



Unconventional fabrication technologies for the elaboration of Lab-on chip in electrochemical bio(chemical) sensors »

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Introduction

Conventional techniques

- Patterning
 - photolithography
 - scanning beam lithography
- Metal deposition
 - evaporation, sputtering, electroplating,...
- Microfluidic-systems
 - Anodic bonding

Sophisticated equipments, time-consuming, not environmentally friendly, only small areas on rigid inorganic substrates

Alternative techniques...



Introduction

Alternative techniques...

- Patterning
 - Soft lithography

Micro-contact printing

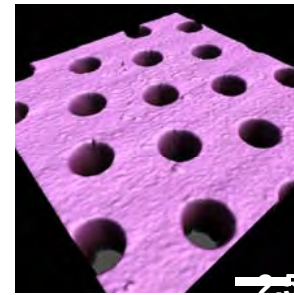
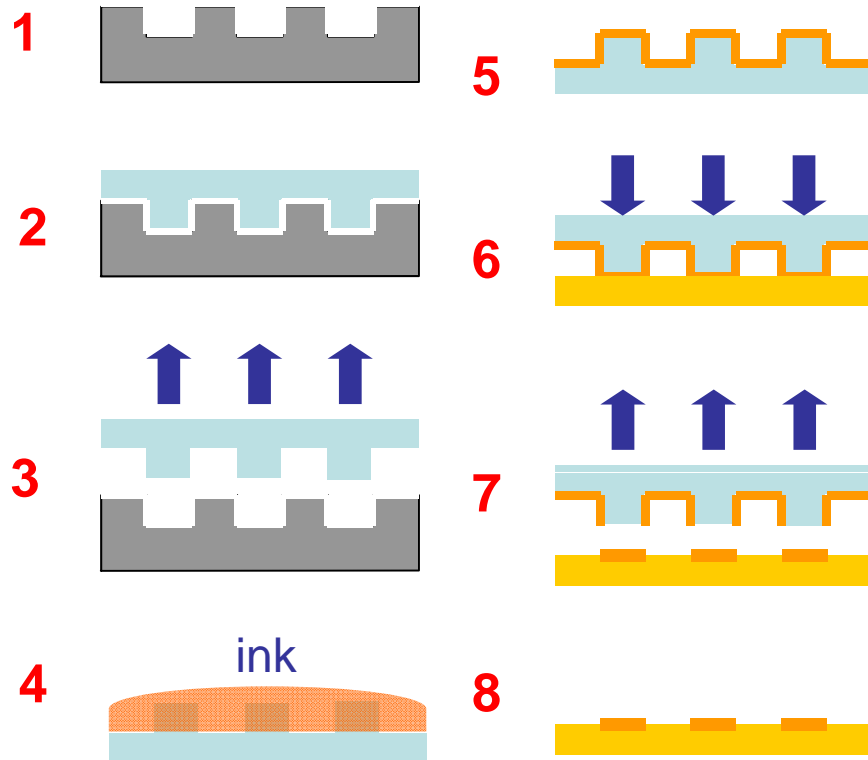
- Metal deposition
 - Electroless plating

Also possible on flexible substrates...

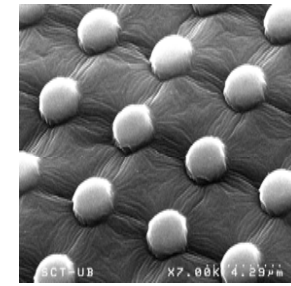
Cost efficient, simple technologies
to develop biological and chemical miniaturized sensors



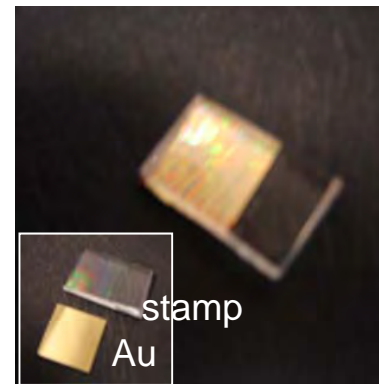
Microcontact printing (μ CP)



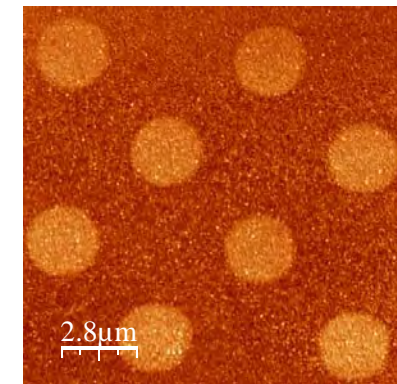
a)



b)



c)



d)

Figure. μ CP procedure schematics.

Caballero et al., Analytical Letters, 39: 1721 (2006)

Figure.

- a) AFM image of the Si master,
- b) SEM image of the PDMS stamp,
- c) Image of the stamping procedure,
- d) AFM image of a well stamped region.



Submerged microcontact printing (S μ CP)

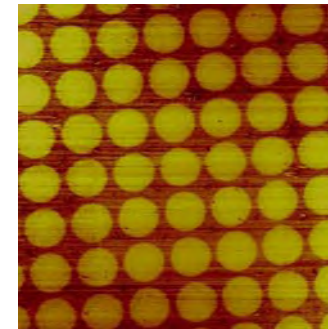
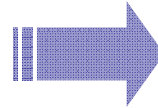
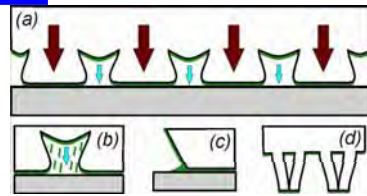
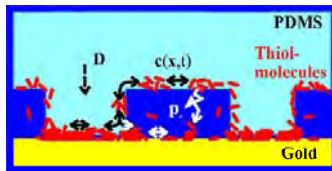


Figure. AFM image of the collapsing of a stamp using standard μ CP.

Standard μ CP

Submerged μ CP

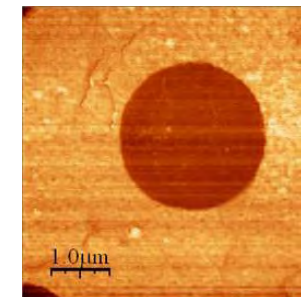
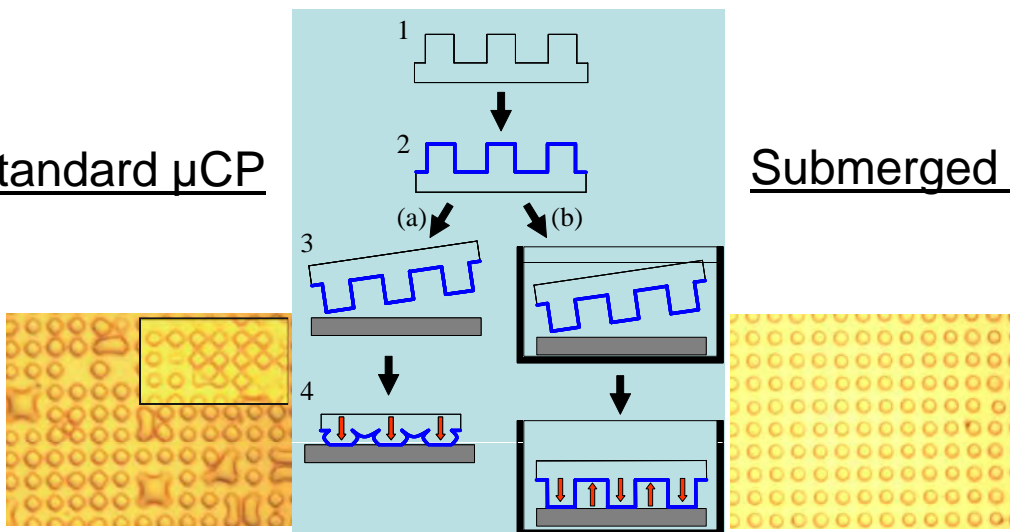


Figure. AFM image of a Au surface patterned by S μ CP using a stamp with an aspect ratio of 15:1.



