Printed Electronics

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Ex-

PARIS DIDEROT

(we moved from Jussieu in 2007)
I. Printed Electronics: Why?
II. The Printing Processes
III. What to Print? Which substrate?
IV. Examples of Printed Electronics
Printed Electronics: Why?

DISCLAIMER: SI-BASED ELECTRONICS ("TRADITIONAL" ELECTRONICS) STILL REMAINS UNBEATEN IN TERMS OF:
- SWITCHING TIME (VERY HIGH MOBILITY OF Si);
- INTEGRATION DENSITY (~ 40 MILLION FETS PER MM²).

PRINTED ELECTRONICS IS NOT A DIRECT COMPETITOR OF SI-BASED ELECTRONICS, IT RATHER OFFERS COMPLEMENTARY SOLUTIONS WHENEVER THE FOLLOWING CHARACTERISTICS ARE NEEDED:
- LARGE-AREA FABRICATION
- LIGHTWEIGHT;
- FLEXIBILITY;
- LOW FABRICATION COSTS.

MARKET PREVISIONS: ~ 70 BILLION $ IN 2025!

Source: Printed Electronic World
Printed Electronics: Processes

**Printing techniques:**

CONTACT Printing (conventionnal)

CONTACTLESS (numerical)

CONTACT printing (conventional) vs. CONTACTLESS (numerical)
Printing techniques:

Conventional printing:
- Sérigraphie
- Flexographie
- Offset, Lithographie
- Hélogravure
- Solvant
- UV
- Eau
- Solvant
- UV

Digital printing:
- Electro-photographie
- Magnétoographie
- Ionographie
- Jet d'encre
- Autres
- Une couleur
- Plusieurs couleurs
- Toner magnétique
- Toner liquide
- Bobine
- Feuille
- Bobine
- Simple buse
- Plusieurs buses
- Encre liquide
- Feuille
- Bobine
- Elcographie
- Thermographie
- Sublimation
- Transfère
Printed Electronics: Processes

Printing techniques:

Conventional printing

- Screen-printing
- Flexography
- Offset, lithography
- Héliogravure

Processes:

- Solvant
- UV
- Eau
- Feuille
- Bobine

Type procédé
Type de séchage / encre
Type de support papier
Screen-printing

Planar screen-printing (sheet)

Roll-to-roll screen-printing

Conventional printing
Conventional printing

Screen-printing machines
Screen-printing machines

Conventional printing
Printed Electronics: Processes

Printing techniques:

Digital printing

- Electro-photographie
  - Une couleur
    - Toner en poudre
      - Bobine
  - Plusieurs couleurs
    - Micro-toner
    - Toner liquide
      - Feuille

- Magnétographie
  - Toner magnétique
    - Bobine

- Ionographie
  - Toner magnétique
    - Simple buse
    - Plusieurs buses
      - Encre liquide
        - Feuille

- Inkjet
  - Jet continu
    - Goutte à la demande
      - Encre liquide
        - Bobine
      - Elcographie
      - Thermographie
        - Sublimation
        - Transfère

- Autres

Type procédé:
- Type de séchage / encre
- Type de support papier
Inkjet

Digital printing

inkjet

Jet

Drop-on-demand (DOD)

Thermal actuation

Piezoelectric actuation

Actuation

Nozzle

Substrate

Moving direction of the substrate

Printing file

Ink

Waveform

Université de Paris
Digital printing

Inkjet printers

Dimatix 2840, Fujifilm (desktop)

PRINTEC@BiOSS
INKJET-PRINTING VS OTHER PRINTING TECHNIQUES

INKJET-PRINTING: ADVANTAGES
- Non-contact technique;
- Digital technique;
- Requires smaller amounts of inks;
- Versatility: from rapid prototyping to large scale production.

INKJET-PRINTING: WEAKNESS
- Very strict tuning of ink properties;
- Limited spatial resolution (~30 μm);
- Very low throughput speed.
**Organic semiconductors**

- 1948. First report of an organic semiconductor
- 1963. Electroluminescence in anthracene crystals (Pope, Kallmann, Magnante)
- 1977. Conducting polymers (Heeger, McDiarmid, Shirakawa)
- 1986. Organic transistors (polythiophene) (Koezuka)
- 1986. Organic photovoltaic cell
- 1987. OLED (Tang & van Slyke)

![Chemical structures of various organic semiconductors](Image)

**What to Print? Which Substrate?**
What to Print? Which Substrate?

PCDTBT

PTB7

PBTTT

DPP-DTT

P3HT

PDPP4

PNDI(2HD)

PBDTT-DPP

2T
**What to Print? Which Substrate?**

**Graphene**

- Aqueous-based Suspension of “nanoflakes” of **graphene oxide (GO)**
- Satisfy the rheological parameters for printing (**dynamic viscosity** & **surface tension**)

- **Surfactant-free** ink formulation: water/ethylene glycol/ 1-propanol GO dispersed by ultrasonic fragmentation

Ink: Suspension of GO flakes

- Dimatix inkjet printer (DMP 2831)
- Ejected droplets

Drop Vol. = 10 pL
No satellite drops
**What to Print? Which Substrate?**

**Metals!**

After sintering: AgNPs « melted » to form a percolation pathway. CONDUCTING.

