



Coatings in printed sensors

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Overview

Introduction to printed sensors

- Challenges and possibilities of printing manufacturing

Our way of thinking

Examples of printed sensor related projects

- gas sensors
- humidity sensors
- movement and activity sensors

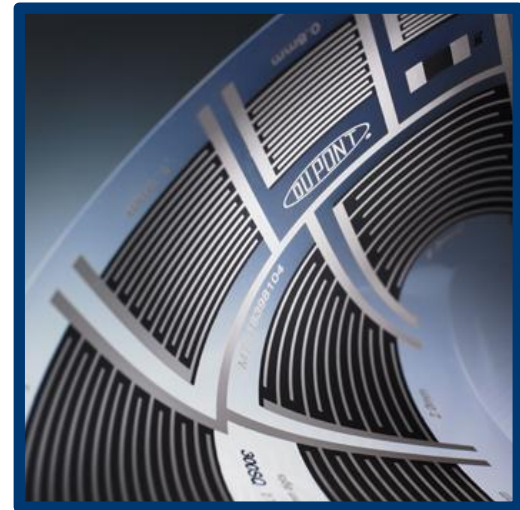
Conclusion



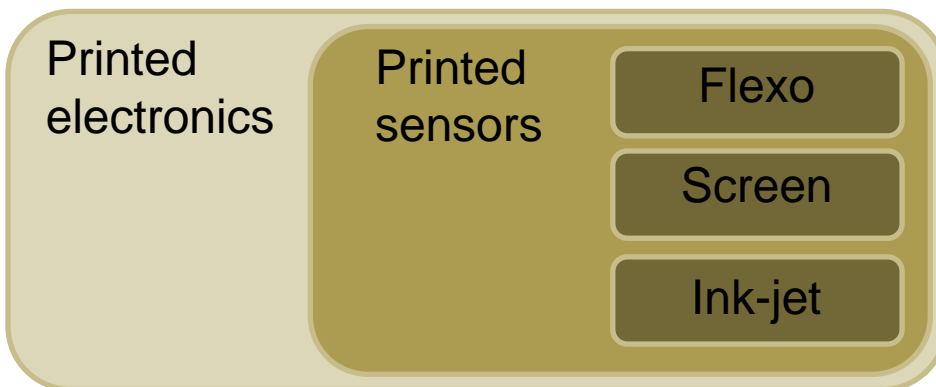
Introduction to printed sensors

What is printed electronics?

- Printed electronics is a rapidly emerging and relatively new technology, which is expected to revolutionize the fabrication of electronic devices like sensors on flexible substrate using electrically functional inks.
- Several printing techniques (gravure, ink-jet, screen) have been utilized also in sensor manufacturing.
- Printed sensors are just in the beginning their commercial evolution having great potential to be used in many applications



(DuPont Microcircuit Materials)

