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One-time Deformable Electronics

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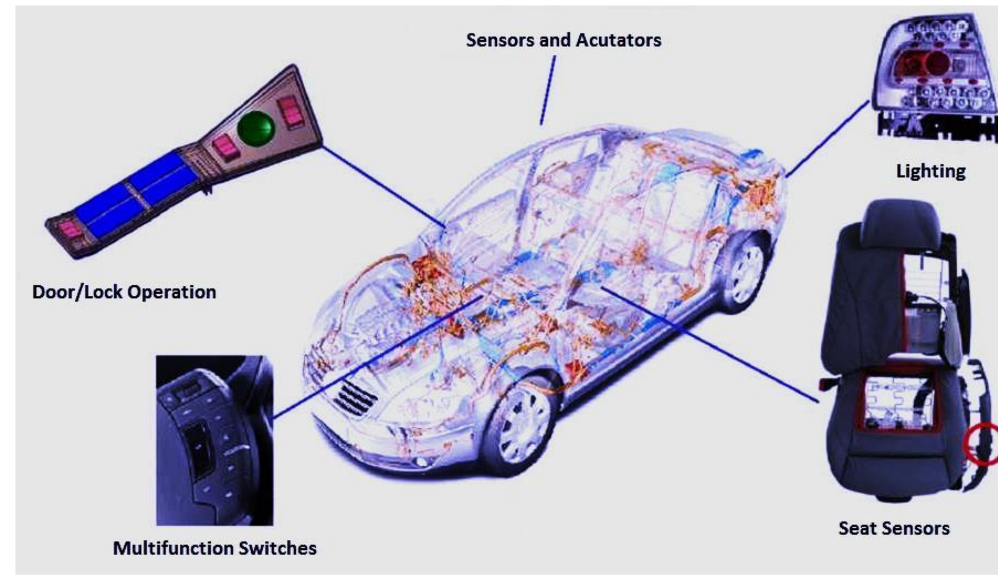
Objective

Low cost shaped smart objects since there is a growing demand for rigid free form (2.5 D or 3D) electronics circuits:

Why?

- Higher level of integration.
- Avoid wiring and connectors.
- Embedded touch sensors, antennas in deformed
- substrates.
- Shaped lighting sources.
- New design freedom in terms of shape.



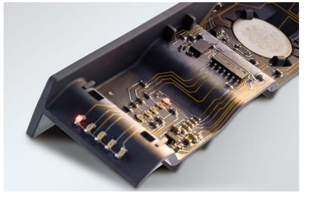
Example of applications in automobile field.

What exists?

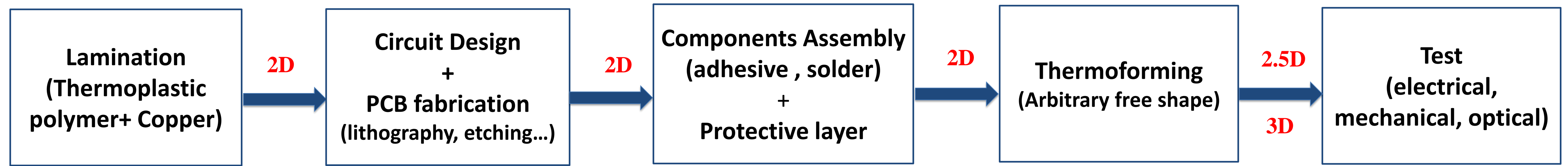
- Composition of flat rigid boards , flexible cables/circuits and mechanical connectors.
  - Extensive use of connectors decrease the reliability.
  - Limitation of freedom of design.

Flex - rigid board

- 3D MID technology
  - Not a standard PCB fabrication and assembly method.
  - Expensive .