Before sintering: separate AgNPs. NON CONDUCTING.


Inkjet-printed silver tracks
Flexible polymer substrates flexibles must present:

- Good dimensional stability,
- Good thermal stability, high $T_g$, low dilatation coefficient,
- Good resistance to solvents,

& be impermeable to $O_2$ and $H_2O$
Example of a printed OFET:

G. Mattana et al. Org. Electron. 2015, 17, 77

OFETs on ultrathin biodegradable PLA (poly lactic acid)
Examples of Printed Electronics

Pressure sensors (printed)
(Capacitive)


(a) Passive layer (PDMS)  Top Electrode (Silver)

(b) Capacitive Response of Fully Printed Pressure Sensor

Bottom Electrode (Silver)  Dielectric Layer (PDMS)
Biotransistors (printed): the OECT

Neuromediators sensor

L. Kergoat et al., Advanced Materials 2014, 26, 5658–5664
Biotransistors (printed): the OECT

Neuromediators sensor

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Examples of Printed Electronics
Examples of Printed Electronics

Humidity sensors for the detection of R.H. in air

- SUBSTRATE: KAPTON® (POLYIMIDE);
- ELECTRODES: Ag;
- SENSING LAYER: CELLULOSE ACETATE BUTYRATE (CAB)

- DEVICE ACTIVE AREA: 10 MM × 15 MM
Humidity sensors for the detection of R.H. in air

Everything is possible...

On living plants (e.g. leaves)

Sensor’s Structure:
- interdigitated electrodes printed in PEDOT:PSS;
- 1 layer of CAB;
- response to breath.

Inkjet-printing on Leaves (Eléagnus)
Examples of Printed Electronics

Fabrication of All-Inkjet-Printed Electrolyte-Gated Field-Effect Transistors (EGOFETs)

- substrate: Kapton® (Polyimide);
- electrodes: Au;
- organic semiconductor:

DPP-DTT

- device active area: 5 MM × 5 MM
Today IJP is practically and successfully used for the following purposes:
- Fabrication of conductive electrodes;
- Deposition of functional layers (adhesion layers, dielectric layers, sensing layers...).

Deposition of semi-conducting layers needs still optimisation!

Challenges to be faced
- Droplets emission and manipulation, interaction droplets/substrate;
  - \(\rightarrow\) Towards sub-micrometre resolution
- Improvement of functional materials (semiconductors) stability and performances;
- Multi-technology integration: surface treatments, printing, lamination,... All integrated on a single industrial device.
Materials (chemistry)

Inks (formulation)

Electronics (physics)

Printing (techniques)

Organic Electronics on Flexible Objects
Implanted sensors in Human / Living organisms
Sensors on Biomedical devices

Concep. / Fab
Understanding

4D Printing (3D + function)
Biosensors

2D Printing (inkjet – beyond the limits)
Electrochemical Systems

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Selected Projects

Hydrogel EGOFETs Applied to Living Organisms
BiOSS / Hôpital Tubingen (DE)

Dielectrophoresis and Reverse Osmosis for Membraneless Sieving
BiOSS / PHENIX / IFREMER / ENS (FR)

Flexible and Printed Electronics (in general)
BiOSS / EPFL (CH)
Selected Projects

Printed Gas Sensors Applied to Dysbiosis
BiOSS / ISEP / IM2NP

Electronic Devices in Living Plants
BiOSS / U-Norkkoping (SE) / U-Bari (IT) / U-Bordeaux

Printed Graphene and Control of its Electronic Properties
BiOSS / MPQ / PPSM / ICMMO

Team BiOSS – Bioelectronics and Smart Surfaces
On-going collaborations

Collab.

• Nationales
• Internationales
• Industrielles
Some Dedicated Equipments

- Sérigraphie 1
- Sérigraphie 2
- Jet d’encre x 2
- Ozone 1
- Ozone 2
- Recuit thermique
- Tapis de séchage
- Recuit photonique

Team BiOSS – Bioelectronics and Smart Surfaces
Some Dedicated Equipments

- Carac. élec. 1
- Potentiostats
- Carac. élec. 2 + carac. optiques
- Viscosimètre
- Tension de surf.
- AFM
- Angle de contact
Réunion de Printemps du Club MicroCapteurs Chimiques

Jeudi 26 mars 2020

THÈME : FLEXIBLE ELECTRONICS

Laboratoire ITODYS
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AFELIM représente la filière de l'électronique imprimée, organique ou non organique

http://www.afelim.fr/

conductivité, légèreté, flexibilité,...
une autre électronique

Paris, mars 2020