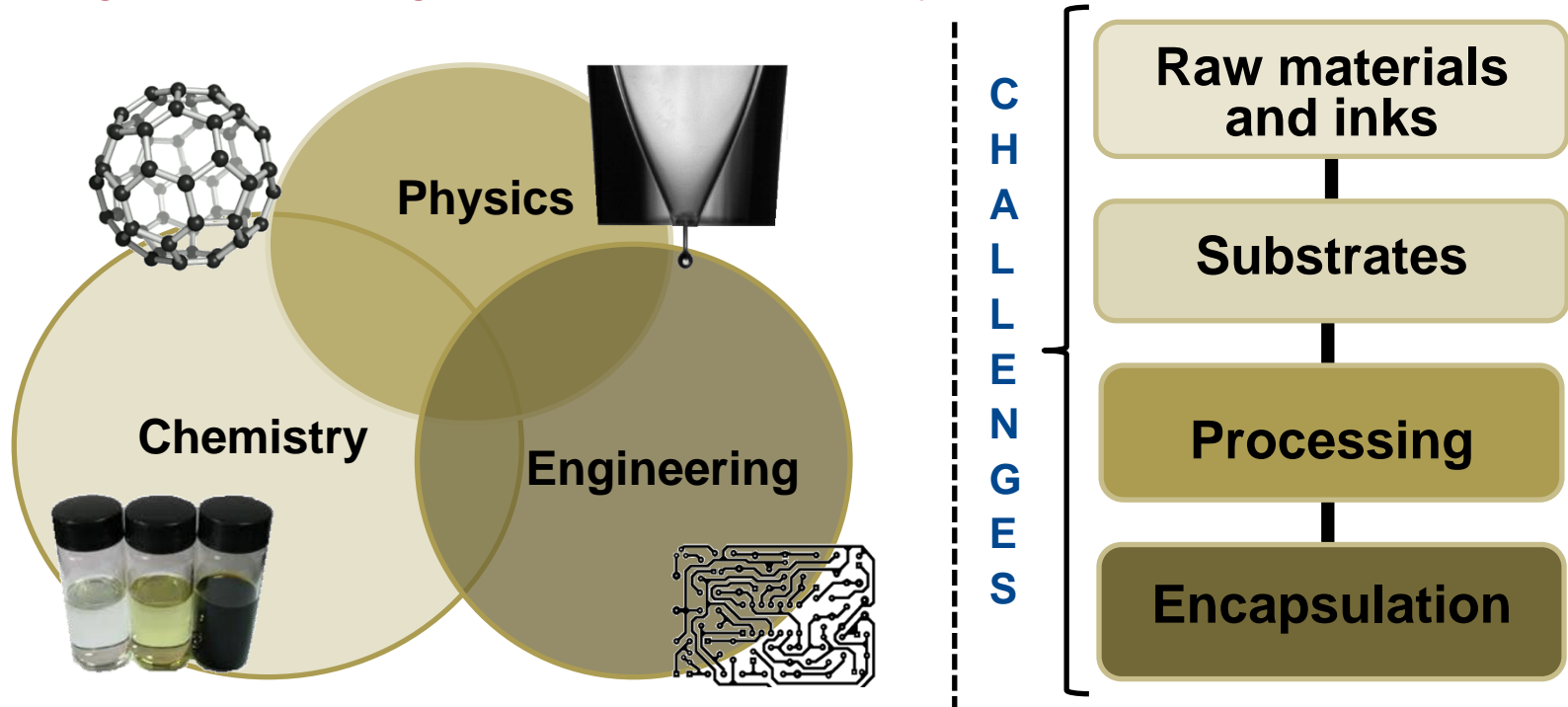


- ✓ Low costs
- ✓ Large area
- ✓ Flexible
- ✓ Low performance
- ✓ Low integration density



Introduction to printed sensors

Printing manufacturing requires multidisciplinary team work:



Printed sensor manufacturing needs number of different materials with completely different properties, but compatible with each other.

- Conductors, semiconductors, dielectrics, functional polymers
- There is several commercially available inks.



Custom made ink formulation often is required!



Introduction to printed sensors

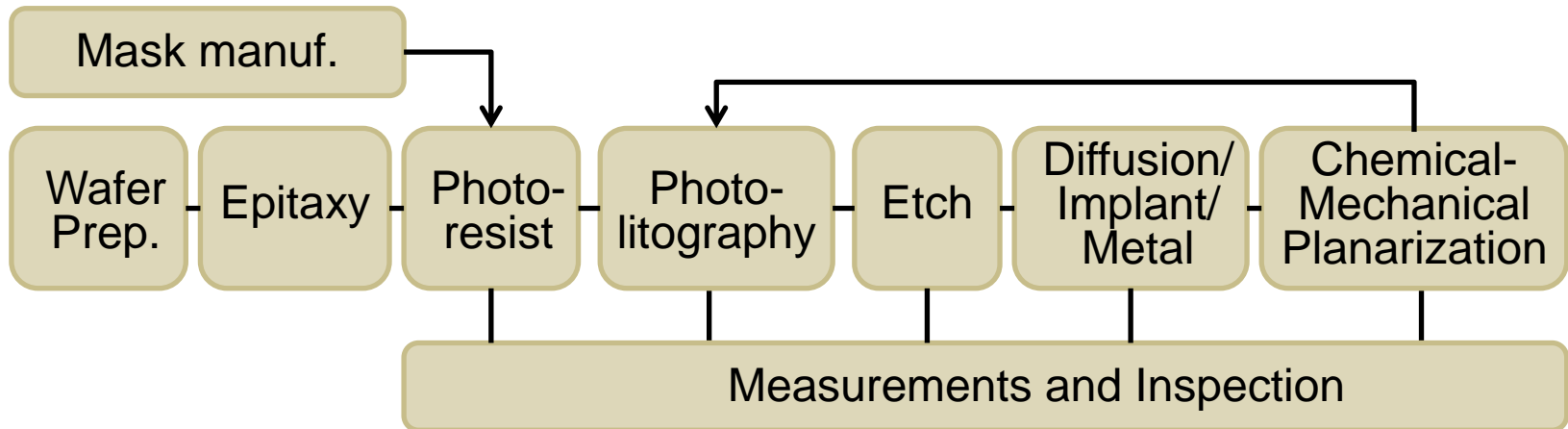
Printed coatings for sensors:

