on an elastic printing plate
2. Ink in contact with the anilox /scraping off any excess of ink with the doctor blade
3. Ink transfer on the elastic printing plate
4. Printing on the travelling substrate thanks to the hard impression cylinder

Gravure off set printing

❑ Gravure printing process



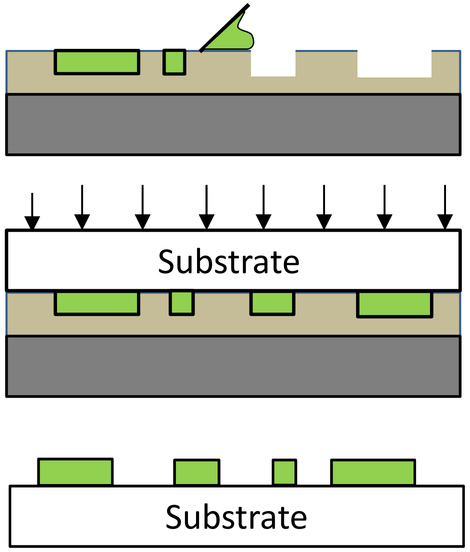
1. Pattern to be printed engraved on the plate

2. Filling of engravings by doctor-blade method

3. Picking up the ink by rolling action

4. Transfer of the ink to the substrate by similar rolling action

❑ Direct gravure printing process



1. Patterned silicone polymer fastened on a smooth metal plate

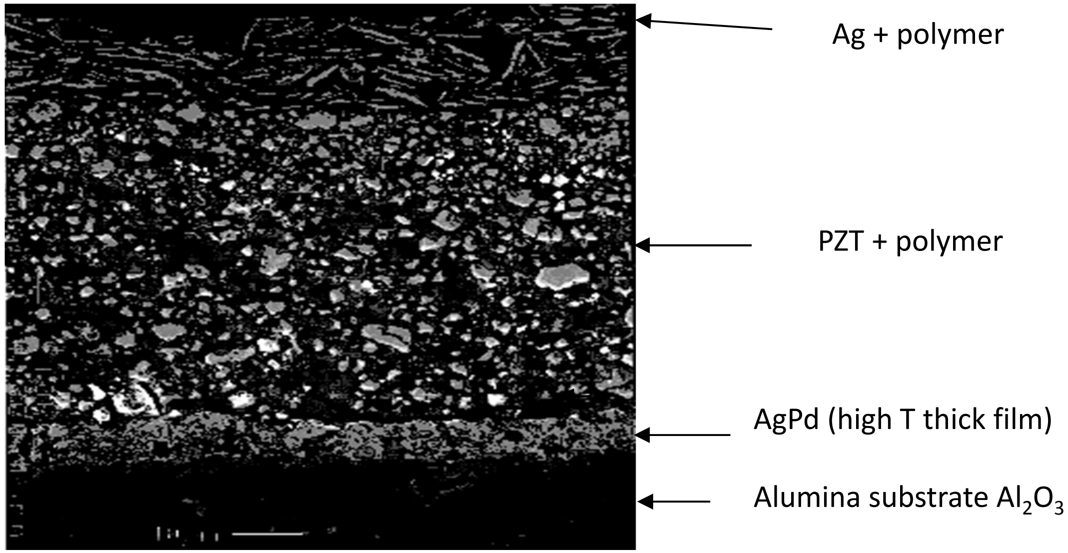
2. Filling of the grooves in the silicone

3. Transfer of ink by pressing the substrate against ink

Kittilä et al, IEEE transactions on electronics packaging manufacturing, 2004

Printed technologies : summary

	Resolution / Thickness	Substrates	Pastes/inks	Viscosity *
			Conductive, resistive, dielectric… ***Polymer inks*** (T_{curing} <200°C) - Organic polymers, - Composites (polymer + powders) ***Inorganic inks*** (400°C<$T_{sintering}$<1000°C) = temporary organic binder + powder	0.1-10 Pa.s
				0.005-500 Pa.s
				<20m Pa.s
				0.1-10 Pa.s
				0.01-0.5 Pa.s



(from Southampton University)

* *Water = 1mPa.s, olive oil = 0.1 Pa.s, Honey= 10Pa.s*

Screen-printed PZT MEMS

Processing of piezoelectric MEMS

Thin films

☺ Combination with Si micro-machining, precise frequency

☹ Poor piezoelectric properties, small displacement , unsufficient forces

Ceramics

☺ Good piezoelectric properties

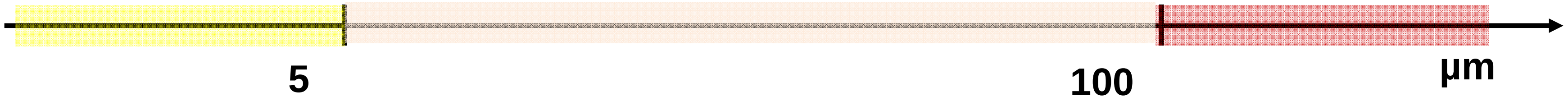
☹ Thickness, component assembly

Thick films

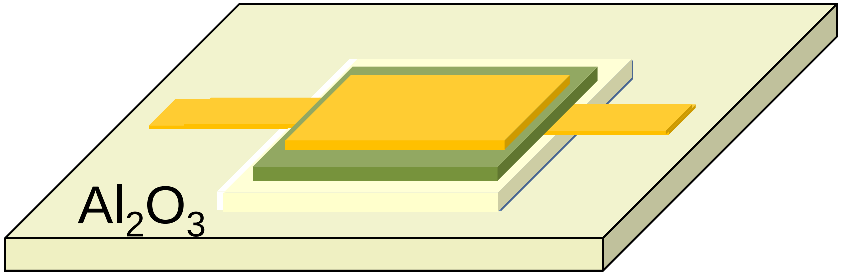
☺ Good piezo. properties

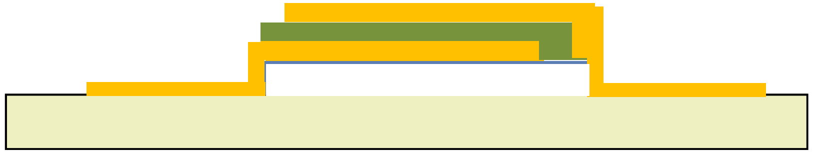
☺ Force > force with thin films

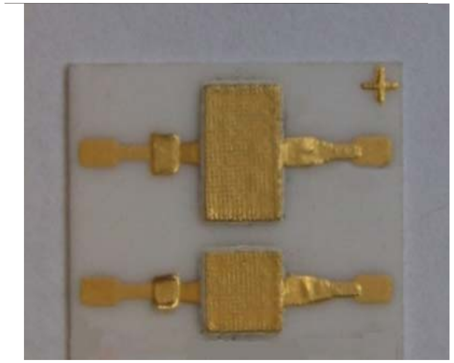
towards free-standing thick films



Processing of piezoelectric MEMS







1. Sacrificial layer (epoxy+$SrCO_3$) curing 20min 120°C

2. Bottom electrode (Au), drying 20min 120°C

3. PZT+ sintering aid drying 20min 120°C

4. Top Electrode (Au), drying 20min 120°C

5. Isostatic pressure (1kBar= 100MPa, 1min)

6. Cofiring 2h, 900°C
   ➔[$3.3 \times 3.3 \times 0.08 mm^3$]

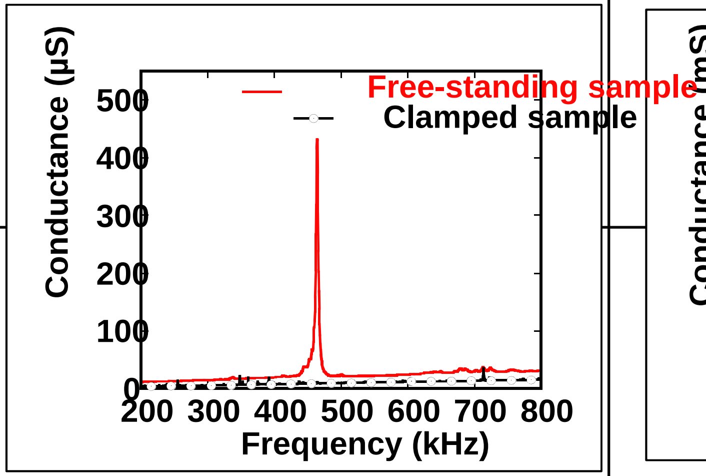
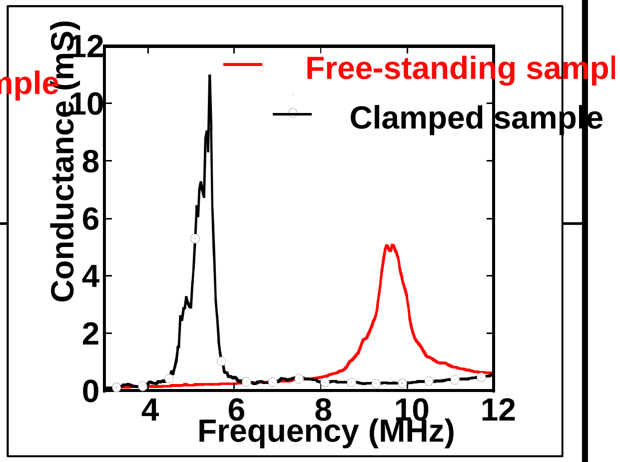
7. Sacrificial layer removal (0.9mole.L^{-1} H_3PO_4)

8. Poling (270°C, 5kV.mm^{-1})

9. Characterization

Comparison clamped/free-standing PZT

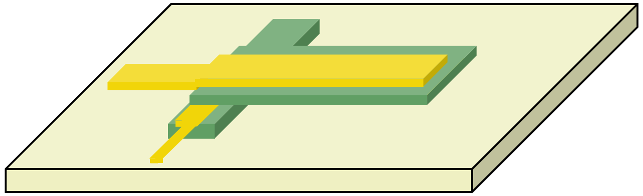
3.3x3.3x0.08mm^3

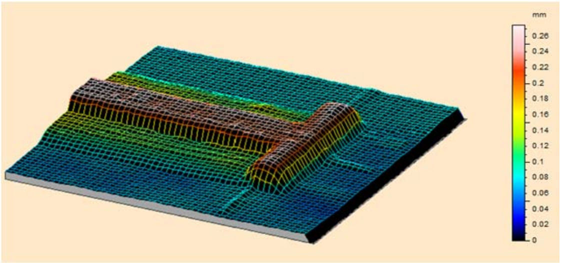
Mechanical vibrations	**In-plane** (perpendicular to the poling axis)	**Out of plane** (parallel to the poling axis)
 Clamped		
 Released		

✓Admittance analysis (HP4194A)

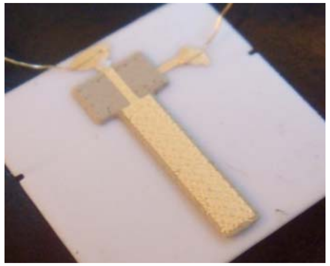
Au/PZT/Au realizations

Cantilever



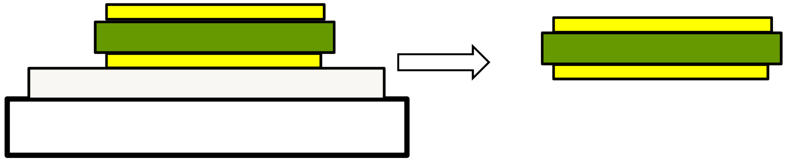


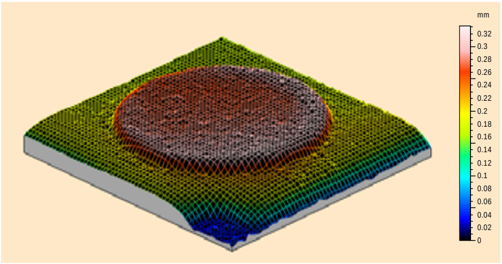
8x2x0.1mm^3

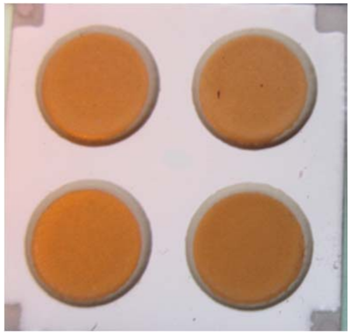


↳ Gas detection and viscosity measurement

Disk



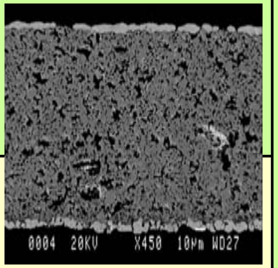
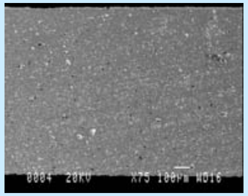




∅9.5mm x0.2mm

↳ Actuation and damage detection (SHM)

