IMPACT-IAAC 2016

TOPIC:
One-Time Deformable Thermoplastic Devices Based on Flexible Circuit Board Technology

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Paper Code: ***EU002-1***
Date: ***Thu, Oct 27, 2016***

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OUTLINE

1	**INTRODUCTION**
2	PROCESS FLOW
3	DEMONSTRATION DEVICES
4	CONCLUSION
5	QUESTION & ANSWER

Introduction

- **Who we are**
  - Research group part of both imec's BAN–group and Ghent University.
  - Located in Ghent, Belgium.
  - Staff of 58 researchers.
- **What we do**
  - Enabling technologies for flexible and stretchable electronics.
  - Polymer photonics.
  - Display technology.
  - Close collaboration with leading industrial partners along the value chain.

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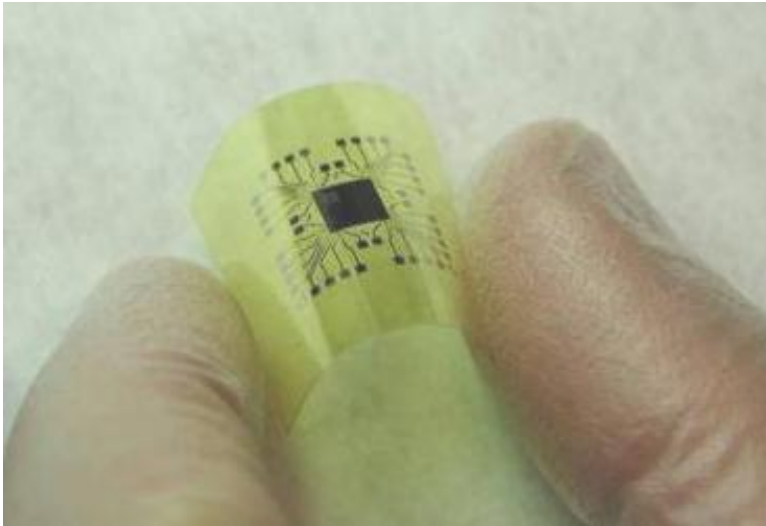
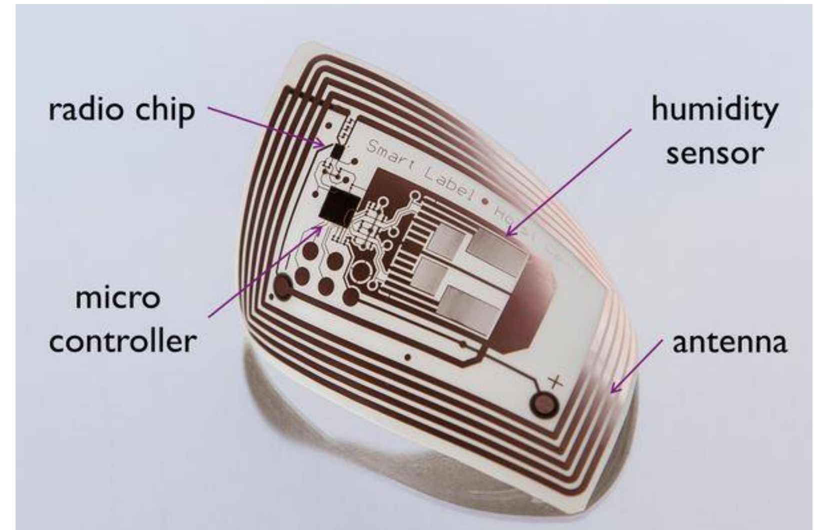
Introduction

