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Ph.D. thesis (2020-2023)
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SAVE Project – SepARation and Valorization of materials coming from the end-of-life of printed on paper Electronics devices

SépARation et Valorisation des matériaux issus de la fin de vie des dispositifs Electroniques imprimés sur papier

Context

Circular Economy

Fibers and metal particles valorisation

- Elimination of waste and pollution production;
- Keep products and materials in use;
- Regenerate natural systems.

Resulting in:

- Business and economic opportunities;
- Job creation;
- Environmental and social benefits.



Waste of electrical and electronic equipments (WEEE)

Commonly designated as e-waste.



Printed Electronics (PE)

- Low-cost production;
- Large-area flexible devices;
- Reduced resources usage;
- Global PE market (2020) = 7.8 b USD
- Expected to grow in 2050 = 20.7 b USD
- **Recyclable?**

Electronics on paper

- Low price substrate;
- Simple fabrication methods;
- Lightweight;
- Flexible and can be folded into 3D structures;
- Biocompatible, biodegradable, and environmentally friendly;
- Porous material (high surface area-volume ratio).

Funded by IRS/Grenoble INP

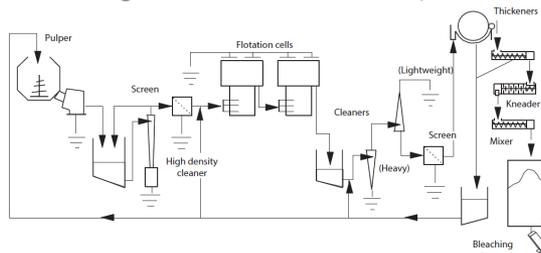
Objectives

Selection of the raw materials

- Functionalized inks;
- Paper grades;
- Production of model printed functionalized electronic device.

Separation of inks from cellulosic fibers

Deinking Process – several unit operations



Analysis of all produced fractions

Evaluation by mass balance (MB)

In separation processes, usually, there are no reactions, so MB can be described as:

$$Input = Output + Accumulation$$

Separation, recovery and valorisation of all materials

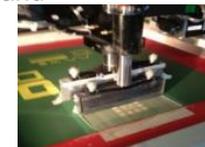
- Implementation of a new separation and recovery strategies;
- Valorisation study of recovered materials:
 - Papermaking ability of cellulosic fibers;
 - Quality of the recovered metal particles – possible valorisation

Methods

RFID tags study case

E-printed paper production and characterization

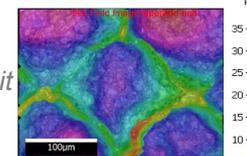
- Ink characterization;
- Screen-printing;
- Optical 3D measurement system for surface characterization (Alicona).



Screen printing press

Development of Recycling Process – unit operation investigation

- Mass balance;
- Ag tracking;
- Fiber analysis.



Printed ink topography (x50)

Ag Extraction by successive leaching, concentration and Recovery

Determination of Ag extraction efficiency (%EE):

$$\%EE = \frac{(C_{initial} - C_{final})}{C_{initial}} \times \frac{V_{initial}}{V_{final}} \times 100$$

where, C (mol·L⁻¹) and V (L) correspond to concentration and volume, respectively.

Evaluation of the following parameters:

- Nature and concentration of leaching agent;
- Volume ratio;
- pH;
- Different molar ratios;
- Different metal ion concentrations;
- Multicycle extraction;
- Stripping (back-extraction) efficiency.



Biochip / FunPrint



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Grenoble - Chambéry