Micropatterning and casting PEDOT-PSS /DMSO layers

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Outline

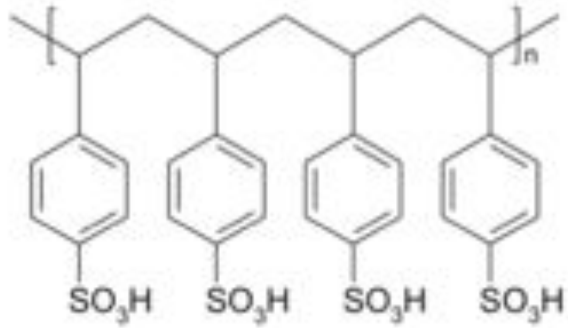
- Introduction
- PEDOT:PSS deposition
- Soft lithography techniques
  - Casting
  - Stamping
- Shadow masking
- Lithography techniques
  - Lift off
  - Protection layer
- Applications
- Conclusions

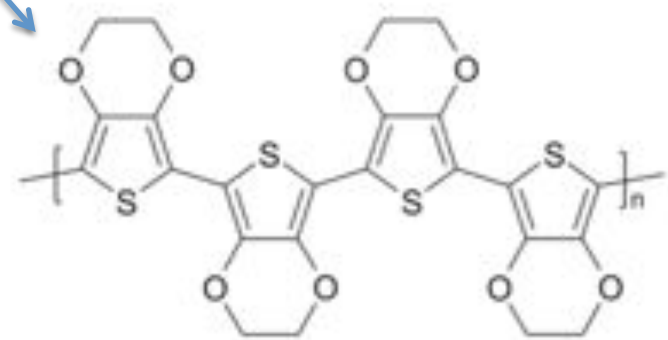
Introduction

PEDOT:PSS is a blend of polymers :

PSS : polystyrene sodium sulfonate

PEDOT poly(3,4-ethylenedioxythiophene)





-Conductive polymer, flexible transparent when deposited in thin film layer

- low temperature , low cost process

- Often use in organic solar cells

- Candidate for the replacement of ITO

- Organic electronics, large area display

But :

- low charge carrier mobility

- Sensitive to moisture, water and UV

$R=5.10^{-3}$ ohm.cm^{-1}

Work function 5.2 eV

Issues of patterning

Ink-jet printing, vapor deposition through shadow masks, soft and hard imprint lithography, and photolithography

Bioelectrode

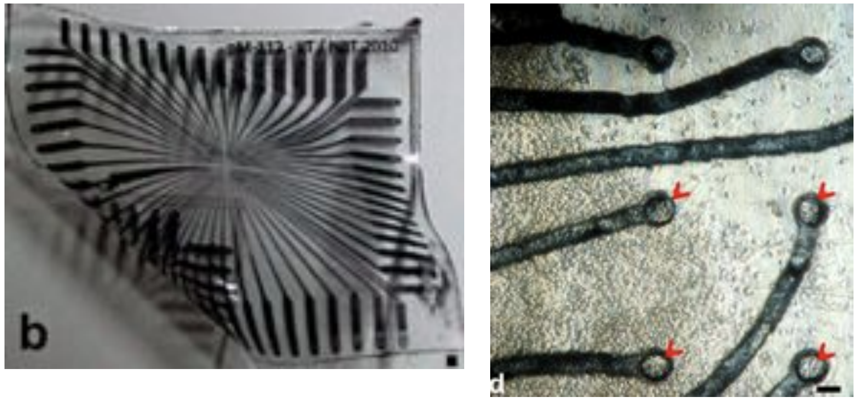
PEDOT-PSS is a candidate material for bioelectrode
Improvement of the neural tissue-electrode interface and lifetime of implants

- highly electroconductive
- hydrophilic and biocompatible
- Softness

silk thread coated with PEDOT-PSS

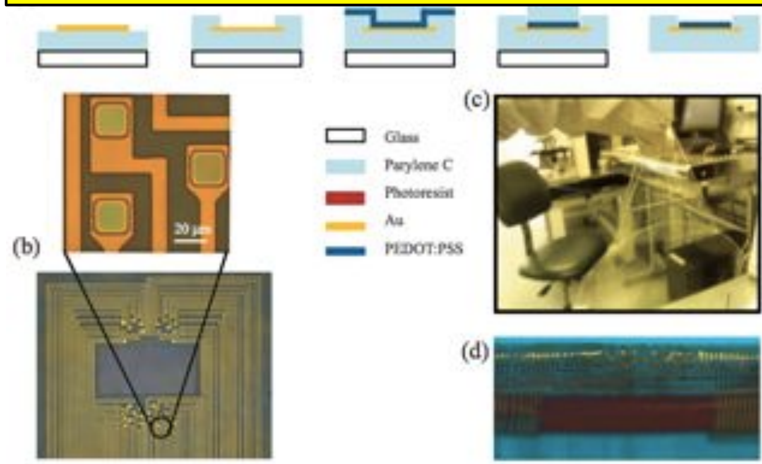
Shingo Tsukada et al. Plos One
Volume 7, Issue 4, April 2012