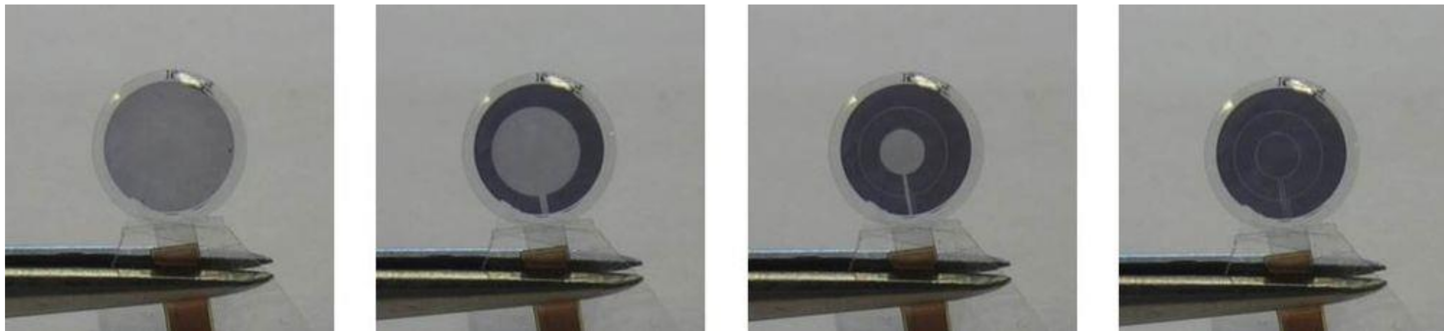
Ultra-Thin Chip Packaging



Smart Wireless Tags

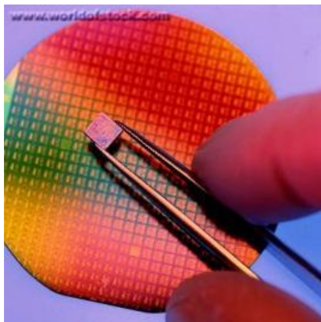


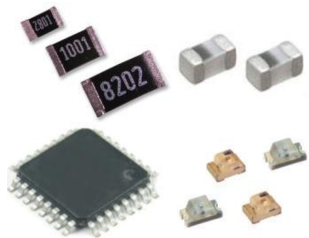
Smart Contact Lens



Introduction

Traditional Electronics: Typically **flat** and **rigid** throughout all steps





Introduction

Flexible Electronics: Lighter, Dynamic Deformability, Compact, …

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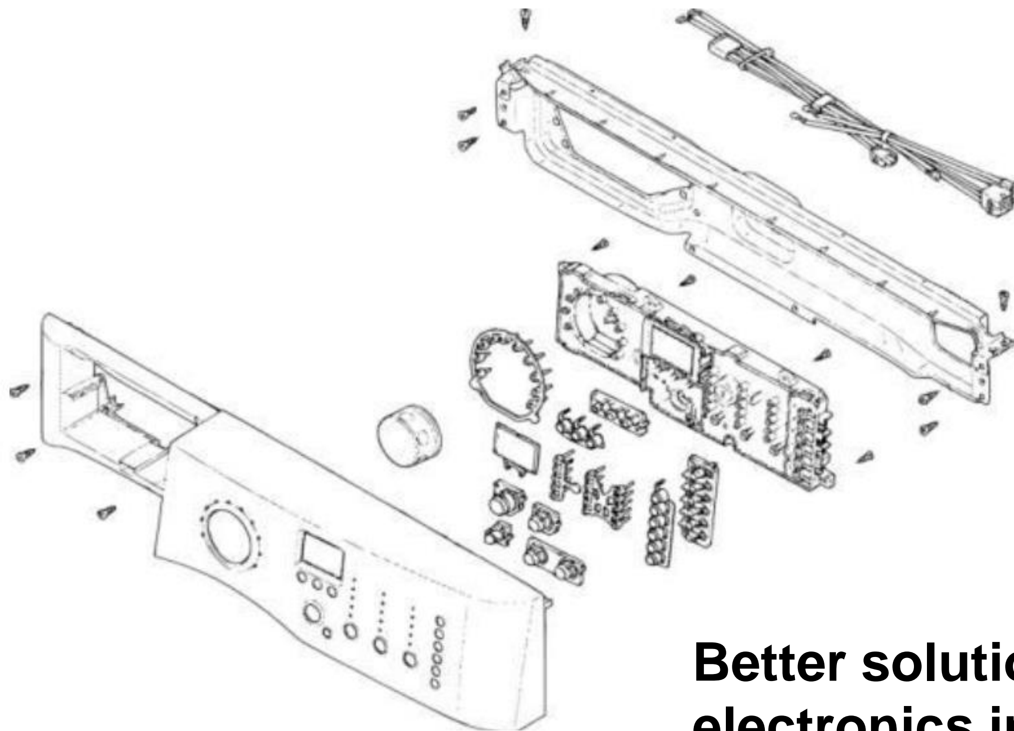
Introduction

Current assembly methods are **complex** and have a **high setup cost**.



Better solutions to free-form electronics integration?

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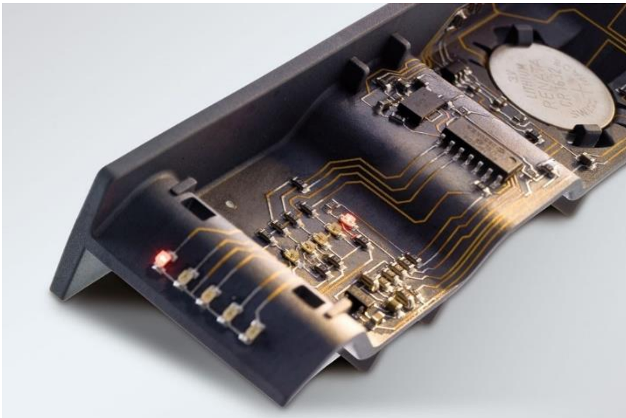
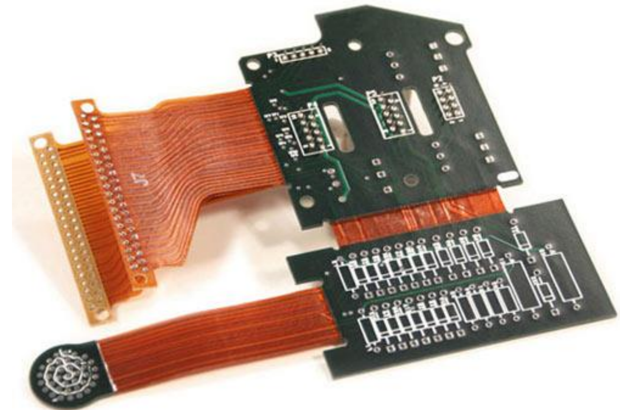
Introduction

3D MID



- Thin copper layers.
- Vendor lock-in.
- 3D assembly.

Flex Rigid



- Increased mounting complexity.
- Multi-layer

Introduction

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Introduction

Requirements

- Standard industrial equipment (avoid vendor lock-in),
- Standard SMT components,
- Lead-free high temperature solder,
- High thermal and electrical conductivity,
- Use unmodified thermoplastic polymers,
- Multi-layer interconnects,
- Free-form 2,5D shapes.

Introduction

- Thermoplastics shrink after high temperature steps.
- Changes in interconnect length during fabrication.
- Most plastics are unable to withstand lead-free high-temperature reflow soldering.

