Organic Electronics, Materials, Devices and Technologies

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Outline

- Materials, devices, technologies, applications of organic electronics

- Development of OE modules/ demonstrators based on the “FLEXNET” FP7 European Project

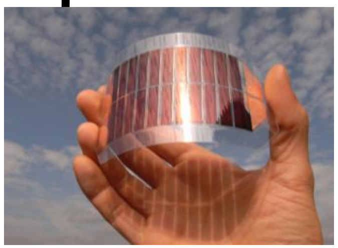
1.
Materials, devices, technologies, applications of organic electronics

What is organic electronics ?

Organic Electronics is a new field of electronics in which the structures that are used are based on organic materials: dielectric, conductive or semiconductor polymers or small organic molecules deposited mainly on flexible substrates.

Other names:
Printed Electronics,
Polymer Electronics (Polytronics), Flexible Electronics,
Plastic Electronics,
Flexible, Organic & Large Area Electronics – FOLAE.

Organic and Printed Electronics



Organic Photovoltaic

Flexible Displays

OLED / EL Lighting

Printed Memory

Organic Sensor

Flexible Batteries

Smart Textiles

Printed RFID

Smart Objects

Comparison between characteristics of Organic Electronics vs. Classical Electronics (inorganic)

Organic Electronics

- reduced costs
- simple process
- flexible substrates
- large area
- small integration density
- high switching times
- reduced performances

Classical Electronics

- high manufacturing costs
- complex process
- rigid substrates
- small areas
- extremely high density
- switching times very small
- high performances

The two approaches are not seen as opposite but complementary!

Materials for organic electronics

- **Semiconductor Materials**

  small molecules: Pentacene, Rubrene

  polymers: PEDOT:PSS, P3HT,PTAA,

- **Conductive Materials**

  organic: PPy, PEDOT:PSS, PANI

  inorganic: metals (Au, Ag), oxides (ITO, ATO)

- **Dielectric Materials**

  Polycarbonate, PMMA, PP, PVA, PET, Parylene X

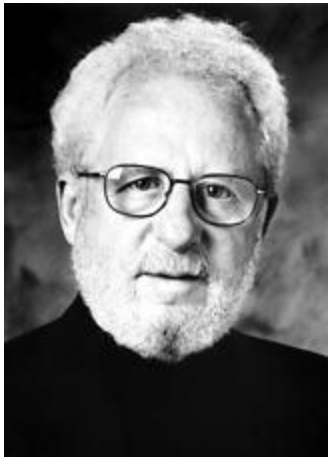
- **Other Materials**

  luminescent, electrochromic, etc.

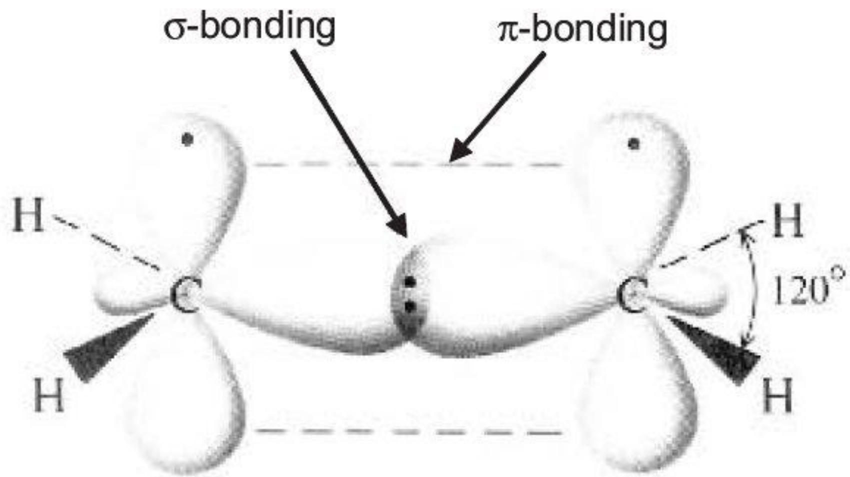
Nobel Prize for Chemistry for conduction in polymers

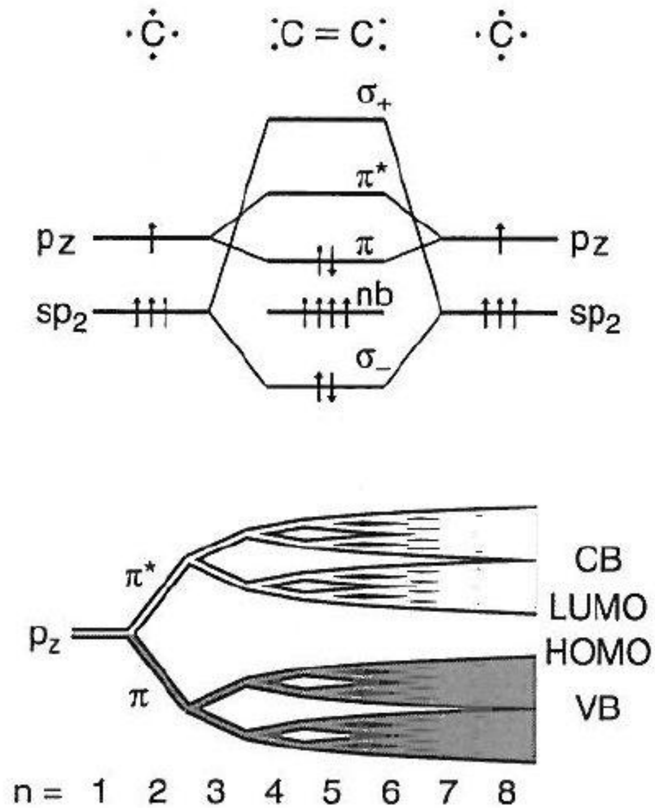
"In 1977, Shirakawa *et al.* reported high conductivity in oxidized and iodine-doped polyacetylene"

"The Nobel Prize in Chemistry 2000 was awarded jointly to Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa (*"for the discovery and development of conductive polymers")"*.



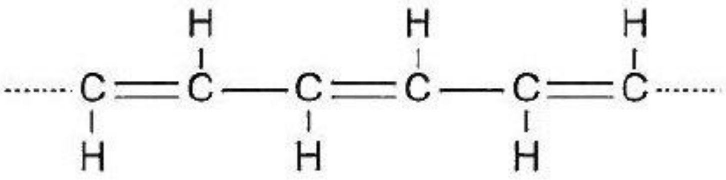
Semiconductor organic materials



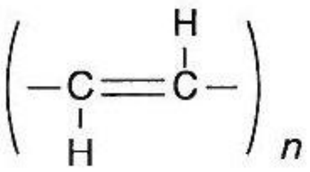


The semiconductor character is determined by the π bonding formed of the electrons in side orbitals p_z.

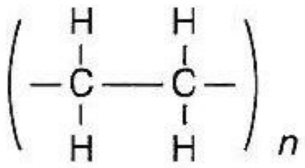
Organic Semiconductor Materials (cont.)



Conjugated Polymers - molecular chain of carbon atoms with alternating simple bonds (σ) and double bonds (σ+π)



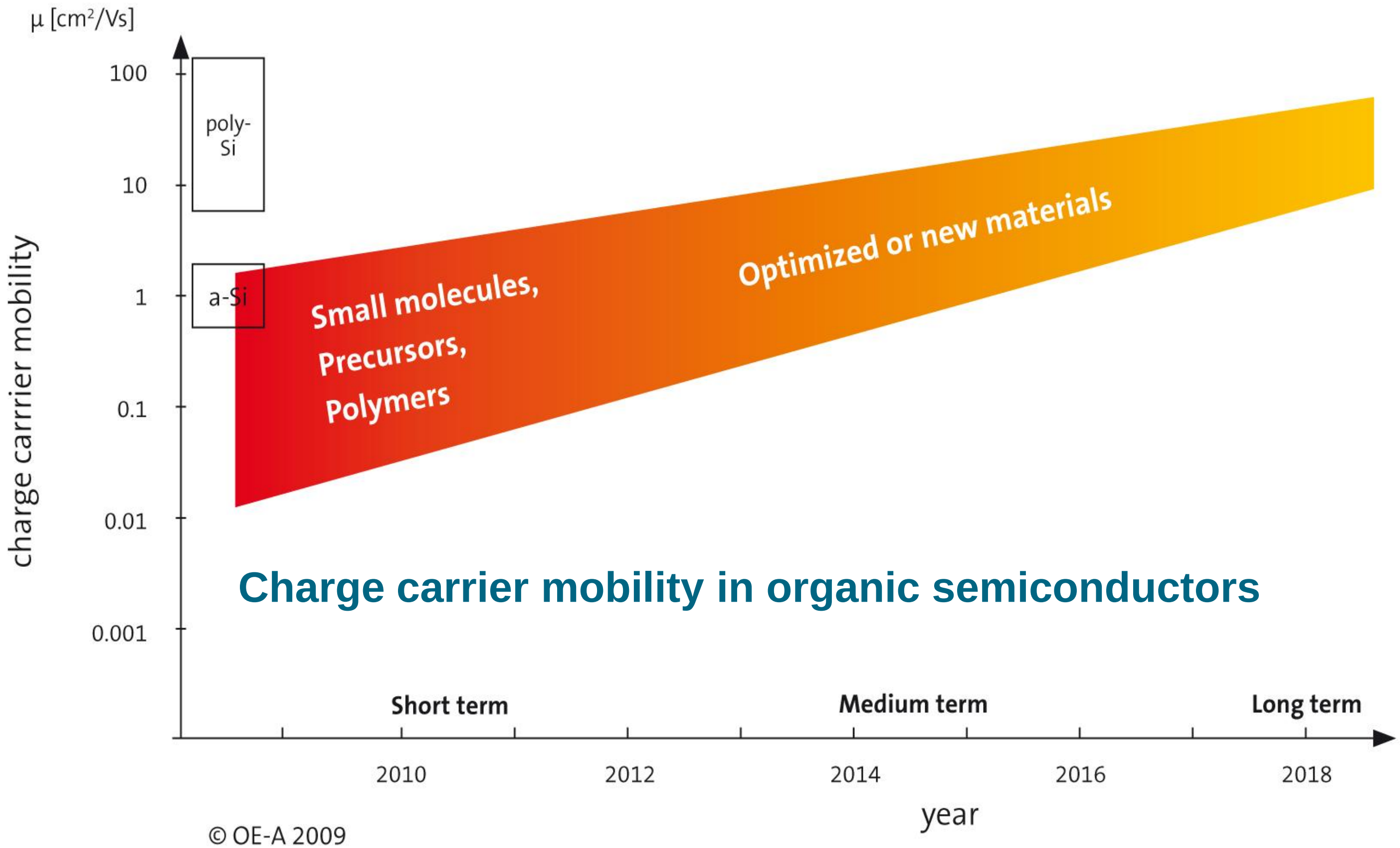
Polyacethylene – the simplest conductive polymer



Polyethylene – the non-conjugate equivalent, has only simple bonds; it is a seven magnitude order in electrical conductivity compared to Polyacethylene

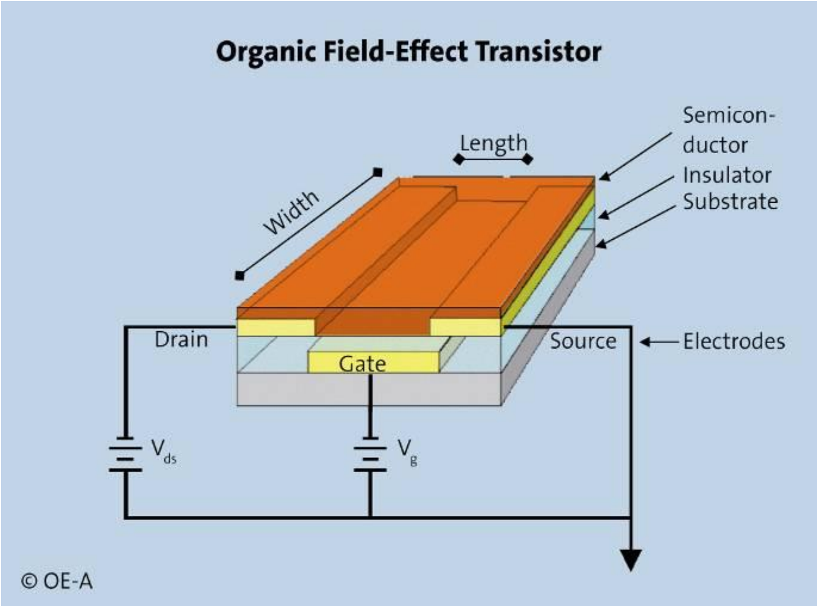
Organic Semiconductor Materials (cont.)