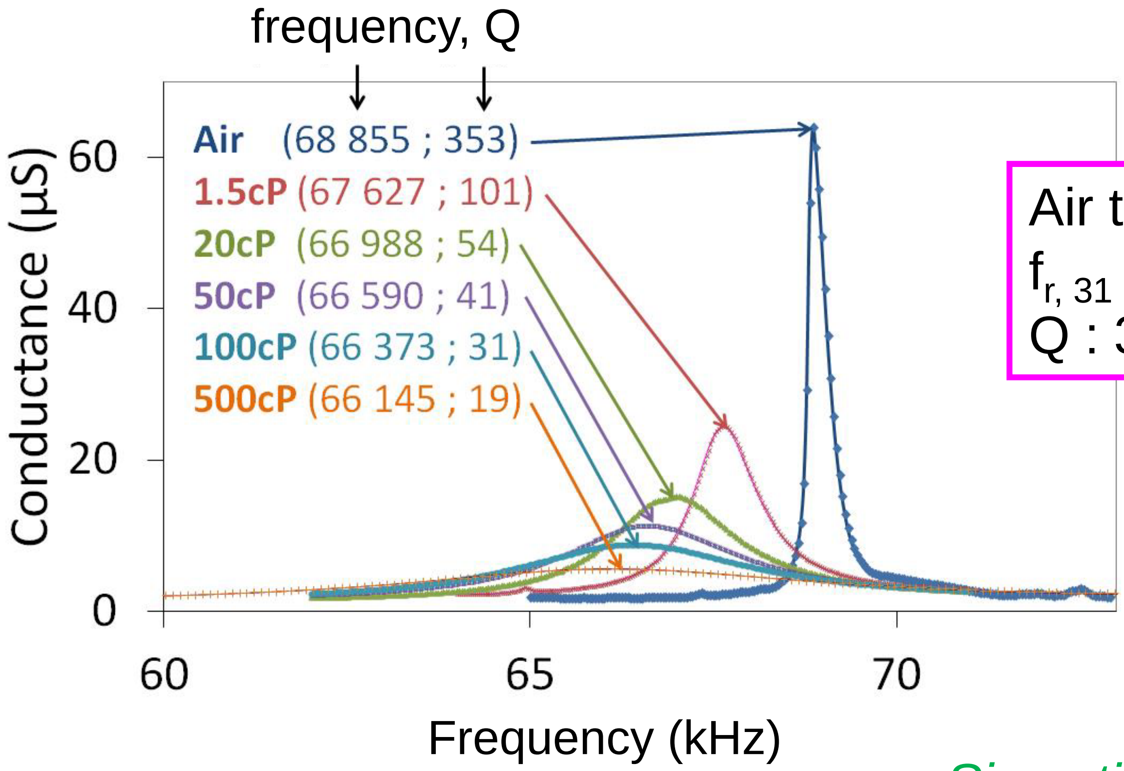
Characterizations (µstructure et electromechanical)

	Porosity	Density (g/cm^3)	K_T^{33}	k_p (%)	$-d_{31}$ (pC/N)	Q	f_{res}(kHz)
Au/PZT/Au disk ∅9.5mm, t=190µm		5.5	410	15	40	350	170
Au/PZT/Au cantilever 8x2x0.1mm			330	-	80	400	70
Au/PZT/Au pellet ∅11.5mm, t=950µm		7.2	900	46	80	280	140
PIC151 commercial ∅10mm, t=0.3mm	-	7.7	2900	66	200	90	240

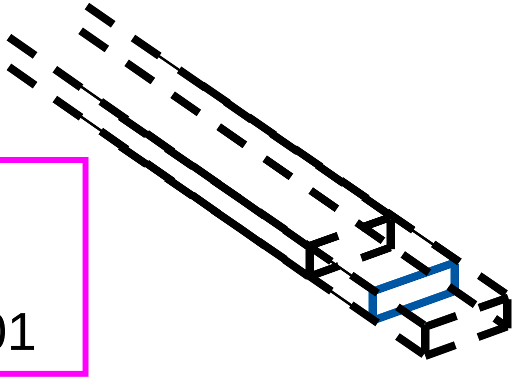
Thick-films properties < ceramics … MEMS tests

Au/PZT/Au cantilever: sensor

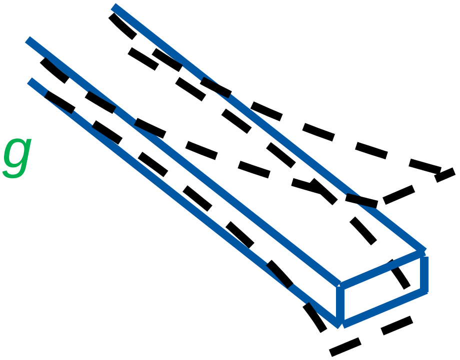
Viscosity measurement, use of longitudinal mode, uncoated



Air to 1.5 cP
$f_{r,\,31}$ ➔1.8 %
Q : 353 ➔ 101

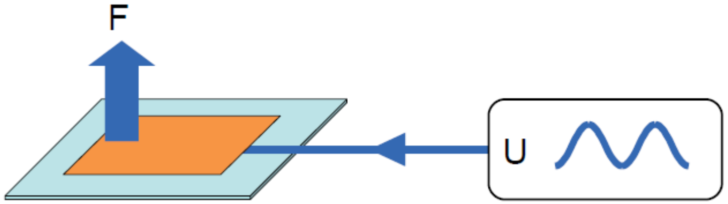


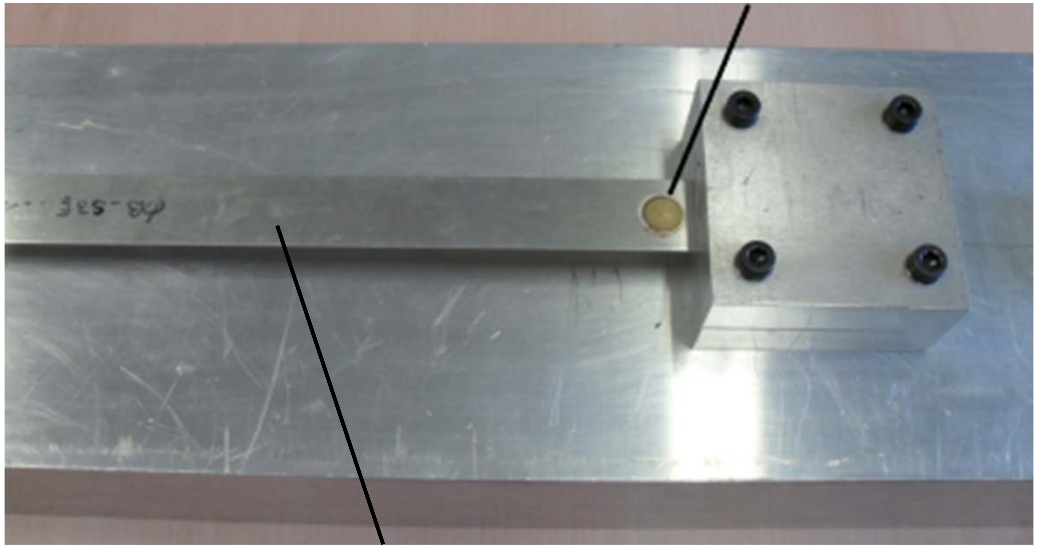
Si cantilever, bending
Air to 1cP (water)
$f_{r,\,flexural}$ ➔ 50 %
Q =1500 ➔ ≈ 10



I. Dufour et al, Sensors and actuators 2014

Au/PZT/Au disk: actuator





Au/PZT/Au disk ∅9.5mm, t=190µm

Steel beam (200x20x0.48mm^3)

U=100 V (peak to peak)

f=10 Hz (beam's resonance)

⇨

Oscillations: speed=73 mm/s

Max amplitude 1.16 mm (tip)

PI ceramic (∅10 mm, t=300 µm)

Oscillations: speed= 380 mm/s

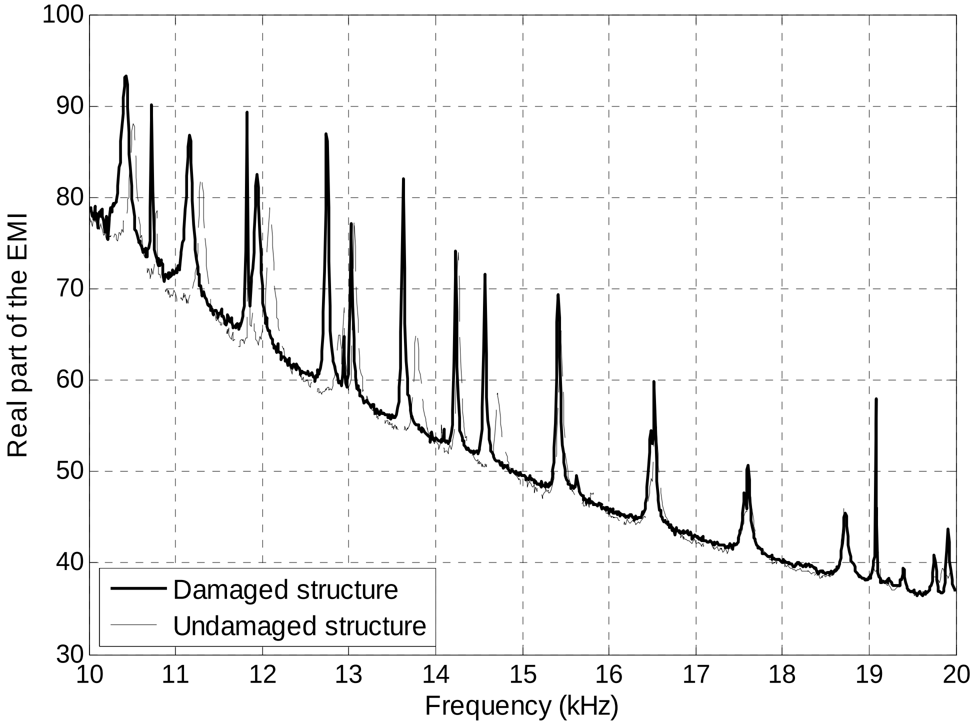
Max amplitude 6.02 mm

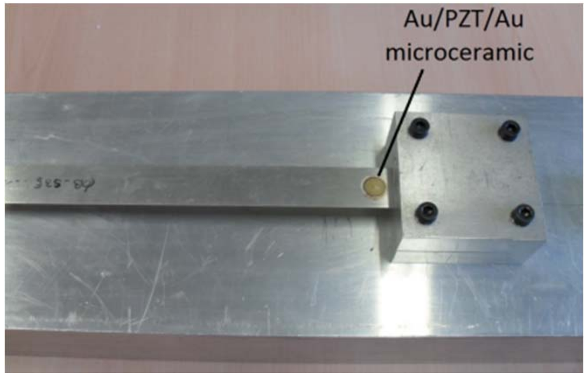
Au/PZT/Au disk: sensor

↳ Structural health monitoring

Electro-Mechanical Impedance method (EMI):

damage ⇨ change of the electromechanical coupling of the ceramic bonded or embedded in structure





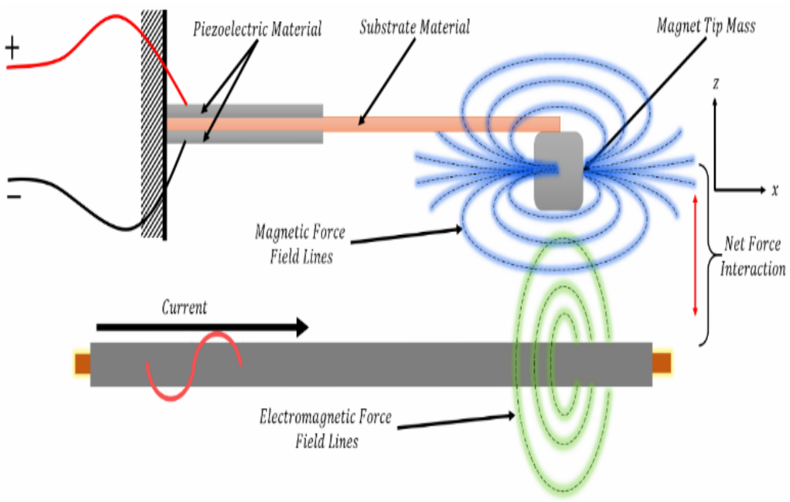
$$\Delta f_{\text{mean}}(\%) = \frac{\sum_{n=1}^{N_{pks}} \left|f_n^D - f_n^{UD}\right| / f_n^{UD}}{N_{pks}} * 100\%$$

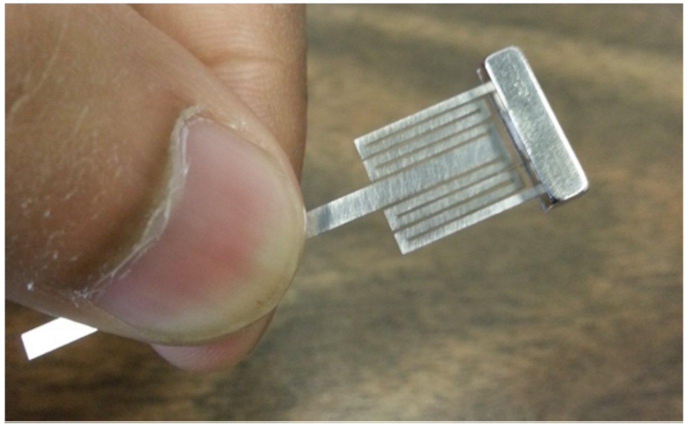
H. Debéda et al, Int. J. Appl. Ceram. Technol., 2014

Alternative to free-standing PZT: PZT supported on stainless steel

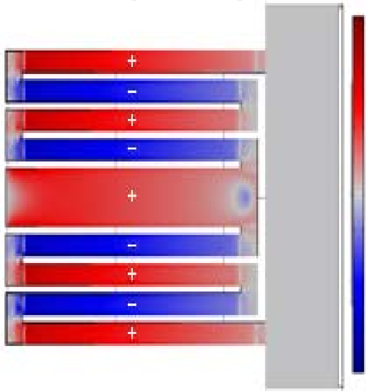
Energy harvesting for smart grid

Piezoelectromagnetic cantilever beam





Optimized ***meander shaped beam*** and Strain contour plot showing tension (red) and compression (blue).