Stretchable Interconnects

- "*Light*" version: No large cycling stresses.
- Rigid thermoplastic encapsulation.
- Deformation using thermoforming

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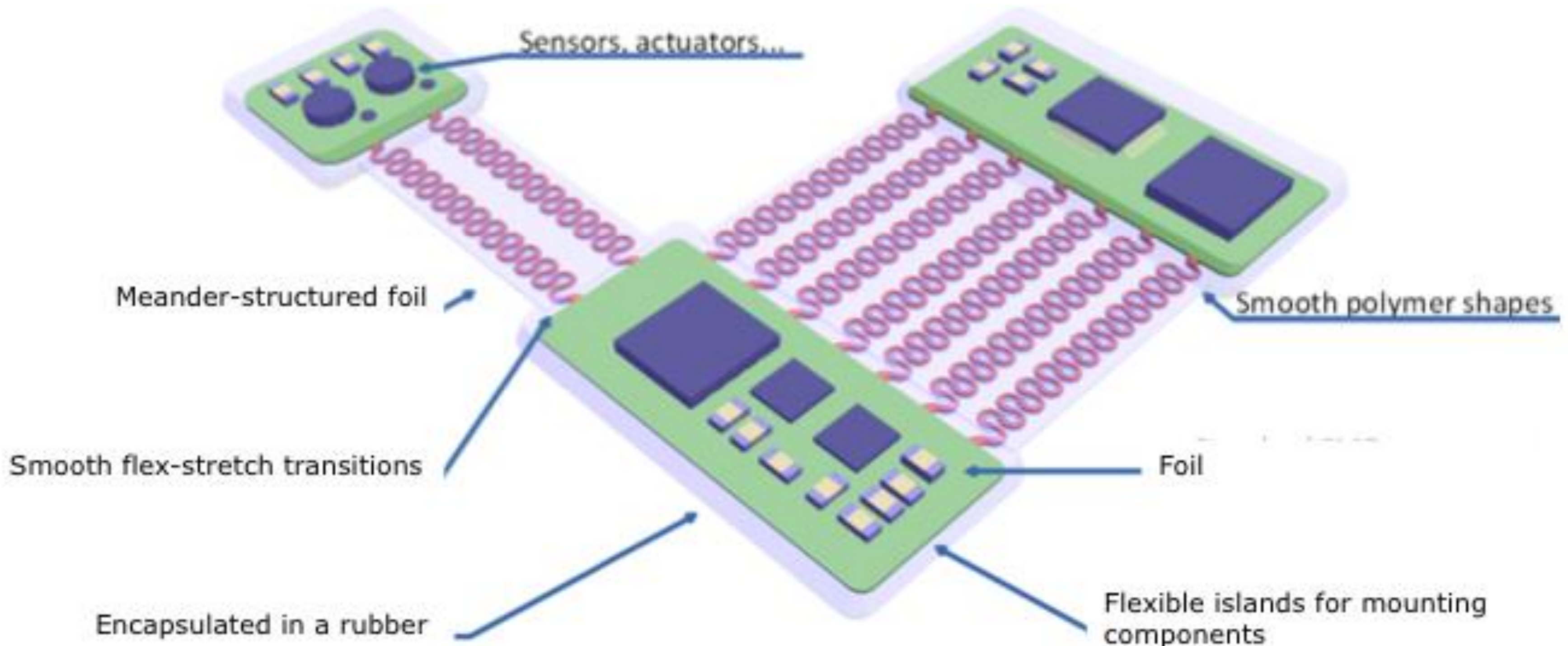
Introduction

Stretchable interconnects approach:

- **Functional islands** with **meander-shaped interconnects**.
- Based on polyimide **flexible circuit technology**.



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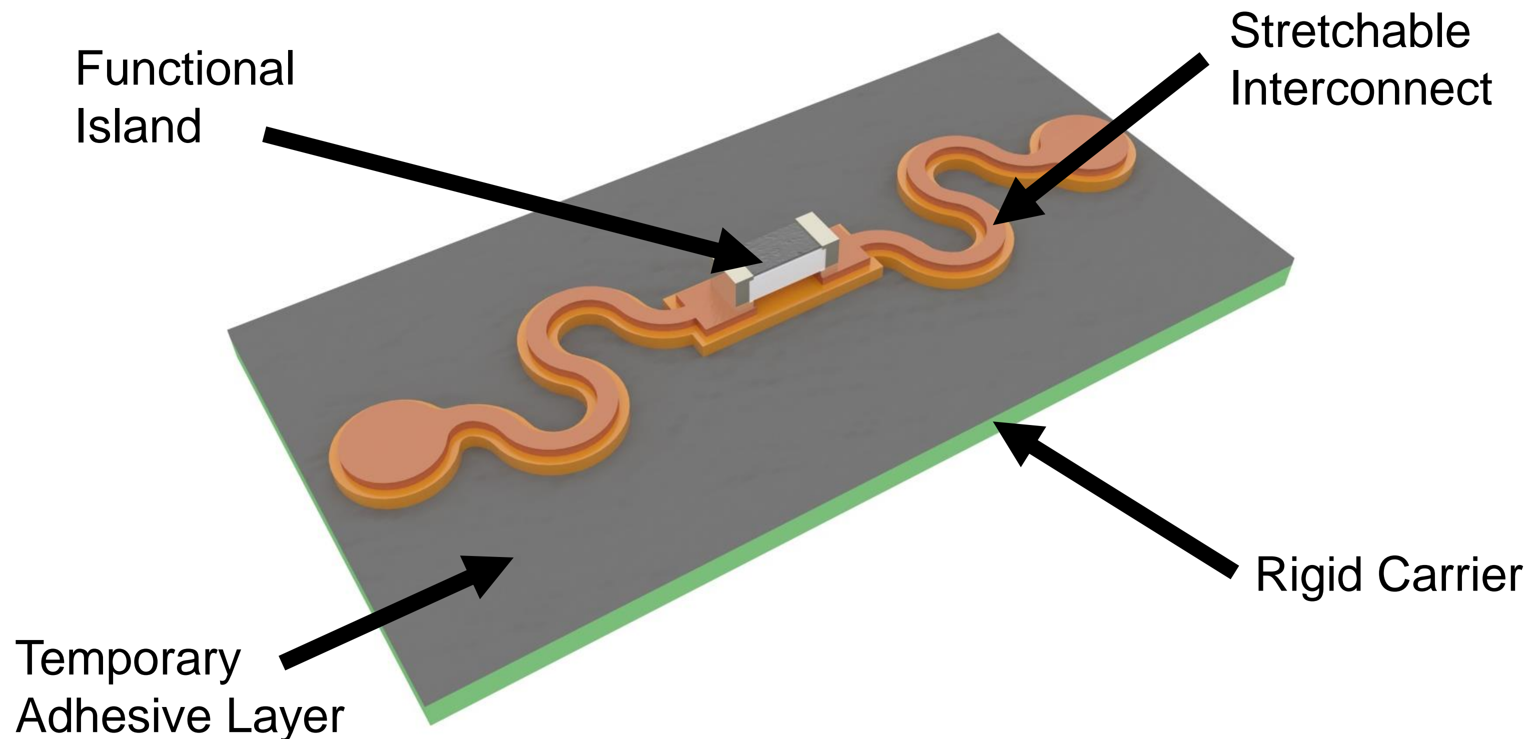
Introduction