Microelectrode arrays for the capture of cardiac and neuronal signals



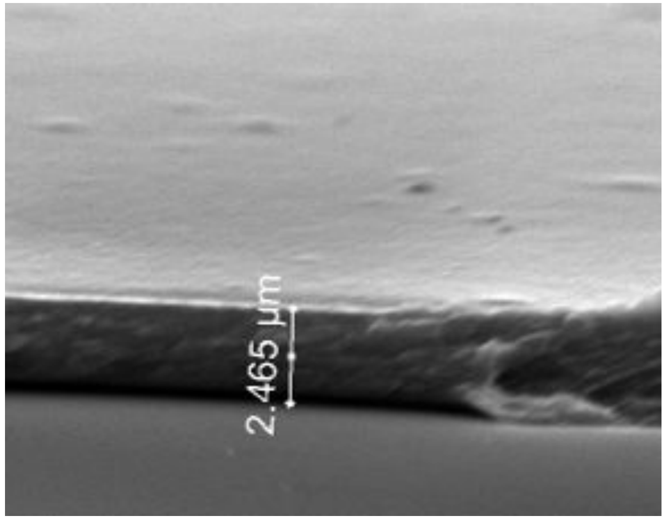
A.Blau et al. Biomaterials
Volume 32, Issue 7, March 2011

Highly Conformable Conducting Polymer Electrodes or In Vivo Recordings



D. Khodagholy et al. Adv. Mater.
2011, 23, H268–H272

PEDOT:PSS deposition



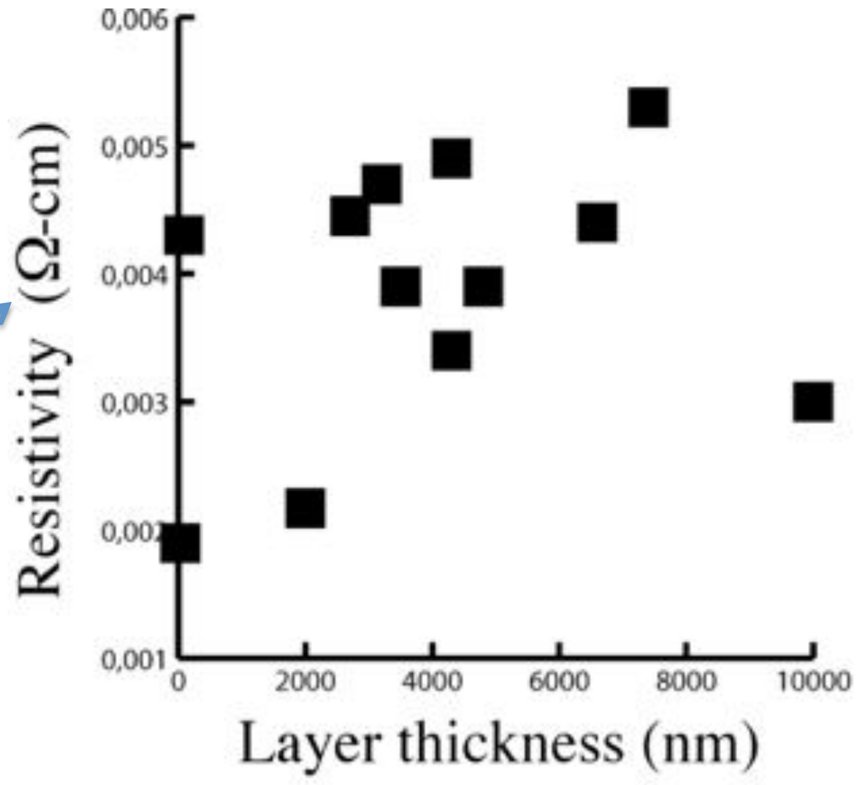
Spincoating
3000 rpm Th=100nm
and drying on hotplate 125°C

Wetting issue can be solved by adding IPA

Mean Resistivity PEDOT:PSS only :
R=6 Ω.cm^{-1}

Additives for increasing conductivity

Ethylène glycol $C_2H_6O_2$
Glycerol $C_3H_8O_3$
Sorbitol $C_6H_{14}O_6$
Dimethyl Sulfoxide DMSO C_2H_6OS
Erythritol $C_4H_{10}O_4$



Mean Resistivity PEDOT:PSS / DMSO
R=5.10^{-3} Ω.cm^{-1}
Mean Resistivity PEDOT:PSS / EG
R=6.10^{-3} Ω.cm^{-1}

Casting in PDMS

Goal : obtaining deformable electrodes in PDMS for large deformations
Direct metalization Problems : Inclusion / deposition of metals in PDMS
adhesion problems / cracks

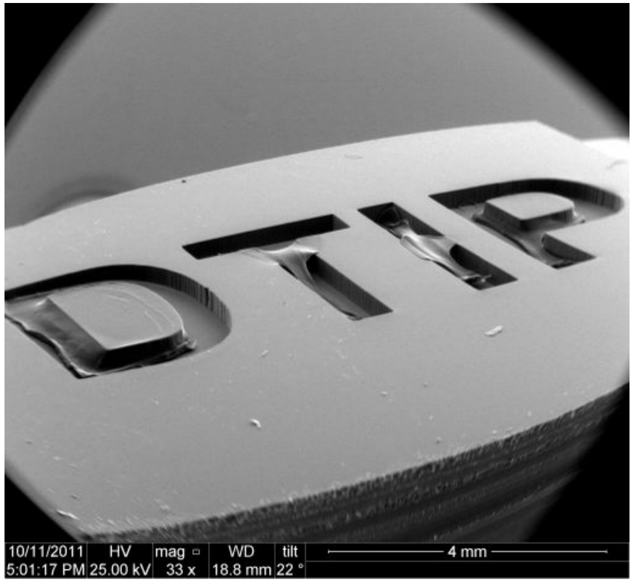
Cristallization of PEDOT:PSS in PDMS grooves