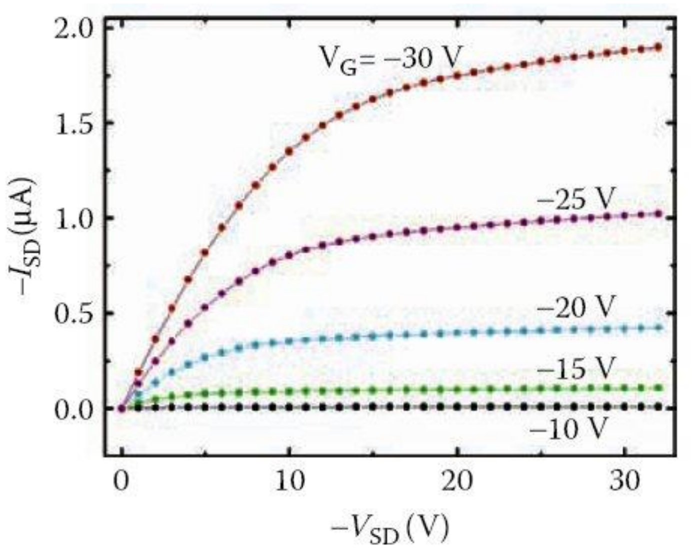
- The majority of organic semiconductors that are used today are of p type, but also n type are available, being possible to implement circuits that are similar to CMOS.
- Charge carrier mobility of organic semiconductors, although much more reduced that the one of crystalline silicon has reached and even exceeded the amorphous silicon mobility.

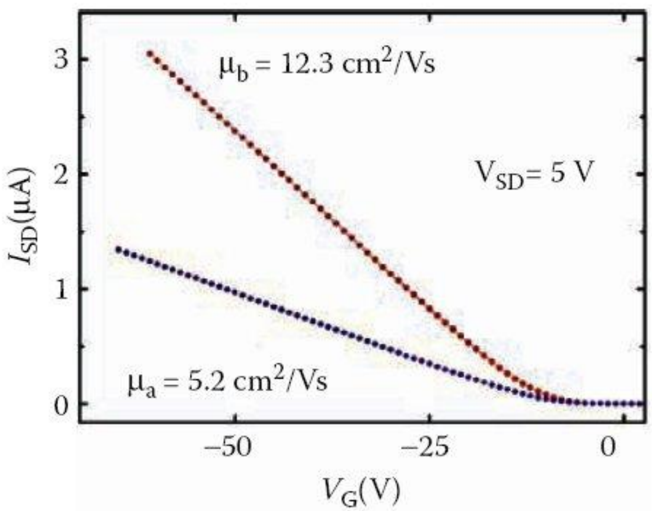


Organic Field Effect Transistor -OFET

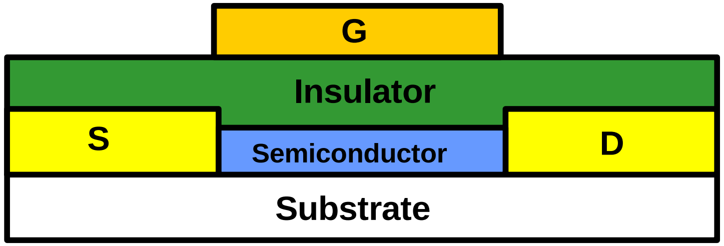
Represent the basic component for integrated circuit development.
For it's realization at least four layers are necessary.



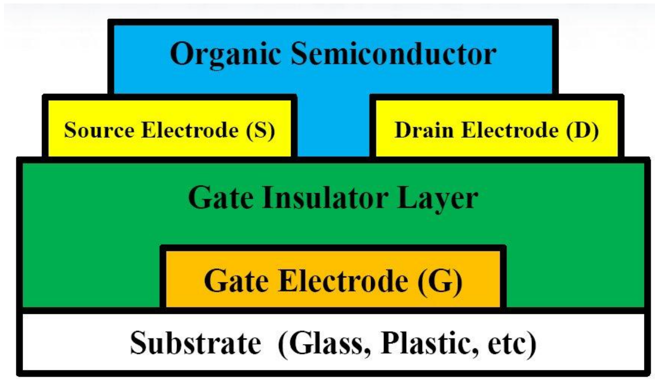




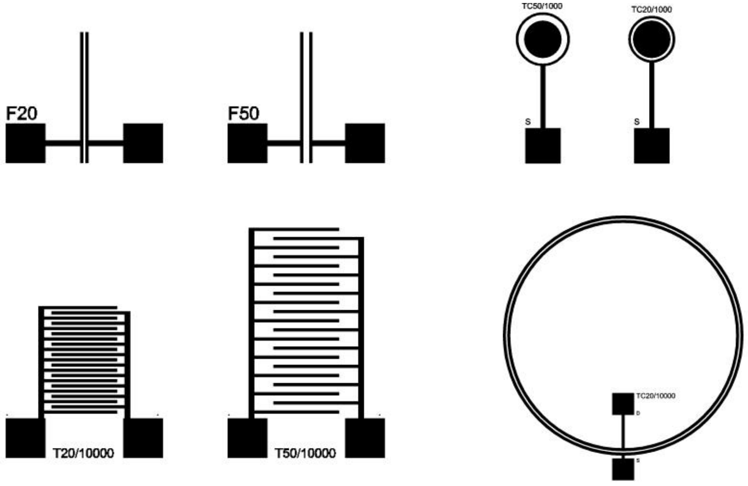
OFETs Configurations



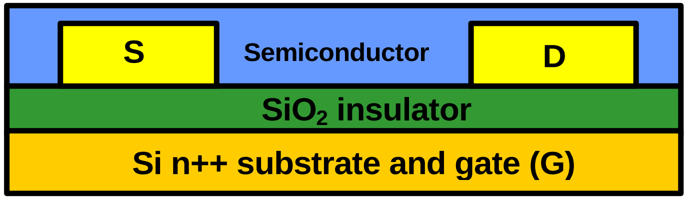
„Top gate" Configuration



„Bottom gate" Configuration

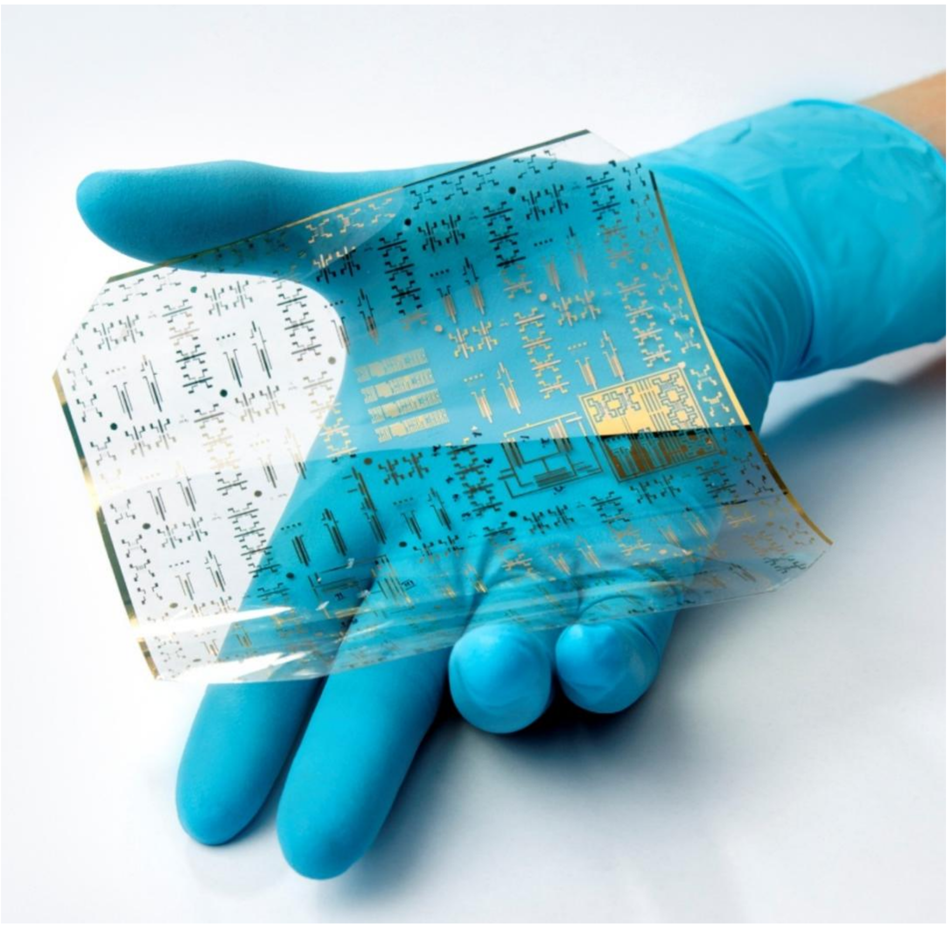


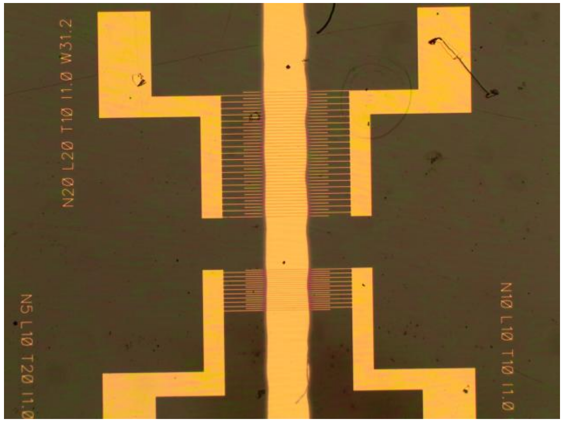
Electrode Configurations



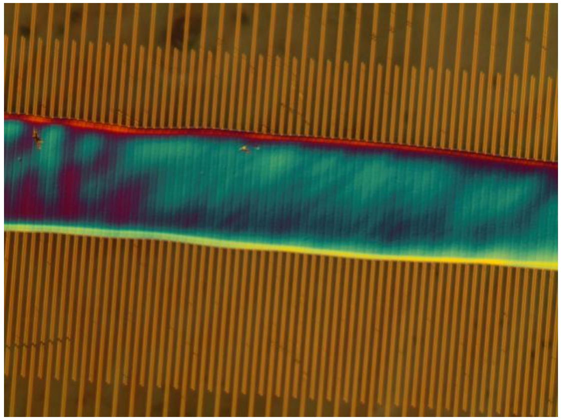
„Bottom gate" Variant

Examples of OFETs: ~100 transistors on plastic 10 x 10 cm foil





Evaporated gold top gate



IJ-printed silver top gate

Substrates

A major advantage of printed and organic electronics is the possibility to use flexible substrates with large dimensions and low costs.