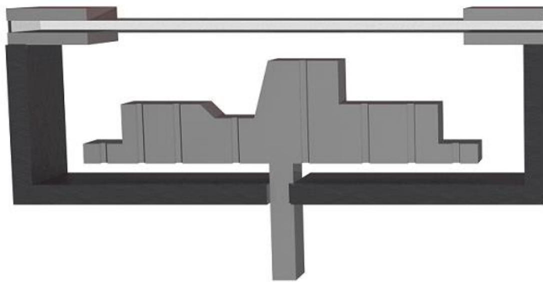
Production on temporary reusable carrier:

- Improve handling and stability,
- Support during harsh PCB processing steps.

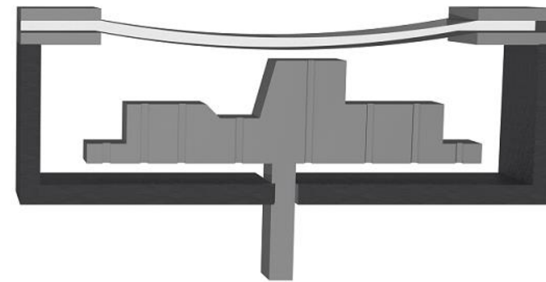


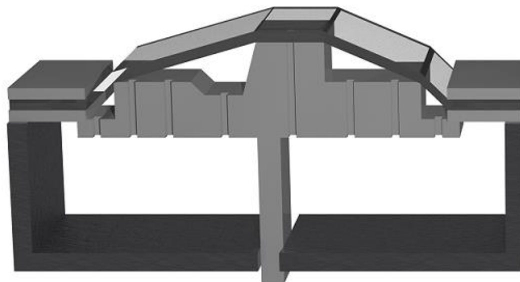
Introduction

1. Heat plastic foil past its glass transition temperature.

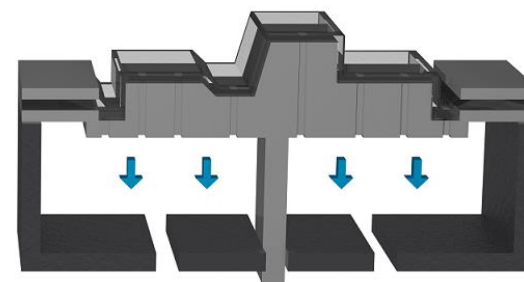


2. Remove heater and let plastic sheet sag.





3. Push forming tool up against the plastic foil.



4. Draw film against tool using a vacuum and cool down foil.

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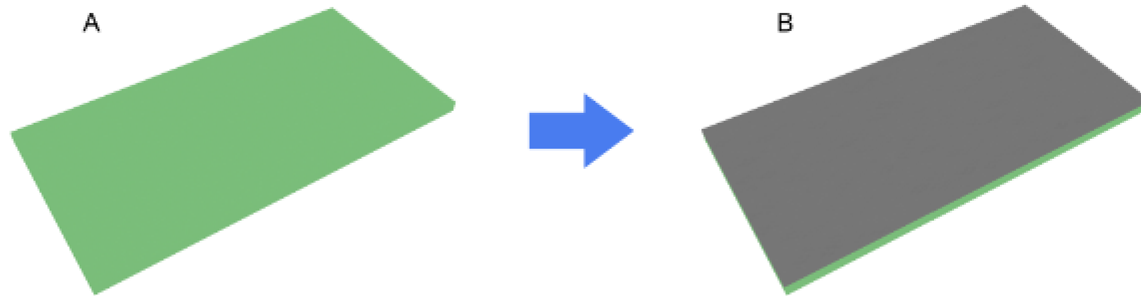
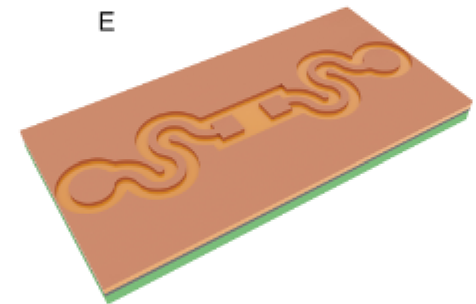
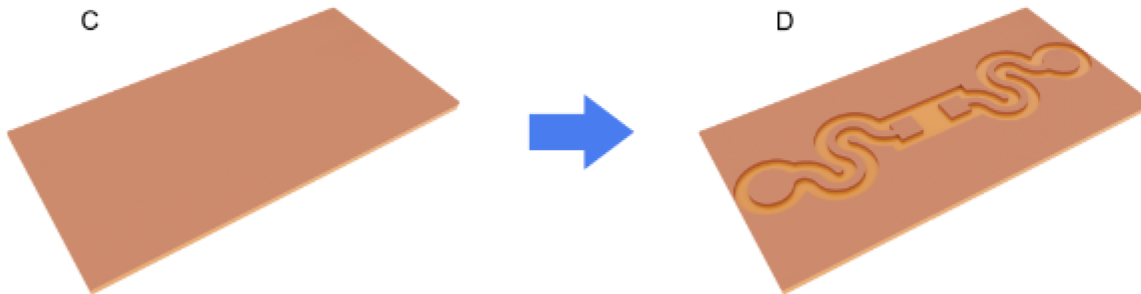
Process Flow