- Term 'printed sensor' is somewhat ambiguous. Screen printing method has been used for years to deposit electrodes. An approach where printing is used to create entire sensor is quite novel.
- Printing enables cost effective fabrication of large area sensor arrays on flexible substrate.
- Printing is well suited for multiple sensing layer sensor fabrication which is one of the main trends in the sensor industry at the moment.
- Applications for printed sensors:

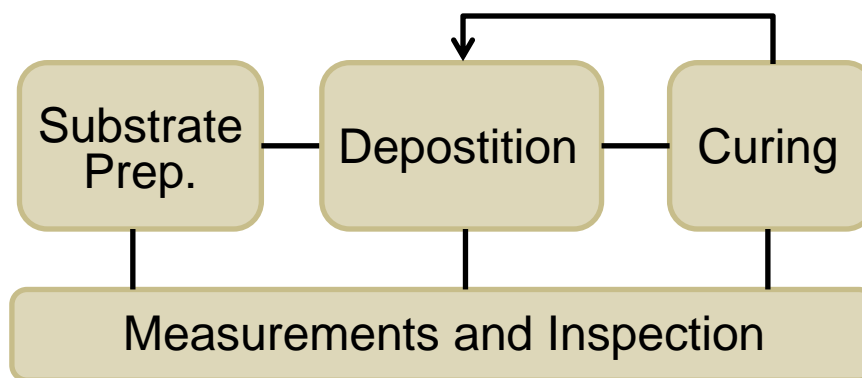


Introduction to printed sensors

Traditional silicon based sensor making process:



Printed sensor making process:



Advantages of printing:

- ✓ Less time consuming
- ✓ Simple process
- ✓ Less material waste

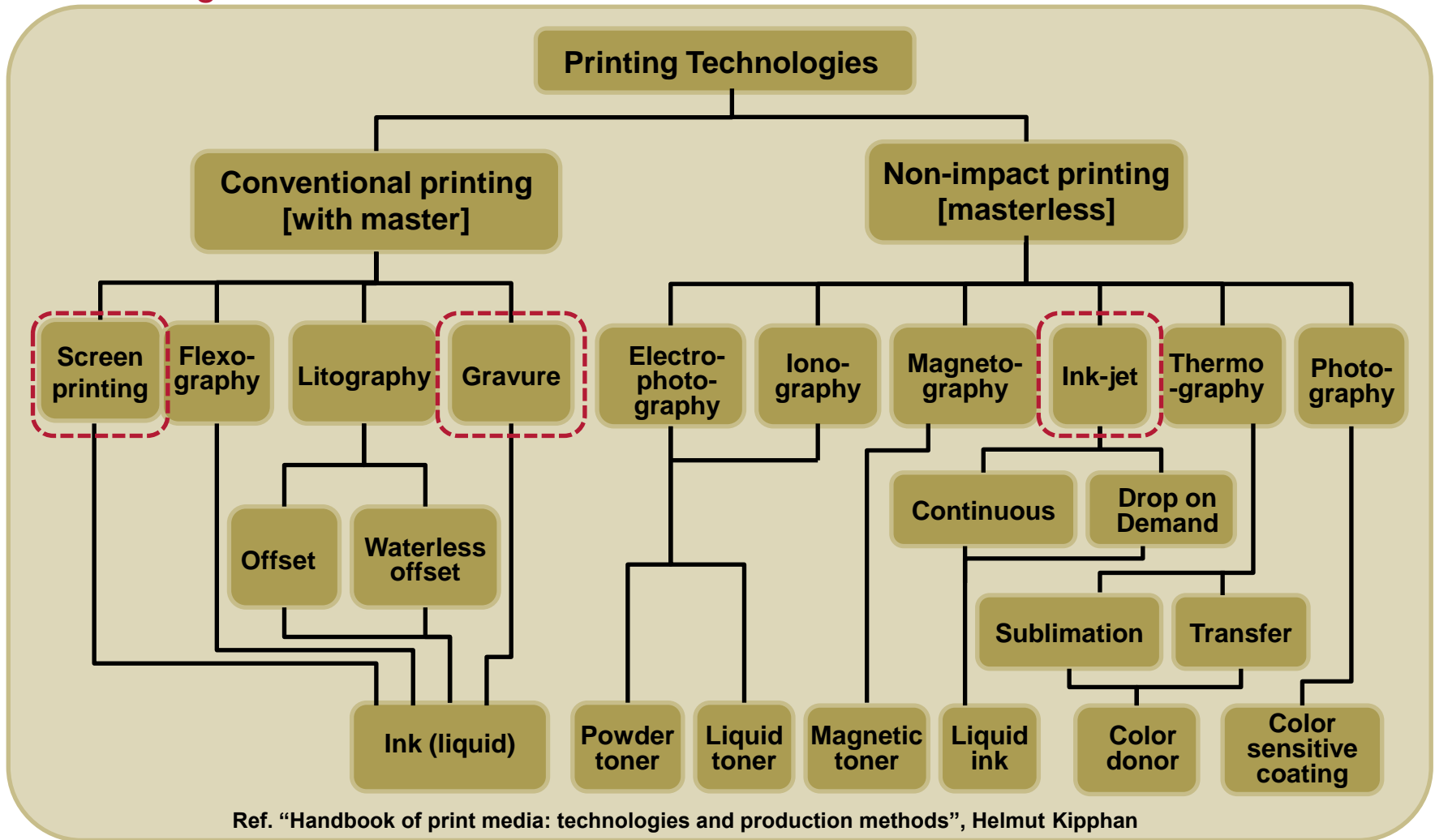


Low cost mass production!



Introduction to printed sensors

Printing methods in sensor fabrication:

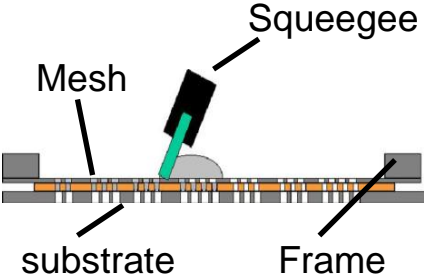
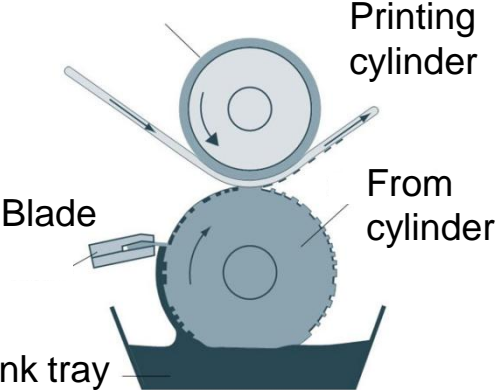
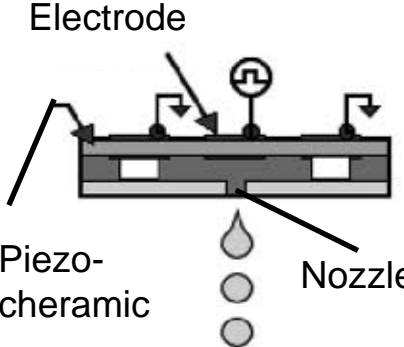


Ref. "Handbook of print media: technologies and production methods", Helmut Kipphan