3D MID sample

Process Flow



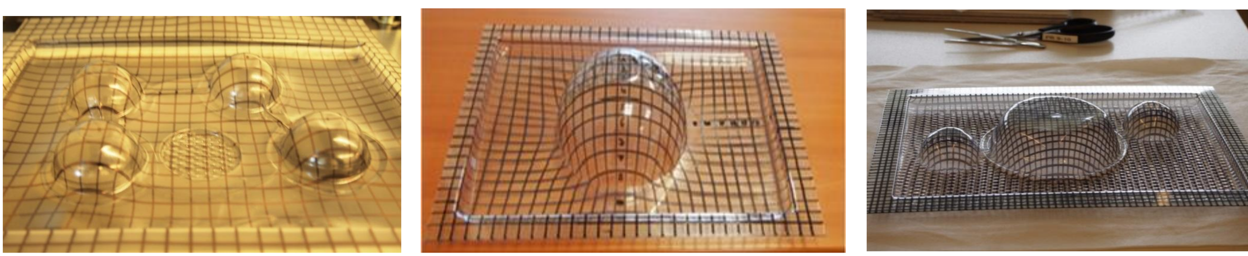
Two amorphous thermoplastic materials have been chosen suitable for thermoforming Polycarbonate Lexan 8B35 (PC) and PETG Polyethylene terephthalate glycol-modified (PETG).

Lamination:

For making the electronic circuit two layers are laminated, either PC or PETG as a substrate with an electrodeposited copper foil TW_YE, 18 micron as a conductor layer .

	The parameters of lamination	Peel Force
(PETG/Cu)	T= 120 °C ,P= 10 bar.	0.7 N/cm
(PC/Cu)	T= 190 °C ,P= 15 bar	0.4 N/cm

Thermoforming:



(1),(2),(3) : These photographs show some experiments with PC and PETG using different molds.

Materials properties:

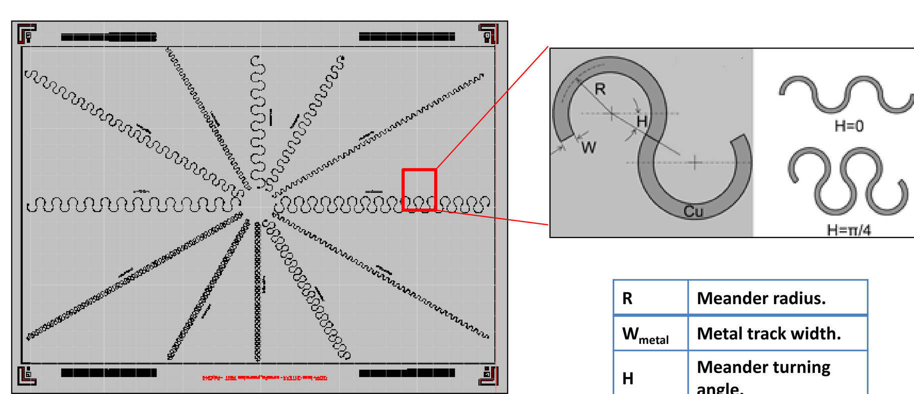
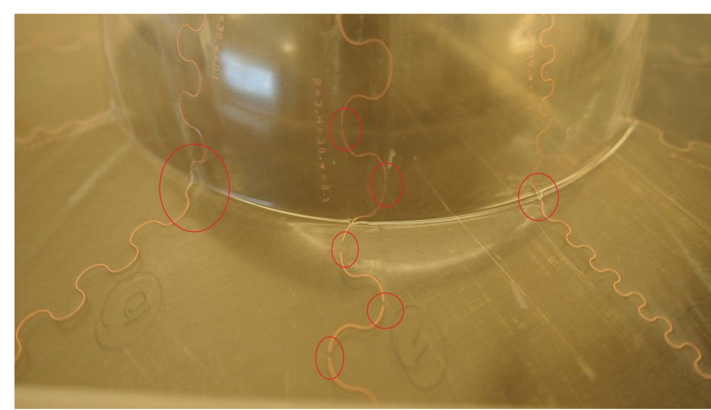
Materials	CTE	Tg °C	Forming temperature	Thickness	Applications
PC	5,8	153	160-200 °C 180°C	500 micron	- Medical devices - Automobile and transportation - Domestic Appliances - Leisure and safety - Packaging
PETG	6,8	80	120-160°C 145°C	1mm	- Medical appliance packaging - Bus shelters - Displays and signs for external use - Food containers - Lenticular lenses

(stretch ratio / thickness drawdown)

Design rules

Starting point: stretch interconnects to overcome local strains.