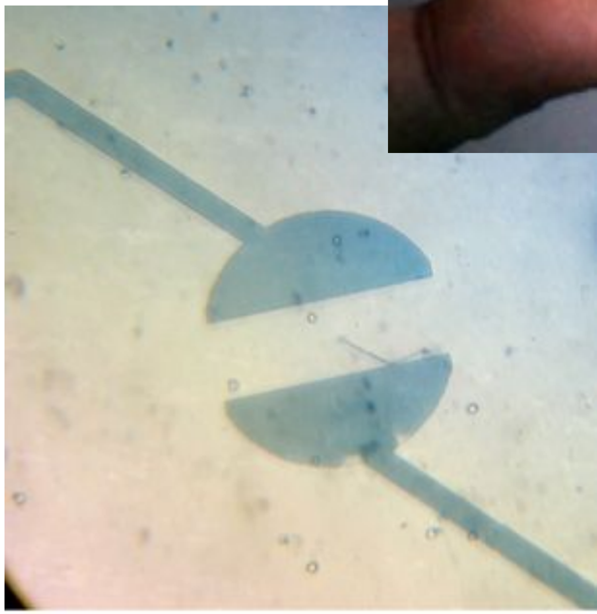
Hydrophilisation : Oxygen Plasma

Filling, squeegee: scrapping with a glass blade

Hot plate cristallization

Repeat…

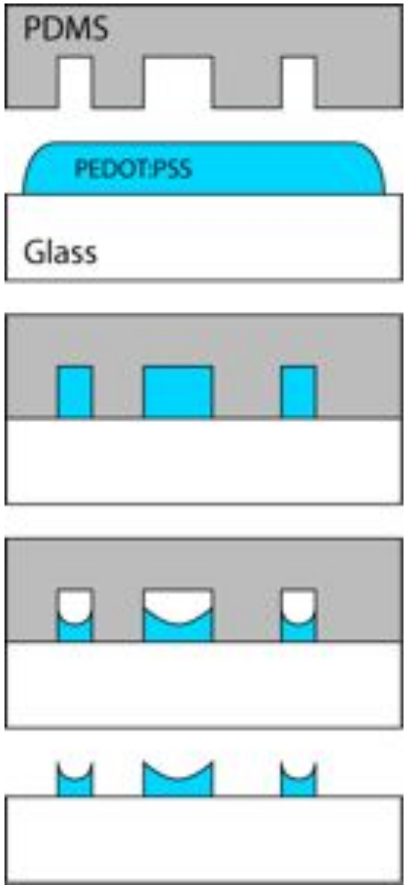




Wettability issues in PDMS, volume diminution during cristallization

Casting from PDMS

Deposition of PEDOT:PSS patterns from a PDMS scaffold

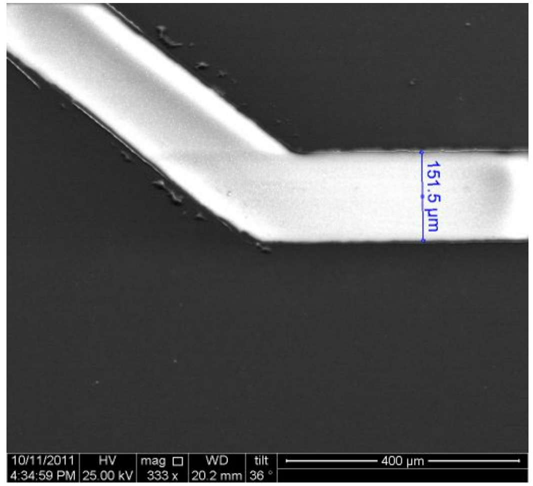