Introduction to printed sensors

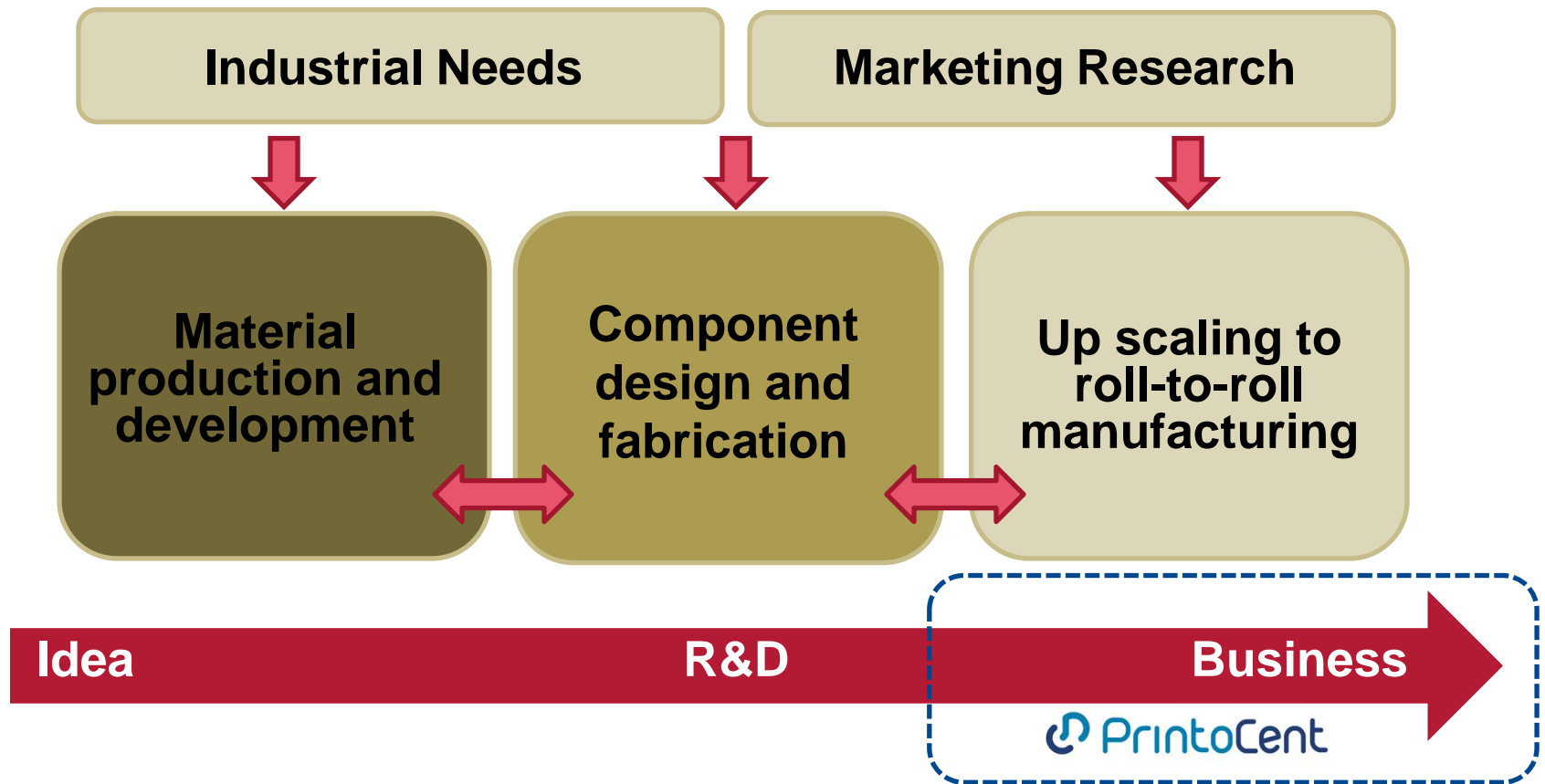
The most commonly used printing methods:

Screen printing	Gravure printing	Inkjet printing
 <p>The diagram shows a squeegee pushing ink through a mesh onto a substrate held in a frame. Labels include: Mesh, Squeegee, substrate, and Frame.</p>	 <p>The diagram shows a printing cylinder and a form cylinder with a blade between them, dipping into an ink tray. Labels include: Printing cylinder, Blade, Ink tray, and Form cylinder.</p>	 <p>The diagram shows a piezoelectric actuator driving a nozzle to deposit ink onto an electrode. Labels include: Electrode, Piezo-cheramic, and Nozzle.</p>
<ul style="list-style-type: none"> ✓ Rather inexpensive ✓ Most mature ✓ R2R combatible ✓ Requires mask ✓ Ink waste ✓ Limited resolution 	<ul style="list-style-type: none"> ✓ Allows thick and thin films ✓ Good scalebility ✓ High layer quality ✓ High resolution ✓ R2R combatible ✓ High cost of cylinders ✓ Highly demanding 	<ul style="list-style-type: none"> ✓ High resolution ✓ Flexibility (digital method) ✓ Substrate independent ✓ High resolution ✓ R2R combatible ✓ Nozzle clogging



