Surface Engineering for Biomedical Sensor Applications using Digital PlasmaPrinting

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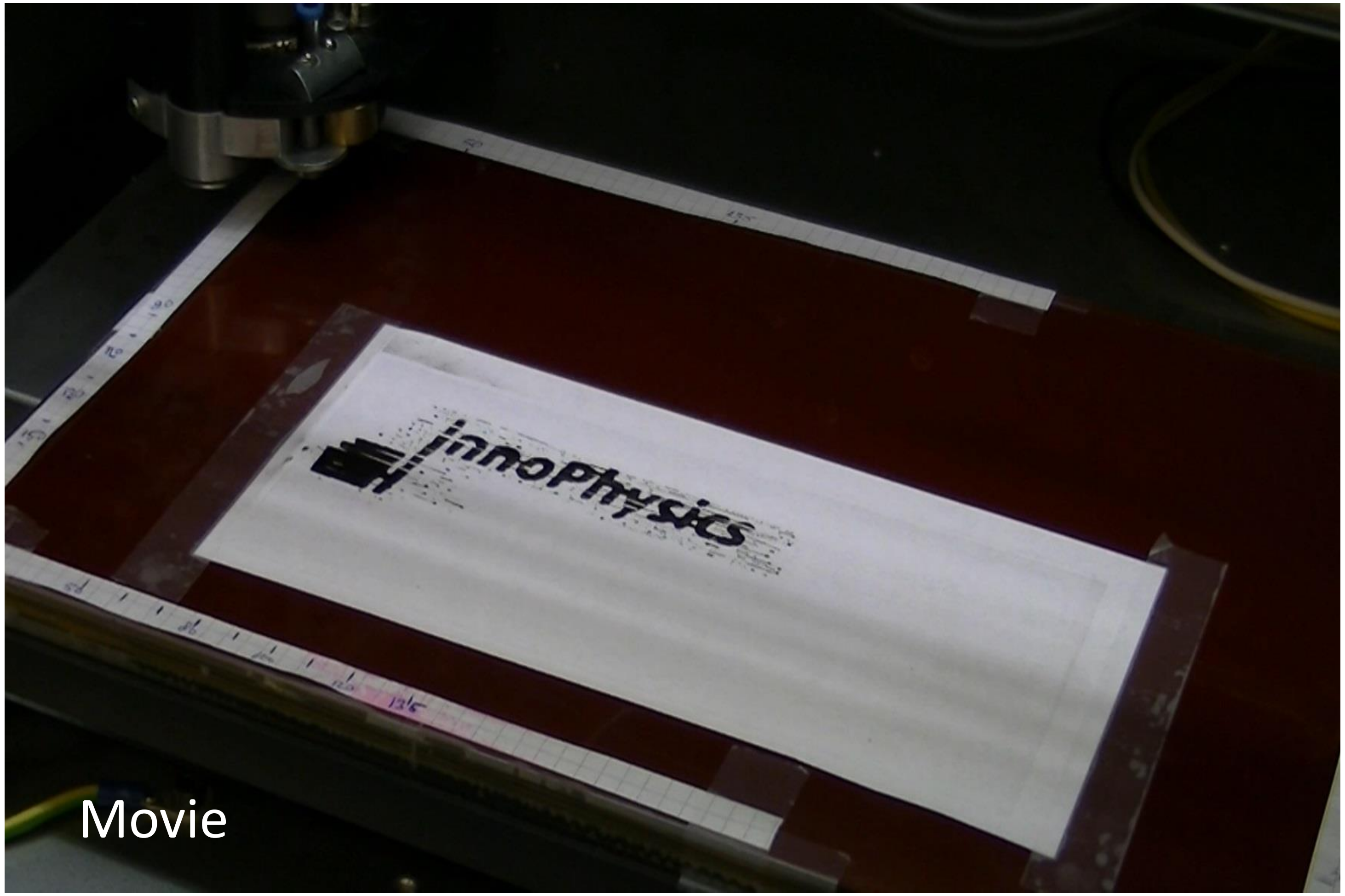
Today's take away

- Introduction into the world of µPlasmaPrint
- and its surface engineering solutions for bio(-medical) sensor application

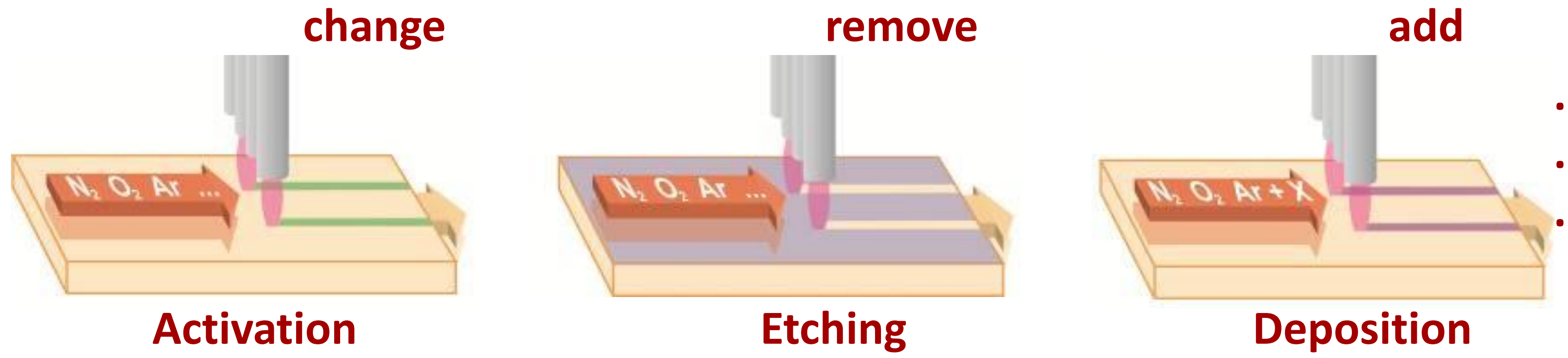
µPlasmaPrint : digital printing with activated molecules