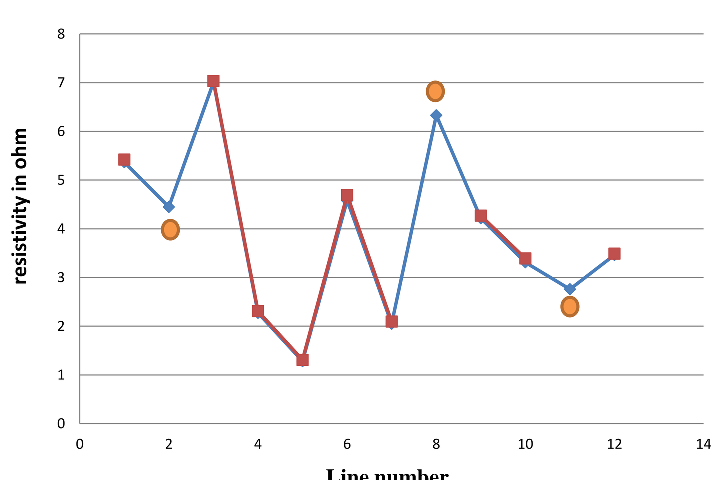
Design 1:A design with 12 meander lines , each consisting of different parameters (**R,W,H**).

Design with parametric meanders

PETG sample with meander interconnects

Resistivity measurement (PETG substrate):

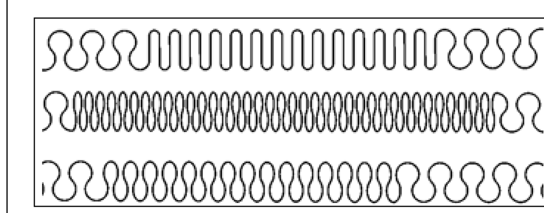


Issues at transition zone :

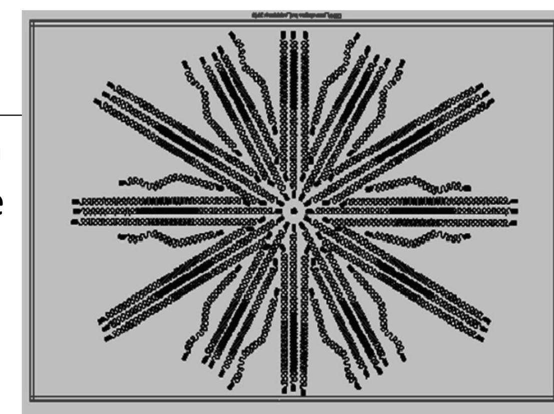
- Breaking of the meander with a large radius R=3 and delamination of the rest of meander tracks (R=1 and 2), this is reduced when H=45,R=1.
- Wider meanders (w=200 micron, 300 micron) showed a lot of buckling starting from 20 % deformation, not the case for 100 micron.
- Same conclusion for PC but the delamination is more severe .

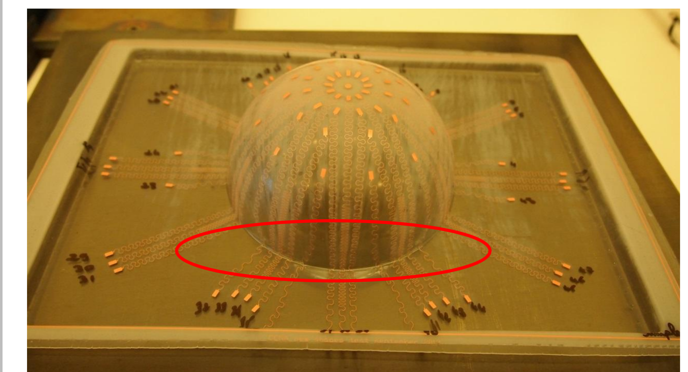
Design 2:

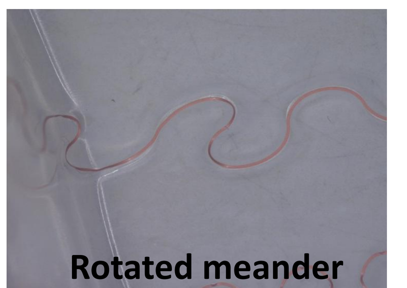
- Width of tracks : 100 micron
- 3 new shapes tested in the transition zone :



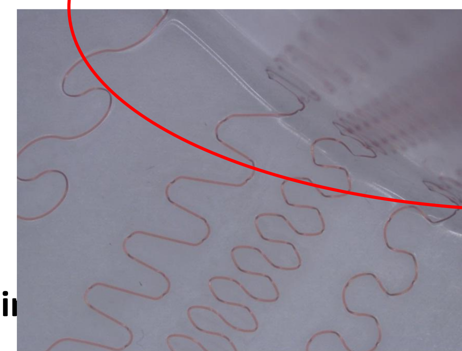
- With a rotated meander.


Design with adjusted meanders

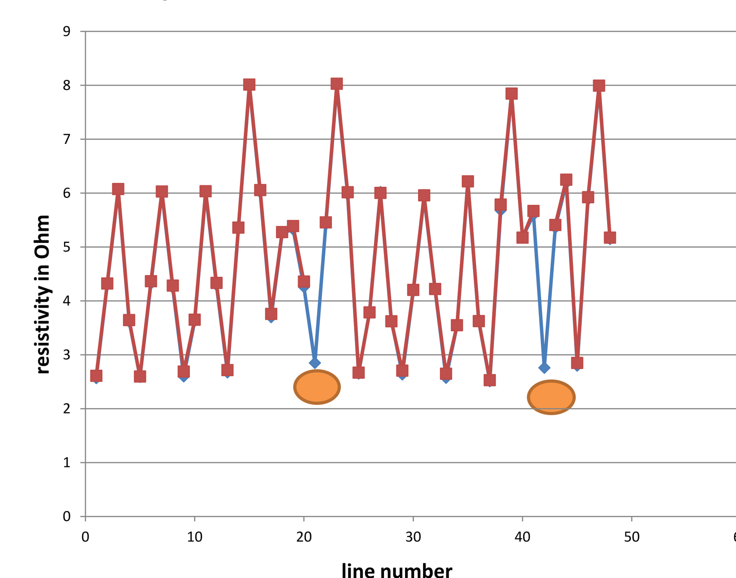

Formed PETG sample


Rotated meander

Before thermoforming


After thermoforming

Resistivity measurement(PETG substrate):



- With the new meander shape design at the transition zone, buckling has been observed and delamination of the rotated meander with breaking in some cases .
- The same issues have been seen for a sample that has been formed from the back side but without breaking of any tracks.
- No significant variation in resistivity in the case of unbroken tracks .
- The same issue for PC .

Conclusion

- **Polycarbonate** is a tough material to be vacuum formed (by literature)while **PETG** is an excellent choice for application that requires deep draw thermoforming (easy formed).
- The mold used has not been adopted for thermoforming , as the radius at the edge is too high compared to what's recommended in practice (radii ≥ 4 minimum thickness formed) [1] .
- The meander design showed its limitation to overcome the local strain 100% in the transition zone with its different parameters (delamination, break),the resistance doesn't make a significant variation in the case of an unbroken track.
- Buckling remains an issue even with a new meander shape design (expected to be more stretchable) at the transition zone however this does not lead to an increase in resistivity.
- Work is ongoing in relation to the components assembly technology (design for contact pads, conductive adhesive…).

[1]:

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