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Thomas Guérin, Philippe Lombard, Tony Gerges, Murat Arli, Hayet Lakhar, et al.. Development and characterization of a conductive ink for In-Mold Electronics.. LOPEC, Mar 2023, Munich (Allemagne), Germany. 2023. hal-04241549

HAL Id: hal-04241549

<https://hal.science/hal-04241549>

Submitted on 13 Oct 2023

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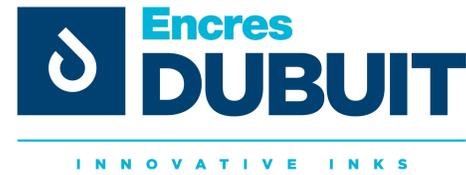
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Development and characterization of a conductive ink for In-Mold Electronics

Thomas Guérin, Tony Gerges, Philippe Lombard, Murat Arli, Hayet Lakhari, Bruno Allard, Jean-Yves Charmeau, Guy Masse, Michel Cabrera

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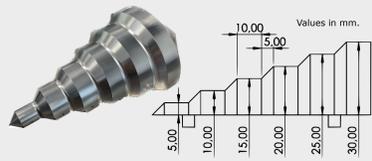
Questions:

- ⇒ How to formulate a conductive ink for thermoforming process ?
- ⇒ What is the effect of the binder in the characteristics of the ink?

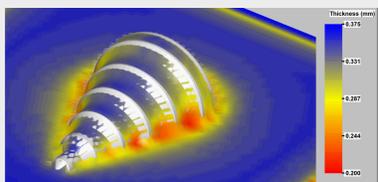
Introduction and context

In the context of the IME process, a conductive ink is formulated to be able to be printed, thermoformed and over-moulded, with a good electric conductivity.

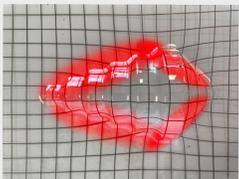
Influence of the thermoforming process is tested with 7 inks with different binders and a commercial reference ink DuPont ME604.



(1) ⇒ Aluminium tool, with 6 radius of curvature, R=5mm to R=30mm and a conical tail.



(2) ⇒ Simulation of the reduction of the polymer thickness with T-SIM software. (Polycarbonate substrate, initial polymer thickness 375µm, Covestro Makrolon®).



(3) ⇒ Thermoformed PC sheet with a grid printed on it (aluminium tool). Stretched areas are highlighted in red.

1-Formulation of the inks with different binders

General formula :

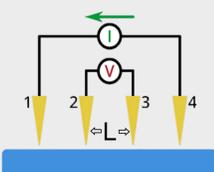
- ⇒ 60%wd silver content (fixed).
 - ⇒ 10%wd to 16%wd binder (variable amount to adapt the rheology).
 - ⇒ 24%wd to 30%wd cetone-type solvent (fixed, amount in function of binder).
- Mixing with planetary system (Hauschild Speedmixer DAC400).

2-Measurement of electrical resistivity

Calculation of resistivity :

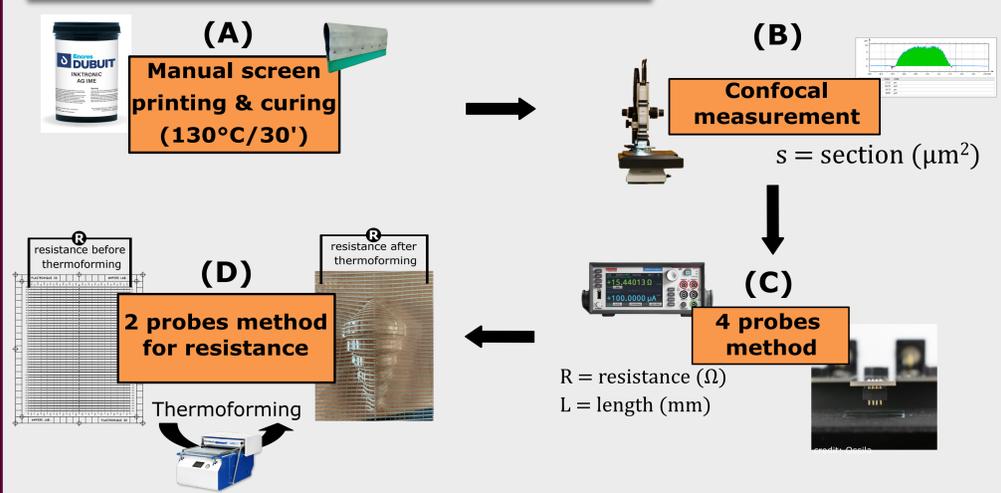
$$\rho = \frac{R \cdot s}{L}$$

where :
 ρ = resistivity ($\mu\Omega \cdot \text{cm}$)
 R = resistance (Ω)
 s = section (μm^2)
 L = length



- ⇒ Determination of the track profile with a confocale probe.
- ⇒ Measurement of the resistance R of a conductive track with a four point probes.
- ⇒ Calculation of the conductive section (s), according to formula.
- ⇒ Distance between internal probes is fixed (1.27mm) (L).

