cemitec
Centro Multidisciplinar de Innovación y Tecnología de Navarra

"Enabling massive printed electronics:

inkjet printing on low cost substrates"

Estibaliz Armendariz

cemitec

NANOTECH 2009

Houston, 03 – 07 May

EXCELENCIA EUROPEA 500+ PUNTOS EFQM

Index - Outline

1. Brief description of cemitec
2. Real Application: *EMBEGA S. COOP's* keyboard
3. Experimental – Methodology
    a. Substrates
    b. Printer
    c. Inks – Selection
    d. Printing & Sintering Processes
    e. Other Sintering Processes
4. Results
5. Conclusions

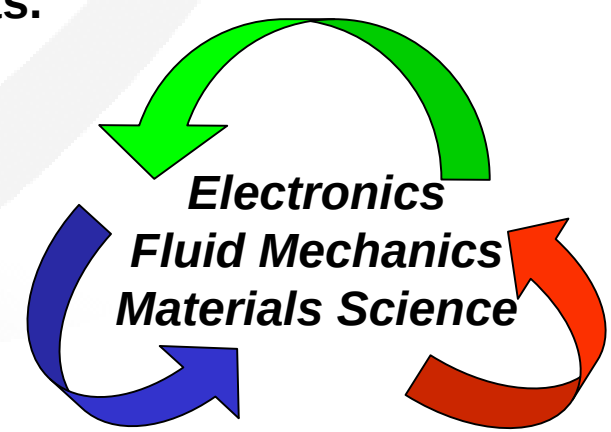
1. Brief description of cemitec

Where is cemitec?

(Although, Pamplona is well known because of …)

- **Technological Centre located in Pamplona, Navarre (Spain)**
- **Established in 1987.**
- **50 people, highly skilled technical staff.**
- **Mission: enterprises' competitiveness enhancement through R&D projects / contracts.**

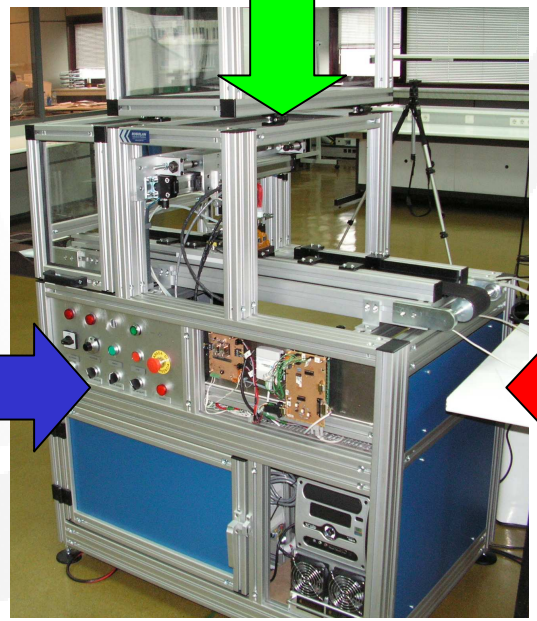
Several ***Knowledge Areas*** interact with each other to tackle R&D Projects:



1. Brief description of cemitec

Inkjet Technology implementation requires the work of many experts among different areas (especially when intended as a manufacturing process)