- In North America AC power transferred at 60 Hz

- Need to tune system to 60 Hz for resonance resulting in maximum power output

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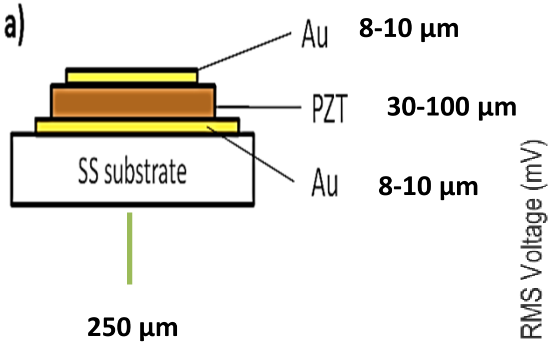
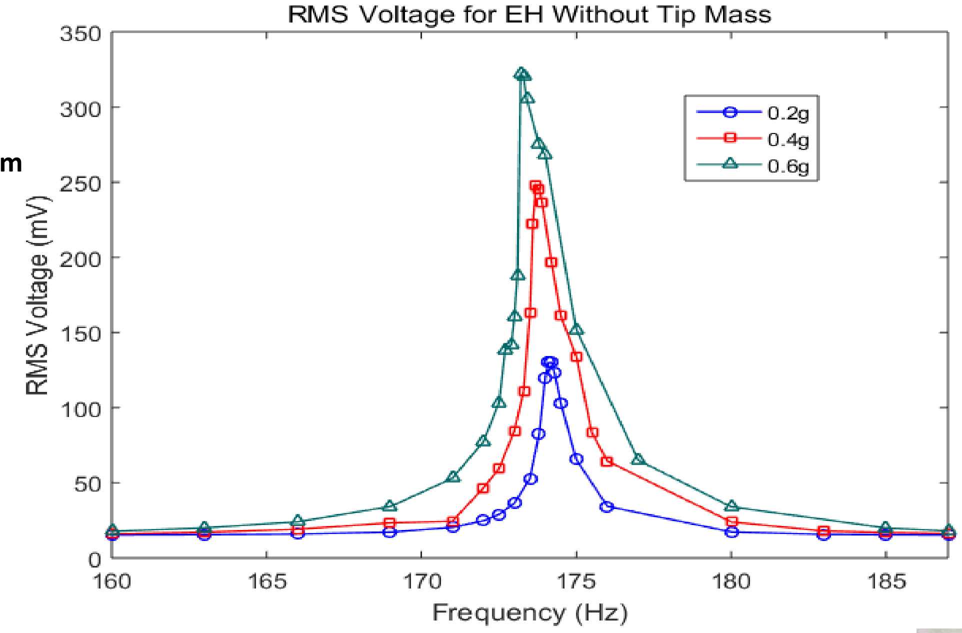
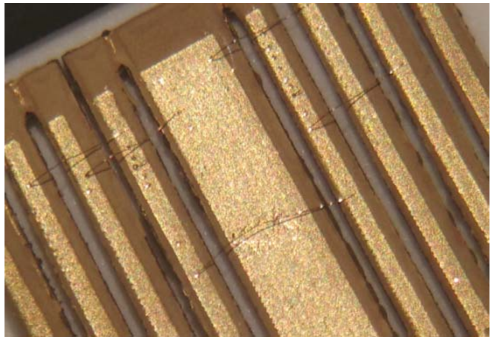
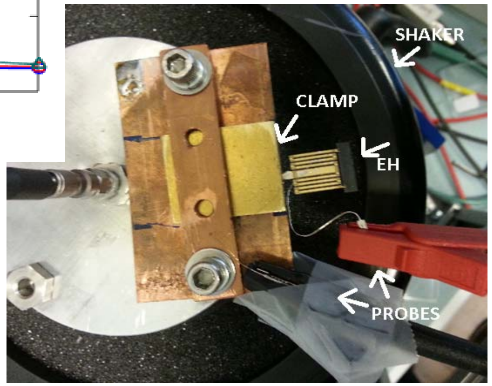
Alternative to free-standing PZT: PZT supported on stainless steel

Energy harvesting for smart grid









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PowerMEMS 2016, E Fernandes et al.

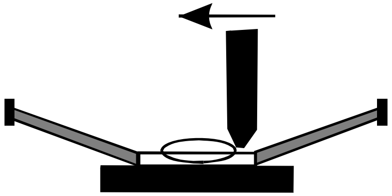
Printed gas sensors:
toward RT detection

ims

université de BORDEAUX

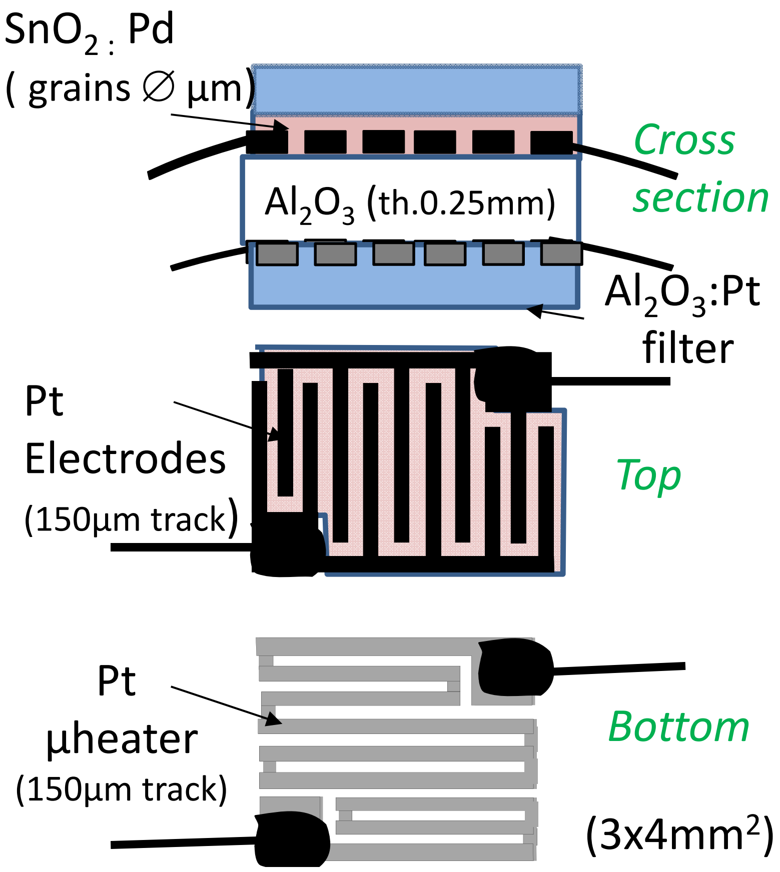
Gas sensor requirements

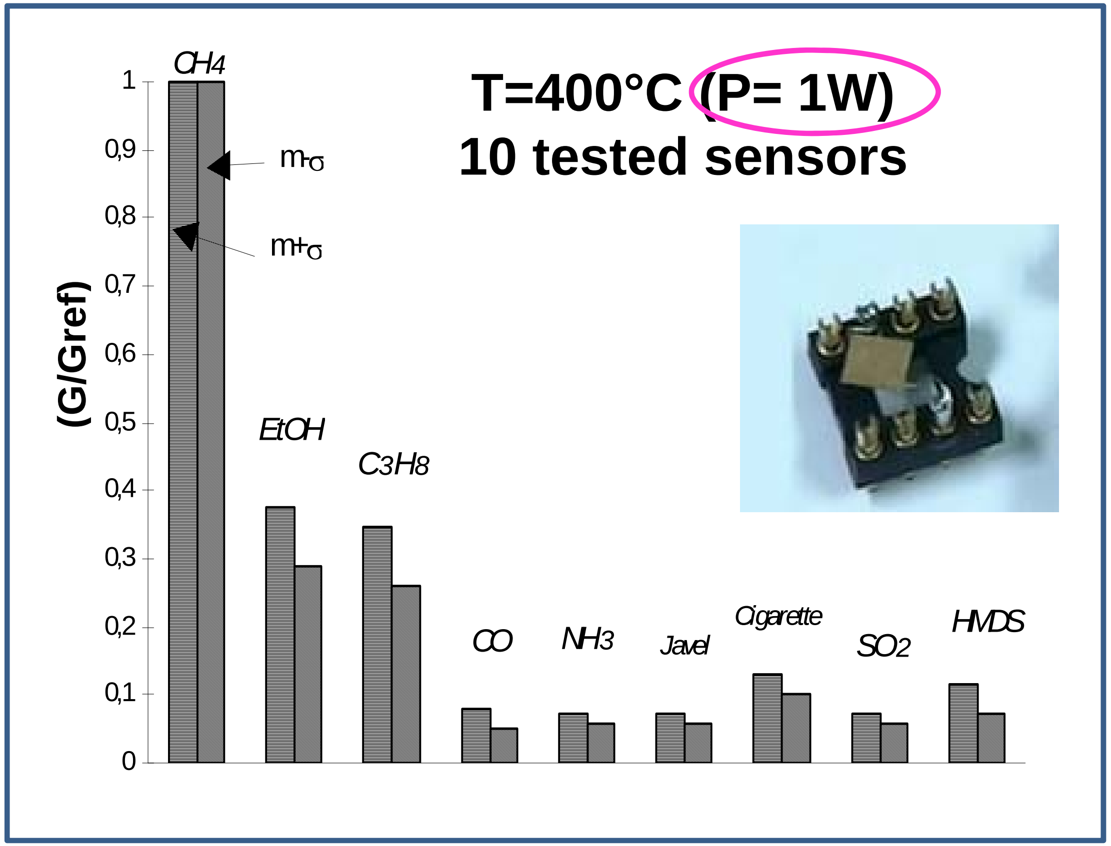
- Low cost → Screen-printed gas sensors
- Portable
- Good sensitivity → Nano-materials
- Selective → Multi-sensors
- Stable
- Low consumption → Toward room temperature
  - Nano-materials
  - UV activation
  - Cantilever gas sensors
- User friendly operation
- Easy calibration
- Cheap and easy maintenance
- Flexible and biocompatible if possible …



Selectivity toward CH_4: multi-sensors

Resistive (SnO_2) and catalytic sensors (Pd, Pt)





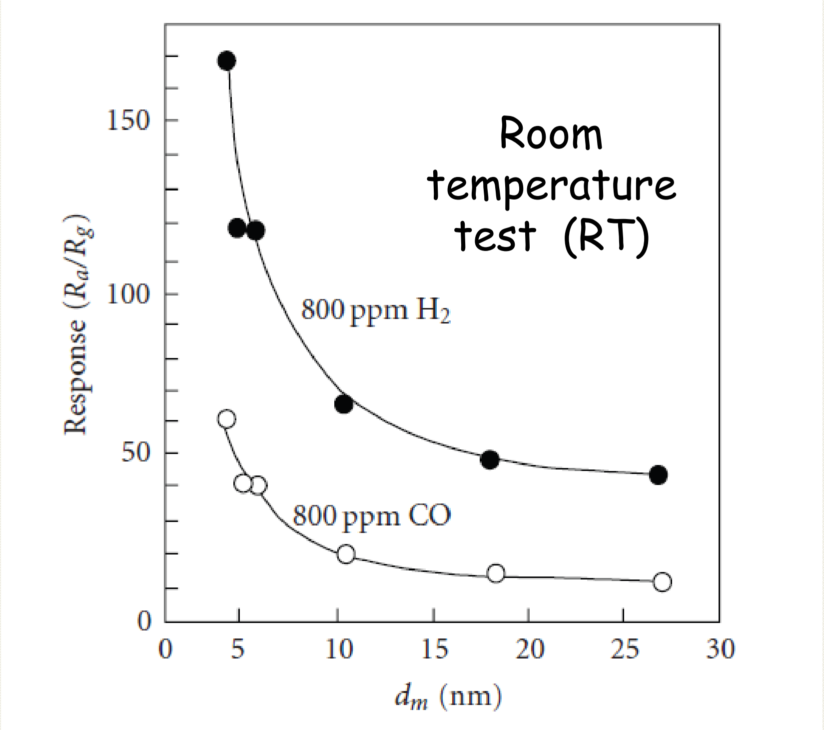
⇨Sensitive (R_{air}/R_{CH4} ~6), selective and stable