µPlasmaPrint : digital printing with activated molecules

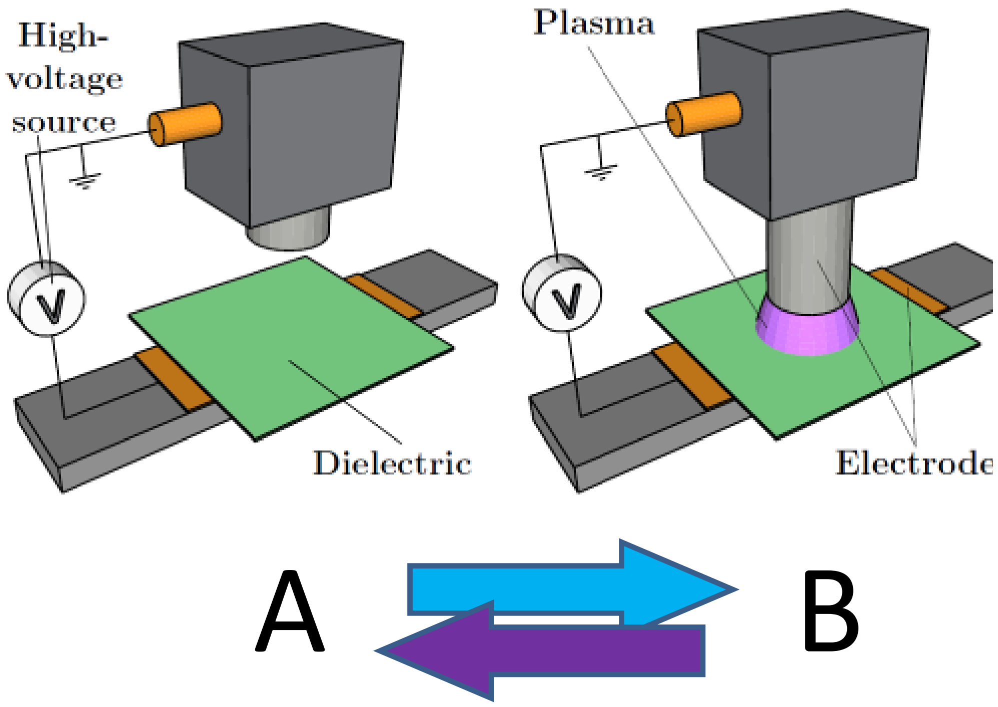
“Instead of ink droplets, we digitally print plasma activated molecules”

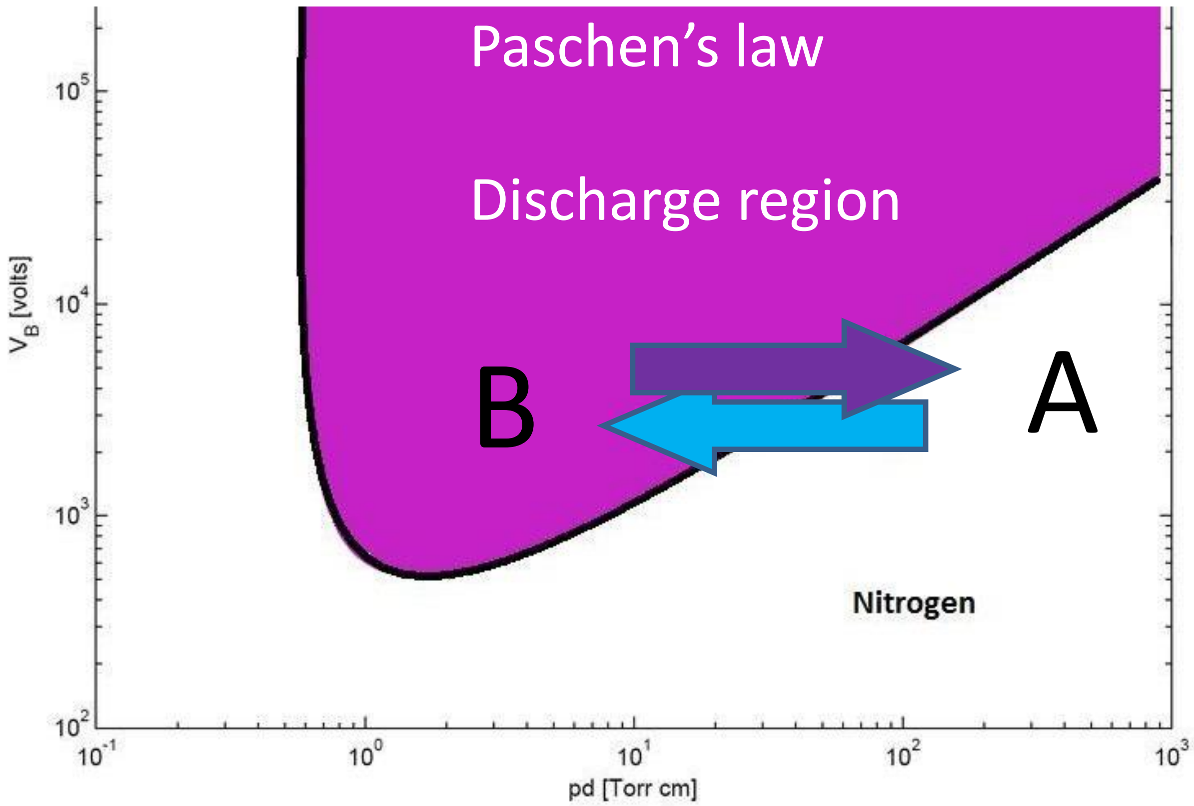
Plasma activated molecules …



.. upon interaction with substrate
.. at low temperatures
.. at atmospheric pressures