Electronics
Control & Driving
Data Transfer



Fluid Mechanics
Microfluidics
Drop – Substrate interaction

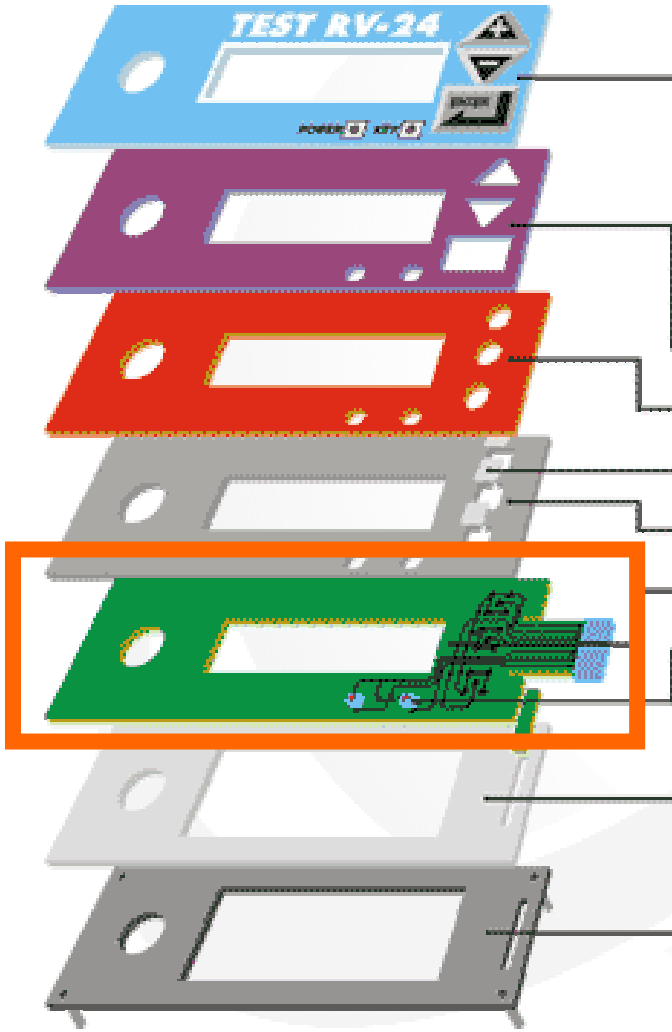
Materials Science
Fluid formulation
Surface preparation

2. Real Application: *EMBEGA S. COOP's* flexible keyboard

Sectors:

Machine tool.
Medical equipment.
Safe boxes and security systems.
Measuring instruments.
Vending machines.
Domestic appliances.
Automotive industry.
Instrumentation.
Military industry.
Telecommunications.
House automation.
Electronic equipment.
Etc.

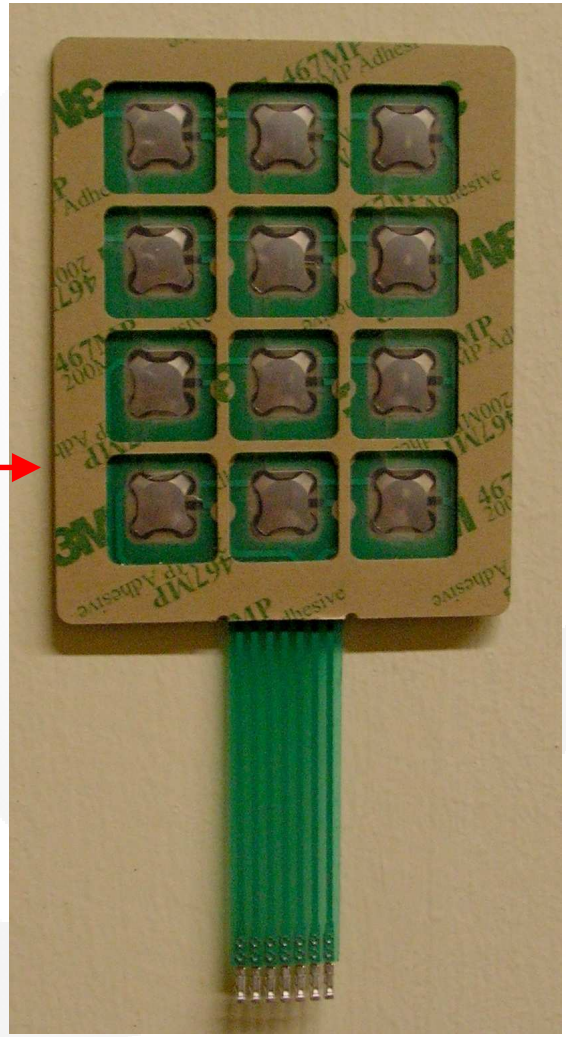
2. Real Application: *EMBEGA S. COOP's* flexible keyboard