≡ Figaro MOX sensors (GDF tests)

H. Debéda *et al.*, Sensors and Actuators B,(1997)

Reduction of operating T ? ⇨ nanomaterials

- Metal Oxide Semiconductors MOX (SnO_2, ZnO, WO_3…)

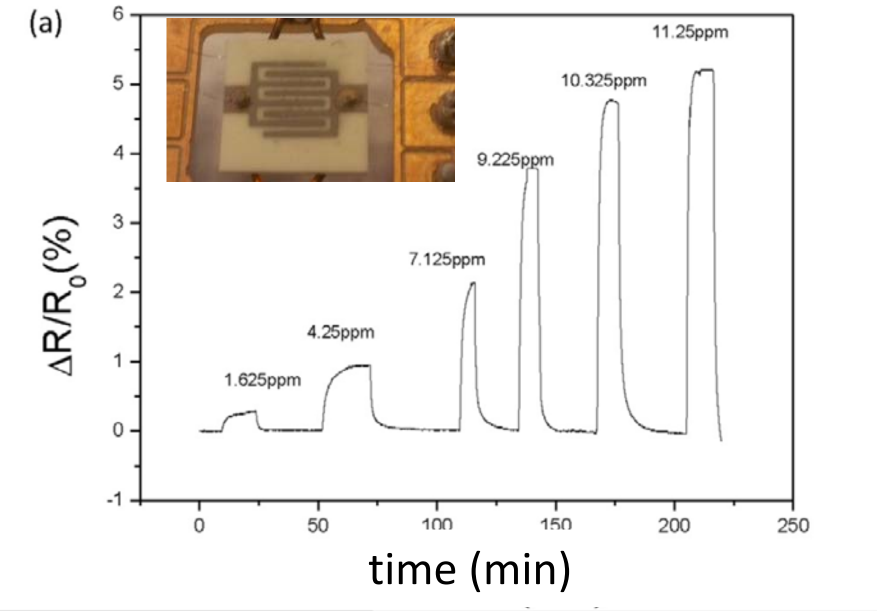


Brush coated SnO_2 thick film, influence of nanoparticle size

Journal of Sensors, 2009

N. Yamazoe and K. Shimanoe

- Carbon nanotubes CNTs



Benzene detection at room temperature

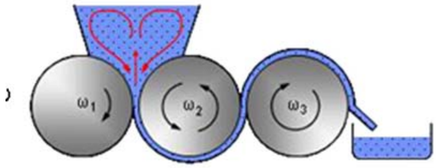
Sensors and Actuators B: Chemical, 2013

I. Hafaiedh, W. Elleuch, P. Clément, E. Llobet, A. Abdelghani

Nanoceramics, H_2 resistive ZnO sensors

1. ZnO nanopowder (**N**anotech ®, APS 40-100nm, S.A. 10-25m^2/g)

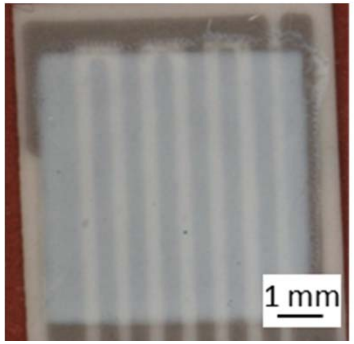
2. Paste preparation
   - 30%wtZnO + organic binder (ESL400)
   - 3 roller mill → viscosity 0.1-10 Pa.s



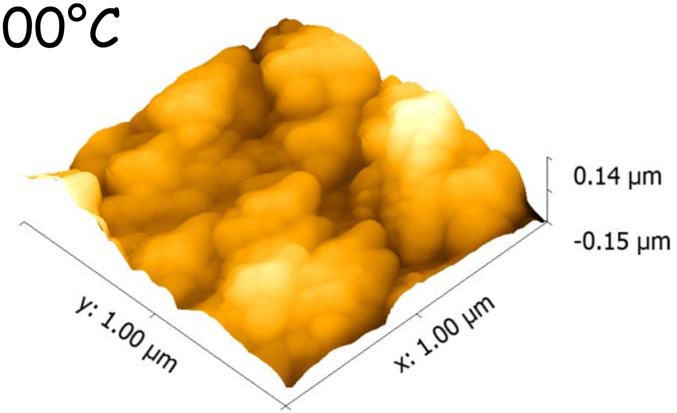
3 roller mill

3. Printing on Al_2O_3 substrate (Pt IDTs + Pt μheater)

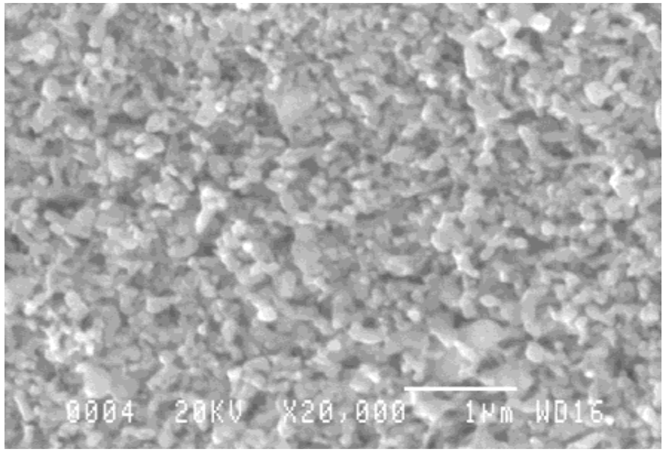
4. Firing 30min 400°C



8.5x6.3x0.6mm^3



AFM image

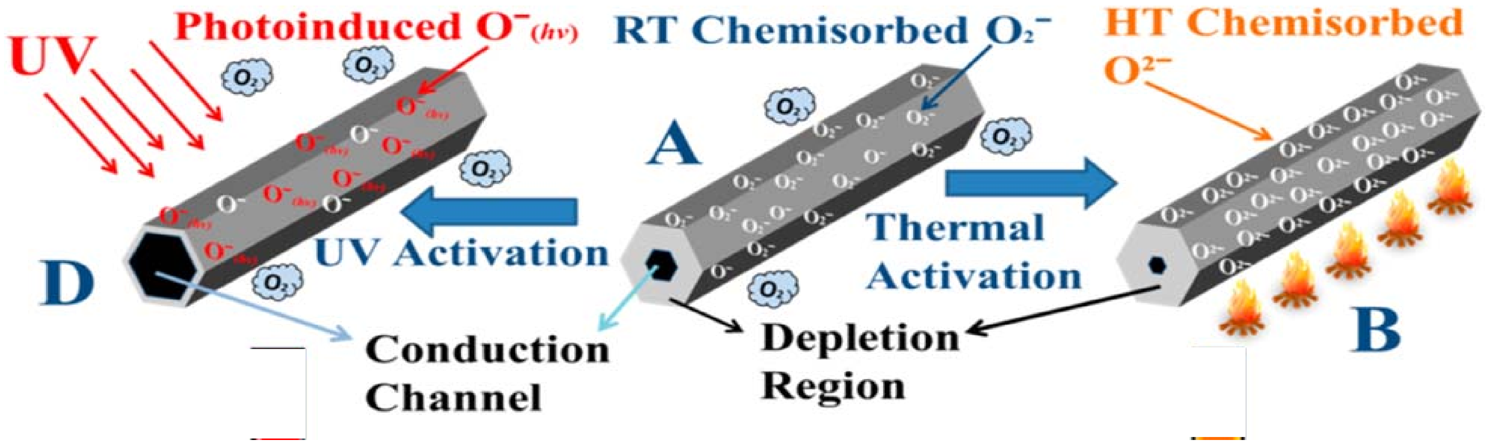


SEM image

Nanograins ~ 100nm

ZnO nanoceramics, RT H_2 detection

Higher sensitivity ⇒ Energy activation, UV or T



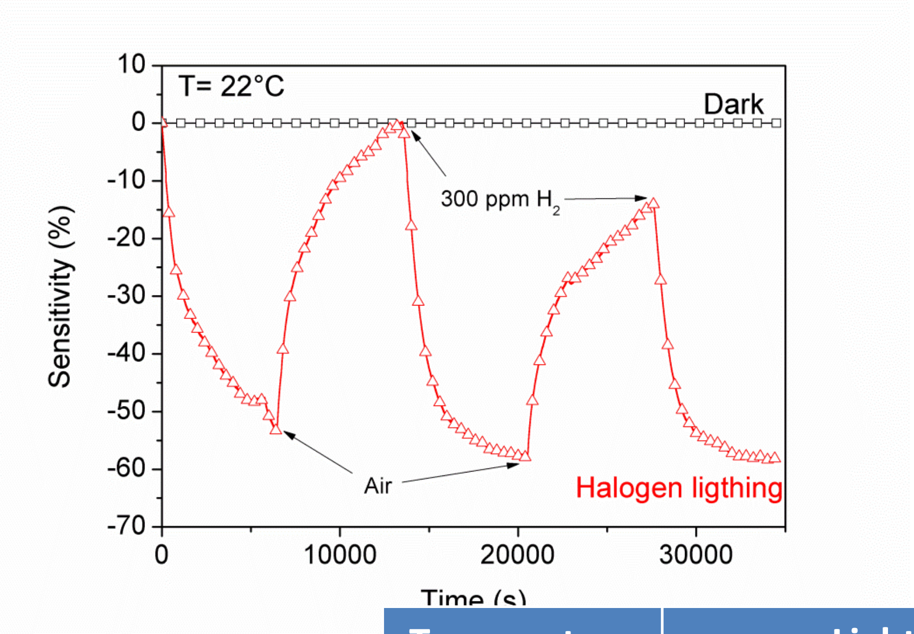
J. Phys. Chem. 2013, M. R. Alenezi

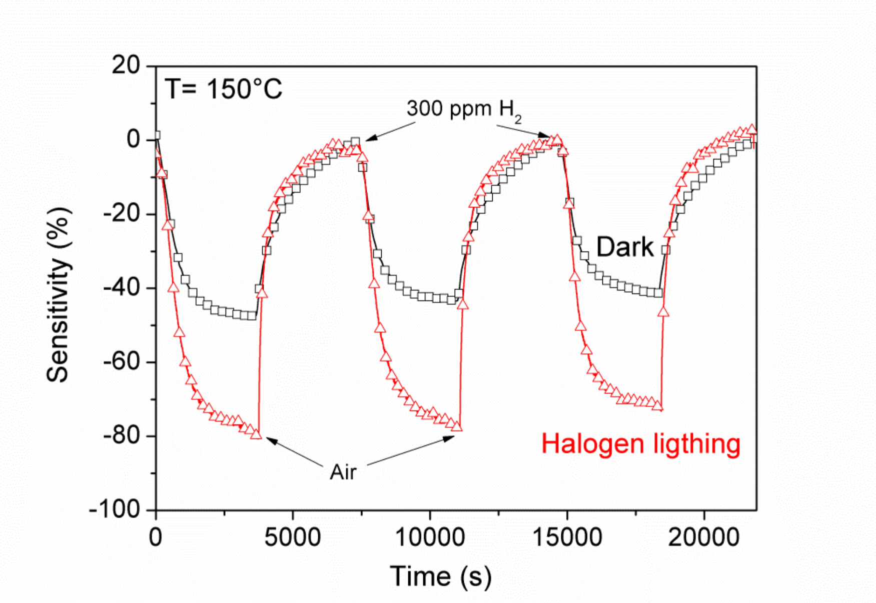
$H_2ads + O^{2-}ads \rightarrow H_2O + 2e^-$

or $H_2ads + O^-ads \rightarrow H_2O + 1e^-$

ZnO nanoceramics, RT H_2 detection

Halogen lighting (15µW/mm²)

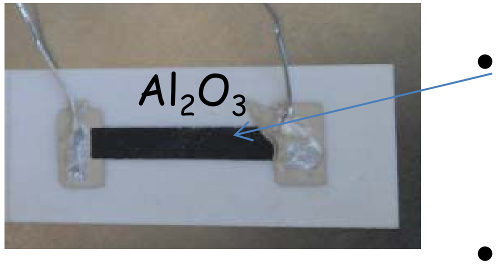




Temperature	Light	Sensitivity (%)
RT	No	0
	Halogen (15µW/mm²)	44
	UV (7.7 mW/mm²)	43
150°C	No	38
	Halogen (15µW/mm²)	71
	UV (7.7 mW/mm²)	94