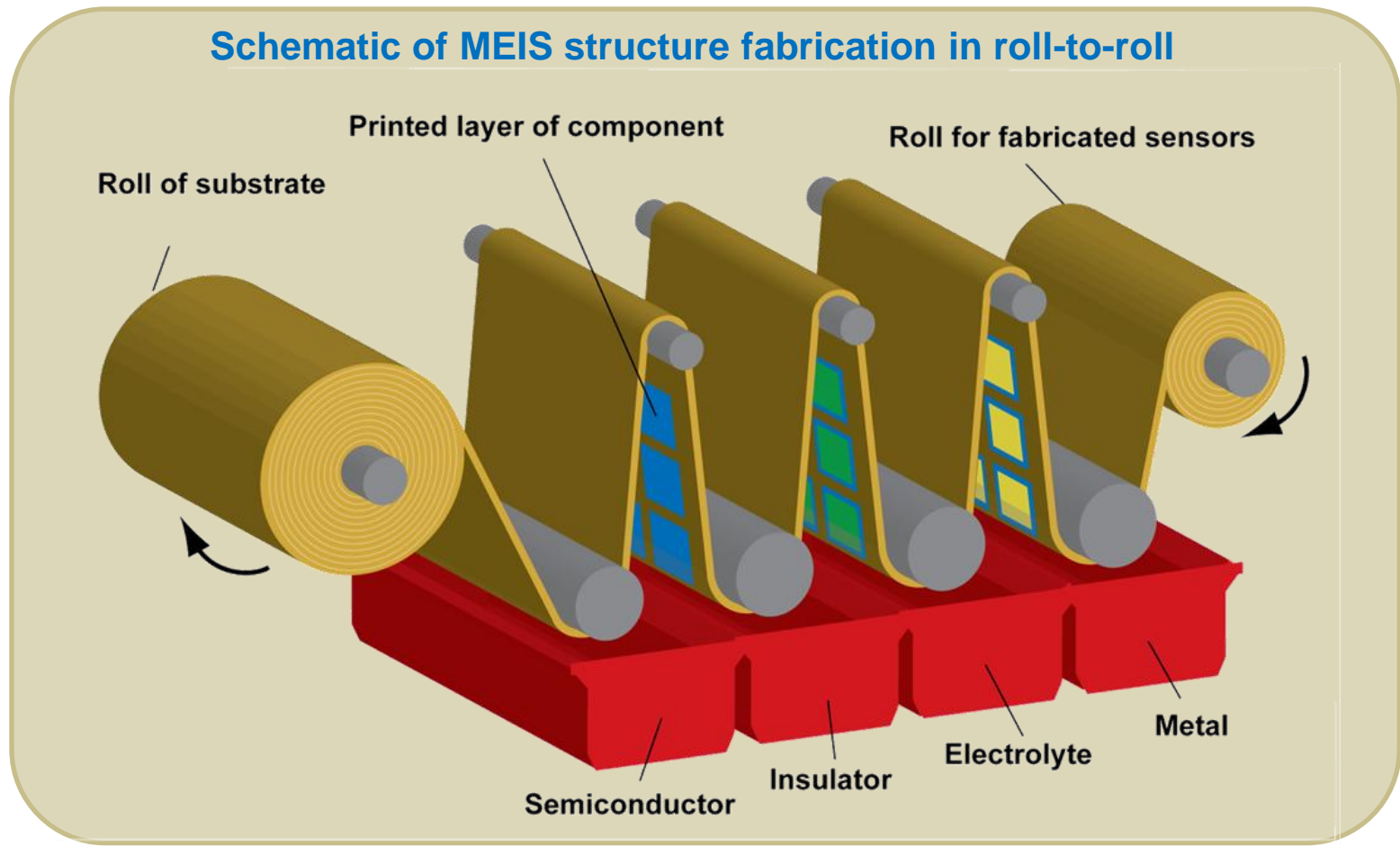
Our way of thinking:

Combination of know-how of academic researchers and needs and specifications of industrial partners will be the most efficient way to bring printed product towards market.



Our way of thinking

Roll-to-roll manufacturing method enables to reduce mass production costs of printed electronics.

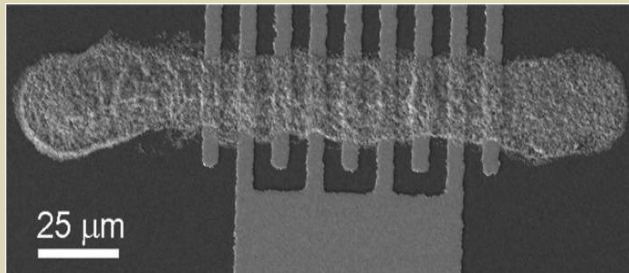


Gas sensor by printing

Resistive type H_2 sensor – metal decorated WO_3 nanoparticle ink:

Simple resistive type of test component is used to evaluate the suitability of WO_3 nanoparticles for gas sensor applications.