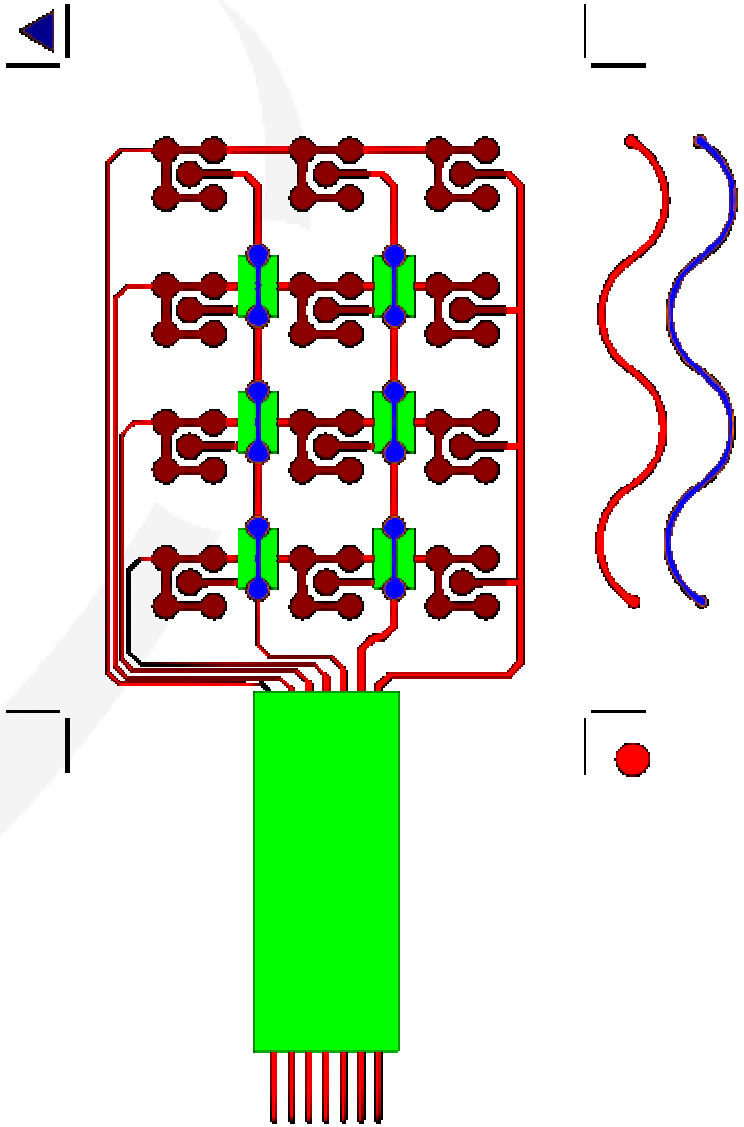


Graphic Overlay
Adhesive Spacer
Dome Retainer
Metallic dome
Adhesive Spacer
Printed Circuit Layer
Leds
Bottom Adhesive
Metallic Support

2. Real Application: *EMBEGA S. COOP's* flexible keyboard

Keyboard Layers





2. Real Application: *EMBEGA S. COOP's* flexible keyboard

Current manufacturing technique:

Serigraphy or Silk Screen, lithography: all contact printing methods

Analogic
(serigraphy)

Digital
(inkjet)

3. Experimental - Methodology

3.1. Substrates

	Properties	Unit	Test Method	
KAPTON	Thickness Micron	µm		125
	Ultimate Elongation	%	ASTM D 882	72
	Tensile Modulus	GPa	ASTM D 882	2.6
	Shrinkage			
		%	IPC TM 650	0.17
		%	ASTM D5214	1.25
	Thermal Expansionn	1/K	D696	1.1E-05
	Glass transition temp	ºC		360 - 410
	Surface Energy	dynas/cm		42 - 50

Kapton®, due to its suitable superficial energy to the inks used and overall mechanical - thermal properties, is established as **test pattern or signature.**

	Properties	Unit	Test Method	
PET	Thickness	µm		175
	Ultimate Elongation	%	ASTM D882	150
	Tensile Modulus	daN/mm²	ASTM 882	400
	Shrinkage			
	MD	%	RPF	1.7
	TD	%	RPF	0.9
	Thermal expansion	1/K		7.0E-05
	Melting Point	ºC		250
	Vicat softening point	ºC		170
	Surface Energy	dynas/cm		30

PET is the **desired** final product **substrate** by the keyboard manufacturer because of its low price and availability.