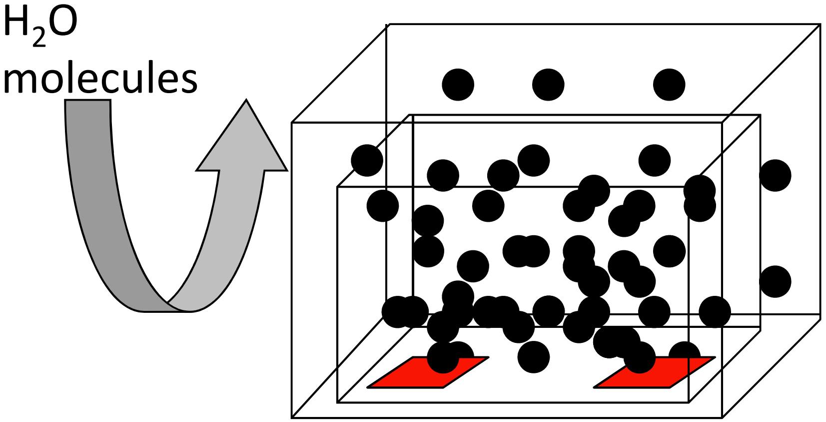
V. S. Nguyen et al, Journal of Applied Surface Science, 2015

Nanocomposite based resistive sensor



- Black carbon + epoxy + bistable nanoparticles (NPs ∅ 45nm, $Fe(Htrz)_2trz]BF_4.H_2O$ SCO complex)
- Printing, drying 120°C, curing 150°C
- Ag contact

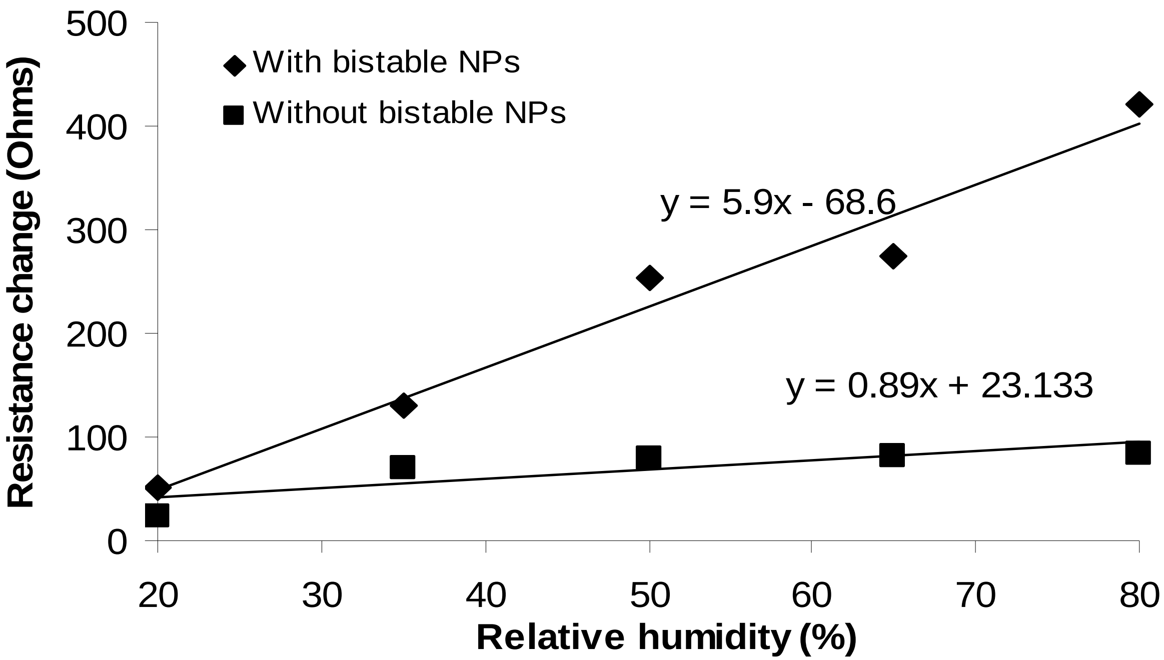
■ Gas sensor principle

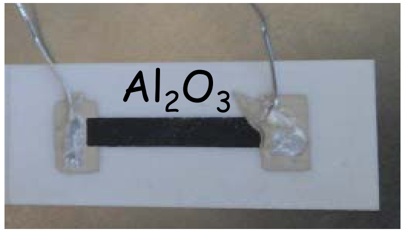


$H_2O \Rightarrow$ Swelling of epoxy + bistable NPs
$\Rightarrow$ Resistance $\downarrow$ (percolation phenomena)

Nanocomposite based resistive sensor

- RT tests





$3x15x0.02mm^3$

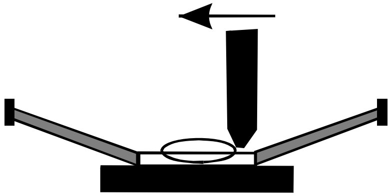
$R_{without\ NPs} = 5.2k\Omega$
$R_{with\ NPs} = 9.4k\Omega$

⇨ 6x higher with bistable nanoparticles
⇨ Possibility to use organic substrate

E. Llobet et al, Procedia Engineering, 2015

Gas sensor requirements

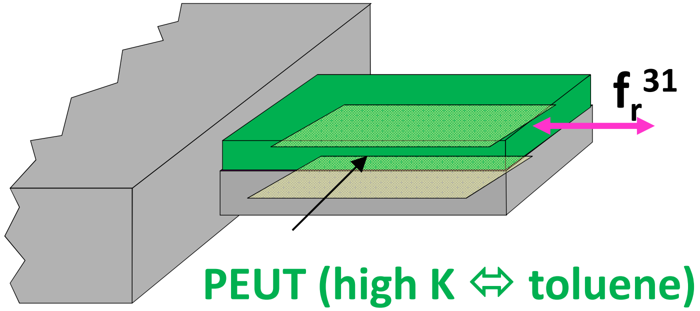
- Low cost → Screen-printed gas sensors



- Portable
- Good sensitivity → Nano-materials
- Selective → Multi-sensors
- Stable
- Low consumption → Toward room temperature
  - Nano-materials
  - UV activation
  - Cantilever gas sensors
- User friendly operation
- Easy calibration
- Cheap and easy maintenance
- Flexible and biocompatible if possible …

Screen-printed cantilever gas sensors

Toluene detection with Au/PZT/Au cantilever



PEUT (high K ⇔ toluene)

- Piezoelectric effect ⇨ actuation and detection

- In plane 31 Longitudinal resonant mode ⇨ high resonant f_r ⇨ high sensitivity S

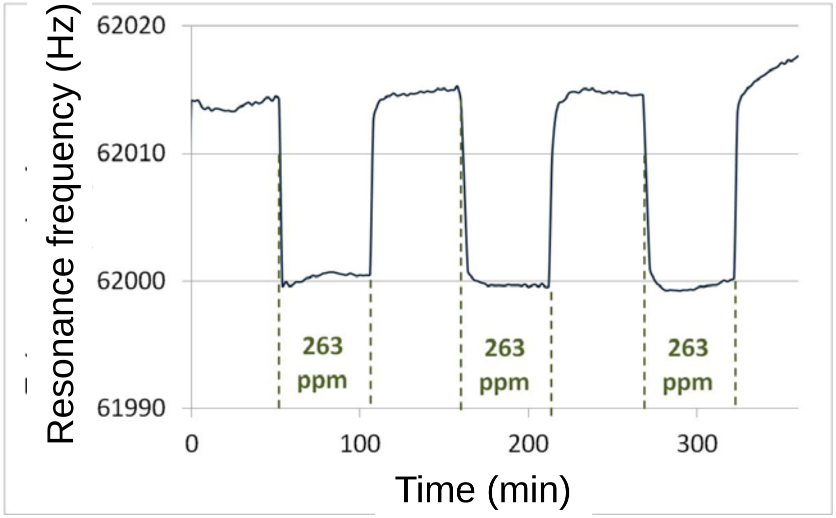
$$S = \frac{\Delta f_{31}}{\Delta C_g}$$

with:

$$f_{31}^{(n)} = \frac{\lambda_{31}^{(n)}}{2\pi}\sqrt{\frac{k_p + k_{sl}}{m_p + m_{sl} + L_{sl}.b_{sl}.h_{sl}.K.C_g}}$$

k_p : cantilever's spring constant
k_{sl} : sensitive layer's spring constant
h_{sl} : sensitive layer's thickness
b_{sl} : sensitive layer's width
L_{sl} : sensitive layer's length
K : sensitive layer's partition coefficient
C_g : gas concentration