Carrier Board Preparation



FCB Application





Flexible Circuit Board Production

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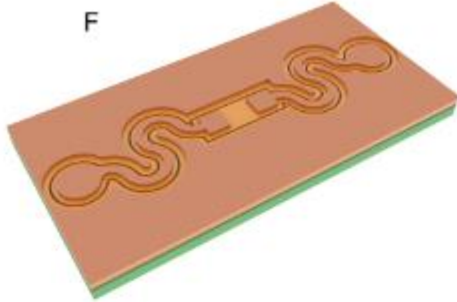
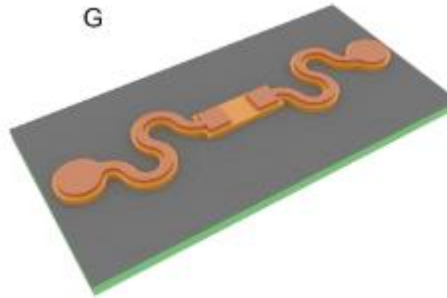
Process Flow

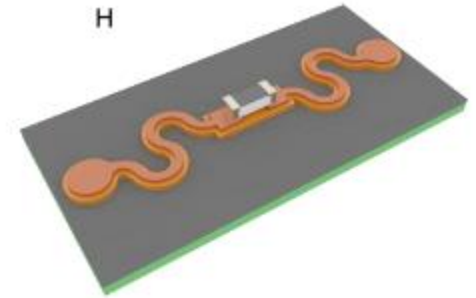
Island & Meander Structuring

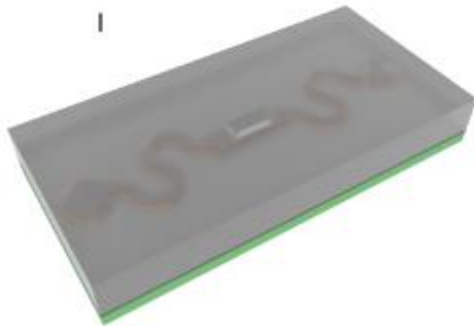


Residue Removal

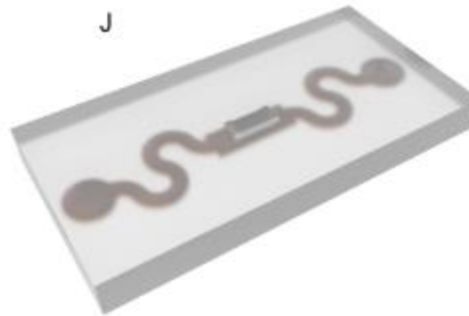


Component Assembly

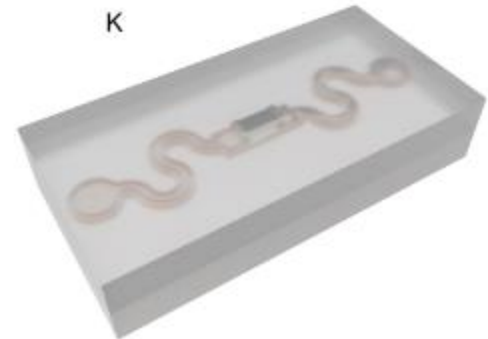




Topside Lamination



Carrier Board Release



Backside Lamination

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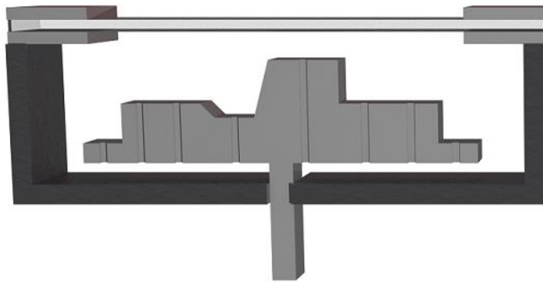
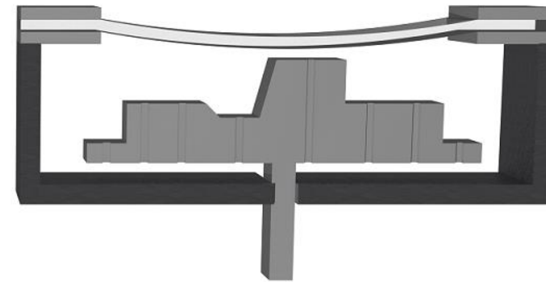
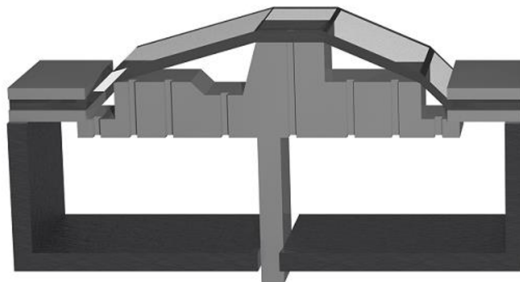
Process Flow

Heat plastic foil past its glass transition temperature.

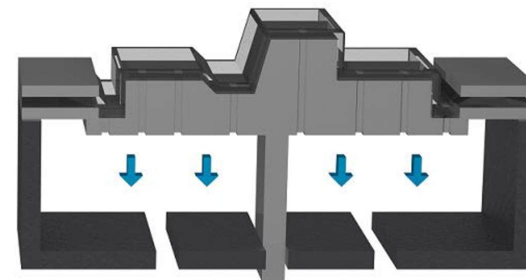


Remove heater and let plastic sheet sag.