Typical substrates for organic electronics:

- Thin glass
- Metal (Si)
- Paper
- Polymers

  Different type of polyesters , especially Polyethylene terephtalate (PET) and Polyethylene naphthalate (PEN)
  Polycarbonate (PC)
  Polyimide (PI)
  Polyetherimide (PEI)
  Polyvinylfluoride (PVF)

Printing Technologies

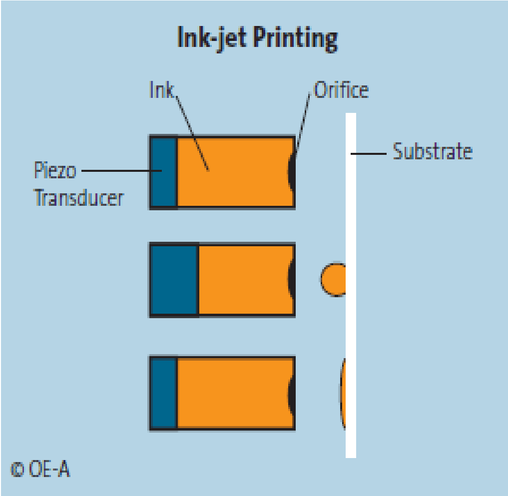
Jet Printing

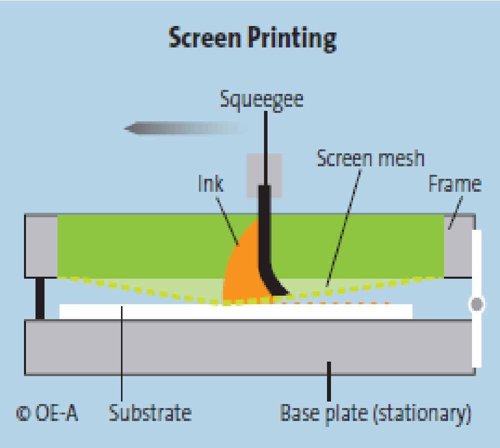
Screen printing

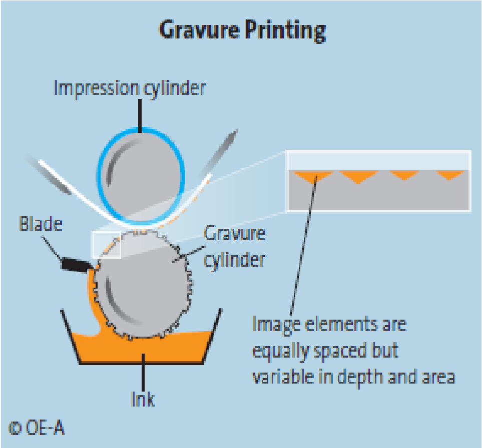
Rotogravure, flexo-gravure, offset

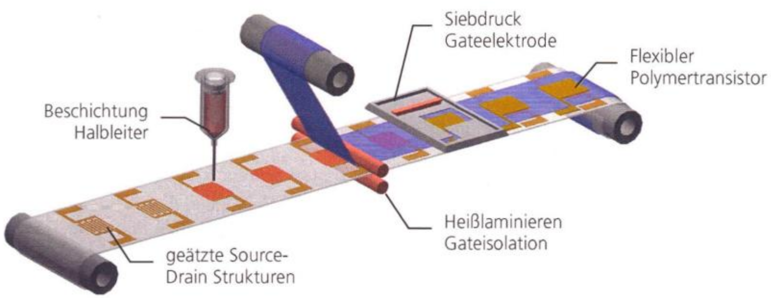
Reel to reel

Ink type materials





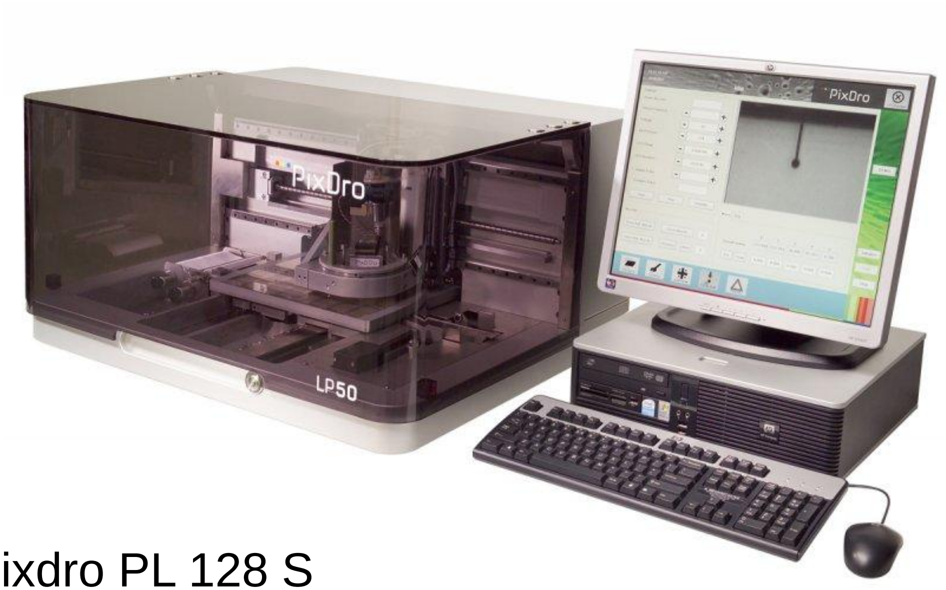




Reel to reel

Realization of organic electronic structures

Advanced Research Printer PixDro LP 50



Printhead Pixdro PL 128 S

- Technology Piezo MEMS glass&silicon
- Nozzles: 128 on two rows
- Deposition sped 0-25000 droplets/sec
- Deposited Volume 15-30pl

2.

Development of OE modules/ demonstrators based on the "FLEXNET" FP7 European Project

FlexNet Project

Seventh Framework Programme
GRANT AGREEMENT No 247745

NoE FlexNet - Network of Excellence for building up Knowledge for improved Systems Integration for Flexible Organic and Large Area Electronics (FOLAE) and its exploitation

FlexNet

www.noe-flexnet.eu

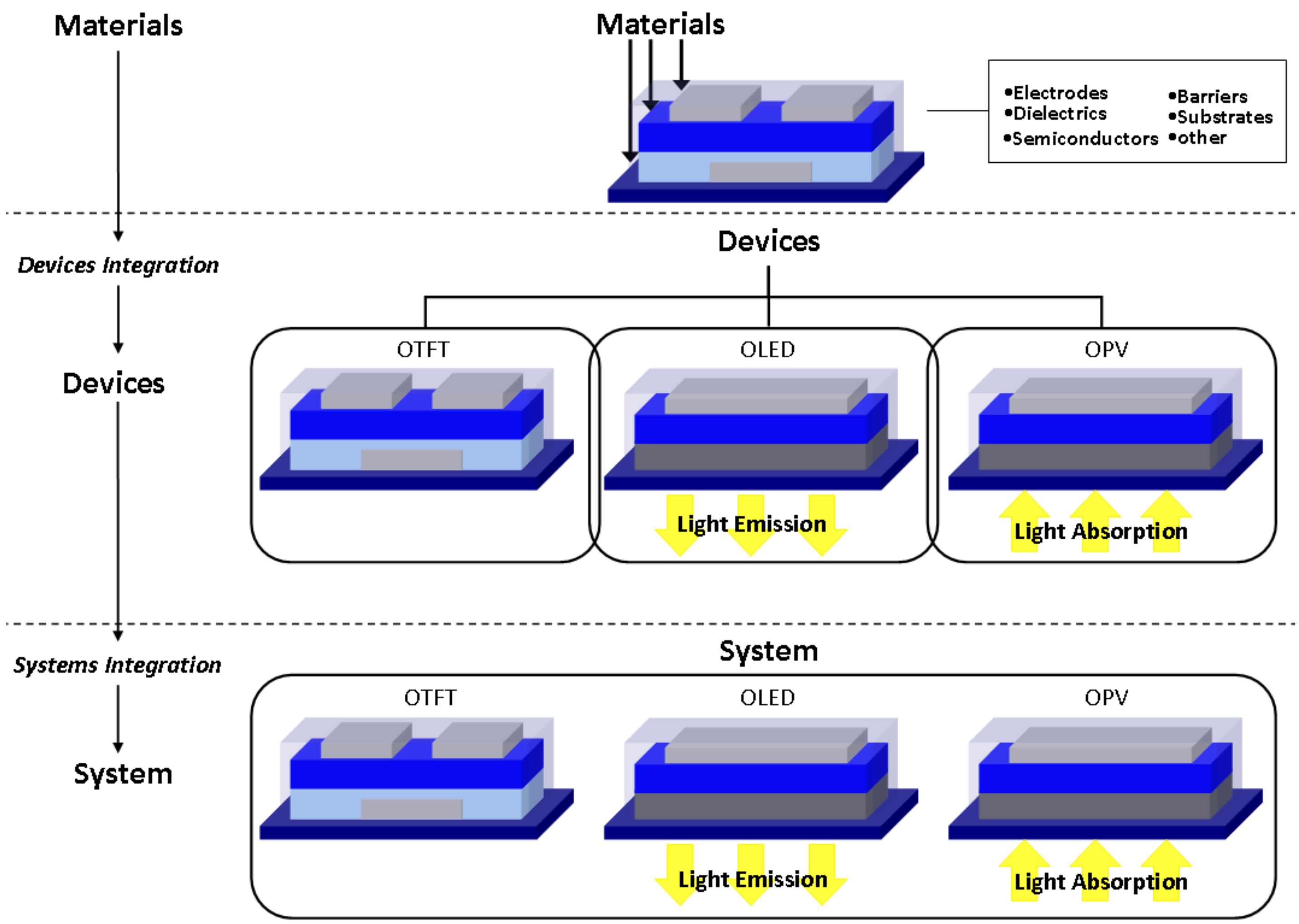
Consortium

- **VDI/VDE Innovation + Technik GmbH,** Germany
- **Commissariat à l’énergie atomique et aux énergies alternatives (CEA) - LITEN,** France
- **Valtion Teknillinen Tutkimuckeskus (VTT),** Finland
- **Politechnika Lodzka (TUL),** Poland
- **Università degli Studi di Catania (UNICT),** Italy
- **Aristotelio Paneptistimio Thessalonikis (AUTH),** Greece
- **Agenzia Nazionale per le Nuove Tecnologie, l'energia e lo Sviluppo economico sostenibile (ENEA),** Italy
- **Univesidade do Algarve (UALG),** Portugal