3. Experimental - Methodology

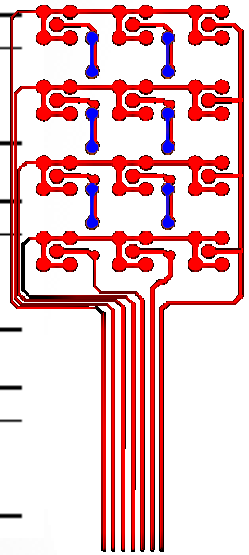
3.2. Inks - Selection

Conductive Inks

Property	Conductive 1
Silver Content wt %	60
Viscosity cps @ 25ºC	5 - 20
Surface tension (dynes/cm)	25

Property	Conductive 2
Silver Content wt %	20
Viscosity cps @ 22ºC	14.4
Surface tension (dynes/cm)	31

Property	Conductive 3
Silver Content wt %	23
Viscosity cps @ 20ºC	24.62
Surface tension (dynes/cm)	36.5

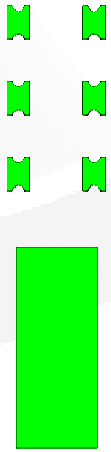


Insulating Inks

Property	Insulating 1
Viscosity cps @ 35ºC	8 -10
Surface tension (dynes/cm)	27 -31

Property	Insulating 2
Viscosity cps @ 35ºC	15 -20
Surface tension (dynes/cm)	30 -34

Property	Insulating 3
Viscosity cps @ 35ºC	8 -10
Surface tension (dynes/cm)	28 - 32



Printer

Dimatix Materials Printer *(DMP - 2831)*, **Fujifilm**

Piezoelectric cartridges, 16 nozzles at 254 µm spacing.

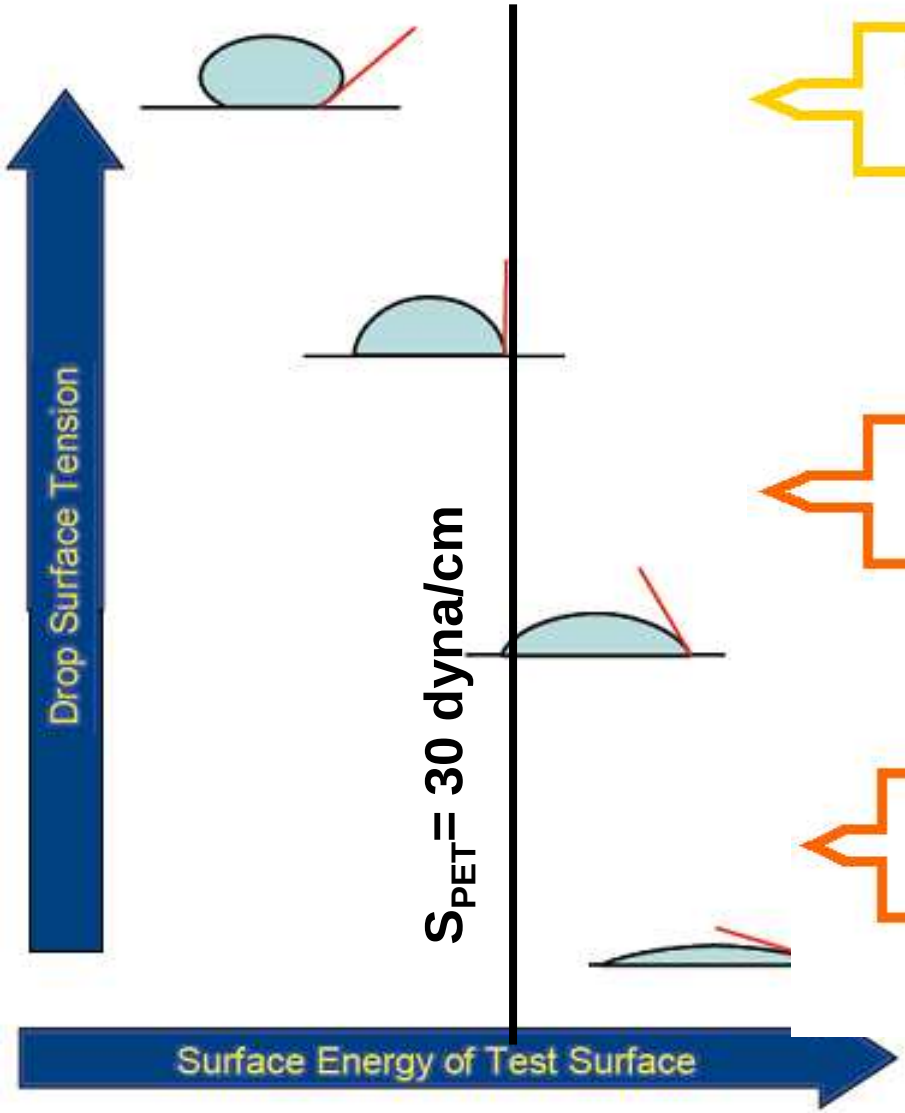
The thickness of the tracks to print allowed the use of the 10pl cartridge.