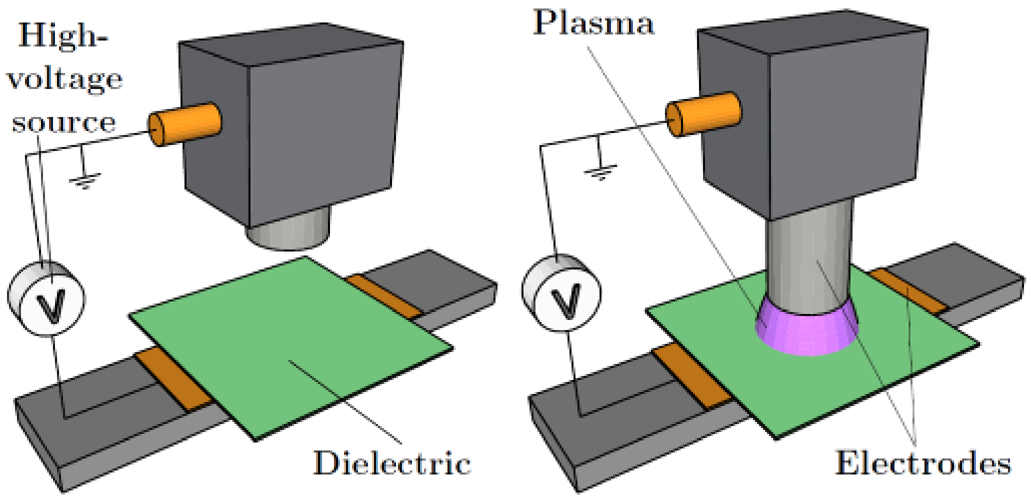
Basic principle and time scales

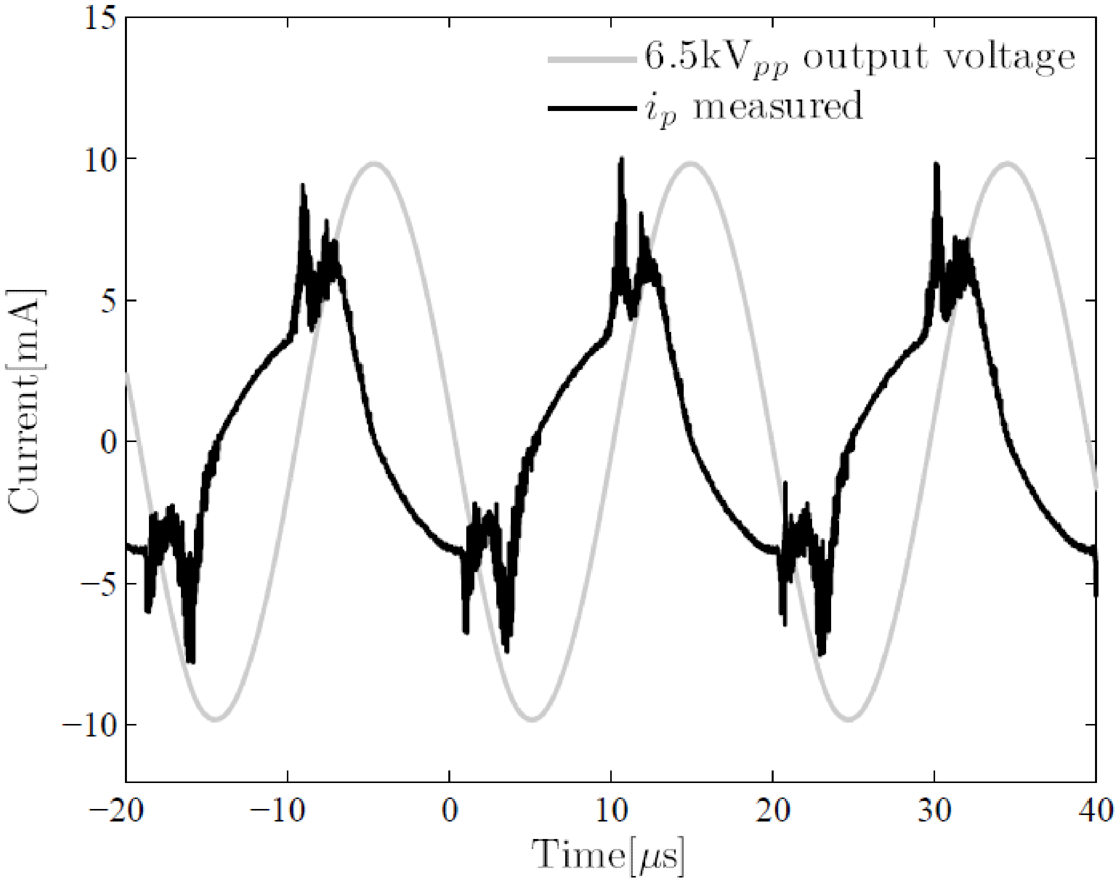




One "plasma dot" of Δt ~ 500 μs

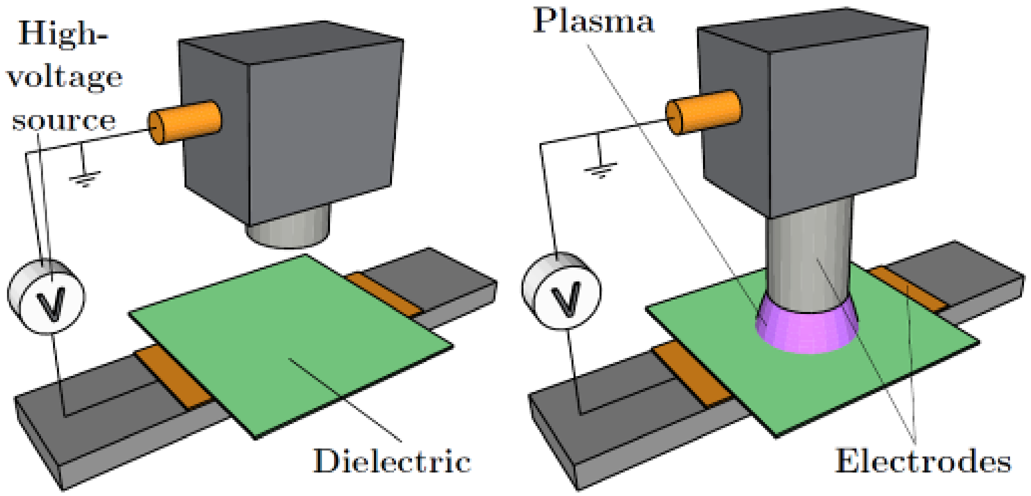
Basic principle and time scales



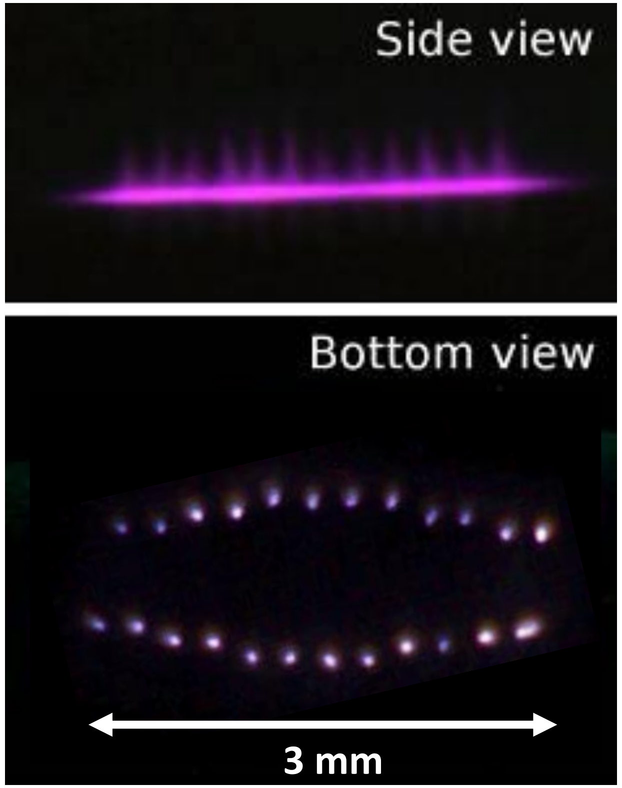


One “plasma dot” of Δt ~ 500 µs **= a multitude of tiny discharges**

Plasma Source Technology



2 x 12 needle printhead



- 24 independently controllable discharges (400 Hz)
- 50 / 200 µm electrodes; 50 – 300 µm discharge gap.
- 2 – 10 kV_{pp} at 10 – 100 kHz.
- Controlled **atmospheric** pressure **gas flow** in discharge gap

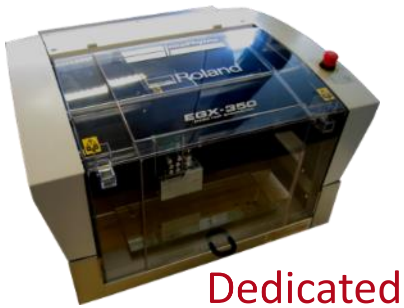
µPlasmaPrint solutions

PiXDRO LP50