FlexNet

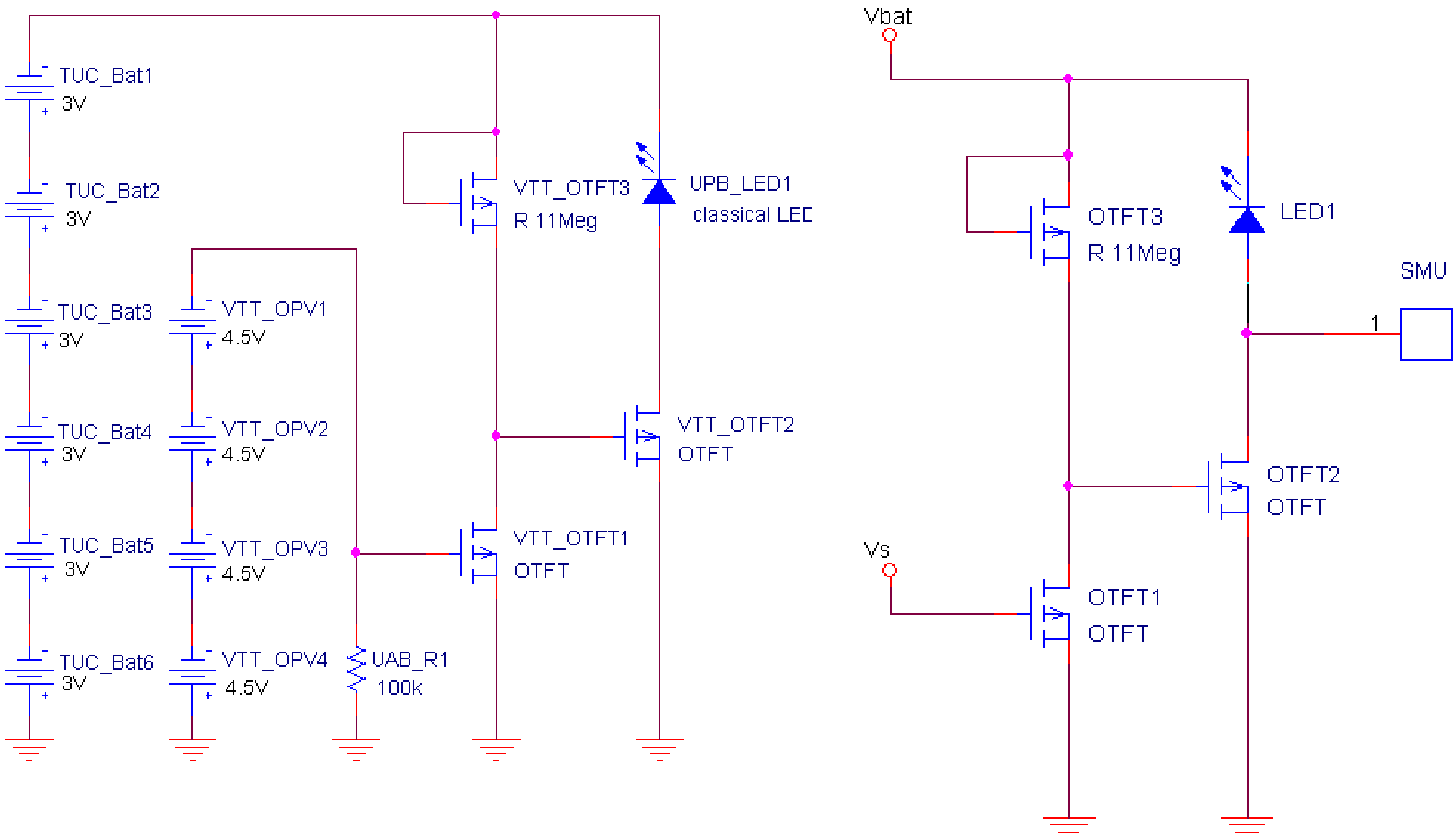
- **Universitat Rovira i Virgili (URV),** Spain
- **Universitatea Politehnica din Bucuresti, CETTI (UPB-CETTI)**
- **Politechnika Warszawska (WUT),** Poland
- **Centre National de la Recherche Scientifique (CNRS),** France
- **Ustav Makromolekularni Chemie AV CR, v.v.i. (IMC),** CzechRepublic
- **University of Patras (UPAT),** Greece
- **CSEM Centre Suisse d'Electronique et de MicrotechniqueSA,** Switzerland
- **Universitat Autònoma de Barcelona (UAB),** Spain
- **Technische Universität Chemnitz (TUC),** Germany

WP 2 and WP3 – Materials, Devices and Systems Integrations

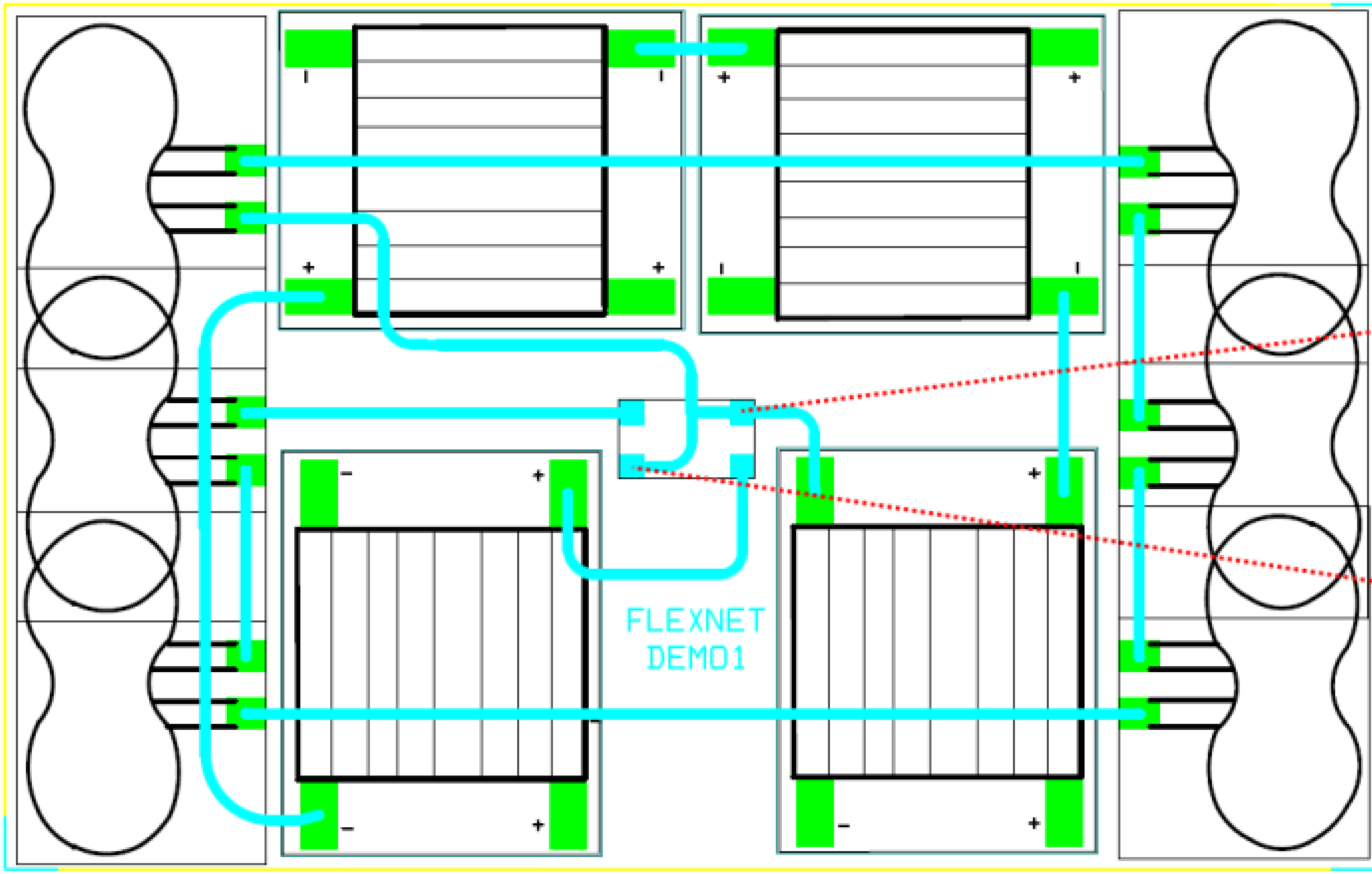


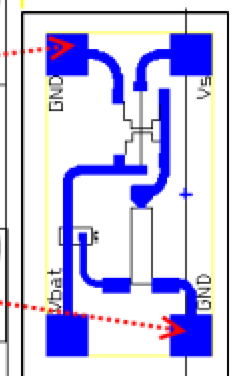
DEMO1
“Low complexity light switch”

Schematic diagram

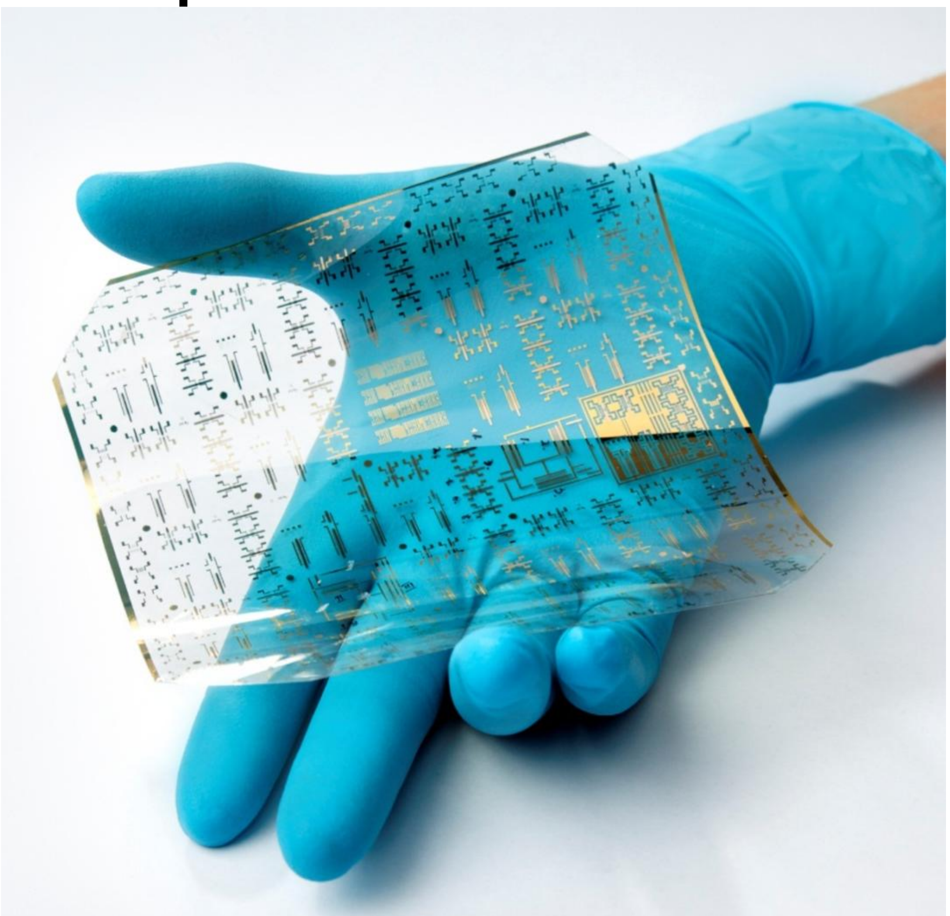


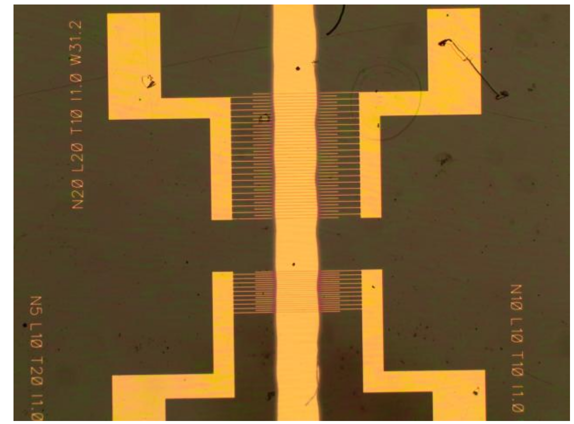
Flexible PCB layout and organic devices/structures