Ejected average drop diameter is of 27µm.

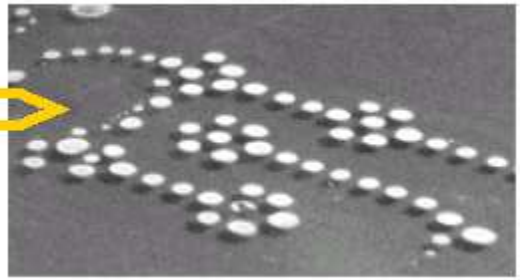
On the substrate, the average drop diameter was estimated to be of 57µm.

3. Experimental - Methodology

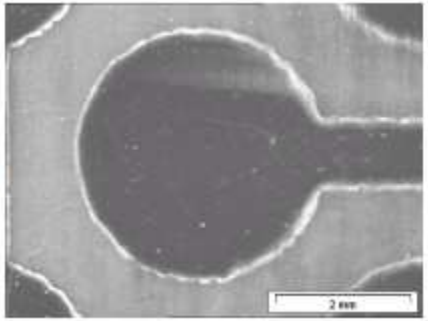
3.2. Inks – Selection: ***CONDUCTIVE***



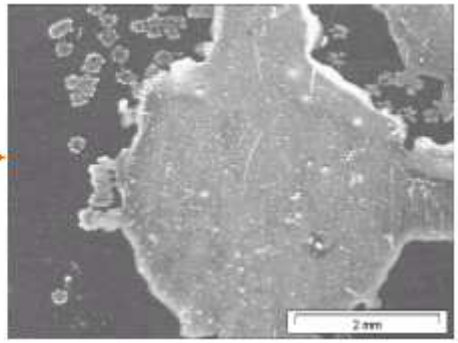
CONDUCTIVE 1
$\sigma = 25\, dyna/cm$



CONDUCTIVE 3
$\sigma = 31\, dyna/cm$



CONDUCTIVE 2
$\sigma = 36.5\, dyna/cm$



Aplicación Excel

3. Experimental - Methodology

3.2. Inks – Selection: ***INSULATING***

Polymer	*Vehicle*	*Reticulant Agent*	*Comment*
Poly – 4 – Vynil Phenol MW 8000 (1.08g)	Hexanol (15ml)	p(melam. co formal)	✓
Poly – 4 – Vynil Phenol MW 8000 (1.08g)	Isopropanol (15ml)	p(melam. co formal)	✗
Poly – 4 – Vynil Phenol MW 8000 (1.08g)	PGMEA (15ml)	p(melam. co formal)	
Poly – 4 – Vynil Phenol MW 20000 (1.08g)	Hexanol (15ml)	p(melam. co formal)	✓
Poly – 4 – Vynil Phenol MW 20000 (0.54g)	Hexanol (15ml)	p(melam. co formal)	✓
PVPh co – 2 – hydroxyethyl metacrylate	PGMEA (15ml)	p(melam. co formal)	
PVPh co – 2 – hydroxyethyl metacrylate	n-methyl pyrrolidone	p(melam. co formal)	

Cured in a convection oven

Conductivity tested using a multimeter (9V DC)