3-Thermoforming characterization

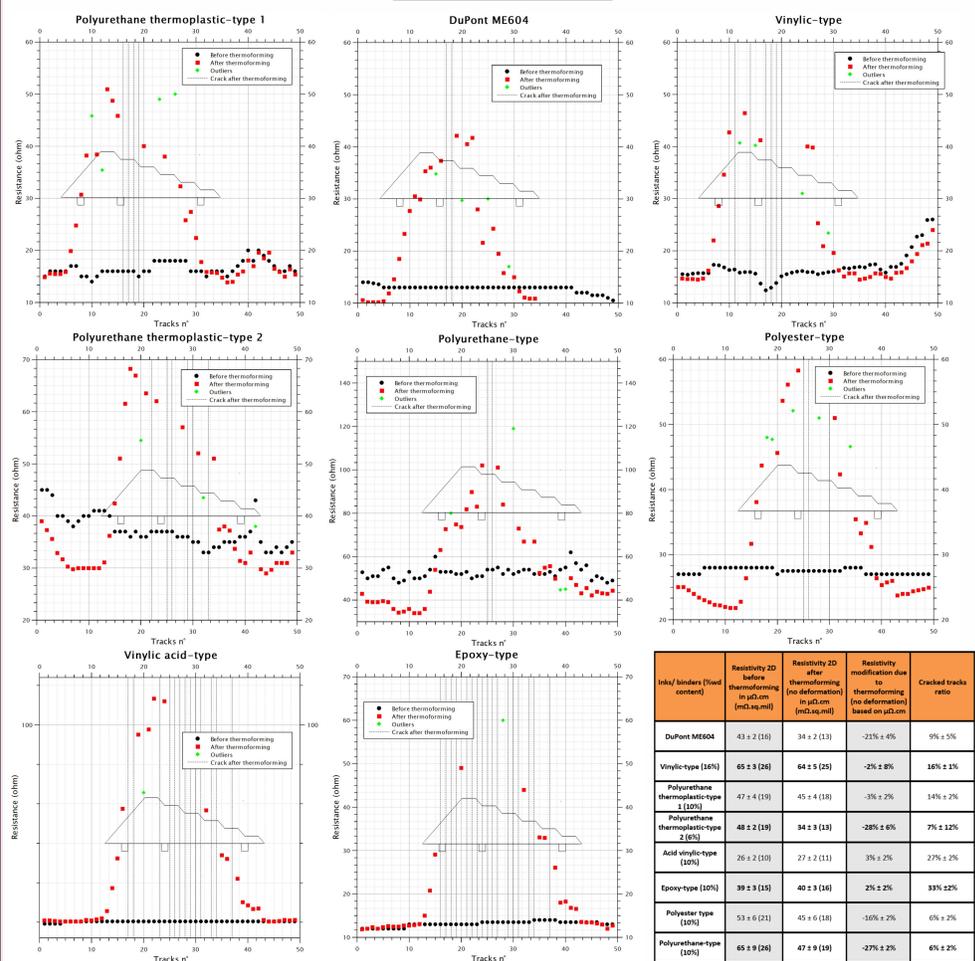


4-Results for different binders

Methodology

- ⇒ Inks are printed with 90.40 or 110.40 threads per cm, on PC substrate.
- ⇒ Resistance is measured before and after thermoforming, on tracks.
- ⇒ Resistivity is calculated after curing (oven), before thermoforming.
- ⇒ Resistivity after thermoforming is measured on no-deformed tracks to exhibit the temperature influence of thermoforming.
- ⇒ The printing pattern is designed with 3 tracks for each stage of curvature.

Measurements of resistance before and after thermoforming of inks with different binders



Results interpretation :

- ⇒ DuPont ME604 is used as a reference ink, with 34µΩ.cm after thermoforming.
- ⇒ Outliers data may be caused by manual screen printing.
- ⇒ Before thermoforming, acid vinilic ink shows the best resistivity value with 24µΩ.cm but cracks easily.
- ⇒ After thermoforming, TPU-type 2 is promising with a conductivity of 34µΩ.cm which can be compared with DuPont ME604.

Conclusions & outlooks

- ⇒ Binders have different behaviours before and after thermoforming. After printing and curing, different values of resistivity are observed from 26µΩ.cm to 65µΩ.cm. On flat surface, the resistivity will decrease from 0% (TPU1) to 30% (TPU-type2 & DuPont ME604), depending on the nature of the binder.
- During 3D forming, all inks will be deformed and the electrical conductivity will gradually decrease, in function of the deformation, until crack.
- ⇒ TPU-type 2 ink formula will be investigated to improve performances.
- To complete the IME process, inks should be tested in over-moulding then tested in electrical resistivity.