Push forming tool up against the plastic foil.

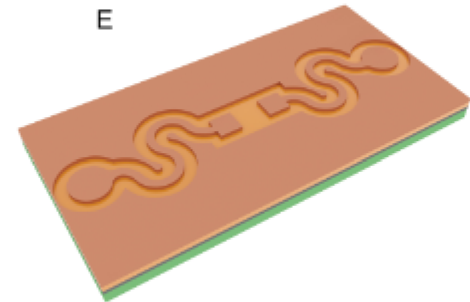


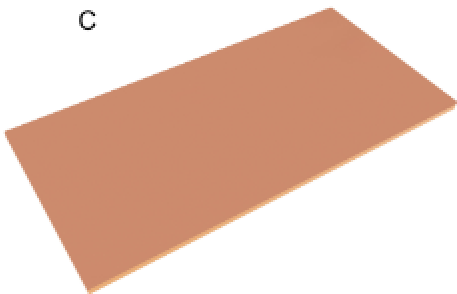
Draw film against tool using a vacuum and cool down foil.

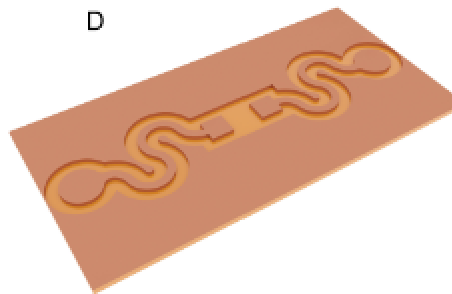
Process Flow

- Multiple flex substrates tested.
- Standard PCB processing.
- Panelization is possible.
- Any standard flex feature can be integrated.
- Cheaply available in high volume.

FCB Application







Flexible Circuit Board Production

Process Flow

Flexible Circuit Production

- Starting from conventional FCCL.
  (e.g. Copper on polyimide, PET, PEN, …)
- Standard production flow.
- Support for all standard FCB features:
  - Multi-layer
  - Fine-pitch interconnect (< 100 µm track/gap)
  - High power applications
    (Copper thickness up to 70 µm tested)
  - …
- Dimensional stability is important!

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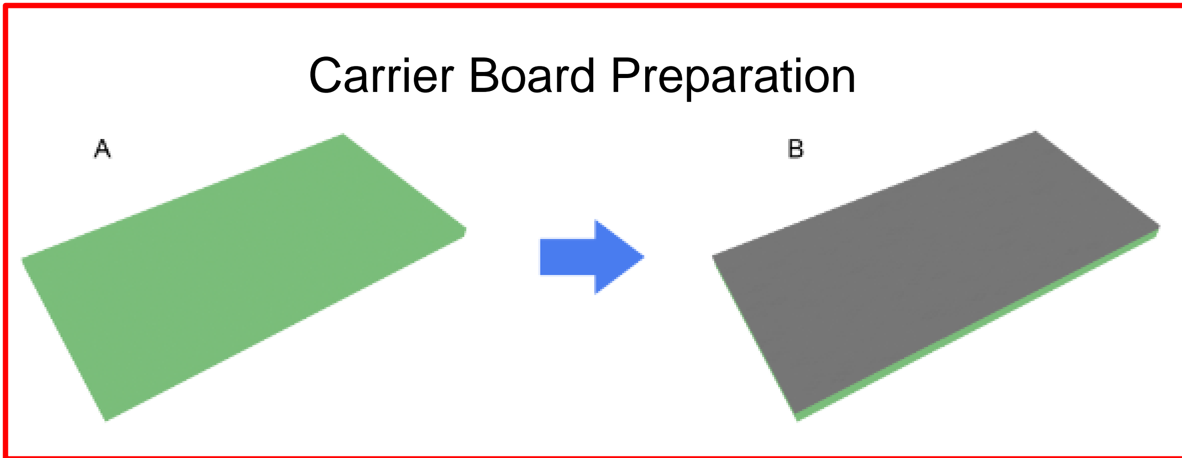
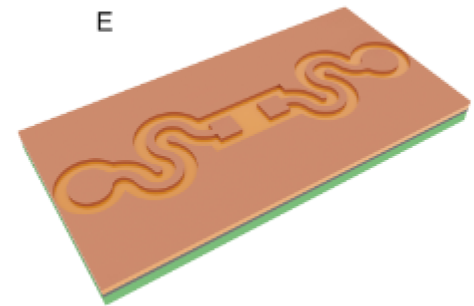
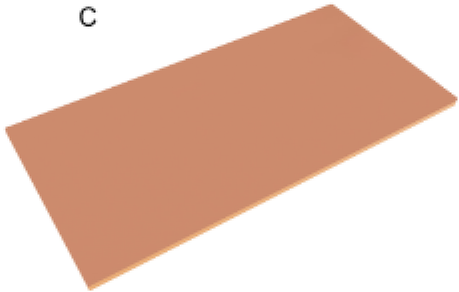
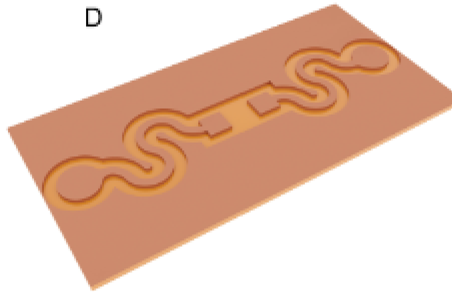
Process Flow



FCB Application





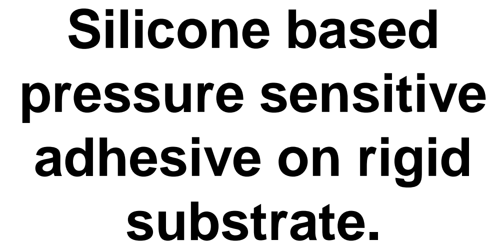


Flexible Circuit Board Production

Process Flow

Carrier Board Production

- Requirements:
  - High dimensional stability,
  - High temperature stability (> 250 °C),
  - Pressure sensitive tacky surface,
  - Reusable,
  - Good chemical resistance.