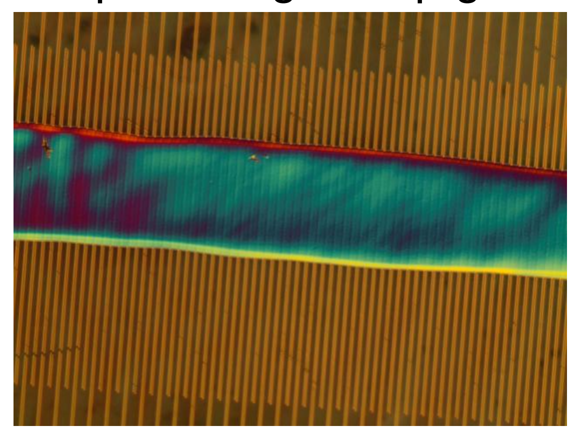


OFETs used in DEMO1





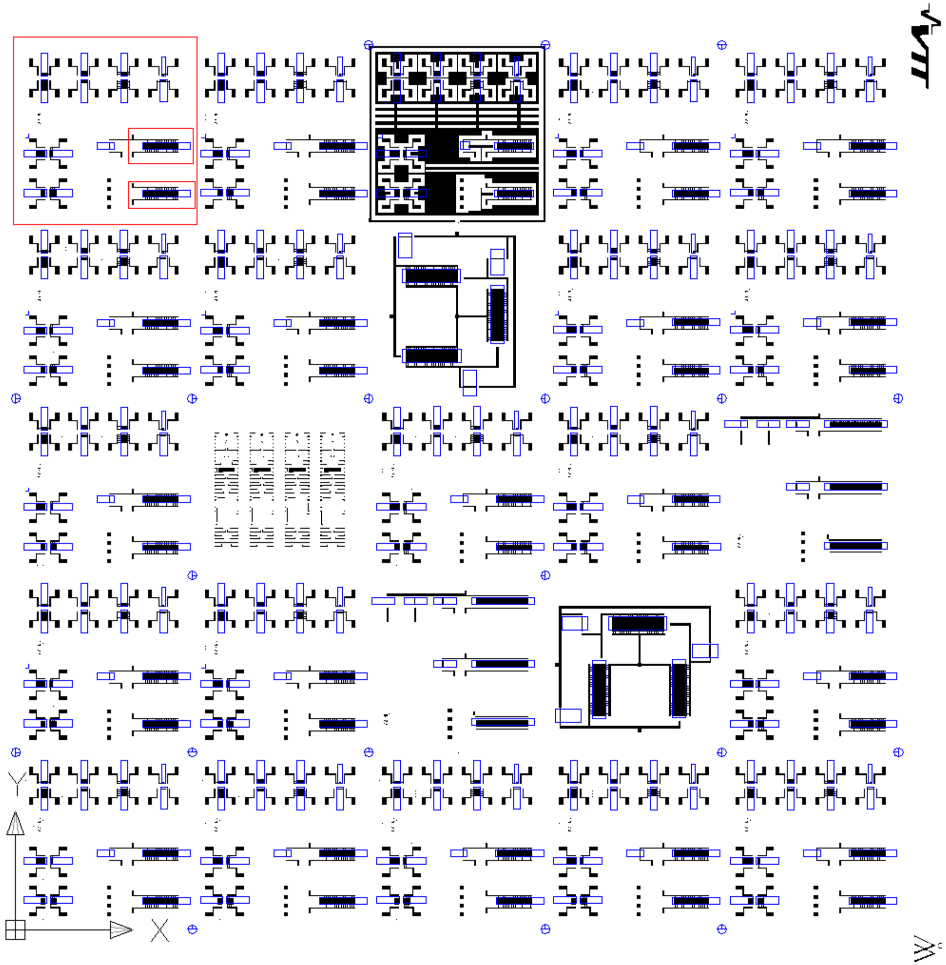
Evaporated gold top gate



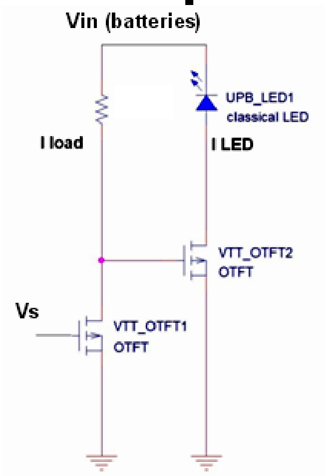
IJ-printed silver top gate

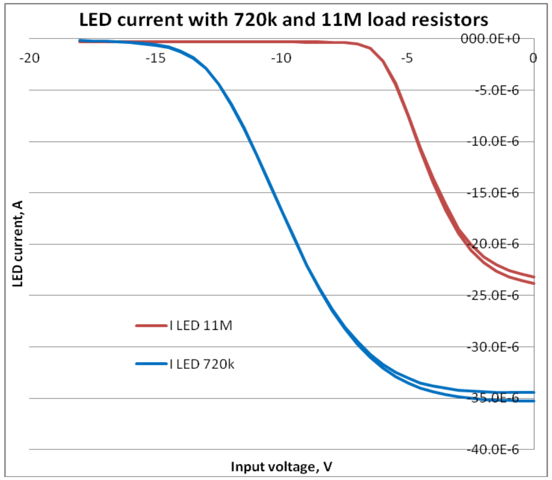
Demo 1 - processing details

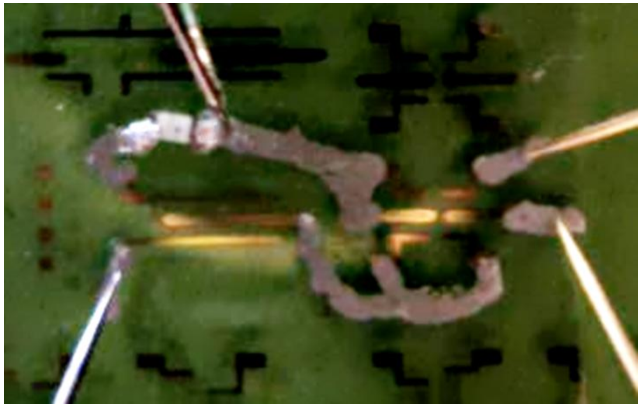
- PET and PEN foil with lithographically patterned source and drain electrodes;
- Patterning of semiconductor and insulator (here spin casting but could be a printing method);
- Addition of top gate and wiring:
- shadow mask (laser processed)
- or direct IJ-printing



The active structure on foil







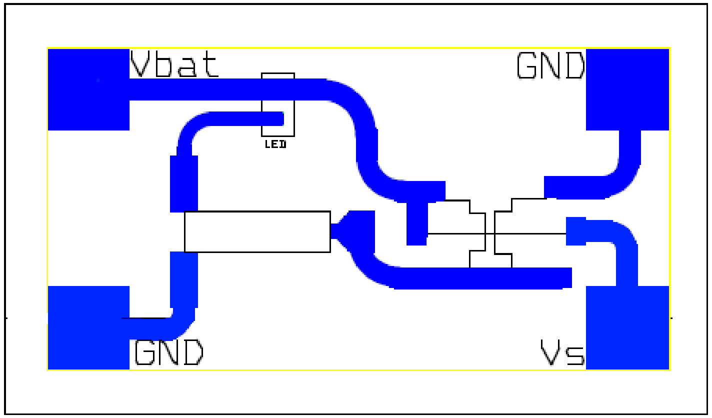
Demo1

2 foils: transistor foil and supply foil

Resistor 1-10MΩ

Partner names on the opposite side of the big foil

Track width 2mm



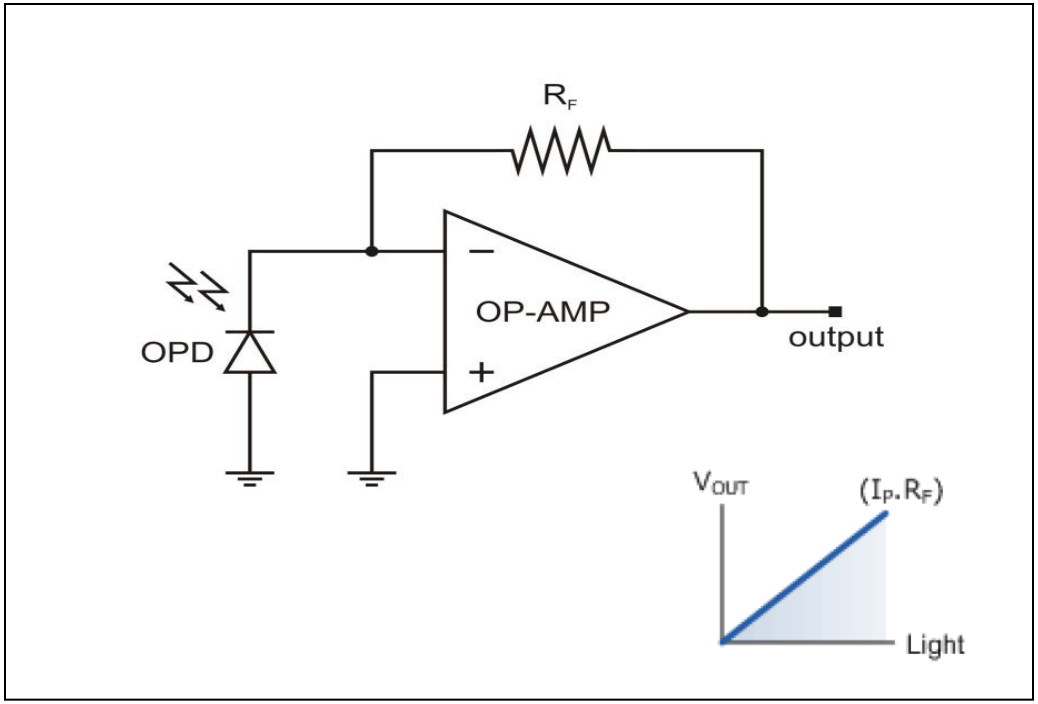
DEMO2
“High complexity level on-foil integrated light sensor”

Block diagram

OPD designed by CSEM

OP-AMP designed by UNICT

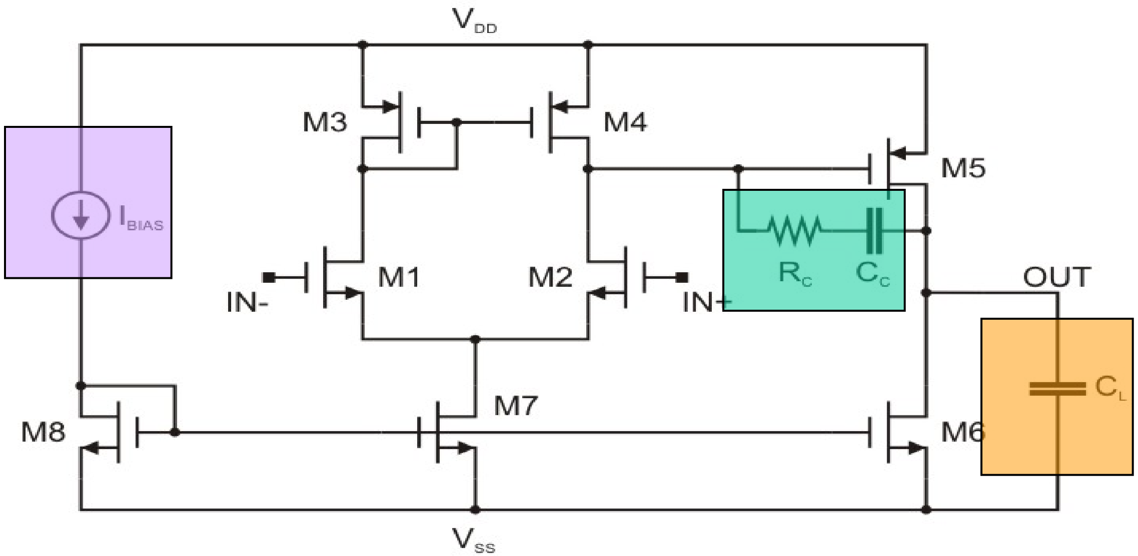
Technology provided by CEA



Two versions of the demo will be produced (within the same mask set):

- Foil-to-foil assembling (DEMO 2_V1)
- On-foil integration (DEMO 2_V2)

OP-AMP circuit design




External in DEMO2_V1, integrated in DEMO2_V2


External load (due to test equipment)