3D-Nanostructuration

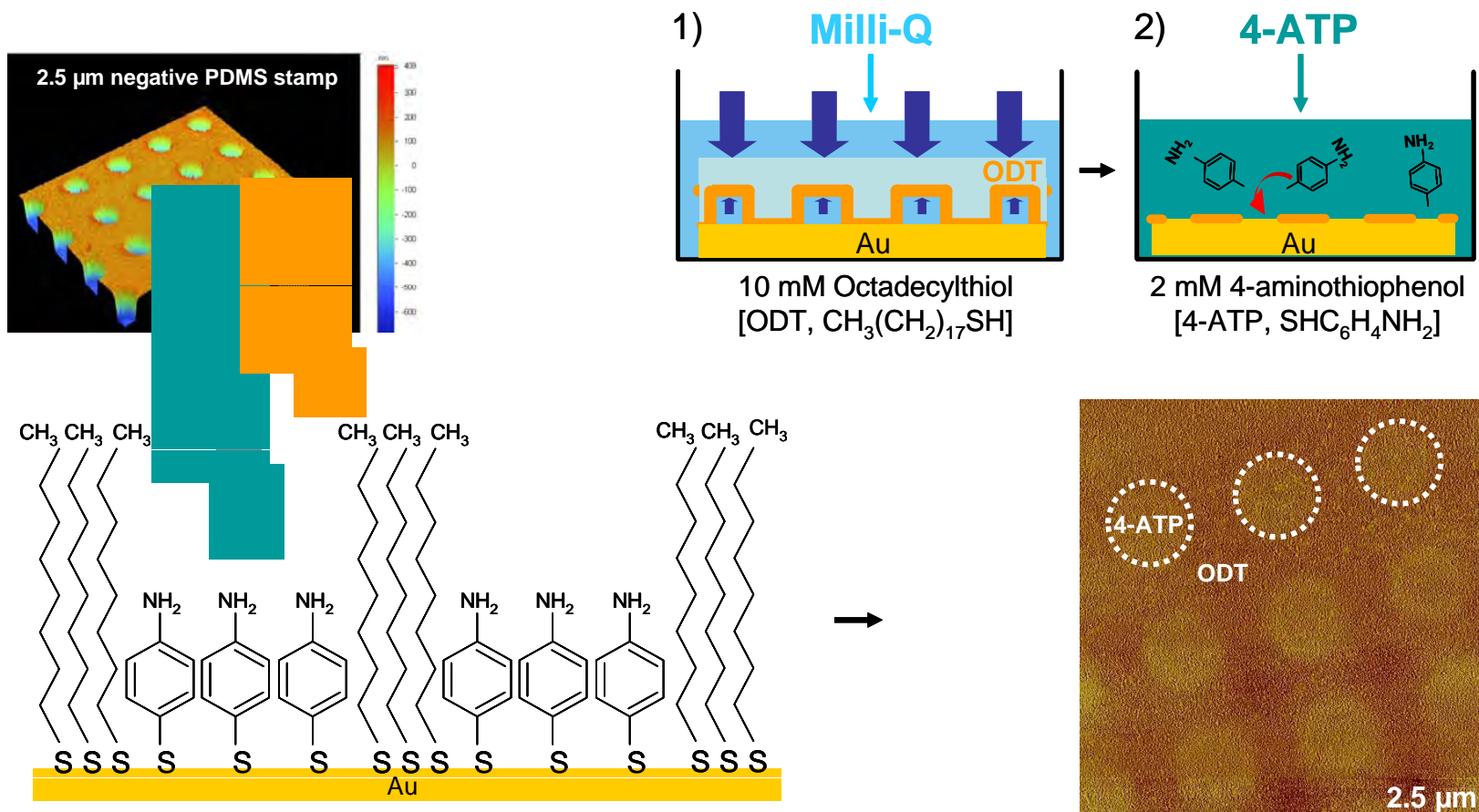


Figure. Schematic diagram of a gold sample with double functionalisation.

Figure. ODT/4-ATP substrate.



PPy / [Co(C₃B₉H₁₁)₂] electropolymerisation

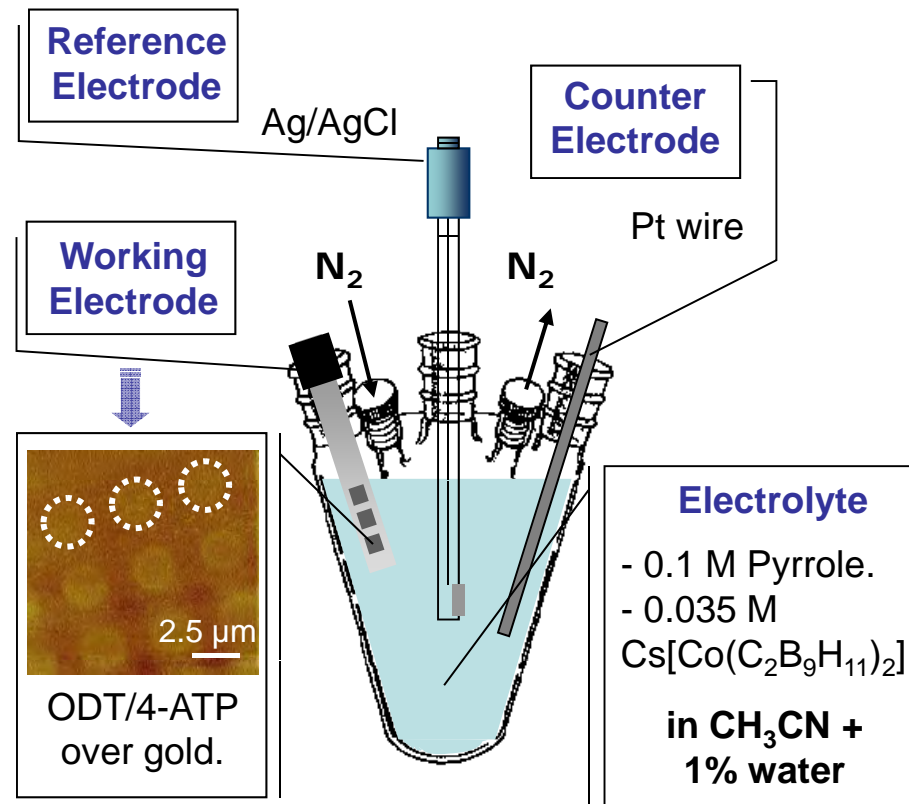


Figure. Electrochemical cell.