H. Debéda et al, Sensors and actuators B, 2013

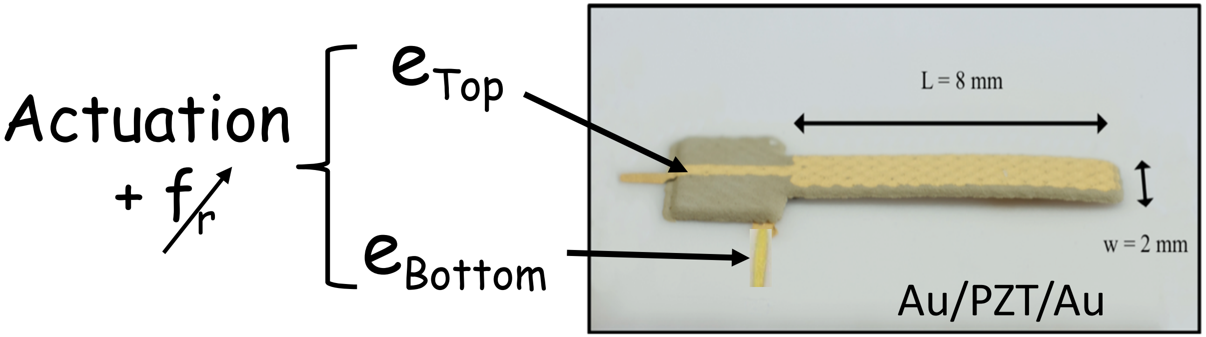


S=465.10^{-4}Hz/ppm, LOD = 80ppm

Si cantilever + PEUT, bending, f_r = 3kHz
S =9.10^{-4}Hz/ppm, LOD =47ppm

Double transduction : PZT + CNTs

- Simple transduction: *resonant*



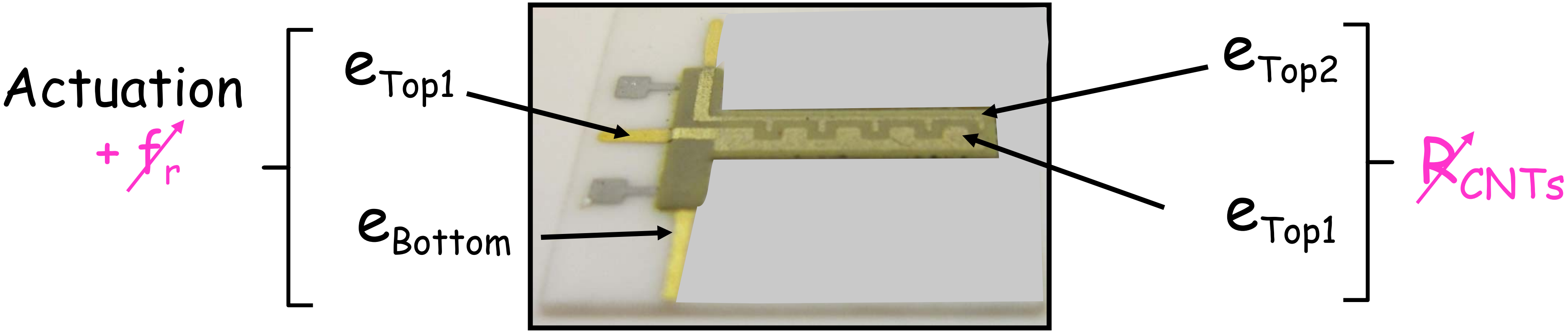
Actuation

$+ f_r \nearrow$

e_{Top}

e_{Bottom}

- Double transduction: *resonant + resistive*



Actuation

$+ f_r \nearrow$

e_{Top1}

e_{Bottom}

e_{Top2}

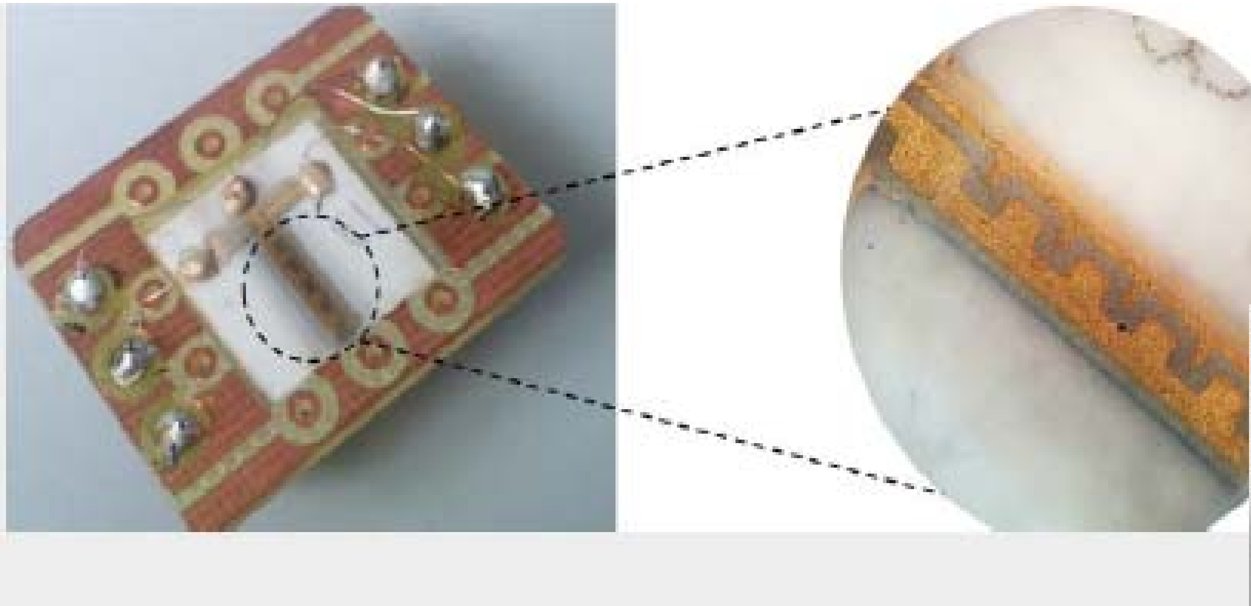
e_{Top1}

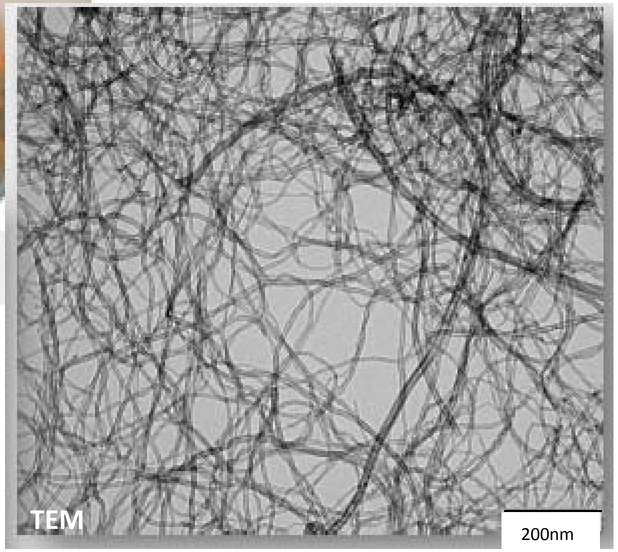
$R_{CNTs} \nearrow$

Double transduction: all printed

Sensitive coating deposition

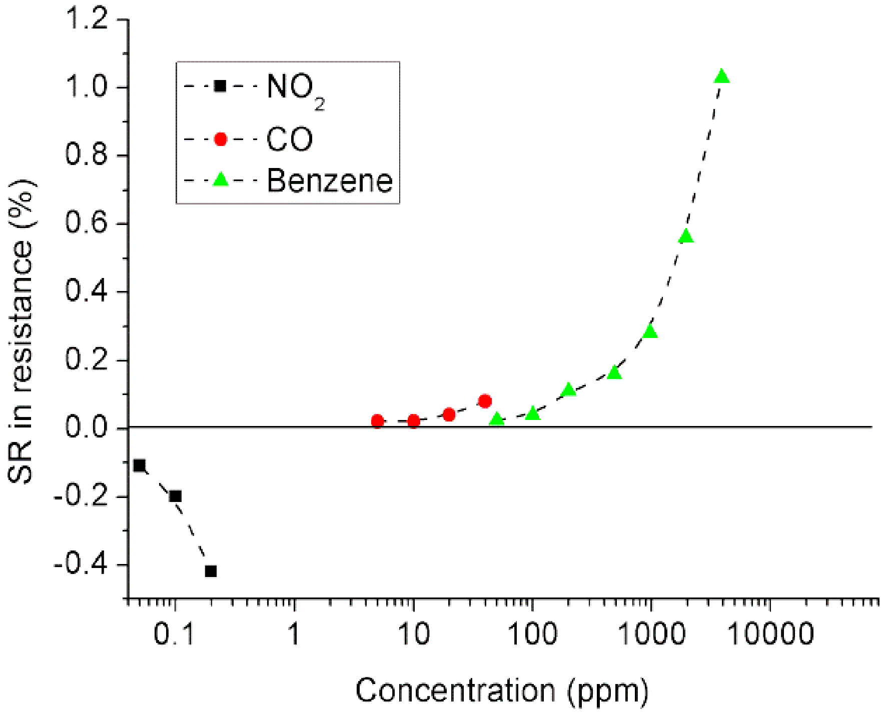
- MWCNTs air brushing





Length 50µm, Outer
∅ 3-15nm, Inner ∅ 3-7nm (Nanocyl) → $300 m^2/g$

Double transduction: PZT + CNTs



- Discrimination between oxidizing and reducing gases with the resistive sensor response

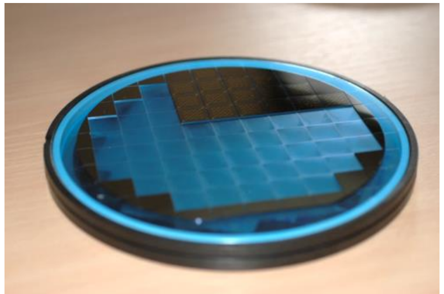
Limit of detection (ppm)	*Benzene*	*CO*	*NO_2*
Resistive	2	30	0.05
Mass	1	5	0.05

P. Clément et al, Sensors and Actuators 2016

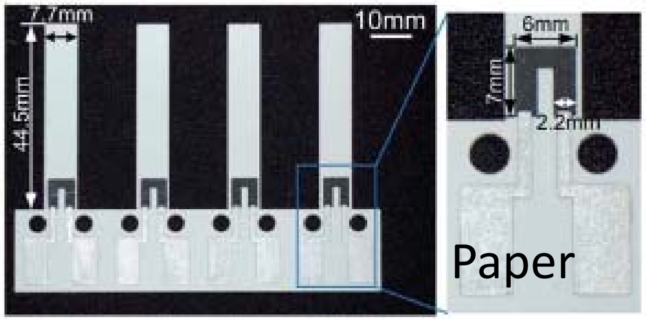
Organic MEMS

Attraction of organic electronics

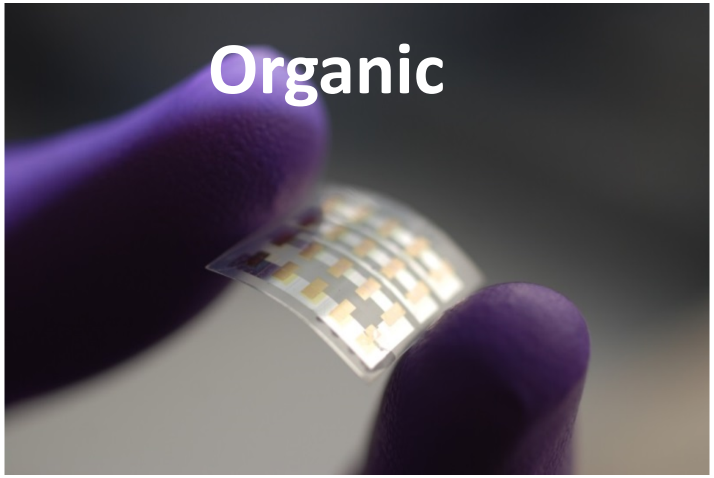
Inorganic



- Rigid, hard, heavy
- Expensive
- Confined in wafer
- Requires clean-room facilities
- Time and energy consuming

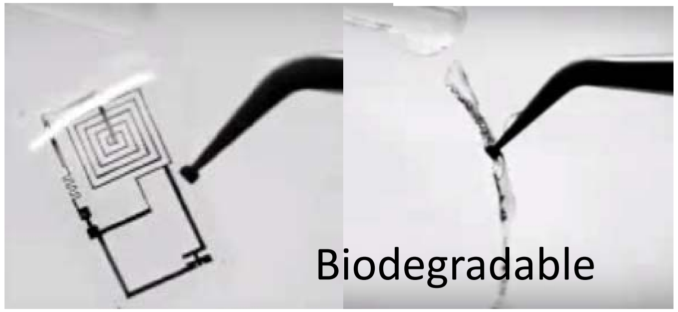


X. Lui *et al*, Lab. Chip., (2011)



Organic

- Flexible, streatchable, lightweight
- Low-cost
- High throughput, large surface
- Non-toxic, abundant
- Solution process, low temperature

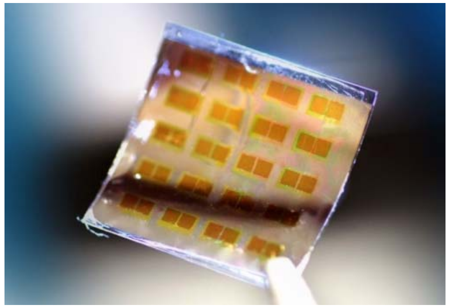


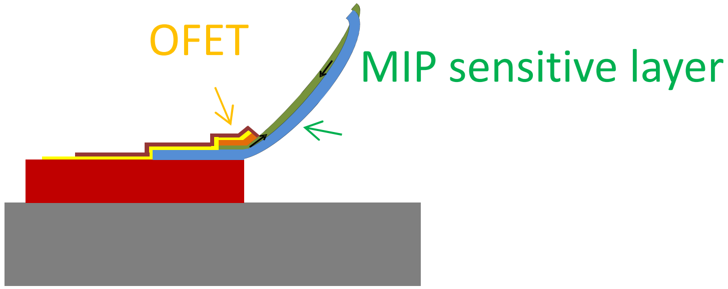
K. Bourzac *et al*, Nature News, (2012)

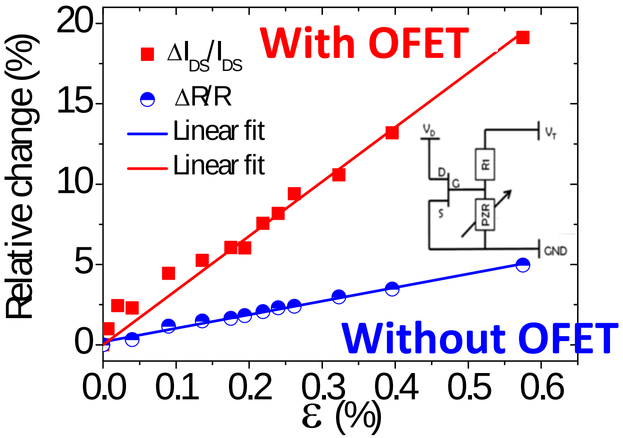
Organic MEMS: gas sensors

Cantilever: static mode

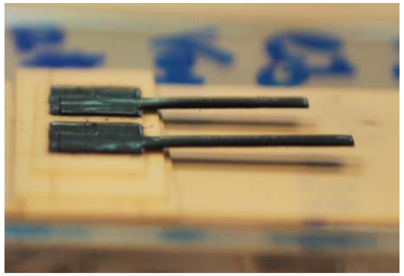
Molecularly Imprinted Polymer (MIP)/ OFET