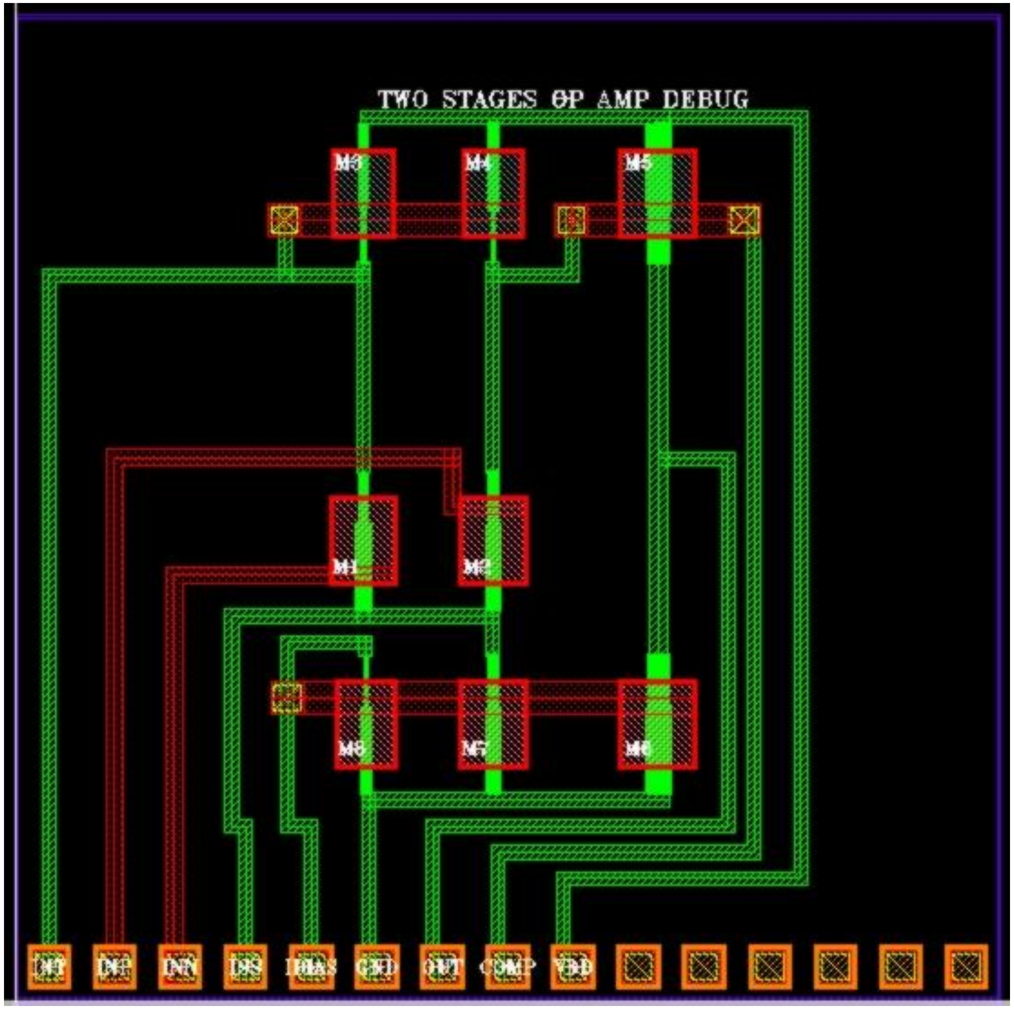

External biasing

OP-AMP layout

Probe-card testing

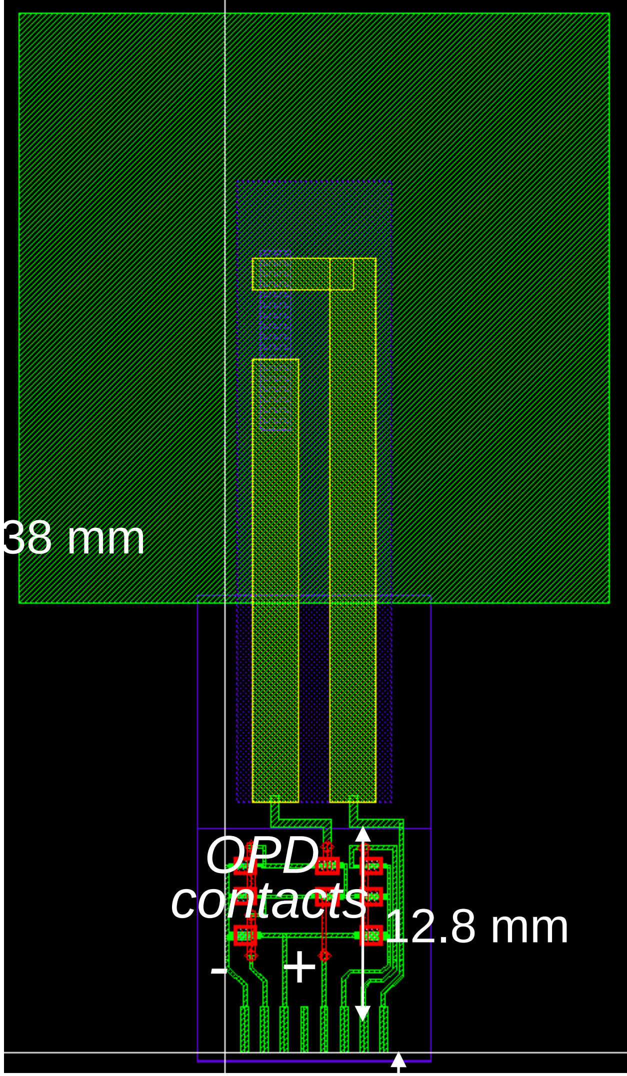
OP-AMP internal nodes are accessible for testing

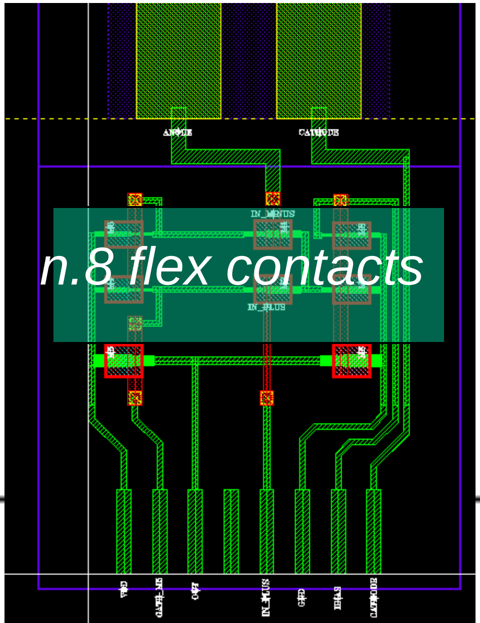
Area occupation = n.1 field



DEMO2_V1

- Design rules for OPD connection are fulfilled
- Specifications of contacts for flex are fulfilled
- Testing will be performed by using an external board connected to the DEMO2 by a flex-cable
- Area occupation = n.2 fields (15 mm x 30 mm)

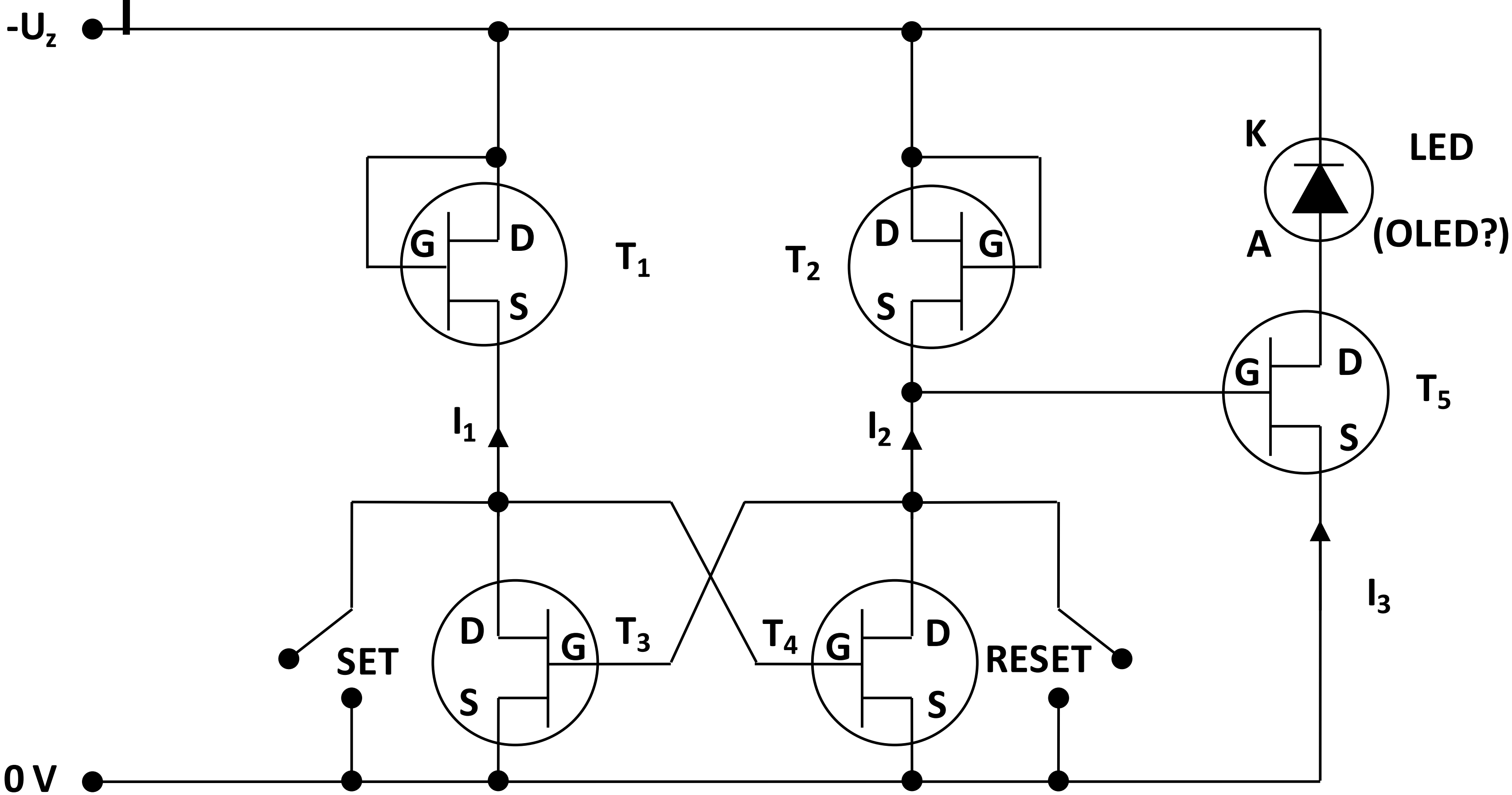




DEMO3
“R-S Flip/Flop”

The “R-S flip-flop” (Demonstrator 3) is under development in collaboration with TUL and IMC, which are engaged in cooperation with Polish companies: QWERTY and 3D-nano and Czech Inotex, Obchodni Tiskarny, Optaglio, Centrum Organické Chemie.