- Adhesive: *Taconic FH20LB Tacsil Tape*
  - Carrier tape for FCB assembly,
  - Maximum operational temperature: 250 °C,
  - Glass fiber mesh coated with PTFE ensures stability,
  - Available on roll.

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Process Flow

Carrier Board Production

- FR-4 as rigid substrate:
  - Easily available for most PCB manufacturers,
  - Board can be re-used after carrier tape removal.
  - Could be replaced by metal plates if desired.
- Preparation of carrier board:
  - Roll lamination of FH20LB on FR-4 at 180°C,
  - Vacuum press cycle to remove entrapped air,
  - Pre-bake boards using desired solder profile.

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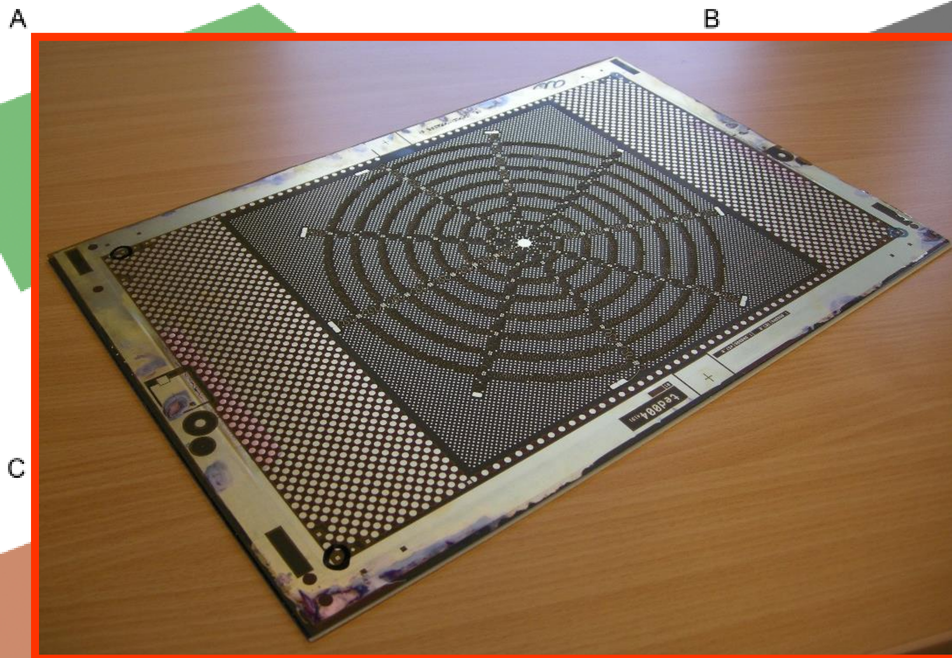
Process Flow

Carrier Board Preparation

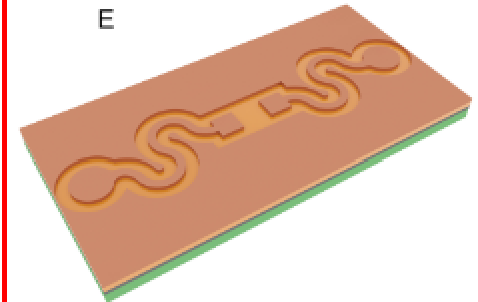
A

B



FCB Application

E



C

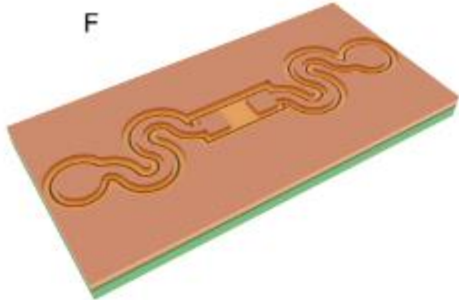
Flexible Circuit Board Production

Process Flow
FCB Application

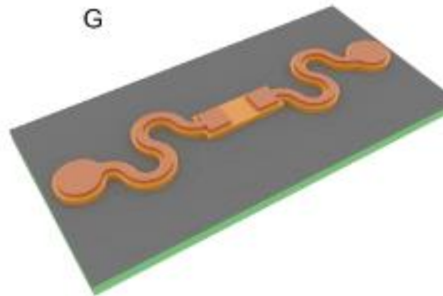
- Placed on carrier board using roll lamination:
  - Avoids stretching FCB material,
  - Reduces risk for trapped air.
- Advantages:
  - Easier to handle during assembly,
  - Increased dimensional stability,
  - Production lines which are unable to handle loose flex can be used,
  - Cheaper than custom fixtures for low volume.

Process Flow

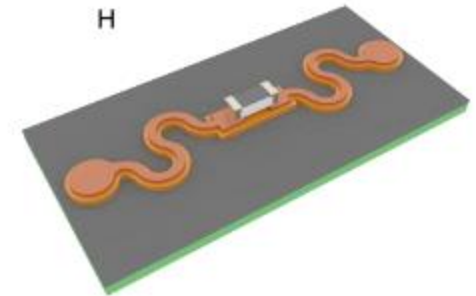
Island & Meander Structuring



Residue Removal



Component Assembly



- Cut flexible circuit board without damaging the carrier.
- Laser routing system for low and medium volume.
- Punching for high volume applications.
- This step determines minimum meander parameters.