Process integration
Combining inkjet, laser, plasma

Tabletop R&D print platforms

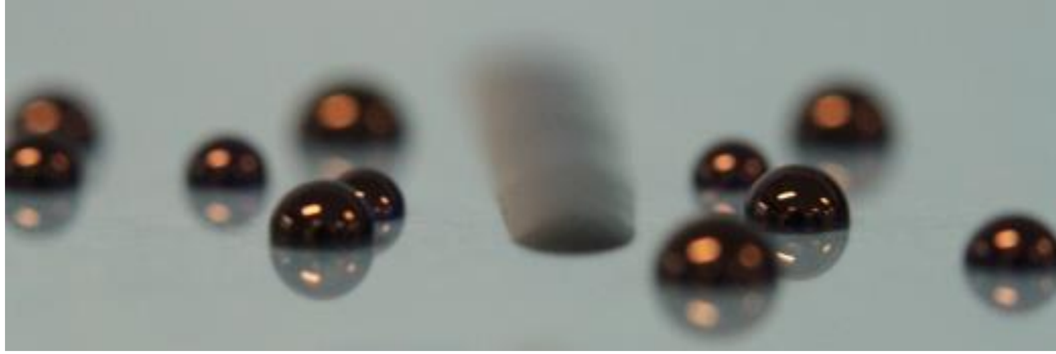
µPlasmaPrint Station



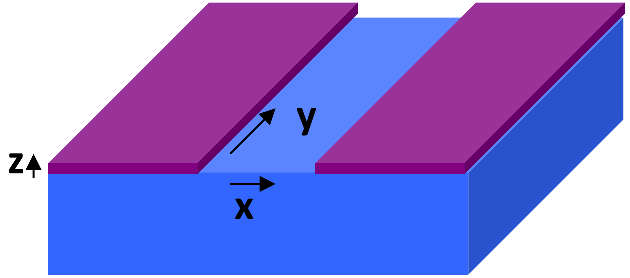
Dedicated plasma printer

µPlasmaPrint head
+ substrate table and controller
+ in-line camera

µPlasmaPrint is …



Software controlled, 100+ µm spatial (XY) patterning of nm scale (Z) functionalities



- Wetting / de-wetting — Bonding, adherence, cleaning, enabling printing
- surface energy tailoring & gradients — fluid-surface interaction improvement
- Selective surface chemistry — Amino, hydroxyl, …

Flexibility of digital printing combined with versatility of atmospheric plasma processing