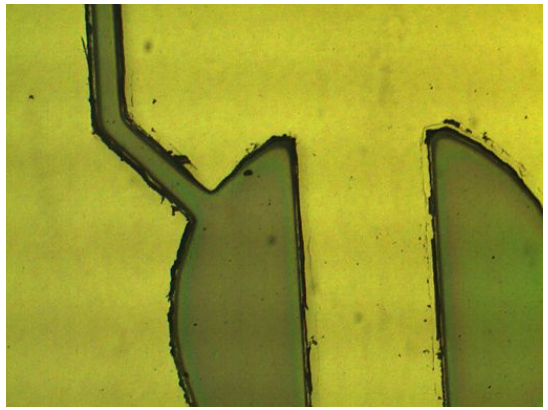
Liquid PEDOT:PSS droplet

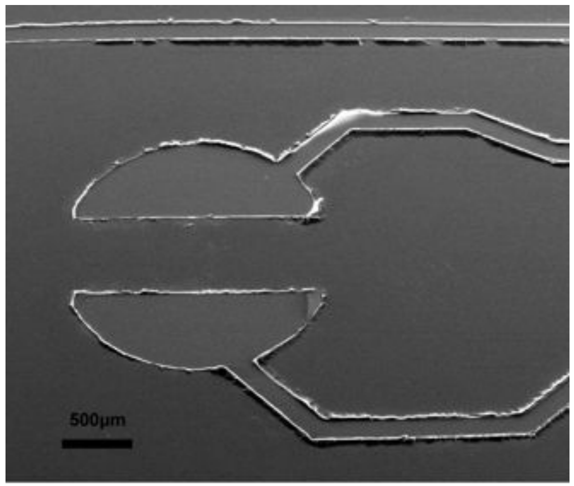
Pressing

Hot plate cristallization

Residues cleaning : Reactive ion etching

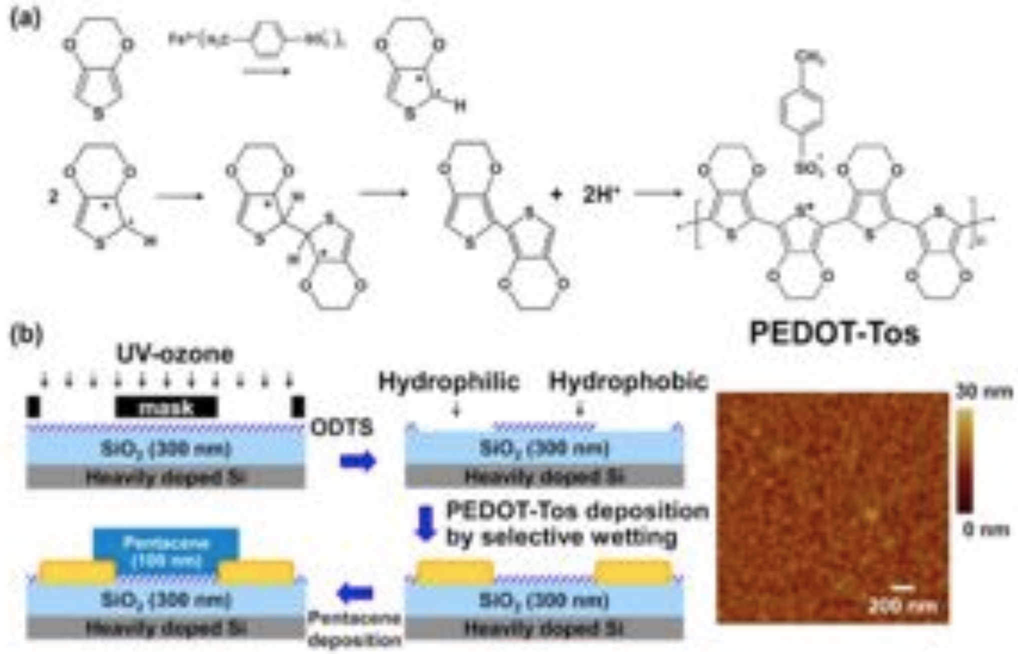






PEDOT:PSS selective deposition

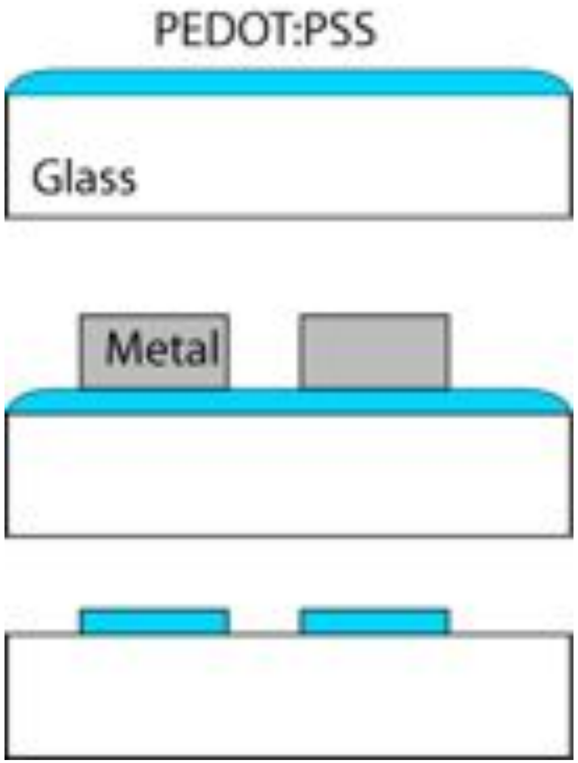
Selective deposition of PEDOT:PSS using hydrophobic surfaces