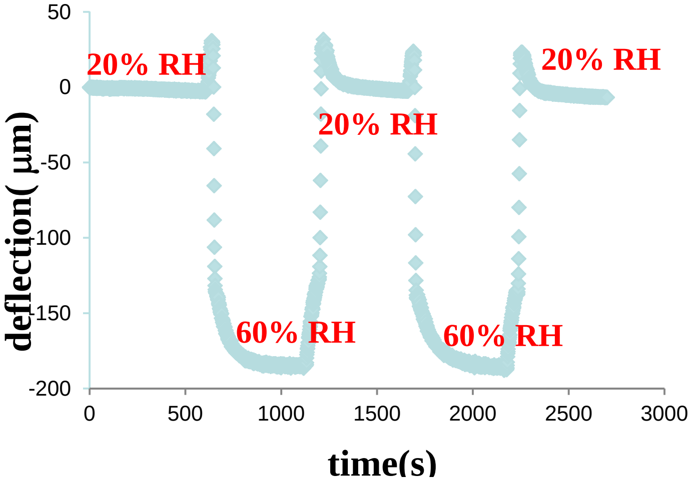




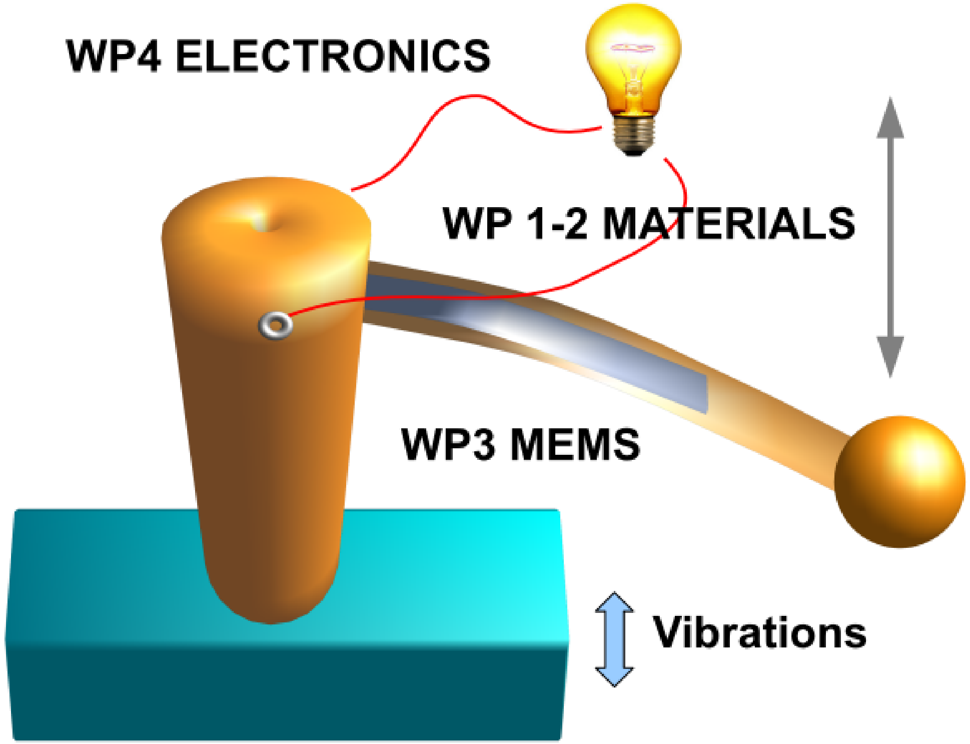
EPOXY/carbon / agarose coating



L=10mm, b=2.5mm, h=80µm



Organic MEMS: energy harvesting



ORGANIC CANTILEVER

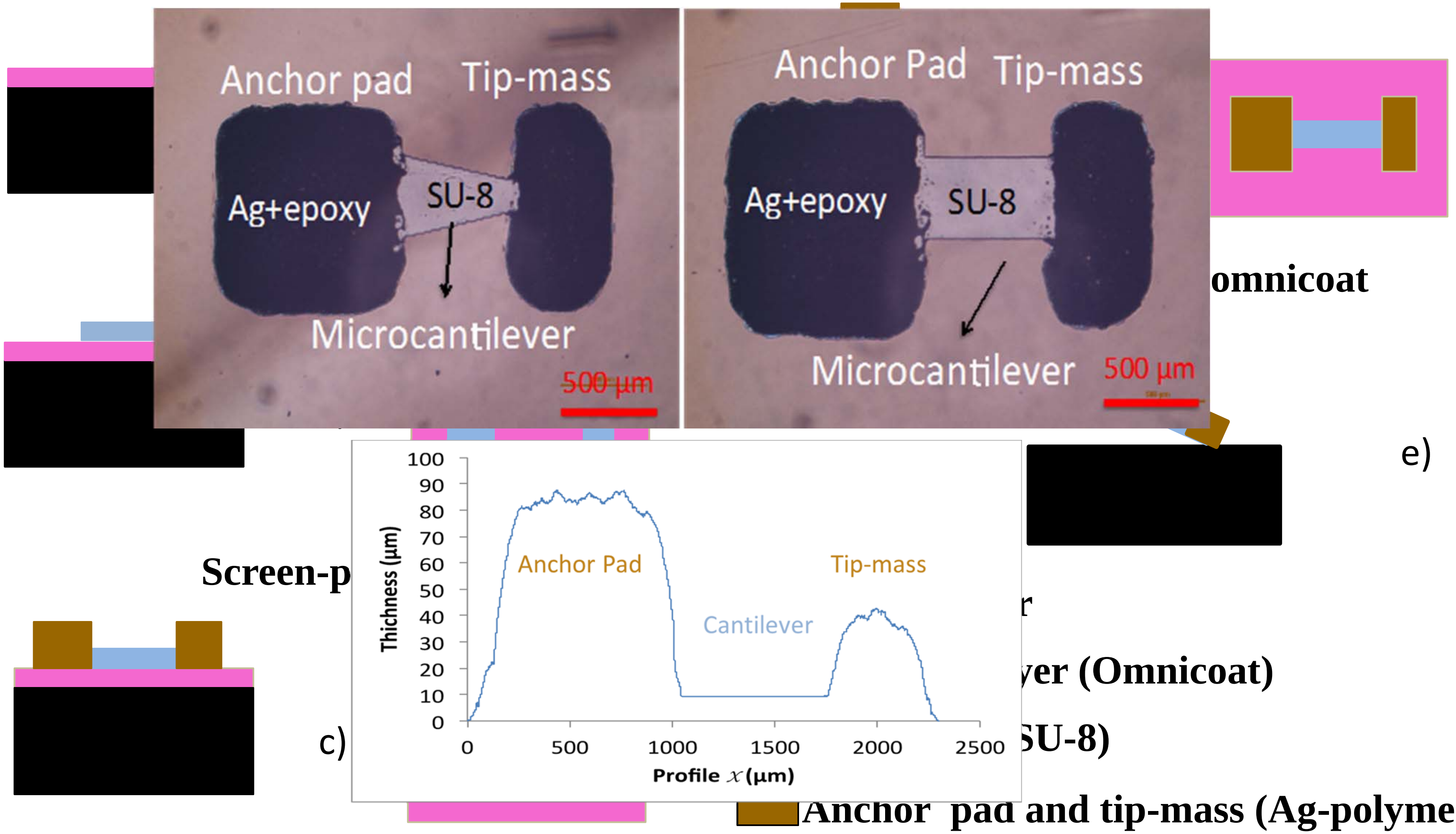
High mass part (composite)
Low stiffness part (organic)
Electrostrictive layer (CNT composite)
Electrodes

PRINCIPLE

Environmental vibrations → stress/strain → permittivity change of electrostrictive layer → capacity change → electronics for energy harvesting

Organic MEMS: energy harvesting

Processing



r

yer (Omnicoat)

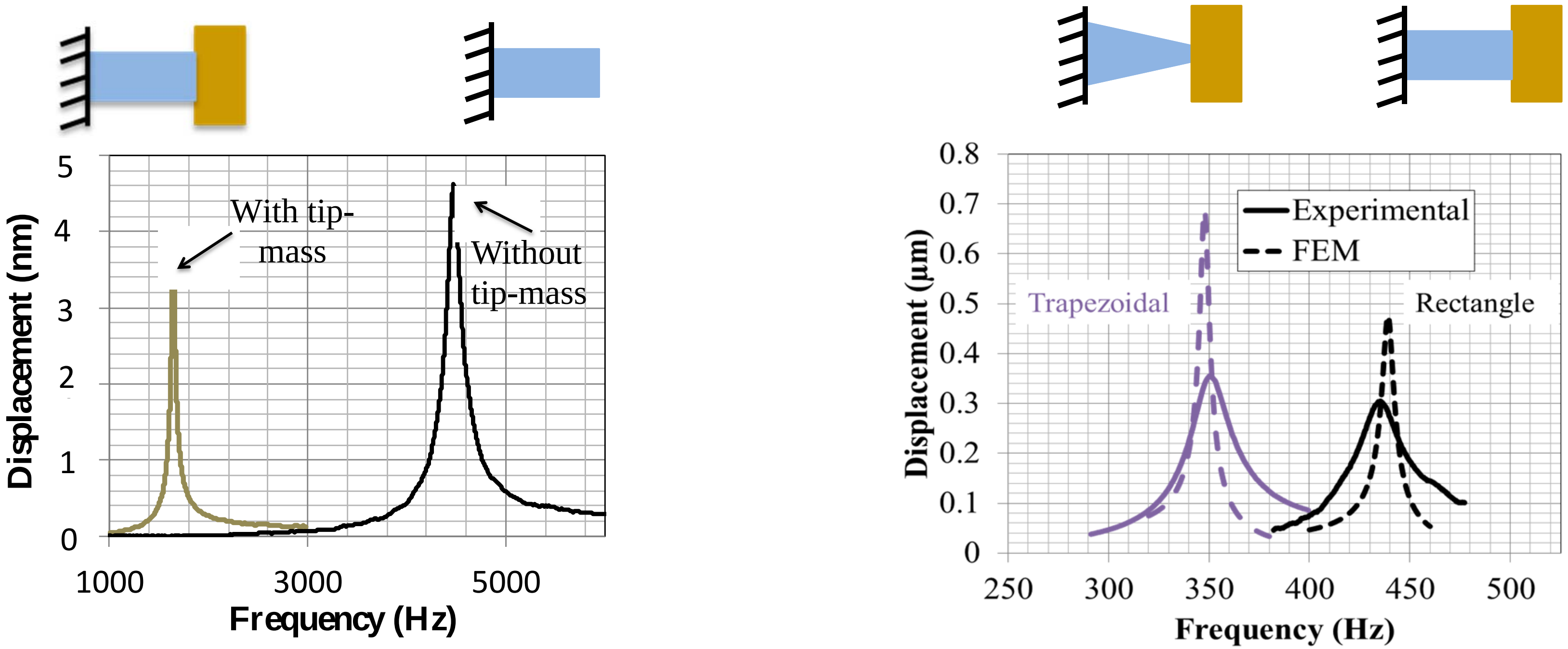
SU-8)

🟫 Anchor pad and tip-mass (Ag-polymer)

H. Nesser et al, flexible and printed electronics., 2016

Organic MEMS: energy harvesting

Resonance frequency



1st vibration mode (out of plane)

- Influence of tip-mass: *fr* (with tip-mass) = *1/3 fr* (without tip-mass)
- Influence of the geometry of the micro-beams + tip-mass: < 10 times
- Repeatability: fr = 372Hz ± 16Hz

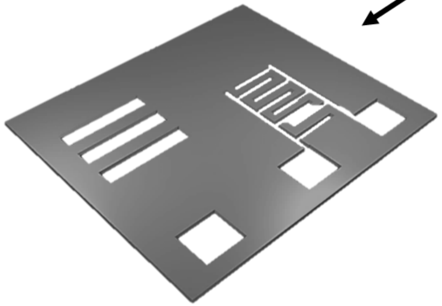
Organic MEMS: xurography processing

Xuron (blade, razor) and *Graphe* (to write)

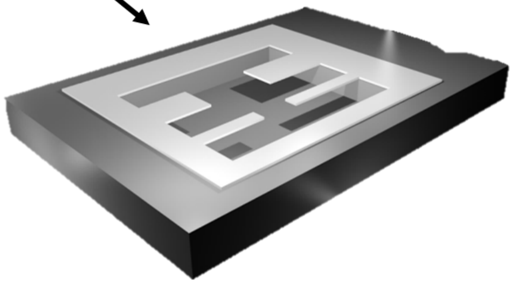
Characteristics:

- Devices can be designed in any CAD program
- Software opens DXF files
- Lateral resolution of 5 µm
- Handle a variety of material
- Cut material up to 250 µm thick
- Large choice of blade

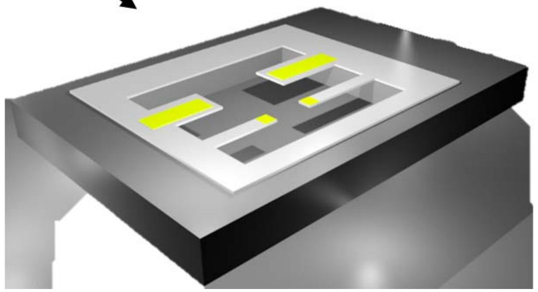
Cutting plotter → Deposition techniques



Flexible masks



Monolayer MEMS



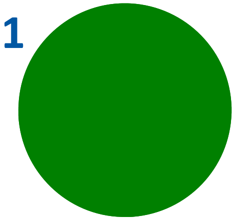
Multilayer MEMS

D. Thuau *et al.*, **Materials Horizons** (2015)

Organic MEMS: xurography processing

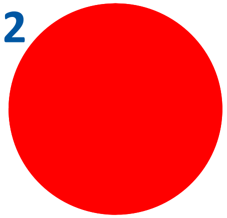
Piezoelectric micro-cantilever resonator

1



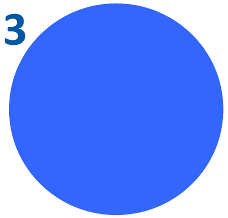
PEN substrate (50µm)

2



Deposition of the first layer of aluminum (140nm)