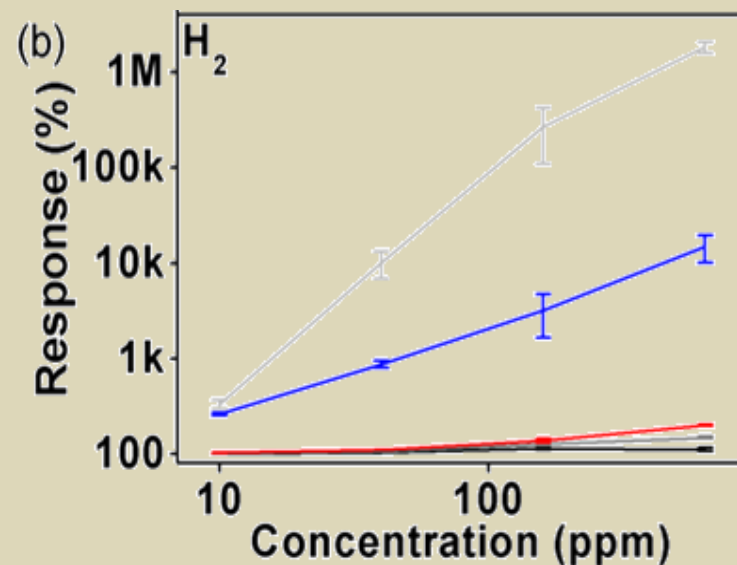
Ink composition: WO_3 nanoparticles in water. Wet impregnation was used to anchor metals on WO_3 nanoparticles. Inkjet deposited on Si/SiO₂ substrate with Pt-electrodes to form resistive gas sensor device.



Fullfills the sensitivity specifications set by industrial partners!

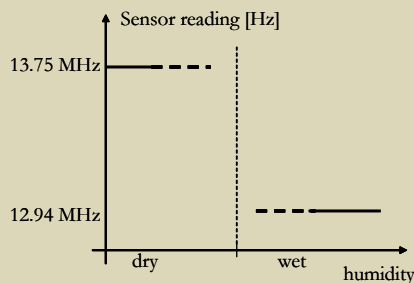
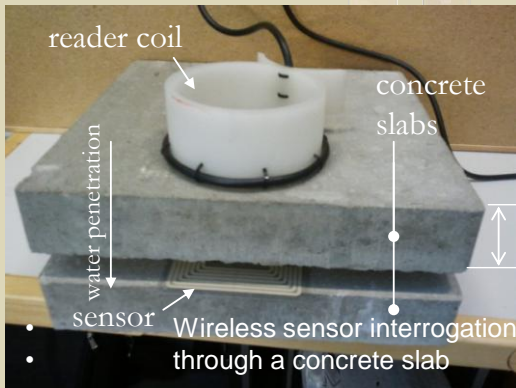
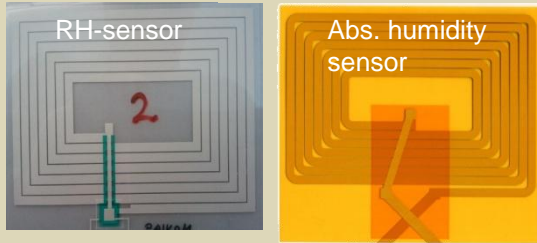
J. Kukkola et al. "Inkjet printed metal decorated tungsten oxide nanoparticles for gas sensing", Workshop of Smart Materials and Sensor Arrays for Nanoparticle and Gas Detection, March 16-17, 2011, Oulu, Finland

Sensitivity for H_2 at 220 °C temperature:



Humidity sensor by printing

Relative and absolute humidity sensors:

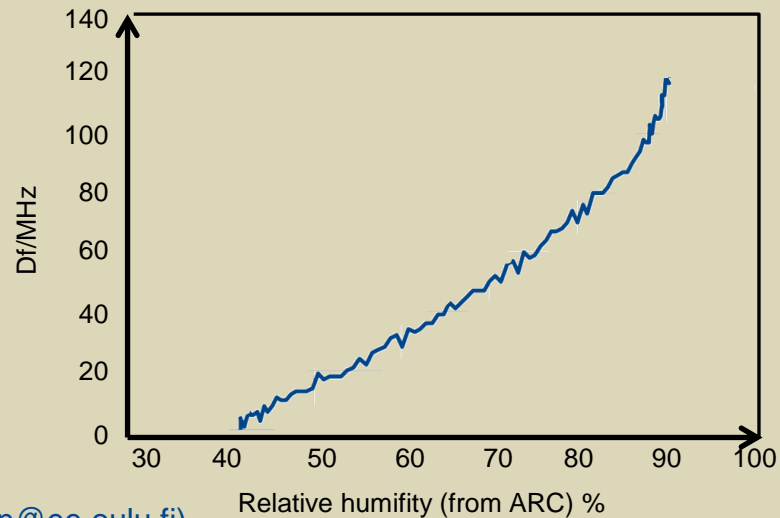


Based on the resonance frequency shift of a parallel LC resonator due to humidity

Sensor structure: Silver/polymer insulator/Silver on top of PET-substrate.