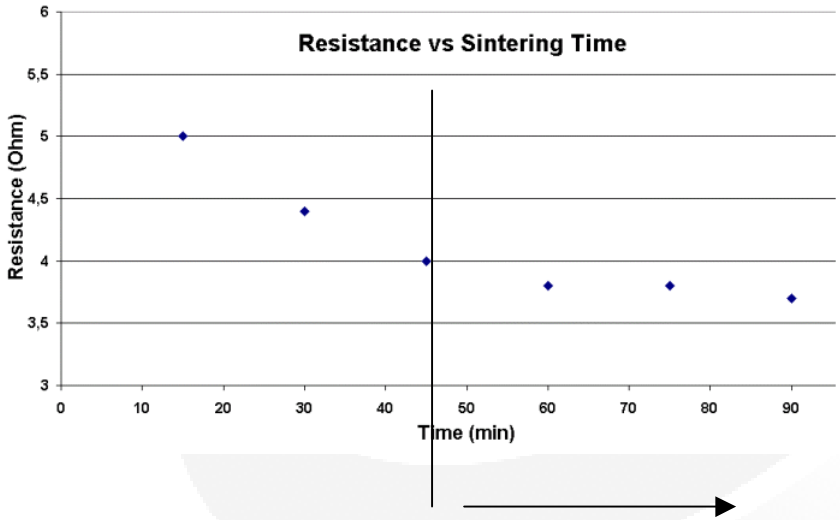
- ✓ OK
- ✗ No OK: poor print and wettability

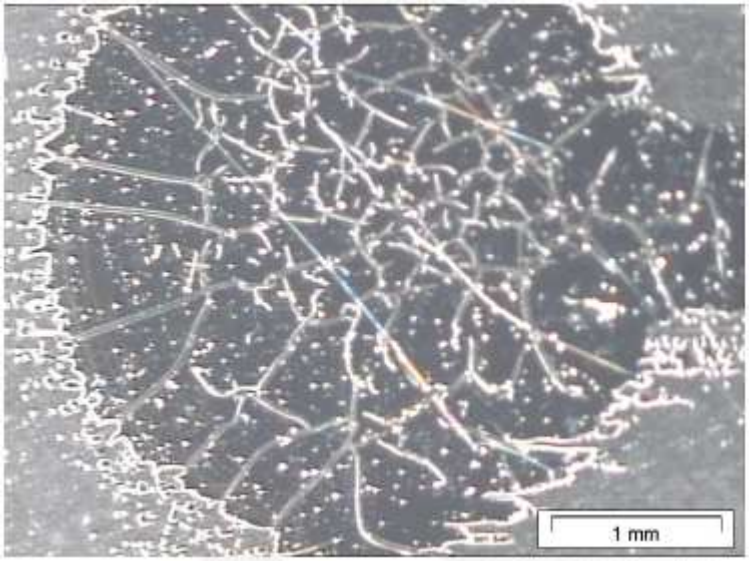
3. Experimental - Methodology

3.3. Printing & Sintering Processes

Curing Time Settings

Printing Motive: 20mm length, 0.5mm width and 0.020mm thickness.
Single Layer
Temperature Range: 130 - 150ºC
Oven Used: SELECTA (*Digitronic* model)**,** convective.





3. Experimental - Methodology

3.3. Printing & Sintering Processes

Mechanical Stress Gradients?

Material	Linear Thermal Coefficient (1/ºC)
Ag	18.9E-06
PET	70.0E-06
PVPh	200.0E-06

→ Same order of magnitude!!!

Corrective Measures:

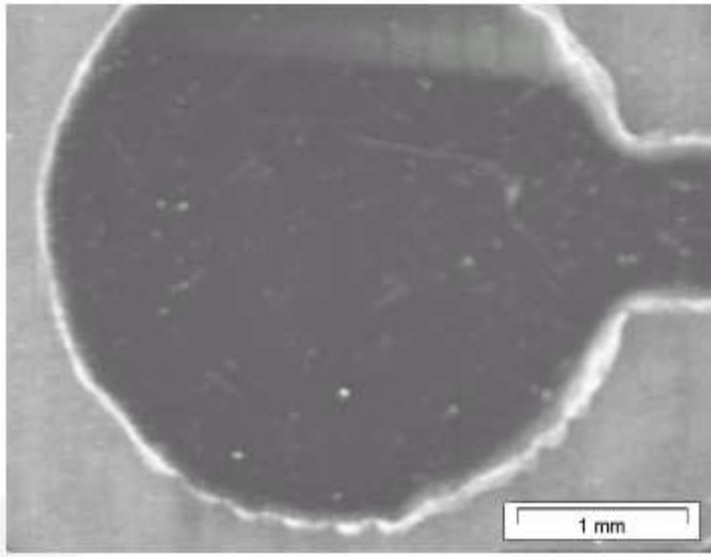
Ultrasound Session: 20min, 20% amplitude.