Surface engineering for biosensor applications

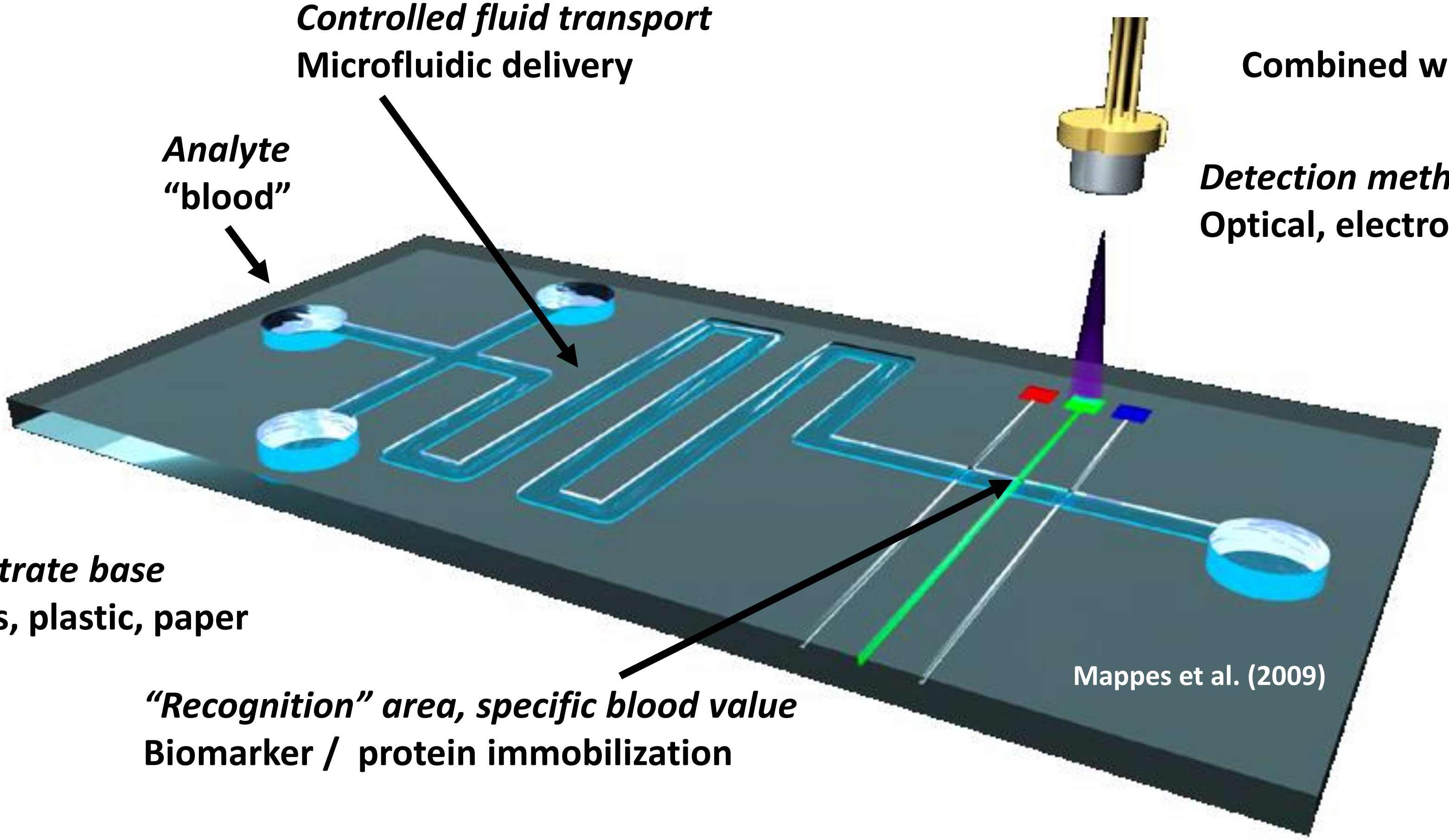
Conceptual example: Disposable Point of Care biosensor cartridge

Controlled fluid transport
Microfluidic delivery

Combined with *Handheld/benchtop analyser* (not shown)

Analyte
“blood”

Detection methods
Optical, electrochemical,…, Silicon,..



Substrate base
Glass, plastic, paper

“Recognition” area, specific blood value
Biomarker / protein immobilization

Vo-Dinh et al., Fresenius J Anal Chem (2000) 366, 540–551
Griesshaber et al., Sensors (2008) 8, 1400-1458
Siow et al., Plasma Process. Polym. (2006) 3, 392–418

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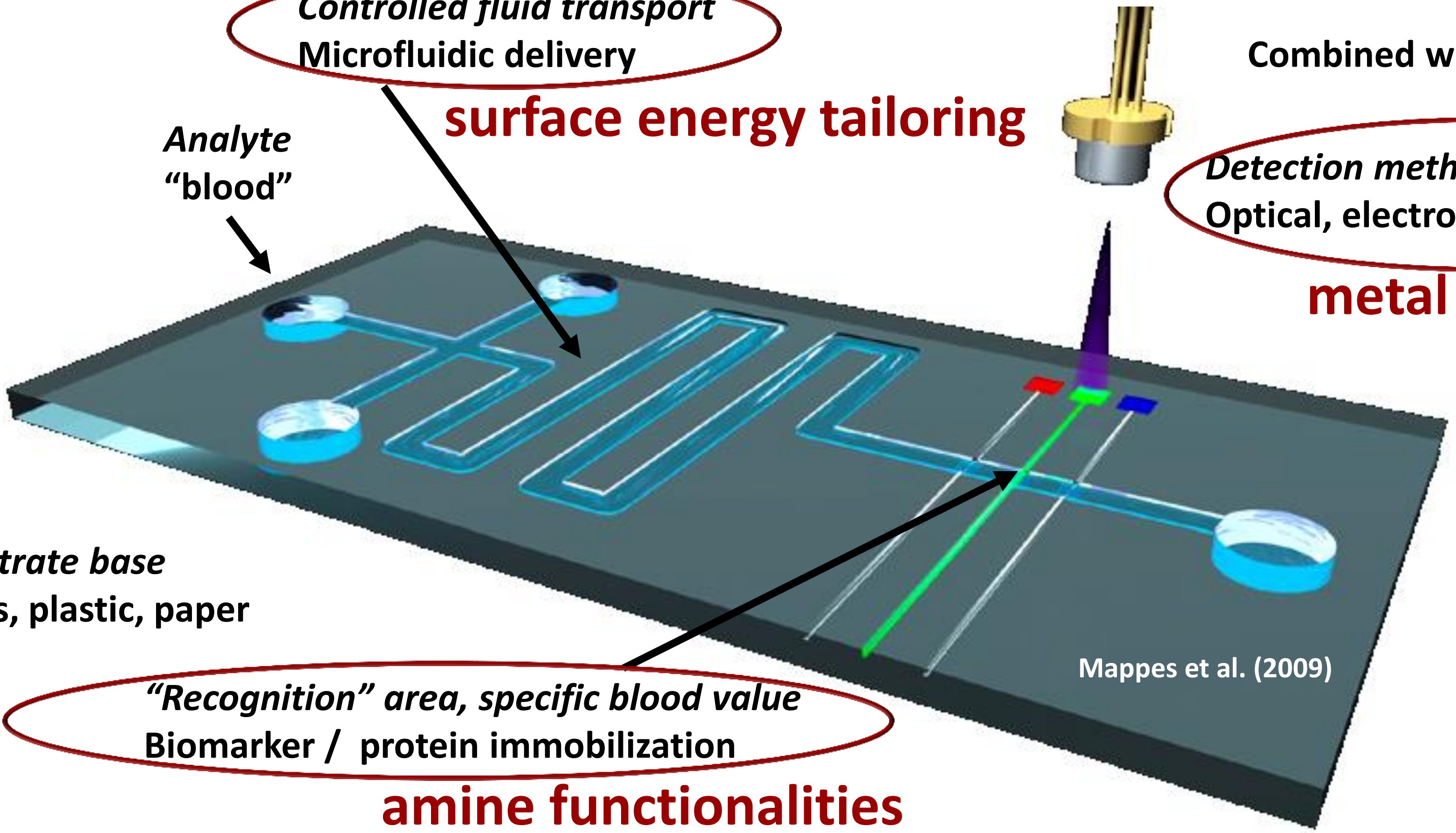
metal tracks & pads