Masalles et al., Adv. Mater., 12: 1199 (2000)



Rings pattern

The use of μ CP allows the PPy SAM pattern to be printed over large areas.

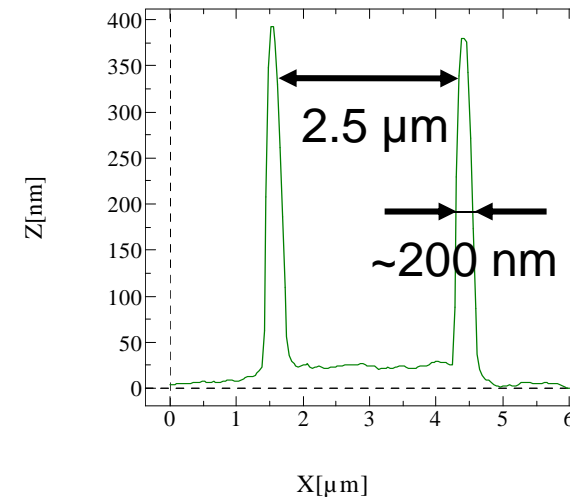
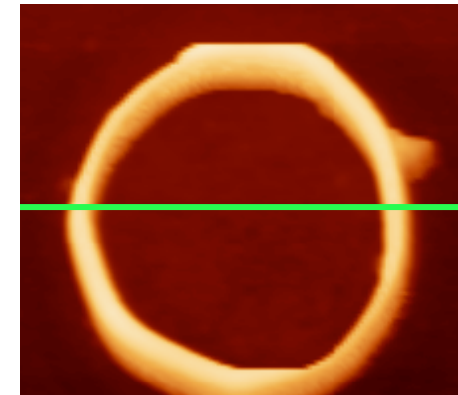
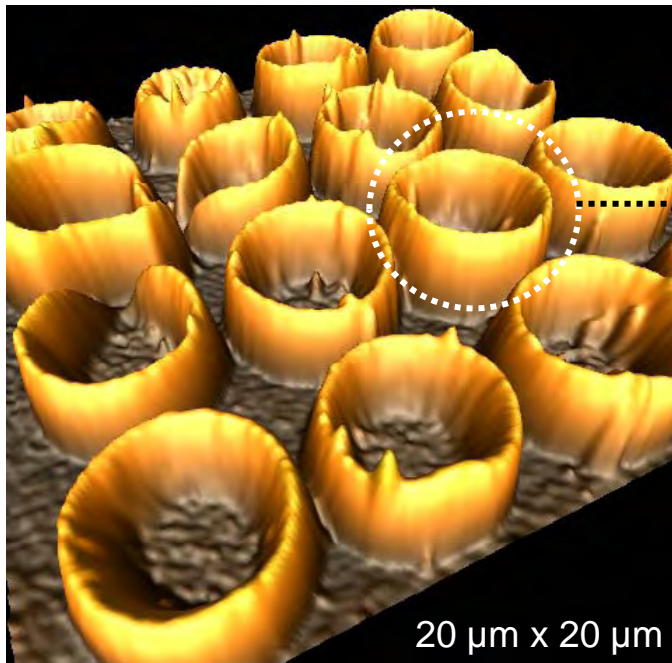
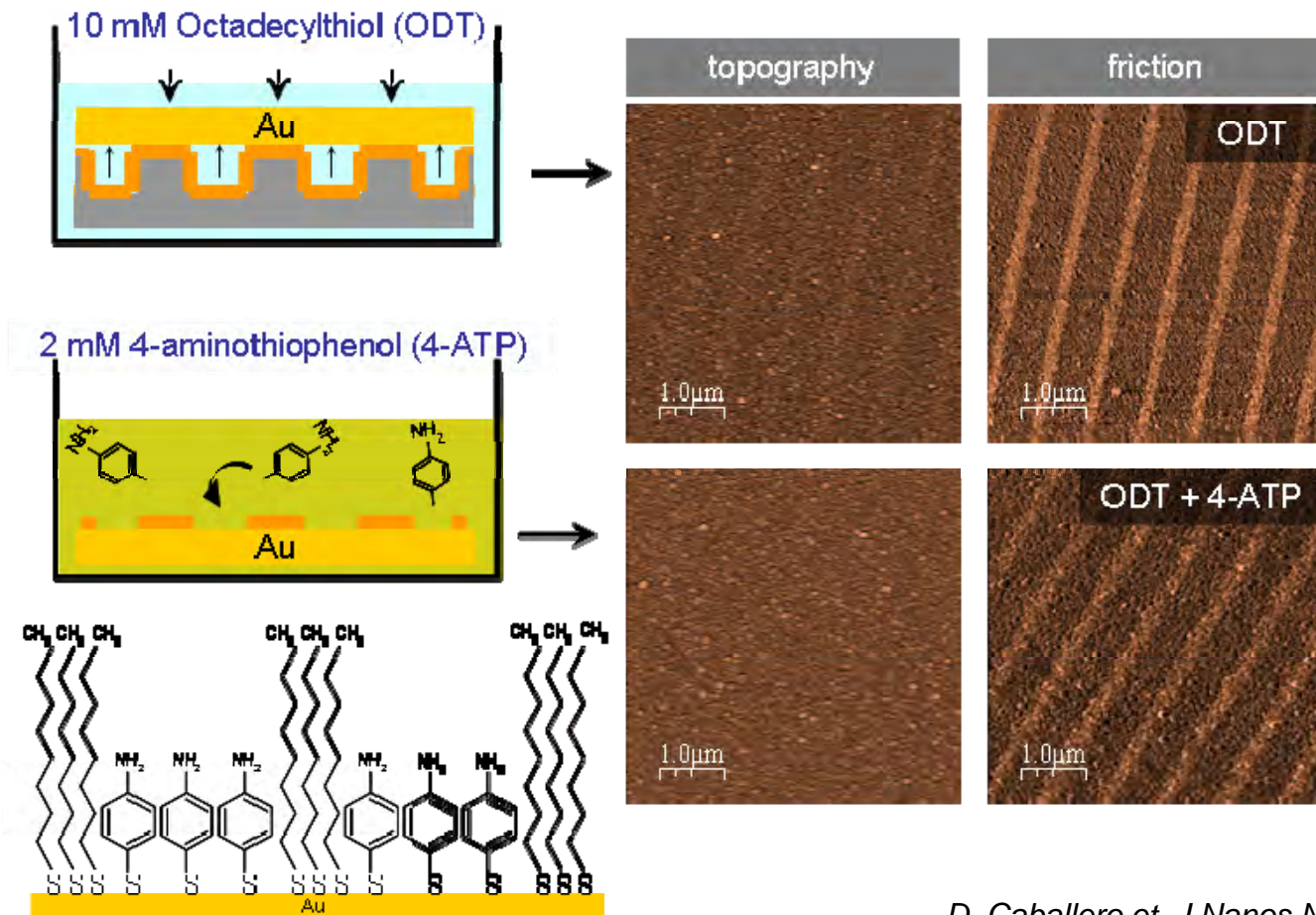


Figure. Formation of polypyrrole rings. 3D AFM topography image of polypyrrole rings over large areas.