3

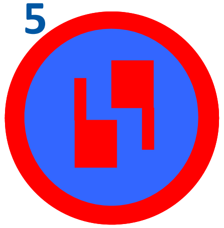


PVDF-TrFE spin-coating and annealing

4

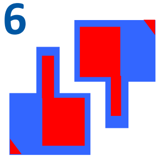
PET Shadow mask

5

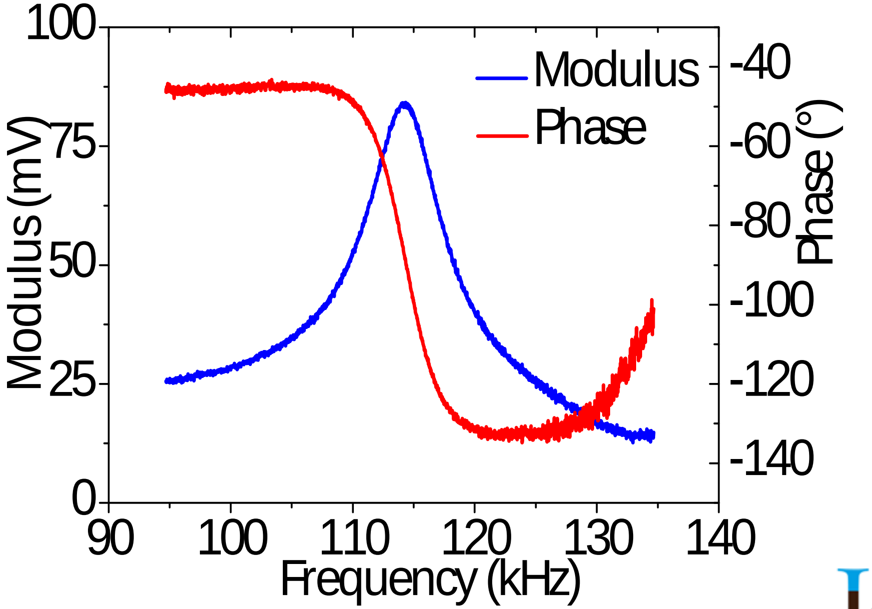


Deposition of the second layer of aluminum (140nm)

6



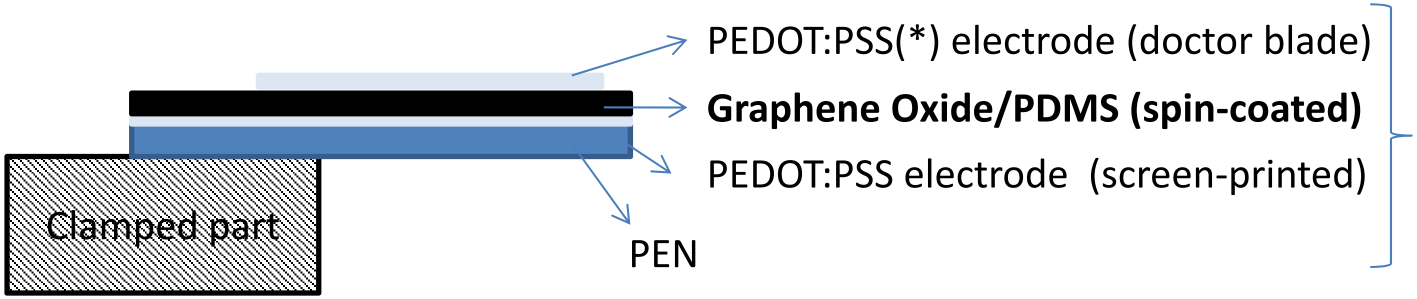
Cutting of the shape with the cutting plotter (Xurography)



P.H. Ducrot *et al.*, **Scientific Reports**, revision (2015)

Organic MEMS: xurography processing

Electrostrictive MEMS energy harvester

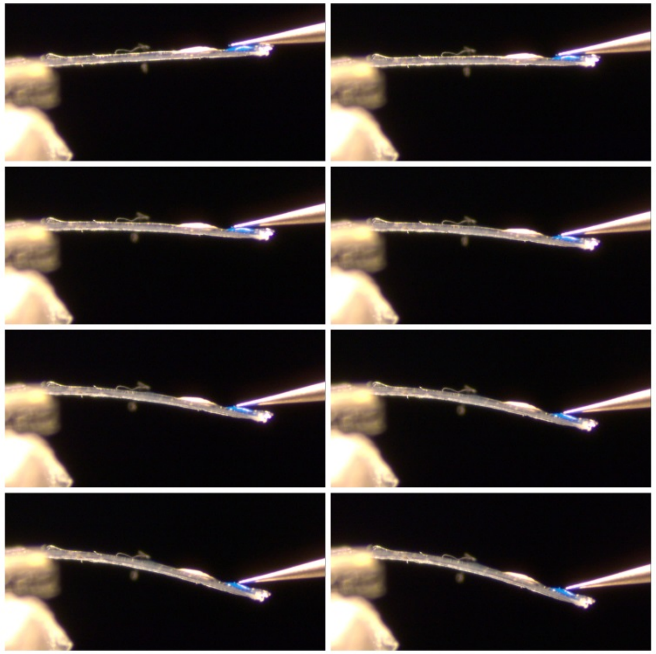


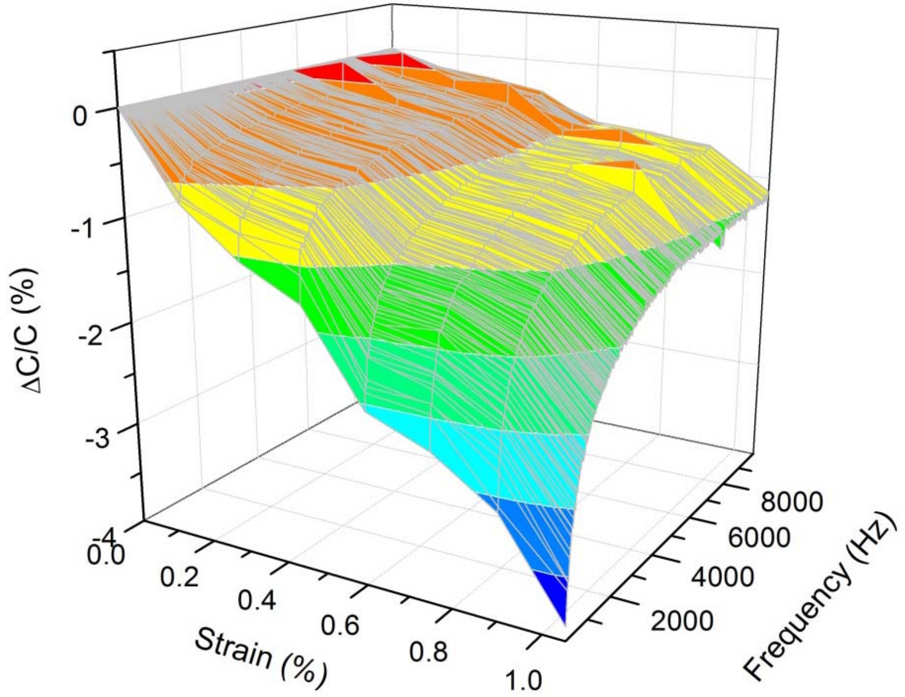
PEDOT:PSS(*) electrode (doctor blade)

Graphene Oxide/PDMS (spin-coated)

PEDOT:PSS electrode (screen-printed)

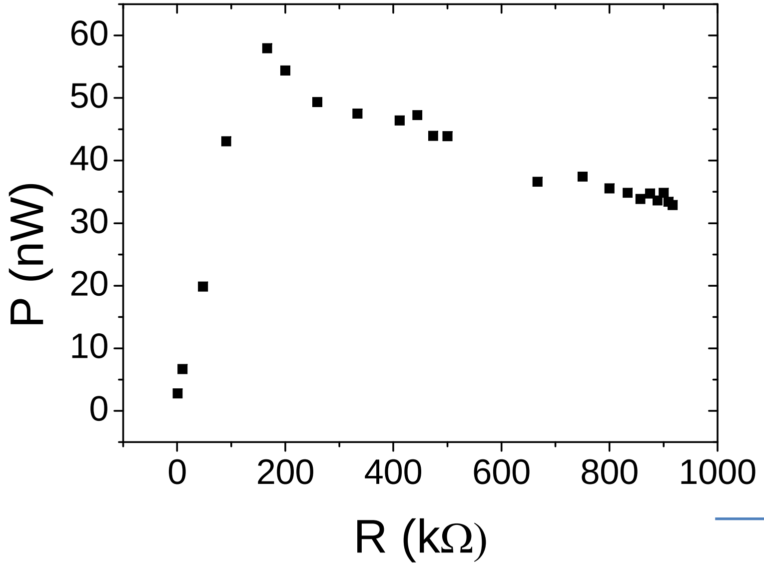
+ Xurography

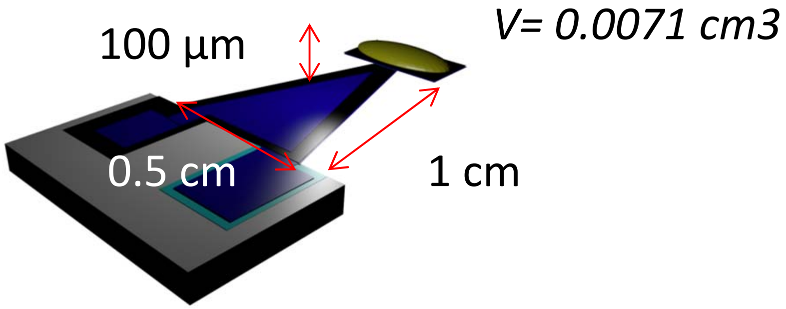




(*) PEDOT:PSS = poly(3,4-éthylènedioxythiophène) : poly(styrène sulfonate)

Electrostrictive MEMS energy harvester





	Electrostrictive polymer	Power density (µW/cm^3)
D Jaaoh et al, 2016	PU	1.11
D Jaaoh et al, 2016	PU/PANI 2wt%	1.54
P.J. Cottinet et al, 2011	P(VDF-TrFE-CFE)	280.00
Our micro-cantilever	**PDMS/rGO 3.7wt%**	**8.15**

PU: Polyurethane, PANI : polyaniline conducteur

Hussein Nesser *et al.*, **PowerMems** (2016)

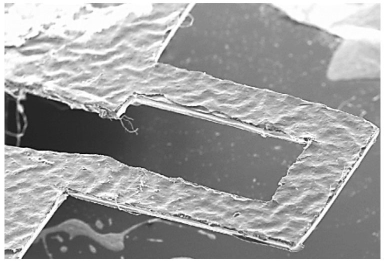
Outline

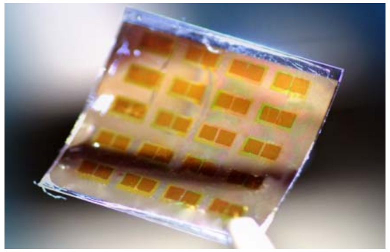
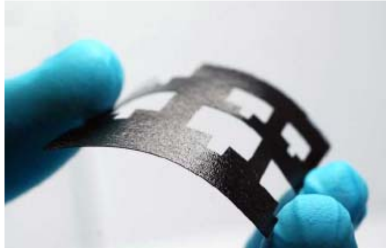
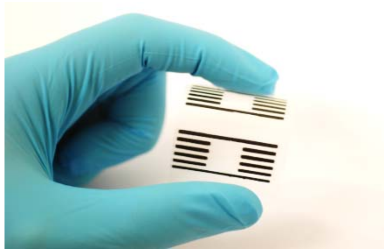
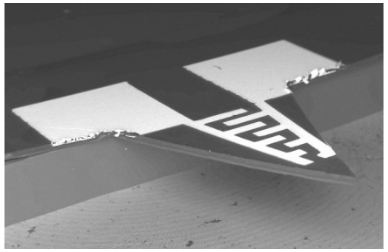
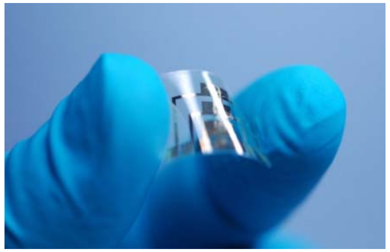
1. Bordeaux, University and IMS Laboratory
2. IMS Lab - PRIMS team activities
3. Printed technologies for electronics and MEMS
4. Screen-printed PZT MEMS
5. Printed gas sensors: toward RT detection
6. Organic MEMS

… Conclusion

Conclusion

- Use of simple, low-cost, versatile and fabrication processes (screen-printing, xurography, spray, etc…).
- It led to successful achievement of state-of-the-art printed MEMS devices
- Toward "green" and flexible electronic: no lead, organic, bio-compatible …



Thank you.
Merci!

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H. Nesser, PH. Ducrot, …

Laboratoire de l’Intégration du Matériau au Système