Substrate base
Glass, plastic, paper

Mappes et al. (2009)

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amine functionalities

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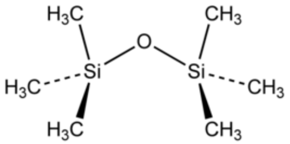
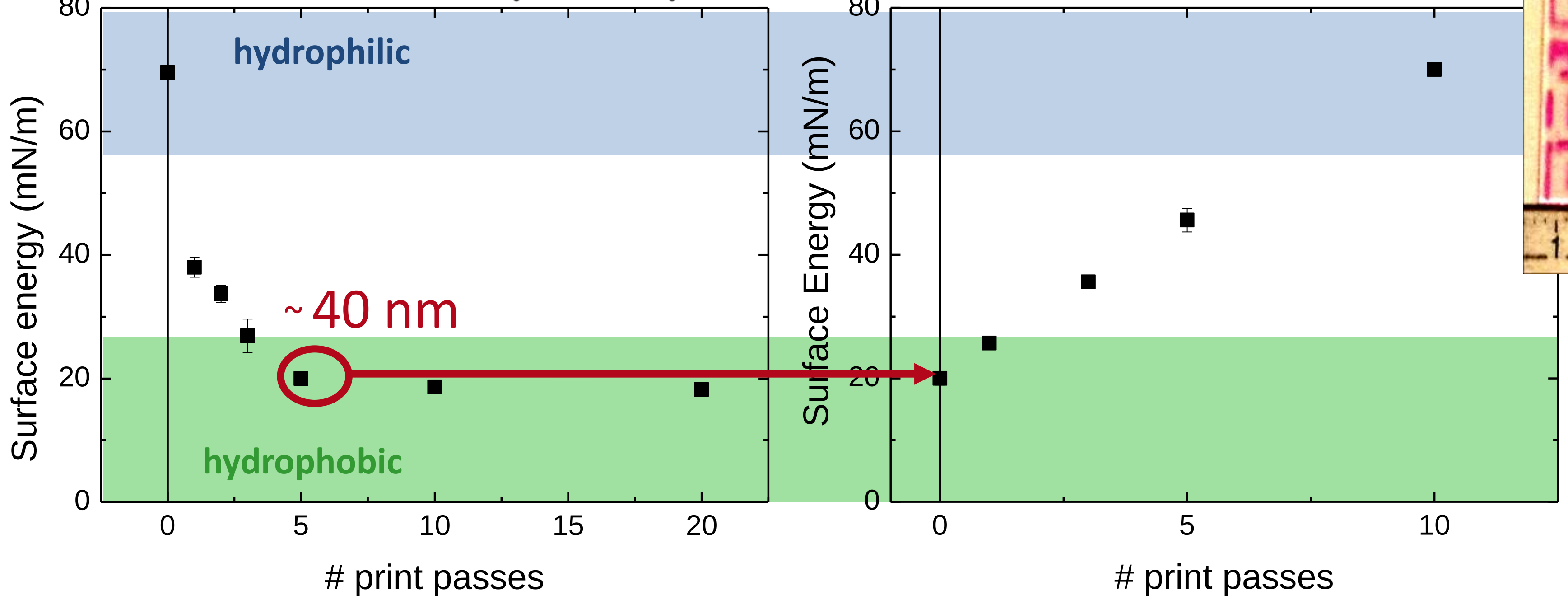
Surface engineering for biosensor applications

A: Surface energy tailoring	Microfluidics
B: Amine functionality printing	Immobilizations
C: Metallization	Electrodes

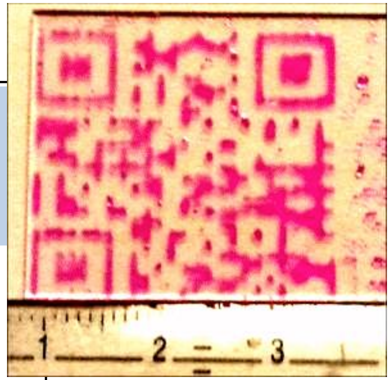
Part A: Surface energy engineering

Step 1: Deposition of SiO_x , layer by layer using HMDSO





Step 2: Post treatment using N_2



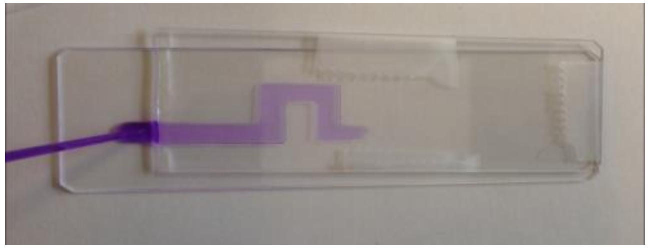
Invisible QR-code
Made visible with color pen