Figure. Sectional profile of one PPy ring.



Nanowires based on Conducting polymers



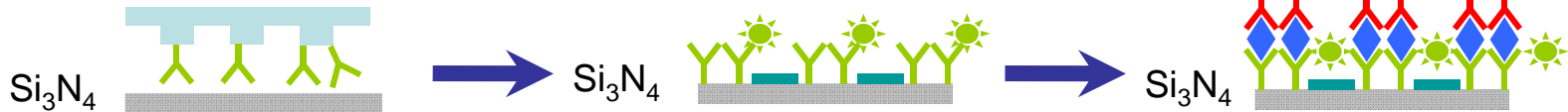
*D. Caballero et, J.Nanos.Nanotech,
2010, in press*



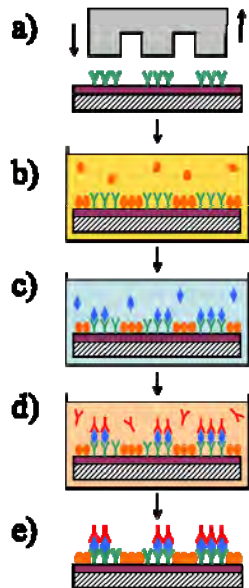
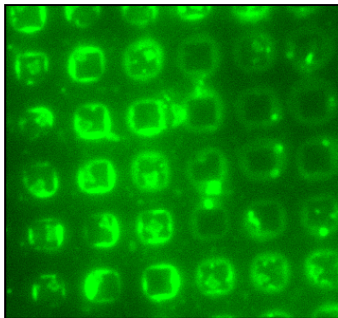
Human Serum Albumin Patterned on Si_3N_4

- Detection of disease markers:

1.- μCP :



Problem:



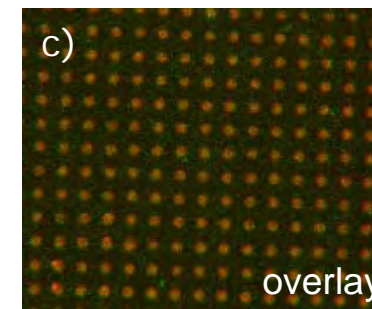
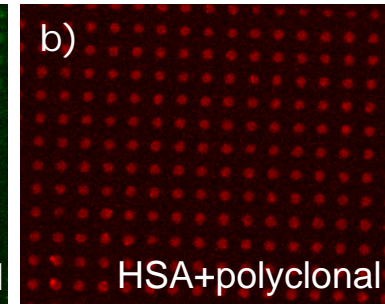
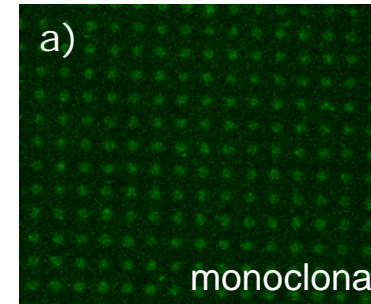
μCP of Anti-HSA monoclonal antibody over TEA SAM