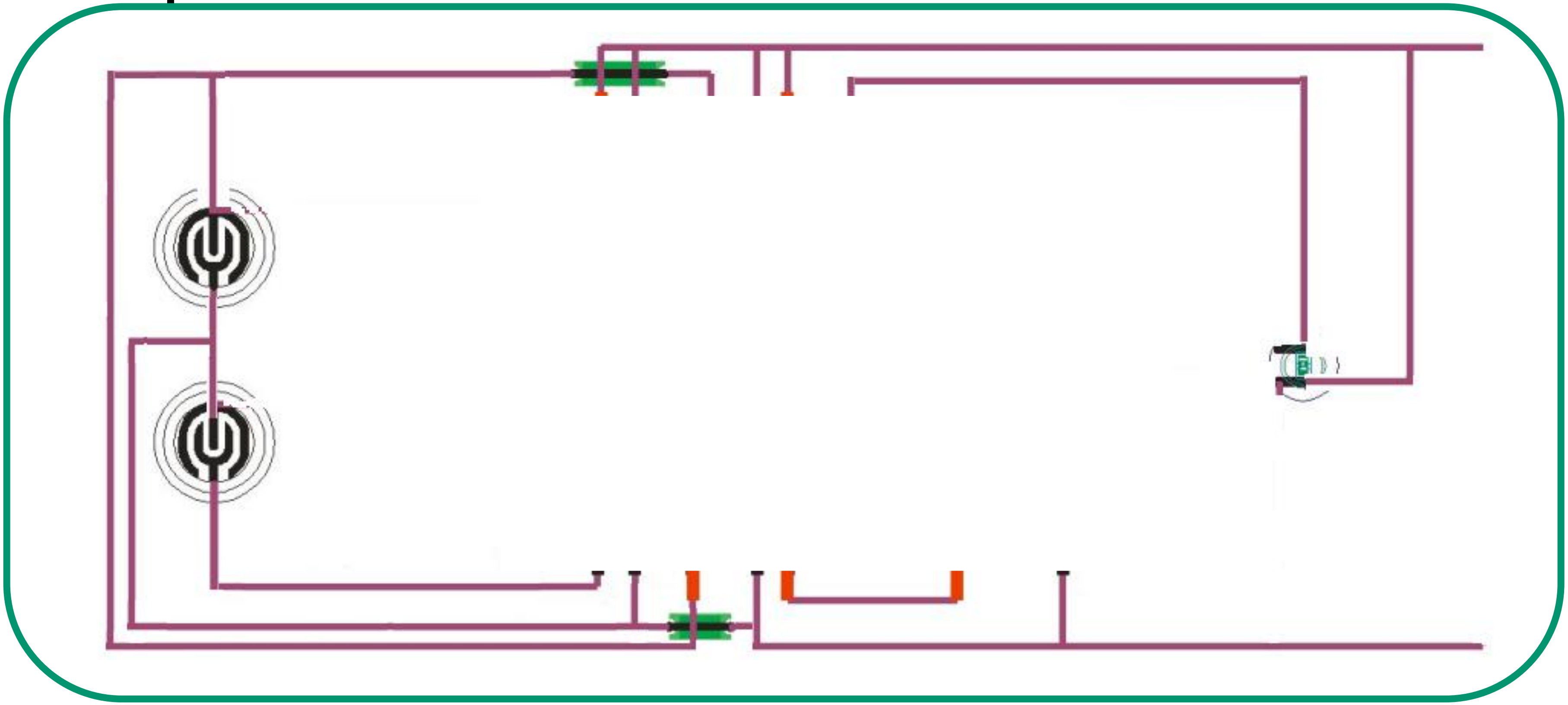
Demonstrator 3 – schematic diagram



Demonstrator 3 - R-S Flip/Flop
1) Polyester substrate

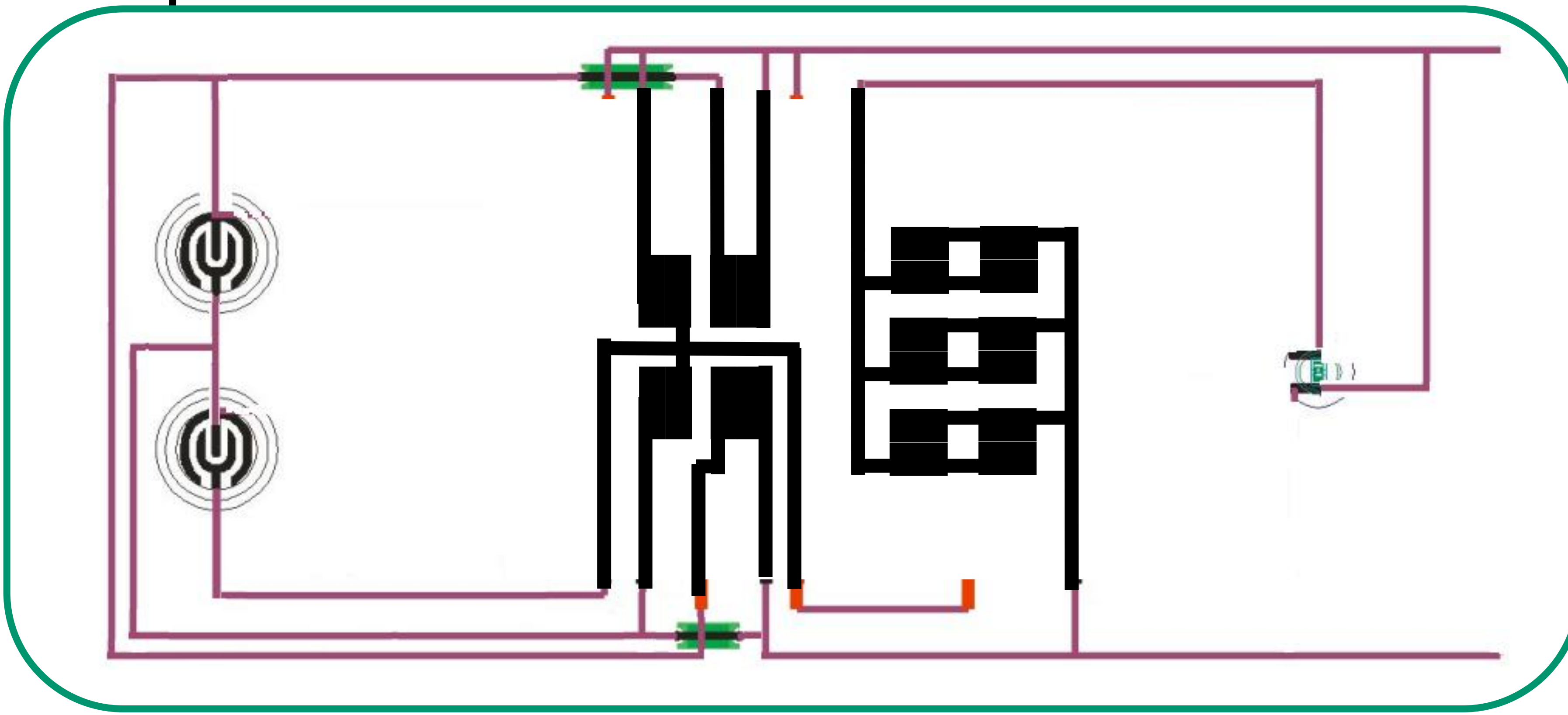
Demonstrator 3 - R-S Flip/Flop

2) Connections printing - commercial silver paste



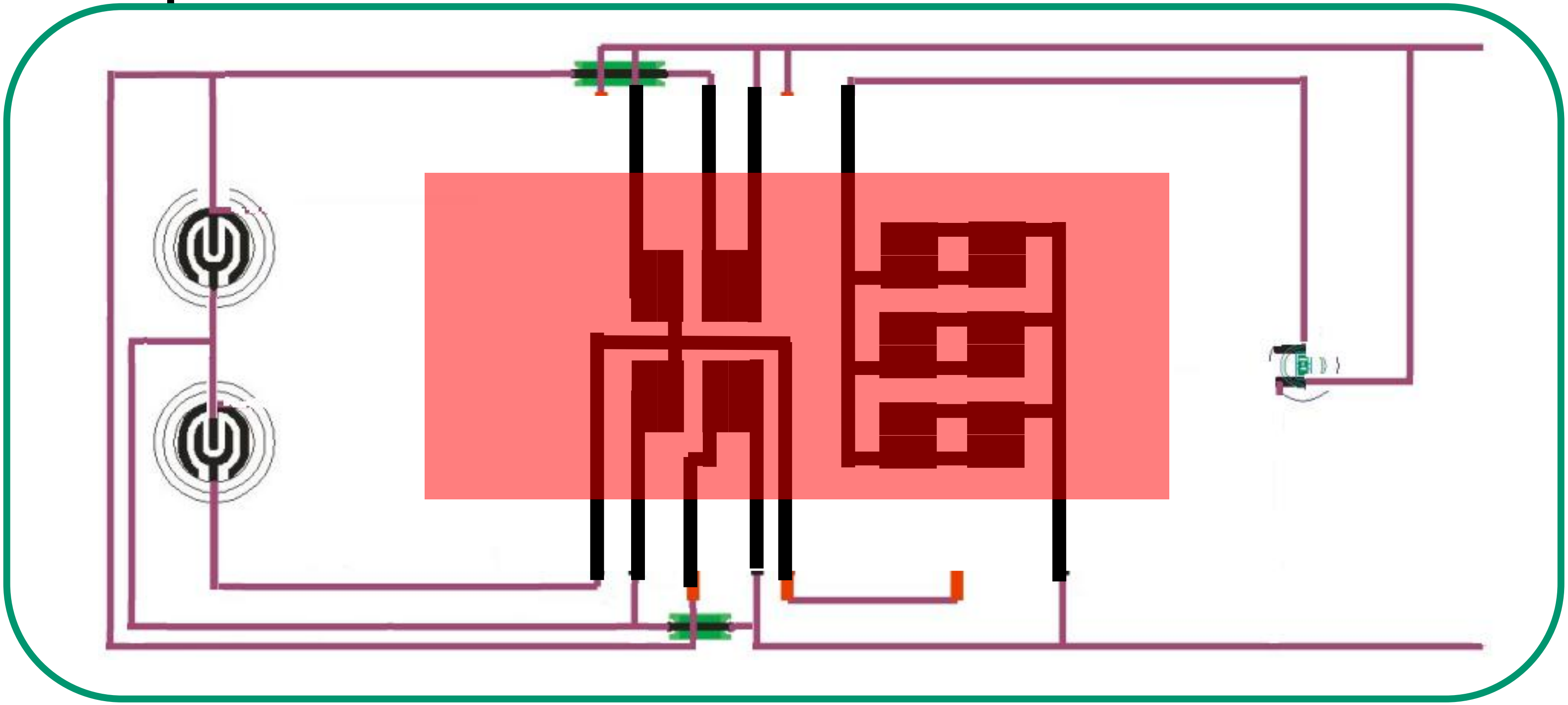
Demonstrator 3 - R-S Flip/Flop

3) Connections evaporation – chromium/gold

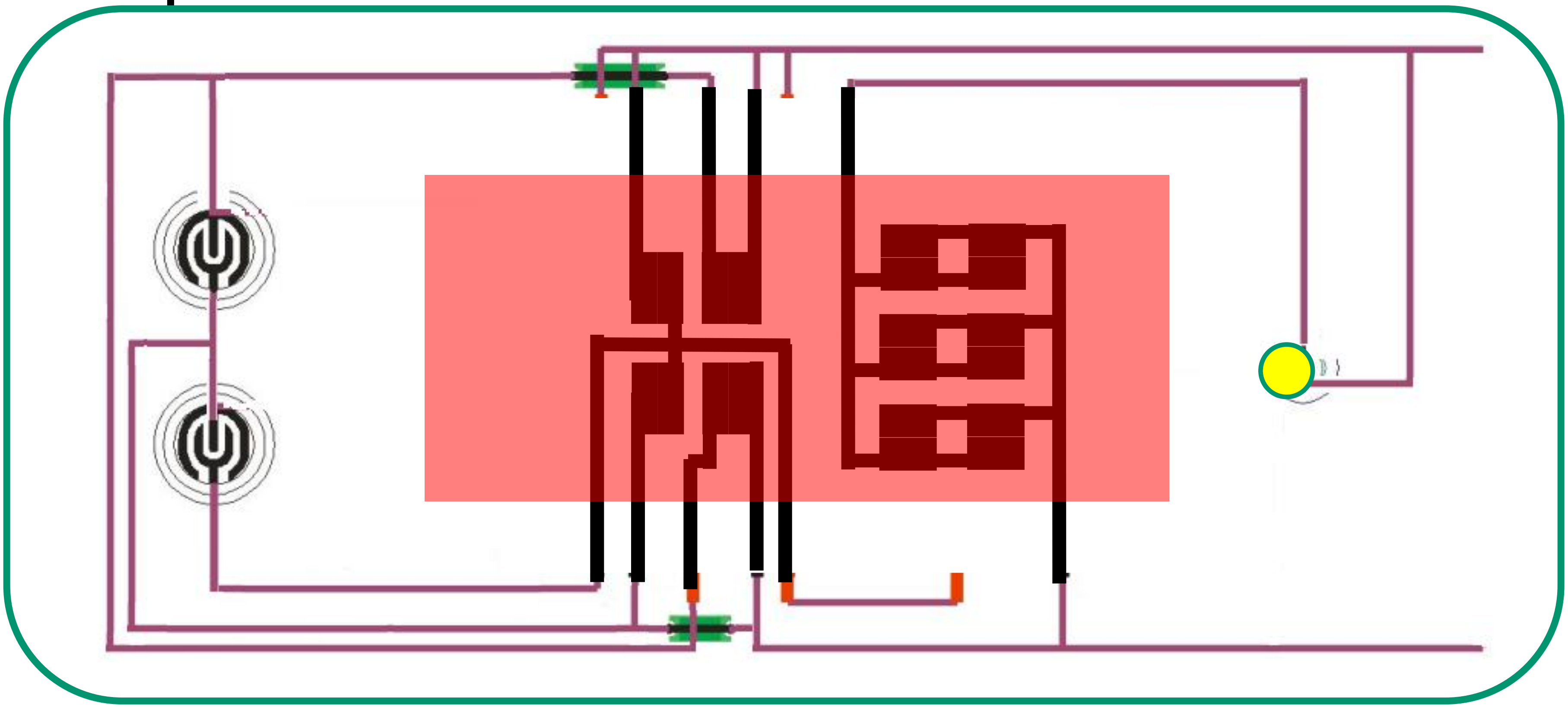


Demonstrator 3 - R-S Flip/Flop

4) zone-cast of semiconductor – TIPS pentacene

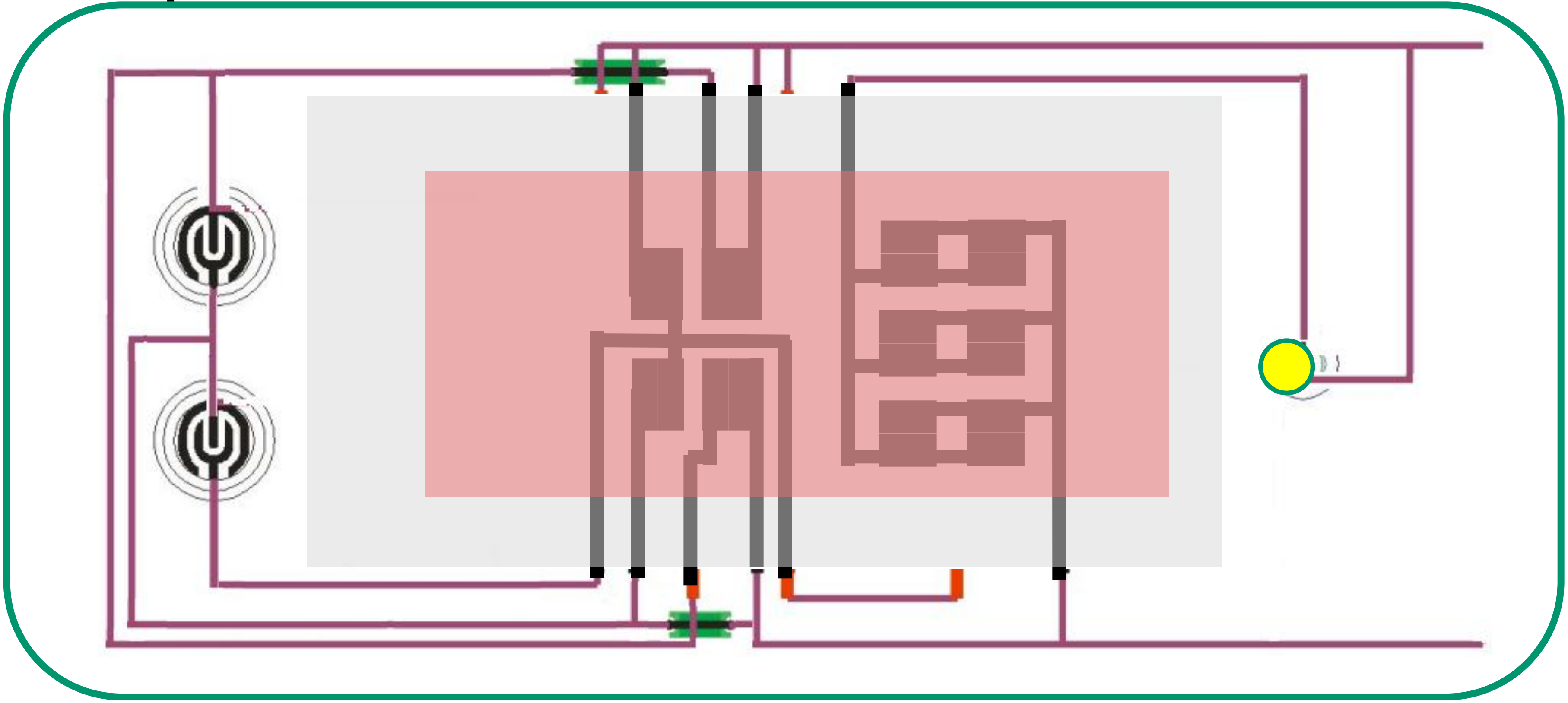


Demonstrator 3 - R-S Flip/Flop
5) Silicon LED mounting



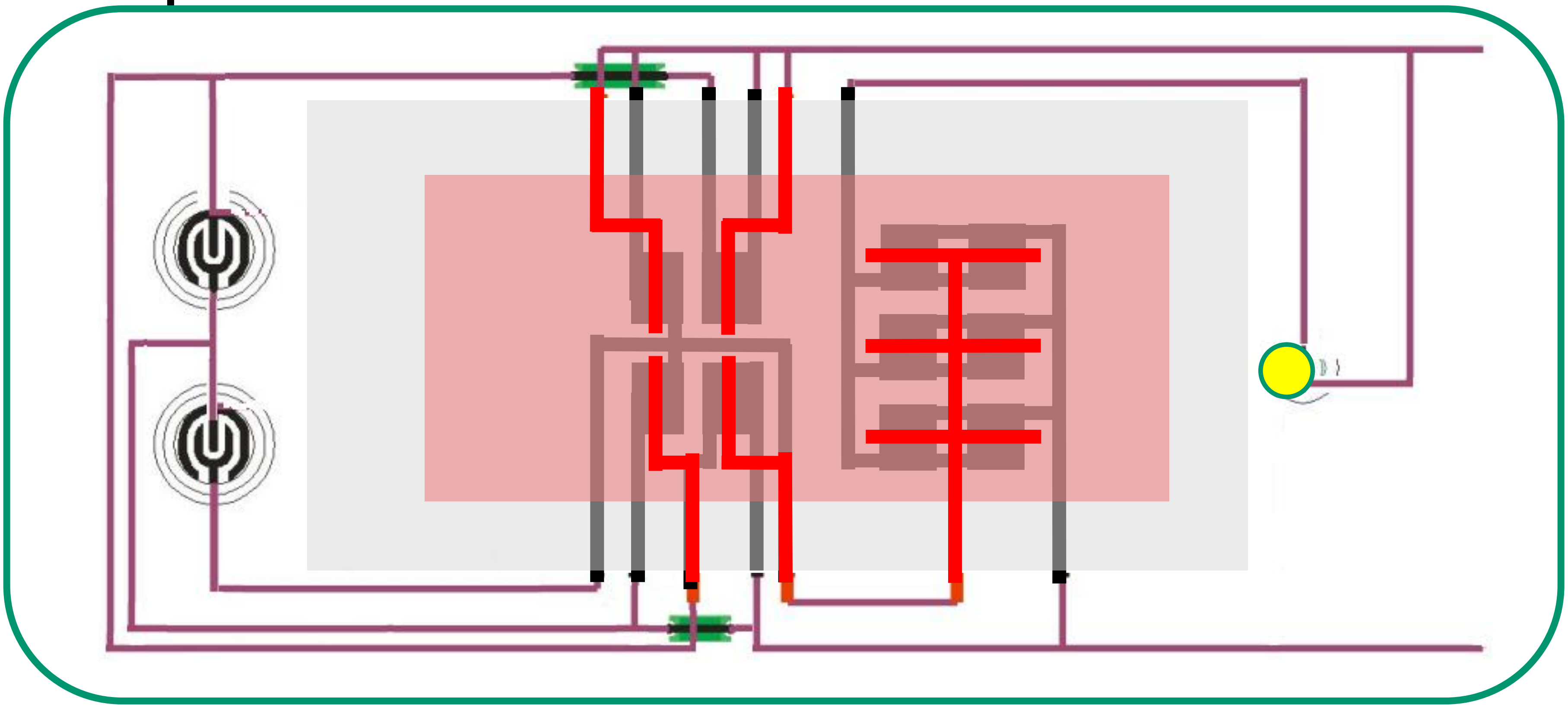
Demonstrator 3 - R-S Flip/Flop