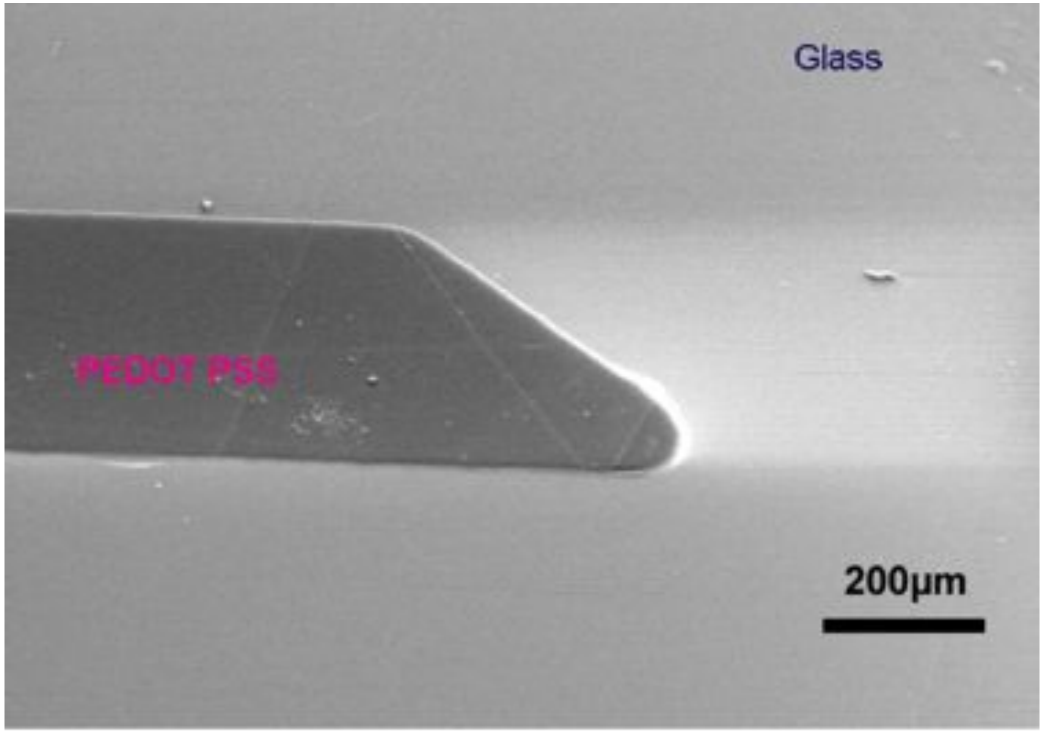


Jung Ah Lim et al.
Appl. Phys. Lett. 95, 233509 (2009)

Shadow masking

Use of metal shadow mask





Need of a perfect contact between mask and substrate
Limitation on design (free standing structures and size)
Magnetic clamping

Lithography

Issues

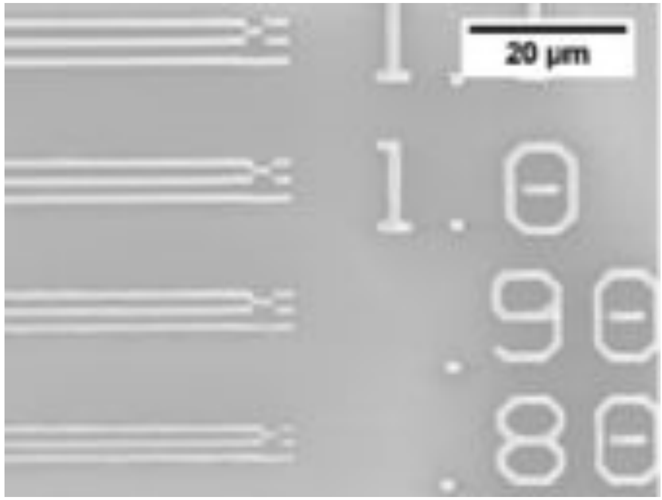
- PEDOT:PSS films are damaged by aqueous solutions, which are standard developers in conventional photolithography
- acid-sensitive photoresists are affected by the acidic PEDOT:PSS.

3 solutions :

- Lithography before PEDOT deposition : Lift off
- Protection coating on PEDOT layer

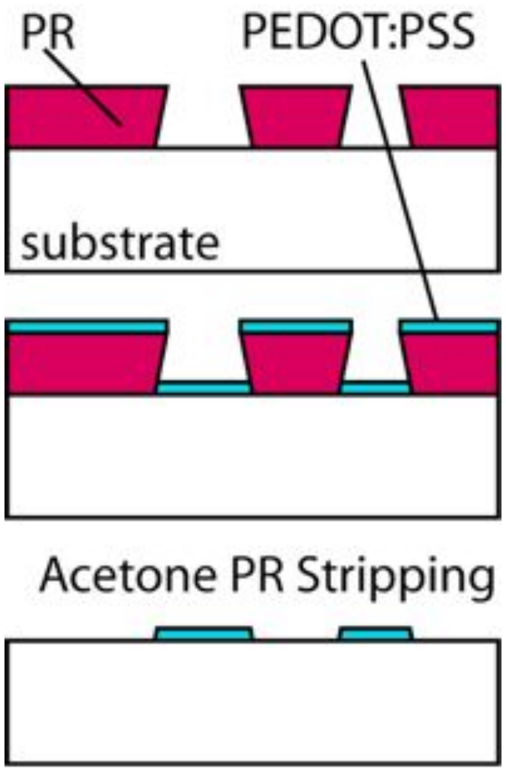
And :