PEG-NH₂ blocking

HSA incubation

Anti-HSA polyclonal antibody incubation

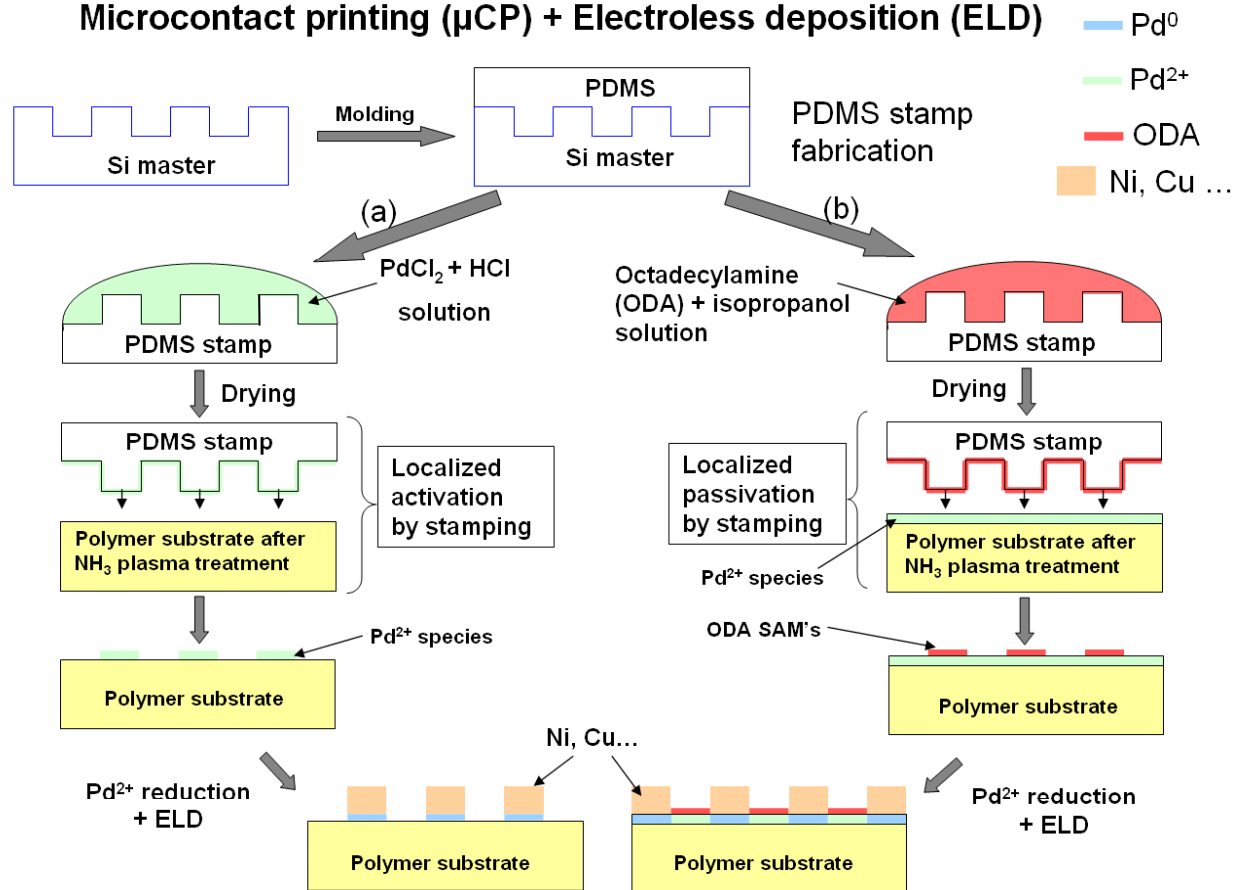
Ab-HSA-Ab sandwich





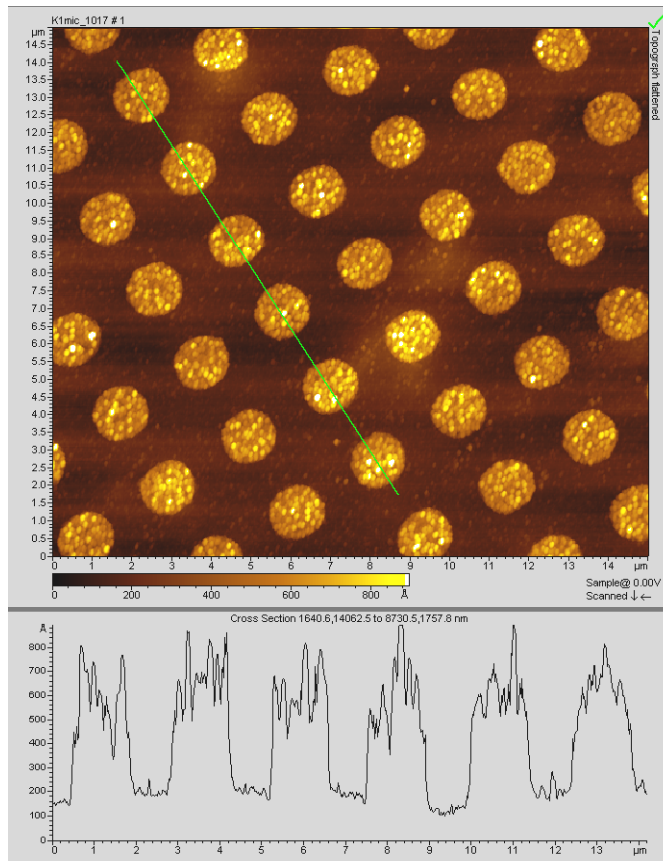
Selective patterning using electroless plating and microcontact printing

Microcontact printing (μ CP) + Electroless deposition (ELD)





Selective patterning using electroless plating and microcontact printing



- surface oxidation
- sensitization (Sn)
- redox reaction between Sn^{2+} and Ag^+ species
- H_2 plasma treatment
- Ag electroless

micro-patterned
Ag structures
(2 μm periodic array)

average thickness
of Ag deposits is about 50 nm

Figure: Tapping mode AFM image

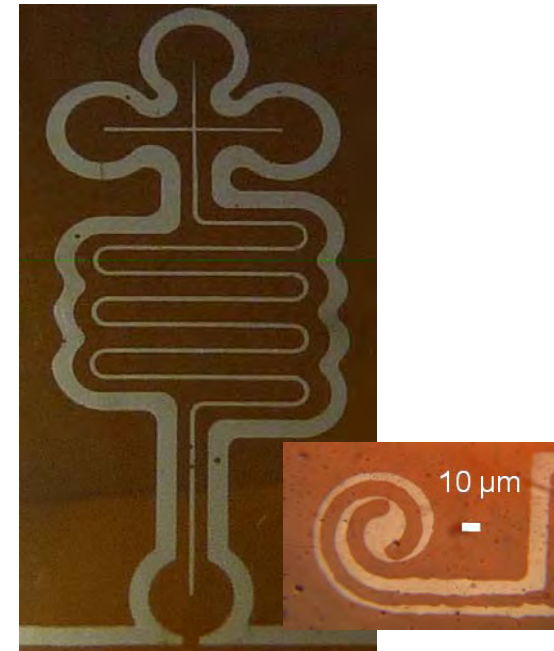


Selective patterning using electroless plating and microcontact printing



Two different steps of fabrication of micro-electrodes (illustrated for two different systems)

Optical micrograph (width of the Ni lines $\sim 100 \mu\text{m}$)



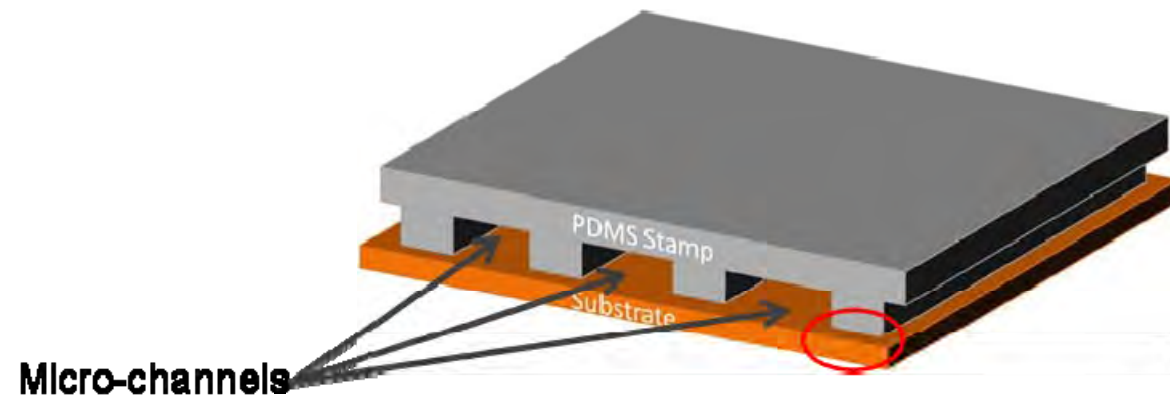
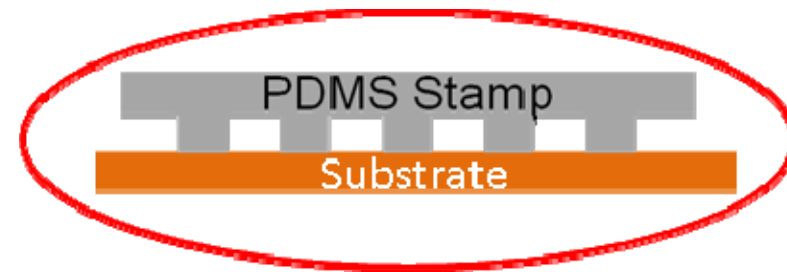
Small Ag central line is about $100 \mu\text{m}$ wide

Optical micrograph



Microfluidic systems based on polymers substrates

- Manufacturing of Microfluidic systems.
- Manufacturing of PDMS Micro channels.
- Substrate Surface Treatment .
- Sealing of Microchannels on the Substrate.