Filtering restrictions: 0.2µm pore maximum.

Increase the platen temperature during printing.

Increase cartridge temperature and decrease piezoelectric voltage needed.

Piezo. Voltage (V)	Cartridge Temp (ºC)	Drop Mass (pg)	Cracking
26	28ºC	10.3	Yes
23	30ºC	5.2	Yes
20	37.5ºC	7.1	Yes
16	***38ºC***	***2.4***	***No***

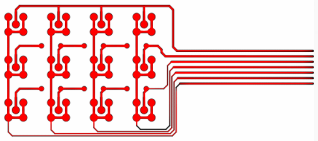


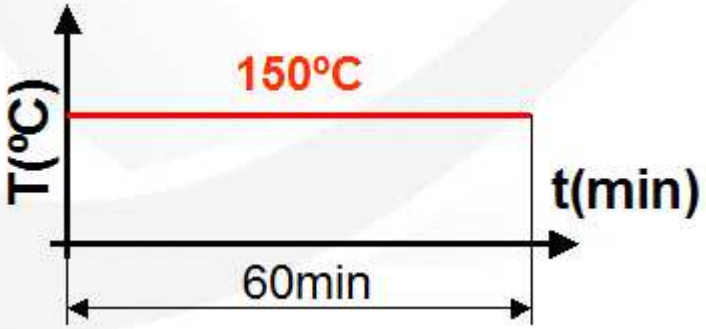
3. Experimental - Methodology

3.3. Printing & Sintering Processes

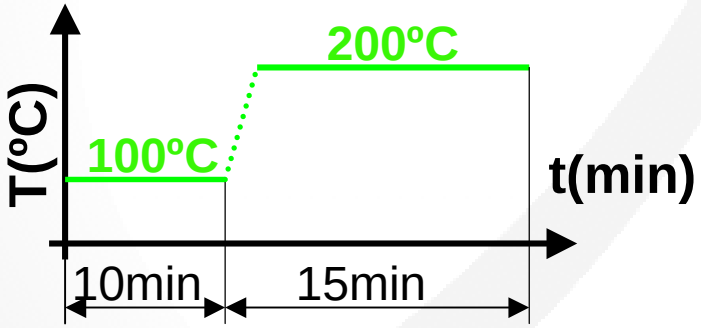
Ovening Time Settings: Three Layers Summary