- Specific photoresists Developed with hydrofluoroethers



P. G. Taylor et al. Adv. Mater. 2009, 21, 2314–2317

Lithography : Lift off

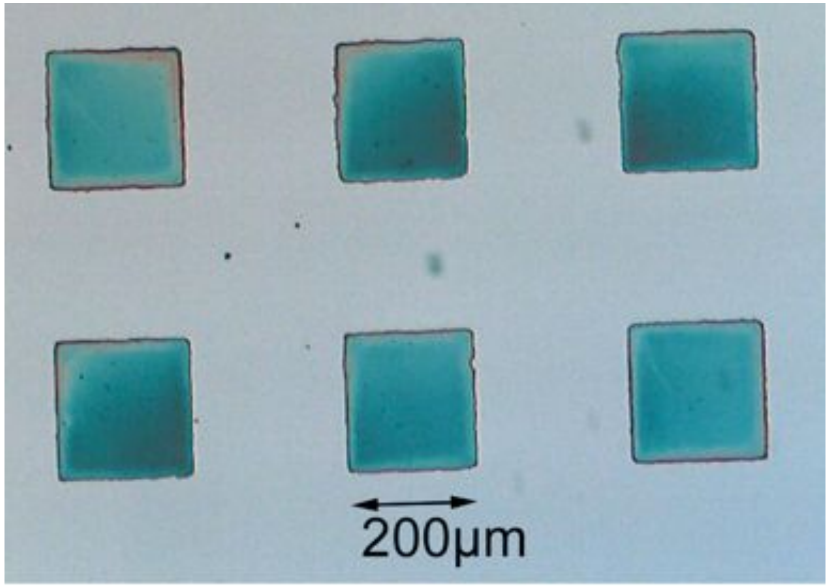


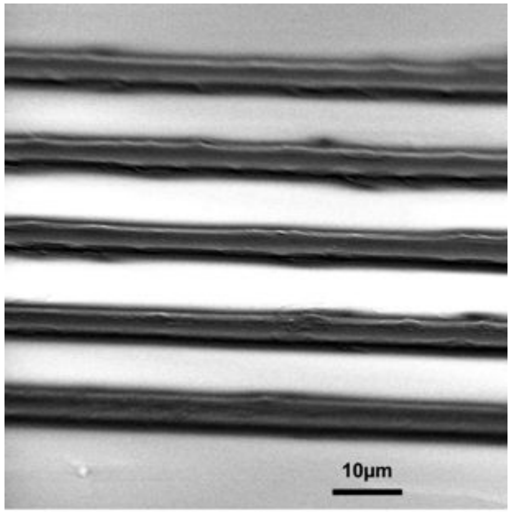
- S1818 with chlorobenzene hardening
- AZ2020

PEDOT deposition and cristallization

Stripping with acetone (S1818)

Or DMSO (AZ2020)



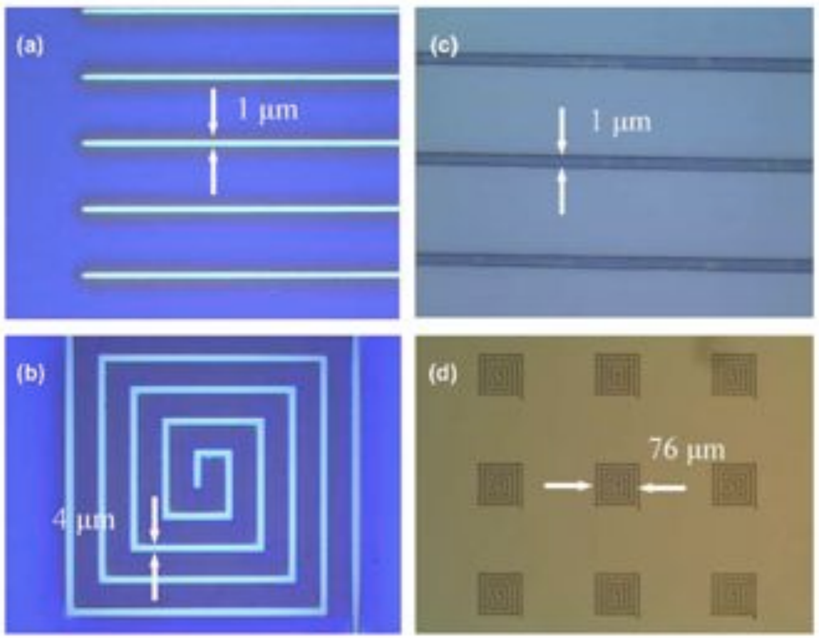


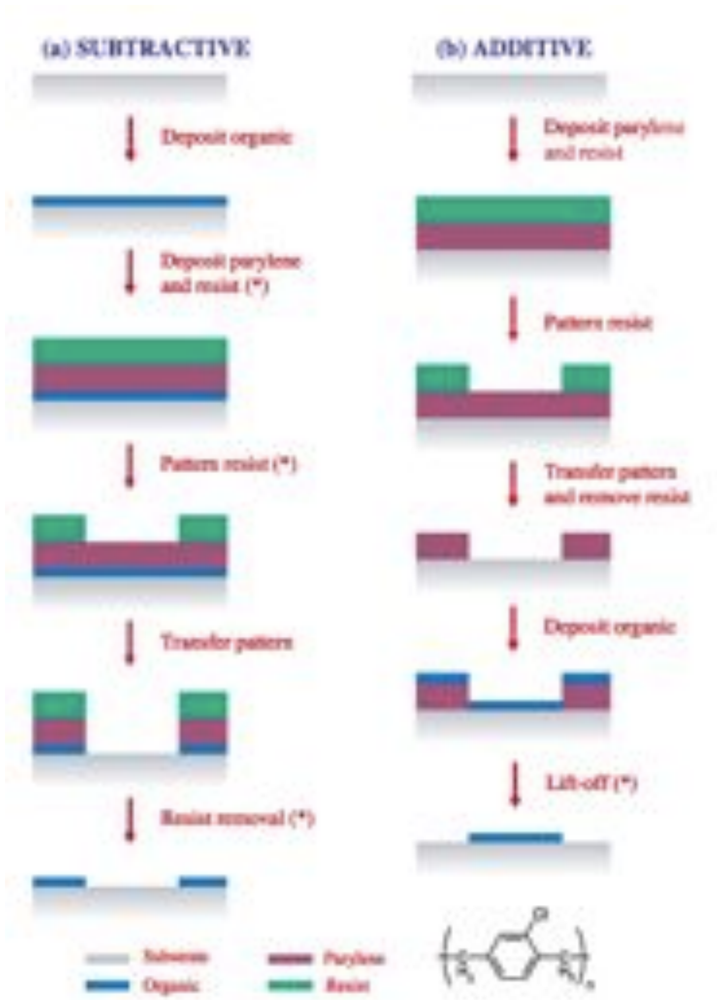
U-shape structures

Lithography with protection : Parylene

Example : use of Parylene-C as protective layer

PEDOTS:PSS thin layer
Parylene
Photoresist
Reactive ion eetching of Parylene and PEDOT
Peeling of parylene (weak adhesion)