6) Gate dielectric evaporation – parylene C

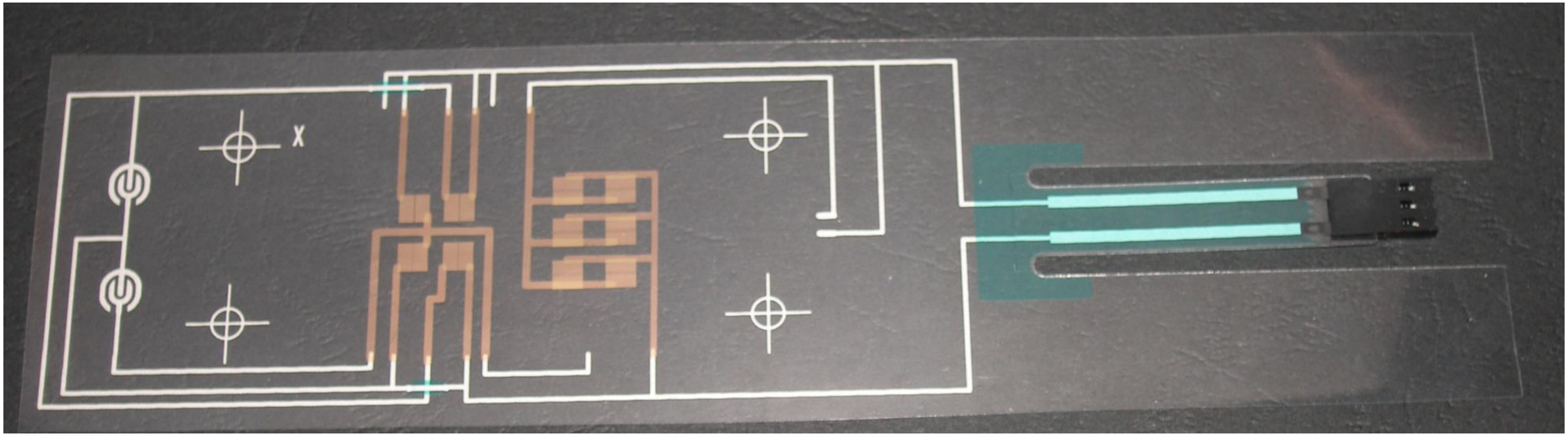


Demonstrator 3 - R-S Flip/Flop

7) Gate connectiond evaporation – chromium/gold



Demonstrator 3 - R-S Flip/Flop
Zone-cast substrate



Conclusions

Organic electronics is a field of opportunities and challenges!

FOLAE new opportunities for users:

- flexible, large area substrates OPV, OLED, displays
- possible low-cost disposable electronics
- reel to reel printing
- new application: intelligent textiles, smart labeling, e-paper

FOLAE new opportunities for research:

- new electrical characteristics
- conduction, charge carriers transport
- interface phenomena
- OFET analytical model

Thank you for your attention!