surface energy engineering solution for microfluidics

Part A: Microfluidics

Courtesy of

Fontys



Created using µPlasmaPrint

Hydrophobic-hydrophilic contrast

By removal of nm-scale hydrophobic films

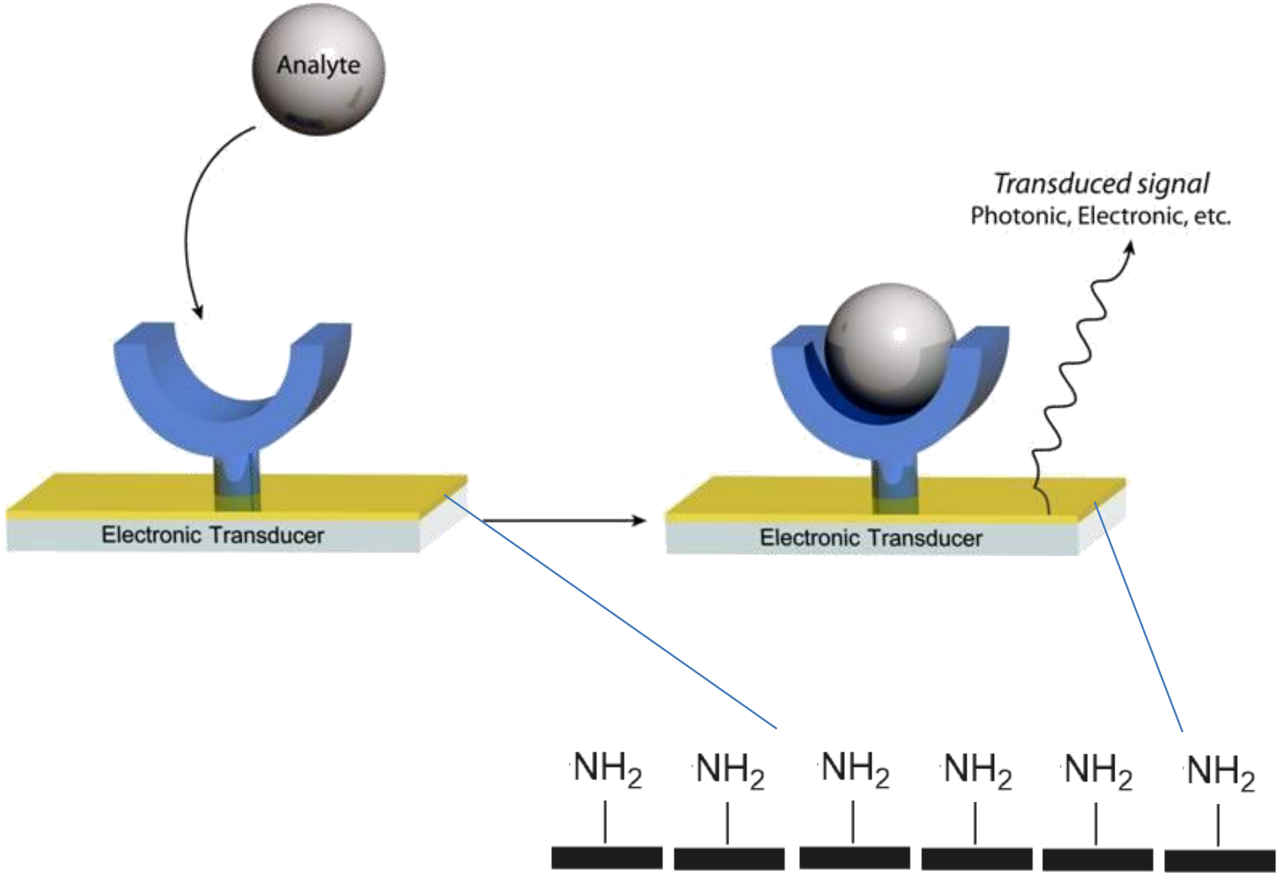
Mirrored image on top and bottom glass slide

With thin spacer to enable fluid flow

"Surface" channels

Alternative for physical channels

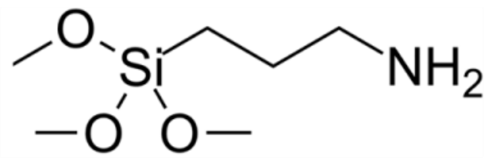
Part B: Biomarker / protein immobilization