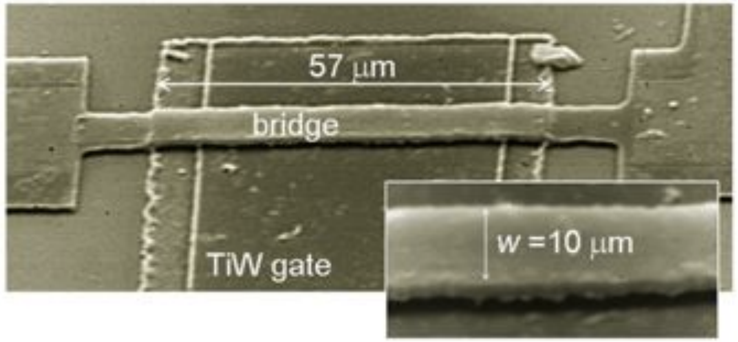
J.A. DeFranco et Al. Organic Electronics 7, 22–28

Peeling Parylene limits the shape of patterns : continuous structures

Lithography with protection : Aluminum

Blend of
PEDOT:PSS
IPA
PMMA

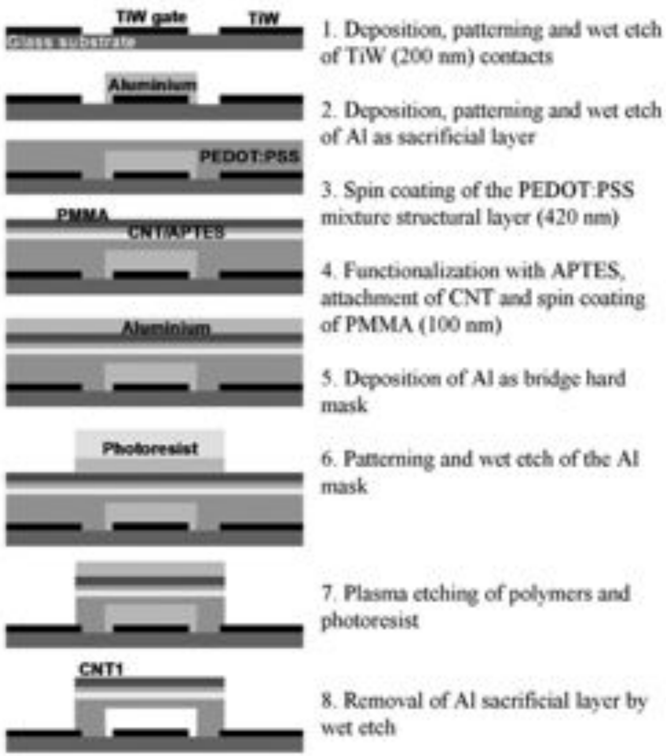
Virginia Chu and Joao Conde,
INESC MN, Lisboa, Portugal