Microfluidic systems based on polymers substrates

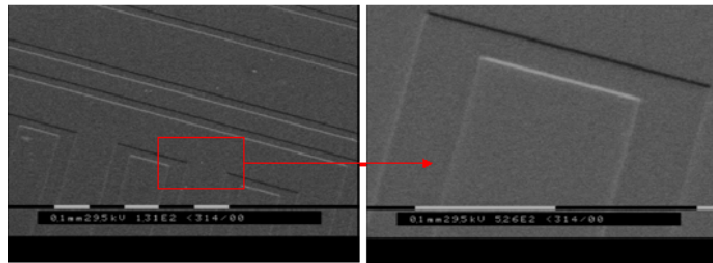


Figure: SEM image of silicon mold with 1 μm of depth

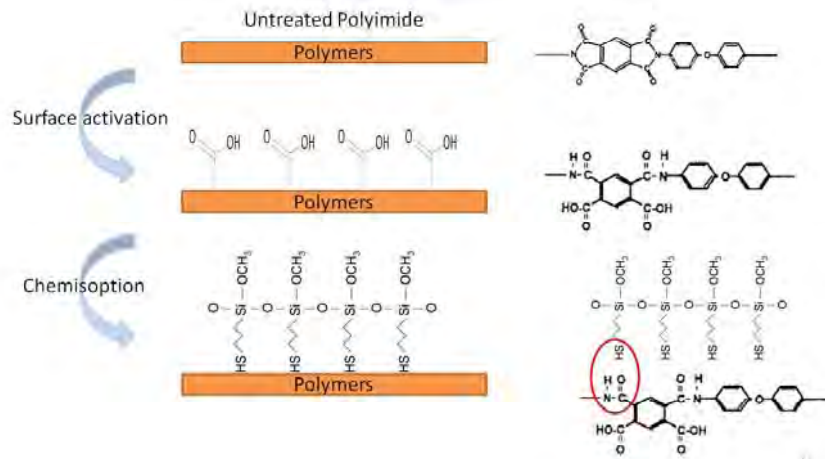


Figure : Schema shows the 3-MPTMS chemisorptions on the treated PI surface by polar bonding

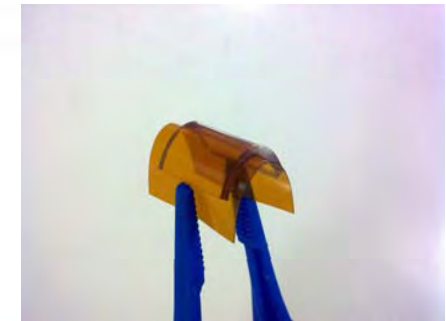
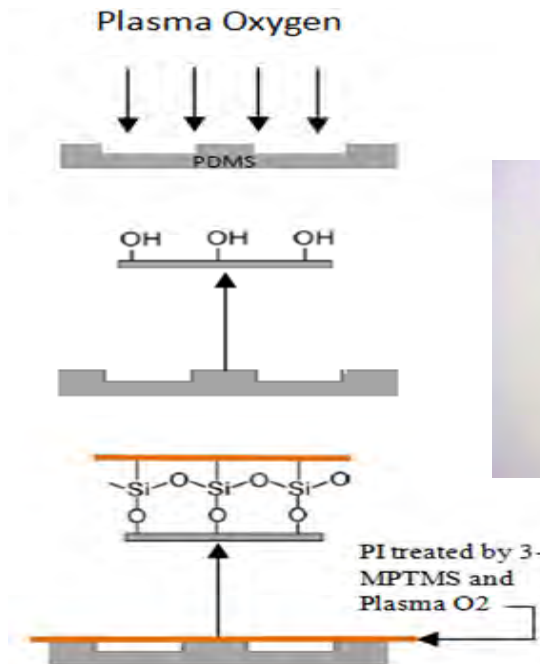


Figure: Scheme shows Si-O-Si bonding between PDMS and PI treated 3-MPTMS.



Microfluidic systems based on polymers substrates

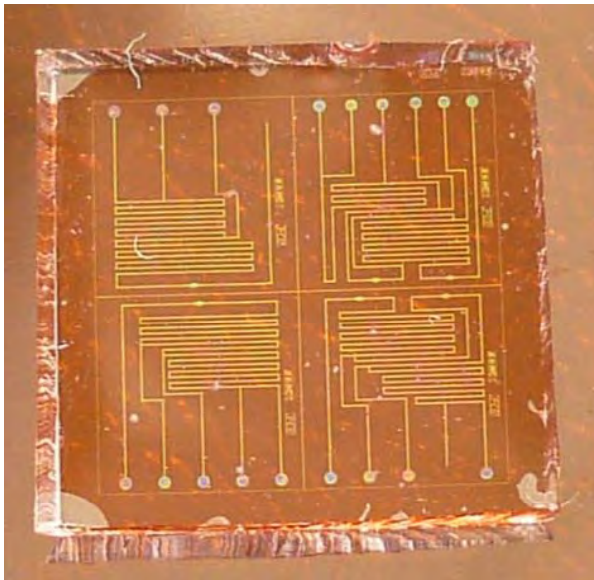


Figure : Micro-fluidic system based on PDMS that has adhered onto PI, by treatment with 3-MPTMS.

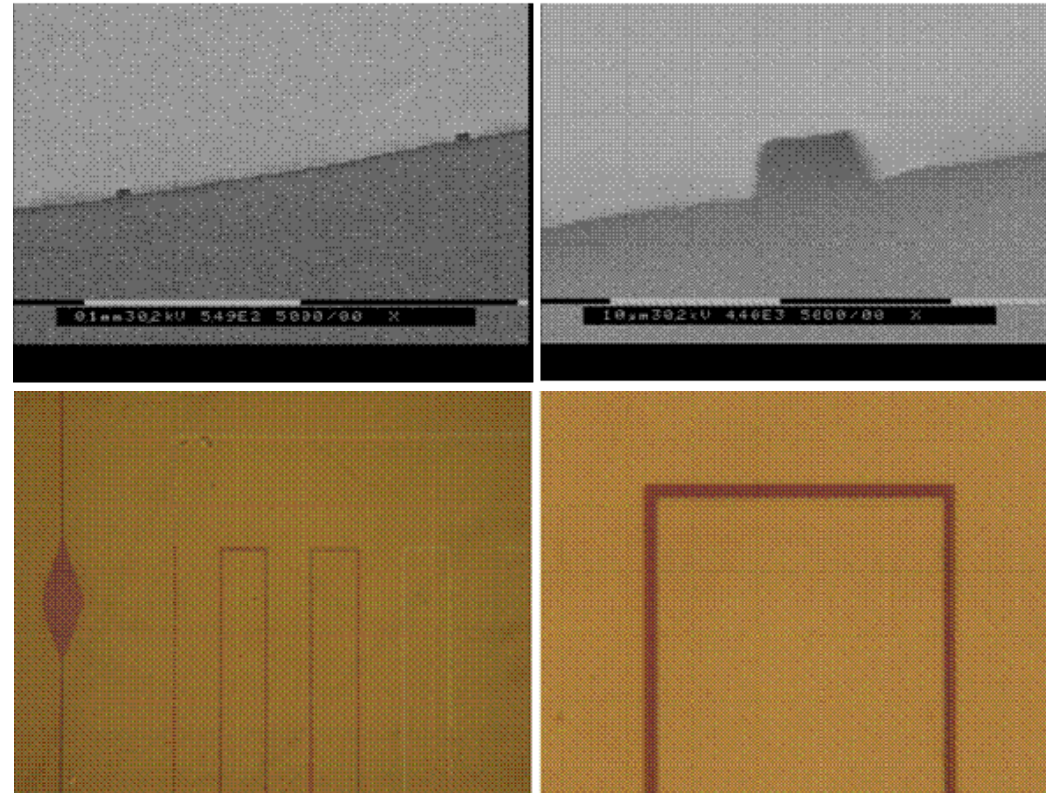


Figure : (a) SEM cross section image of Micro-channels of PDMS onto PI substrate, (b) optical microscope image of Micro-channels on PET.