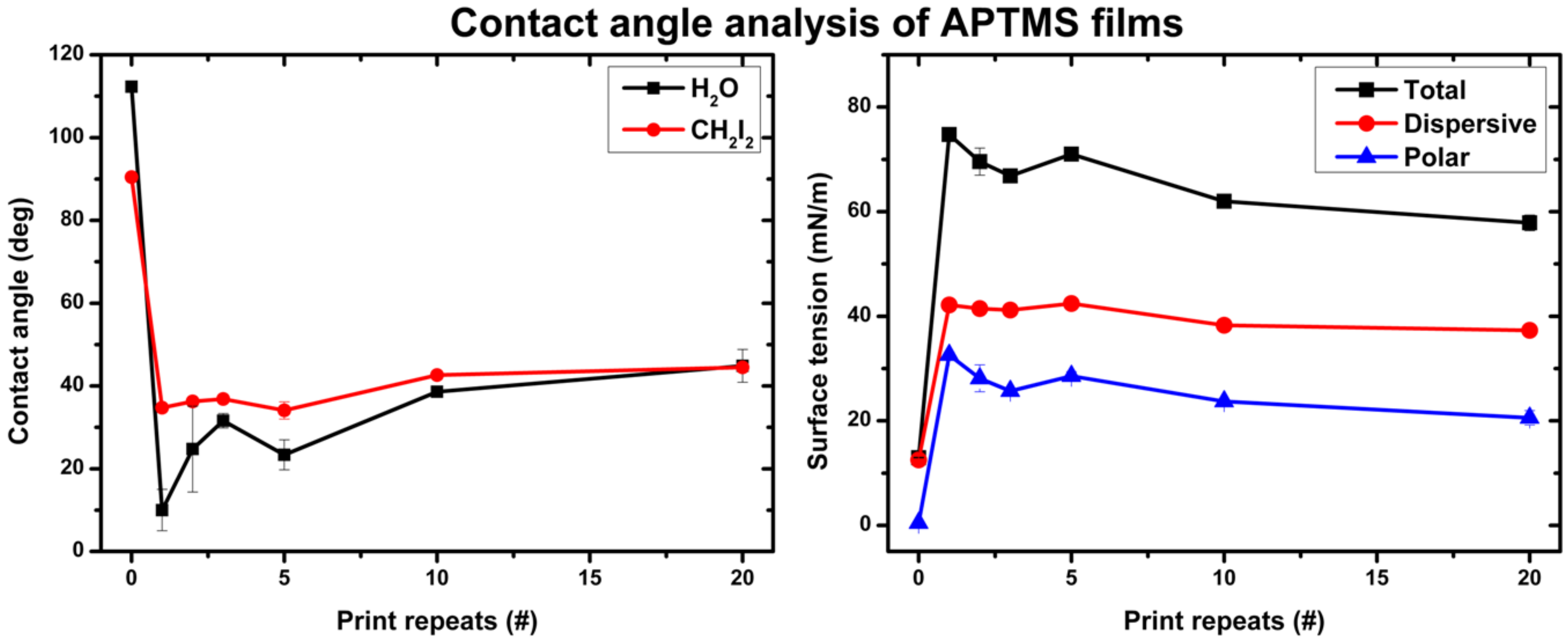


Local plasmaprinting of amines

Part B: Amine functionality printing on fluorinated polymer

Deposition of amines, layer by layer using APTMS

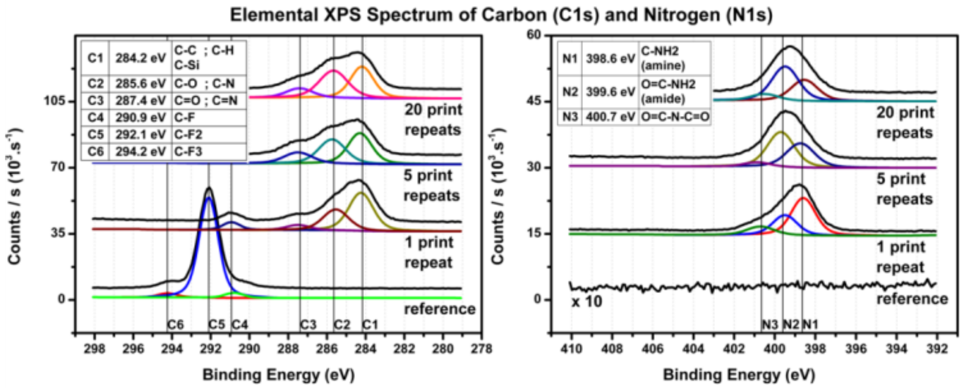




Surface energy decrease with increasing # print repeats

Part B: Amine concentrations from XPS

In collaboration with
Jean-Paul Schalken
Wytze Keuning , Adriane Creatore



	C	C1	C2	C3	N	N1	N2	N3	F	Si	O
FEP substrate (Ref.)	**33.5**								**66.5**		
1 PR	**41.9**				**13.4**				**5.5**	**11.9**	**27.3**
		24.9	10.8	2.7		9.1	2.5	1.7			
5 PR	**39.6**				**13.6**				**1.2**	**12.3**	**33.8**
		17.8	14.3	7.5		5.2	6.3	1.7			
20 PR	**41.3**				**13.0**				**0.0**	**12.2**	**33.5**
		17.4	17.1	6.8		4.7	7.4	0.9			
Borris et al.	**41.9**				**10.2**					**13.2**	**34.7**
		22.2	15.1	4.6		2.5*	*CD-XPS				

Biomedical sensor : Protein/biomarker immobilization

4 - 9 % amine surface coverage, comparable with lit.
= Surface density control

Borris et al., Plasma Process. Polym., 4, S482-S486 (2007).

Part C: Metallization for electrodes / metal tracks

Step 1: Amine functionality print using µPlasmaPrint

Step 2: selective metal-salt chemistry to enable

Step 3: electroless Ni, Cu metal tracks & pads (-> galvanic strengthening)

Ni pads Ø 2- 5 mm on FEP

Indirect, digital, metal printing on foil
Low temperature, no curing required

In summary

Introduction into the world of µPlasmaPrint surface engineering solutions

digital printing with molecules to achieve spatial, surface chemical & physical properties control

plasma activation enables low temperature processing at nm scale sensitivity

Direct, digital plasma printing of surface functionalities for biosensor application

A: surface microfluidics printing

B: immobilization through amines printing

C: indirect metal electrodes / tracks printing

Flexibility of digital printing combined with versatility of atmospheric plasma processing

Acknowlegdements

TU/e Jean-Paul Schalken, Wytze Keuning, Adriane Creatore, Erwin Kessels

Fontys Martijn van Dongen, Jan Bernards

SIA Stichting Innovatie Alliantie **RAAK Pro Inkjet Project**

.. and funding & partners in..

eniac JOINT UNDERTAKING Prominent **Silicon MEMS** by inkjet enhanced technologies

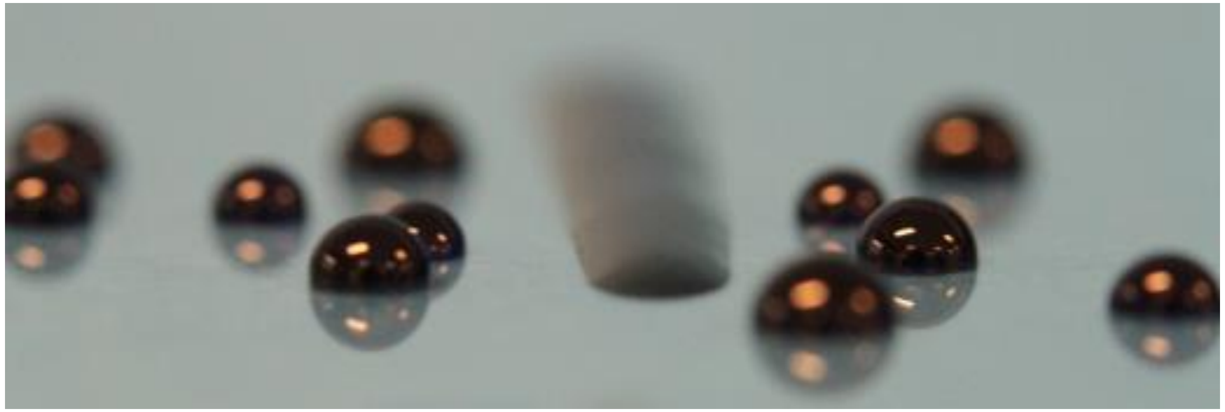
SEVENTH FRAMEWORK PROGRAMME CLEAN4YIELD DETECTION • CLEANING • PREVENTION • REPAIR Local cleaning & repair strategies to improve yield in **organic printed electronics** manufacturing

MARIE CURIE ACTIONS RAPID Atmospheric Plasma Chemistry MC - ITN Reactive Atmospheric Plasma Chemistry
Started 1st October 2013, PhD positions available

NEW Starting soon : **tissue engineering** solutions

All PlasmaPrinted biomedical sensor substrate base

- **Design and process *flexibility* in R&D**
- **Scaling capability for *low cost* disposables production**



Thank you for your attention!
Questions?