Fabricated by screen printing and R2R compatible method

Application examples include embedded building and infrastructure humidity monitoring

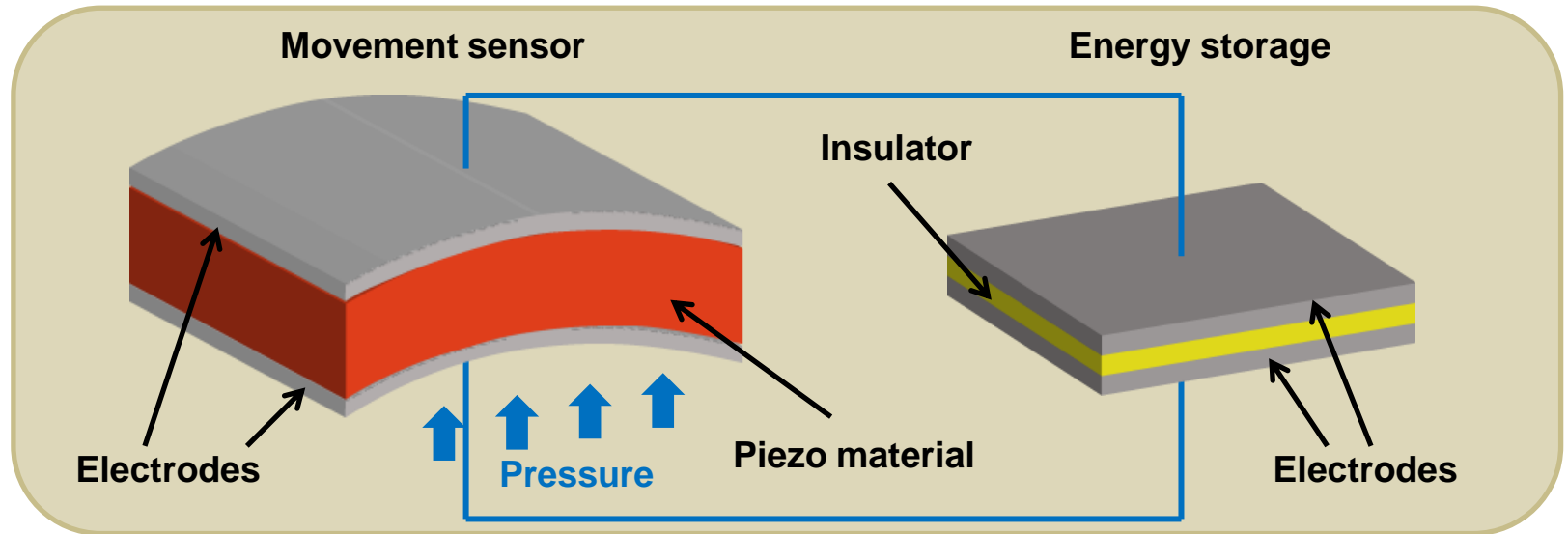


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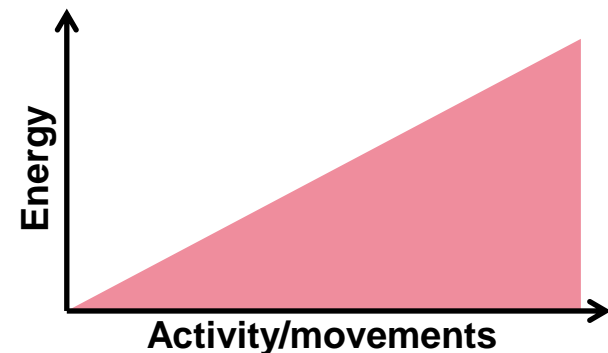
Concept of printed activity/movement sensor

Ultimate goal is to fabricate an autonomous and low cost activity sensors using printing technologies.



Movement/activity generates electric current over piezo element. Energy can be stored to capacitor/memristor.

Cumulative energy of capacitor indicates the activity !



Conclusion

- Printing enables cost effective fabrication of large area sensor arrays on flexible substrate for various applications.
- Printing is well suited for multiple sensing layer sensor fabrication which is one of the main trends in the sensor industry at the moment.
- Printing has been used to fabricate some elements of the sensors like electrodes. However, fully printed sensors are not yet in the market at the moment.
- ‘Killer’ concept for printed sensors is still lacking. We are trying to find it!





THANK YOU FOR YOUR ATTENTION!