Layer 1: Silver

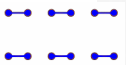


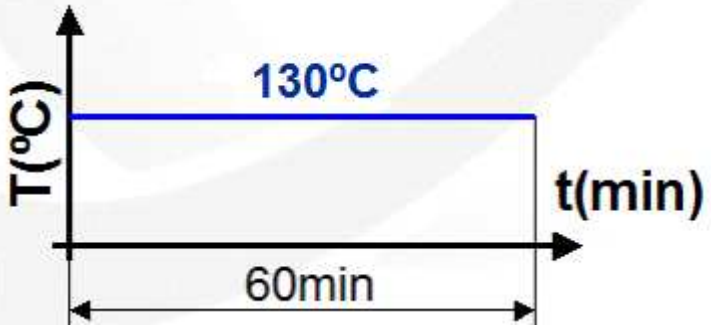


Layer 2: PVPh



Layer 3: Silver



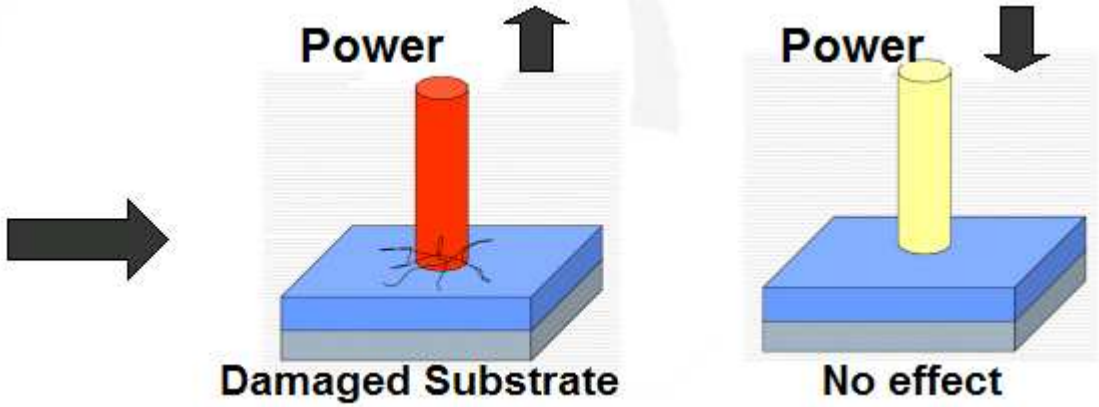


3. Experimental - Methodology

3.3. Other Sintering Processes: ***LASER***

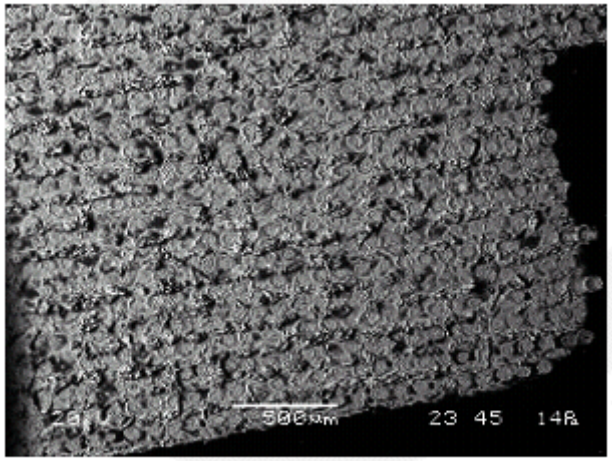
Key variables

- Time Exposure
- Intensity
- Pulse Distance

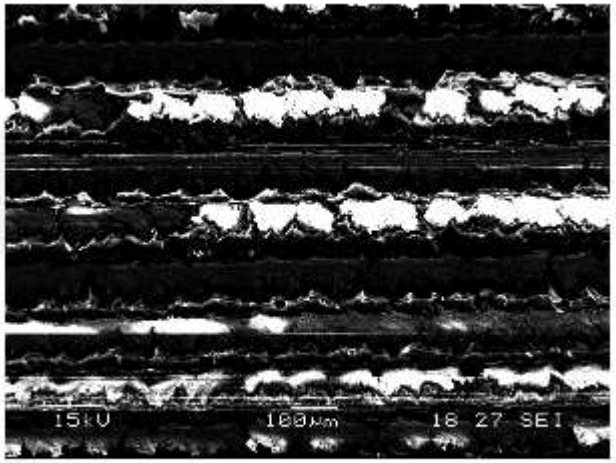


- ✓ **H2O based inks**
- ✘ **Oils and some organic compounds**

Laser en acción



KAPTON



PET

4. Results

Fourth Layer currently under development.

Performance tests about to start.

5. Conclusions

Together with the feasibility study, **a printing procedure was described for the keyboard manufacturer in order to facilitate the technology implementation**, covering aspects like **ink selection**, **substrates**, **key properties knowledge** and **printing and sintering parameters' setting and control**.

The work done also shows the key role of Technological Centres on new manufacturing technologies implementation and knowledge transference to companies.

Project's Current State:

WP4: Pre - Industrialization

Pre – Industrial Evaluation of Digital Deposition
Process validation, liability evaluation, technical and economic viability.

New Inkjet Materials Development Platform
R&D Platforms for new materials development protocols, characterization and pre – industrial supply.

Thank you kindly for your attention!

Acknowledgements:

Departamento de Innovación, Empresa y Empleo

Fondo FEDER
Programa EUROINNOVA

Ministerio de Ciencia e Innovación