Microfluidic systems based on polymers substrates

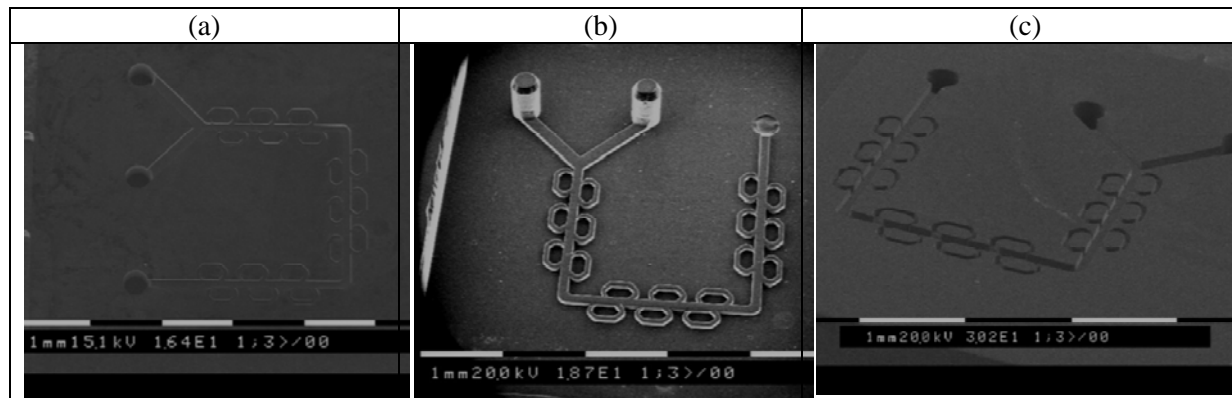


Figure : SEM images (a) A silicon microfluidic channel (negative master) produced by DRIE and wet etching, (b) Positive PDMS replica manufactured from (a). (c) A negative replica of silicon master (a) fabricated using PDMS replica (b).

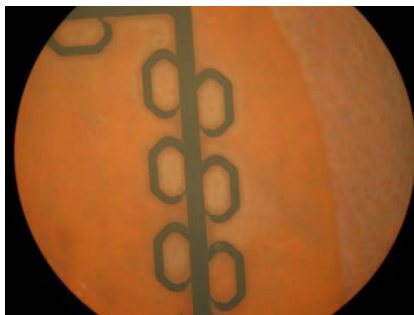


Figure : Optical microscope image (100x) of a microfluidic PDMS replica (negative) bonded onto PI. One dye was injected into one injection ports.

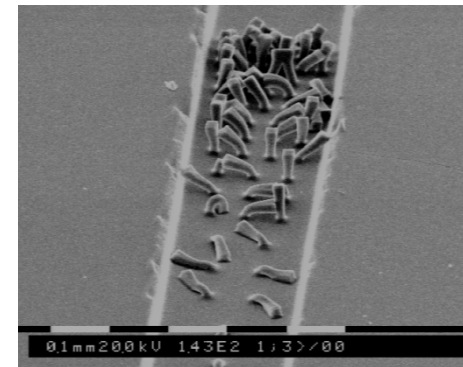


Figure : SEM image of a microfilter with collapsed filters along the microfluidic channel.



Lab-on-chip based on polymers substrates

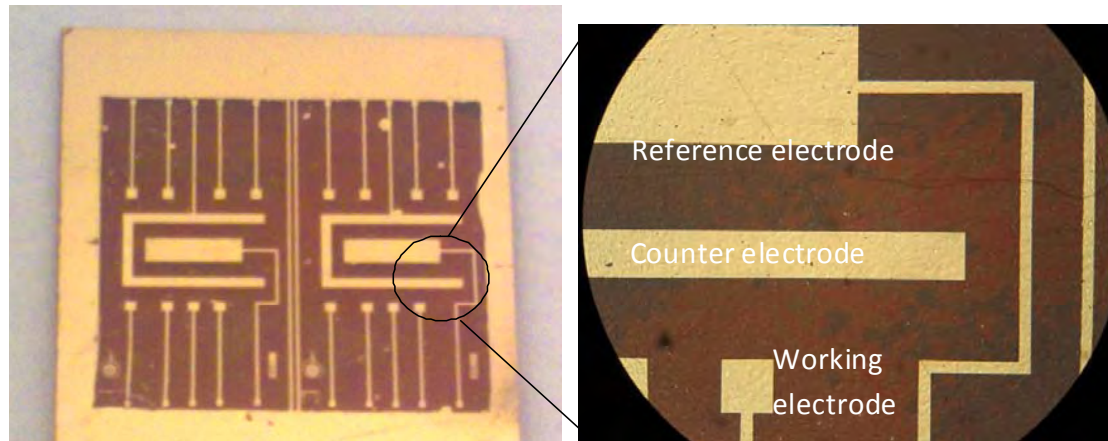


Figure: Gold Micro electrodes on polyimide substrate fabricated by microcontact printing.