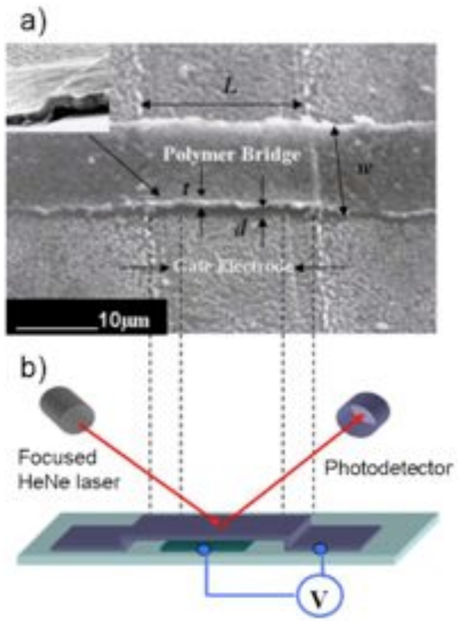


And addition of CNTs attached by surface functionalisation

Use of Aluminium for both Hard mask for etching and Sacrificial layer

Wet etching of Aluminium compatible with PEDOT:PSS compound

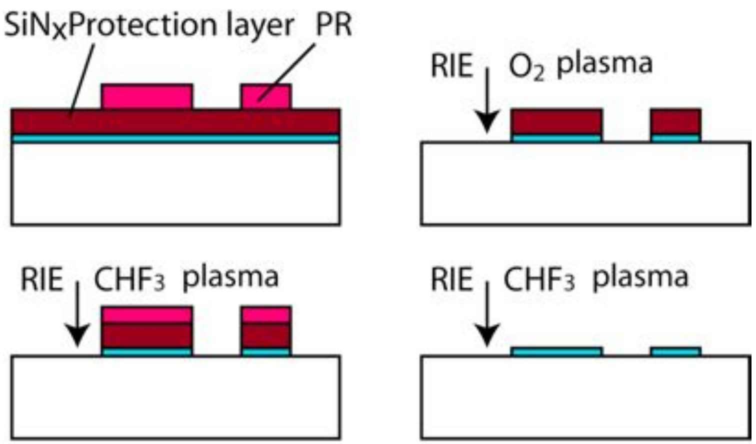


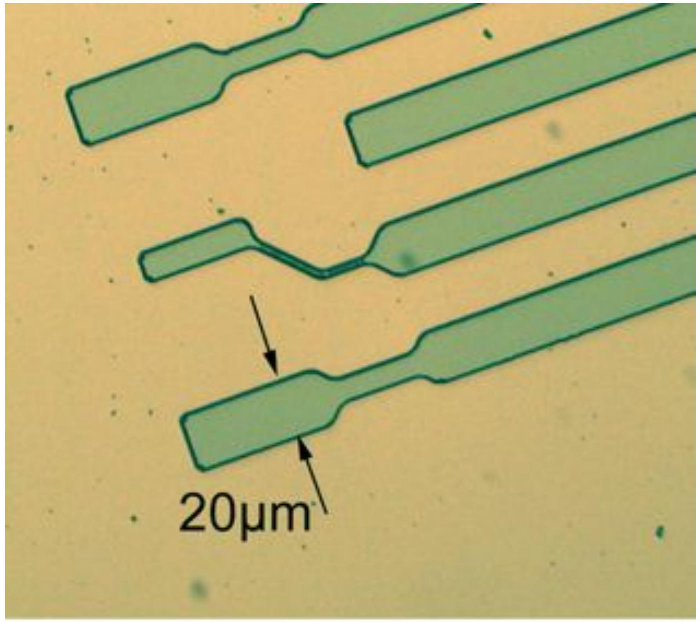


P. M. Sousa, APPLIED PHYSICS LETTERS 99, 044104 (2011)

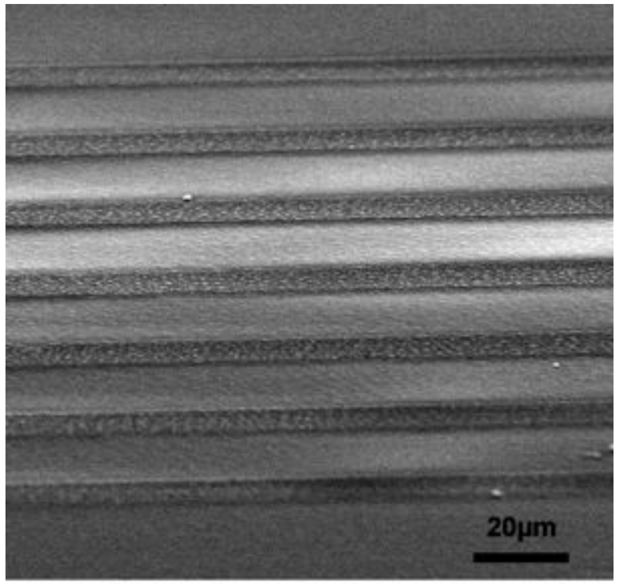
Lithography with protection : Si_3N_4

Silicon Nitride protection layer





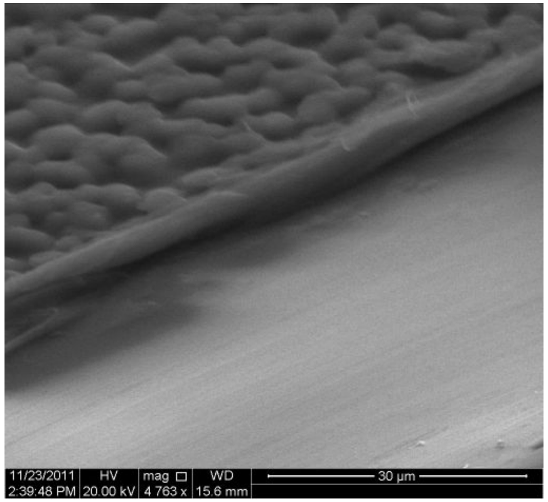
PEDOT:PSS deposition
SiN_x **PECVD** deposition **(200°C)** 100nm
Lithography
RIE selective etching
CHF3 for SiN_x
O_2 for PEDOT:PSS



Flat profile, but requires precise etching control

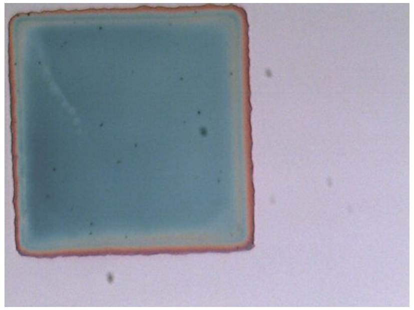
Applications

Electrodes for all polymer pyroelectric sensor



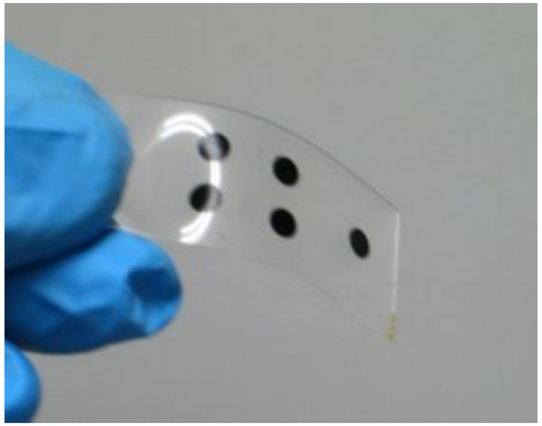
PEDOT / PVDF /PEDOT

Carbon Nanotube interface with PEDOT:PSS



Deformable electrodes for tactile sensor
(graphite PDMS force sensor)

BioElectrodes for electrophysiology



Conclusions

PEDOT:PSS is an interesting material for implementation of deformable electrodes in several applications

Patterning techniques includes
- Soft lithography
- standard lithography / RIE etching with process adaptation

Potential use in bioelectrodes for neuro interface

Further work :

Effect of RIE on polymer, degradation?
Best gazes for etching CHF_3? CF_4? O_2