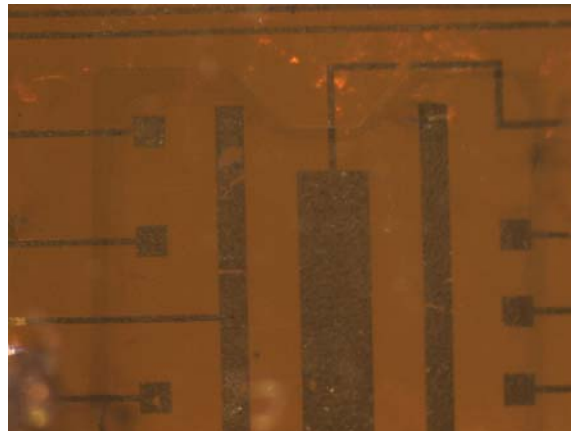
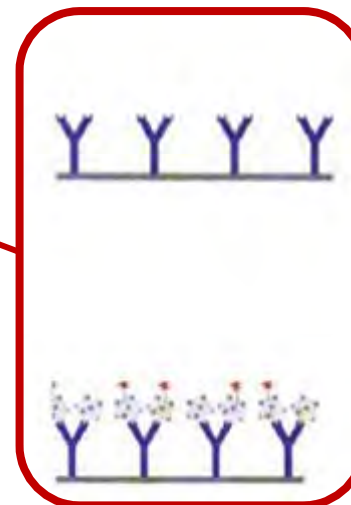
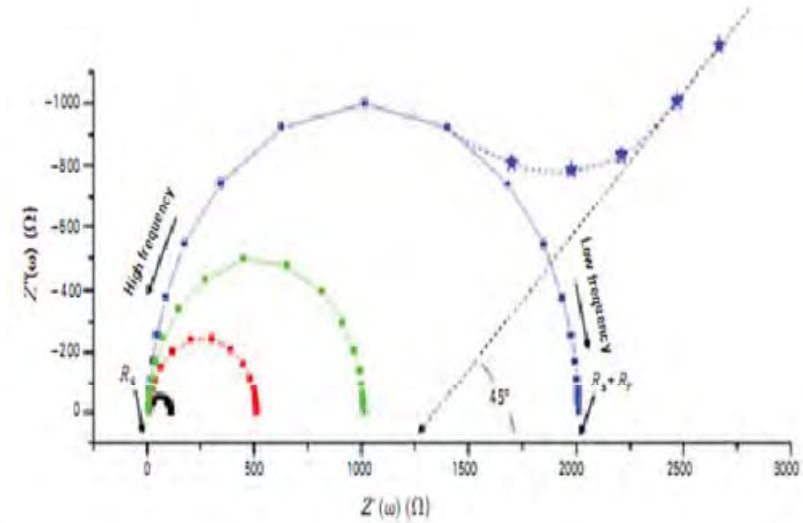
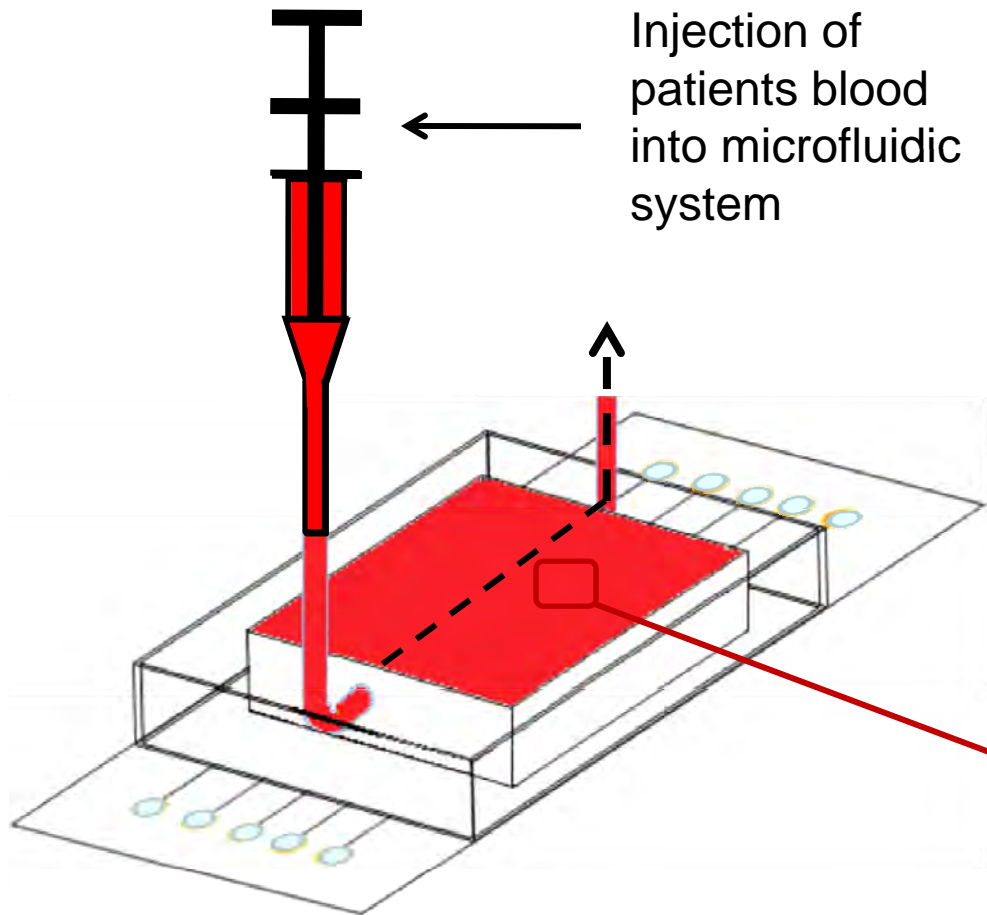


Figure: Optical image of the Lab-on-chip

Lab-chip, 2010 (Submitted)



Perspectives: Manufacturing of Lab-on-chip





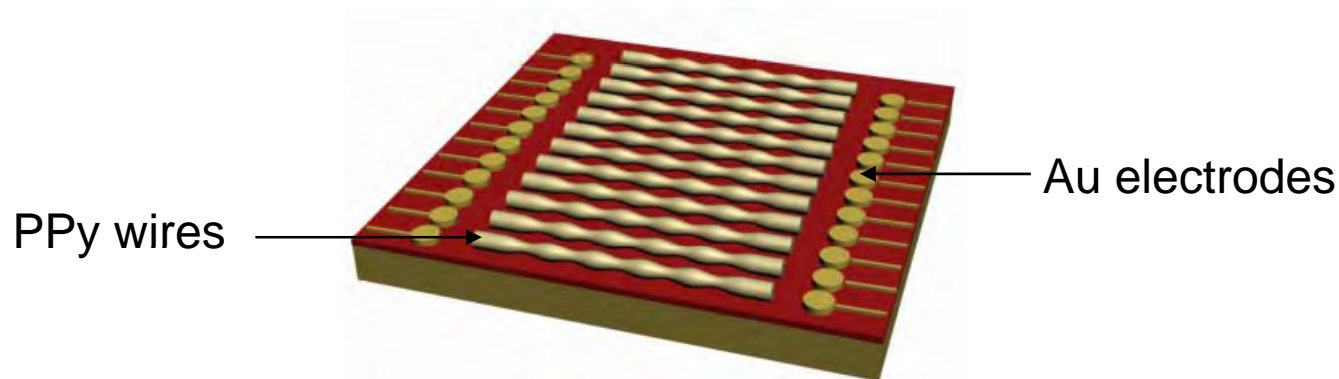
Conclusions

- Simple cost-effective processes are developed for the production of devices and Lab-on-chip systems
- Nano 3D Objects can be obtained using a specific control of surface chemistry based on S- μ CP
- Flexible Process to Manufacture Microfluidic Systems on Polymer Substrates
- PDMS Microfluidics Structures Irreversibly Bonded to Modified Polymer Films by Silanol Surface Activation



Future Work

- ✓ Use different PDMS stamps to replicate different structures at the nanoscale.
- ✓ Perform AFM conductive measurements over the doped PPy structures.
- ✓ Combine conductive PPy structures with standard circuit technology.



- ✓ Development of nanowire sensors arrays based on polypyrrole capable of simultaneously detecting multiple (bio) chemical species.



Acknowledgments

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Dr. J. Bausells, Dr. J. Antonio Plaza and M. Zabala (CNM) for
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