Topside Lamination

Carrier Board Release

Backside Lamination

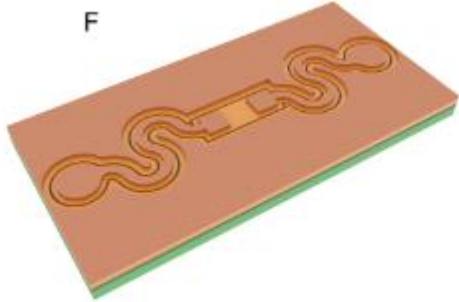
Process Flow

Island & Meander Structuring

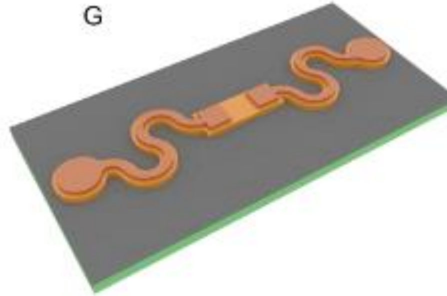
- Definition of outline of meanders and islands:
  - Cut through polyimide layer without damage to the carrier board.
  - Precise alignment vs. Cu layer necessary.
- Laser cutting:
  - Available at most board houses.
  - Optical alignment with etched fiducials.
  - Possible to scale to high volume.
  - IPA rinse after cutting to remove debris.

Process Flow

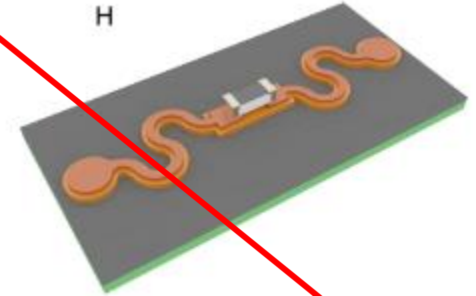
Island & Meander Structuring

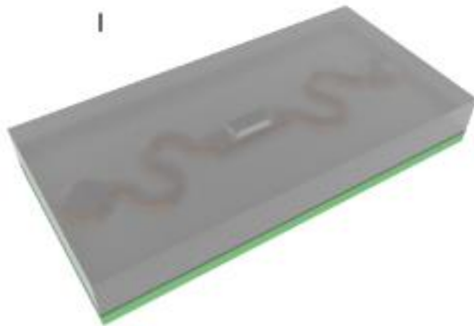


Residue Removal

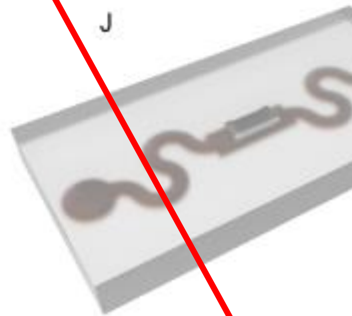


Component Assembly

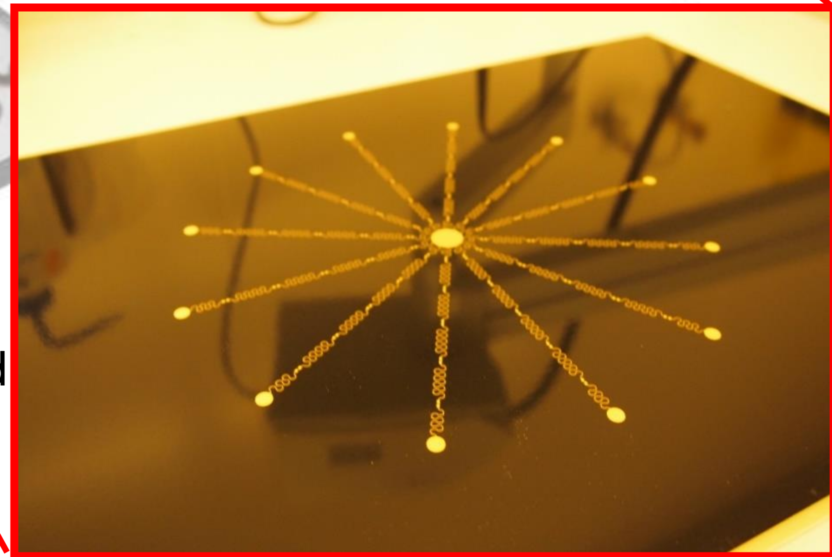




Topside Lamination



Carrier Board Release



Process Flow
Residue Removal

- Removal of residual FCB material.
- Peeled away from carrier.
- Effort is heavily design dependant!
- Open for automation for higher volumes.
- Not necessary in case of carrier-less design.

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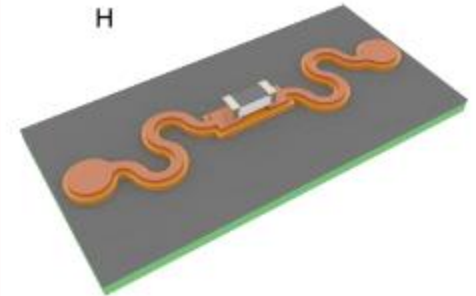
Process Flow

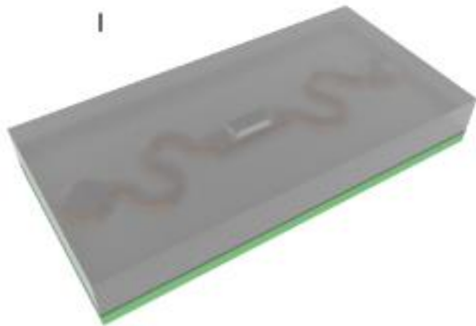
- Standard flat assembly process.
- High temperature lead-free solder (SAC305).
- Any standard SMT component works.
- Preference for hot air tunnel oven.

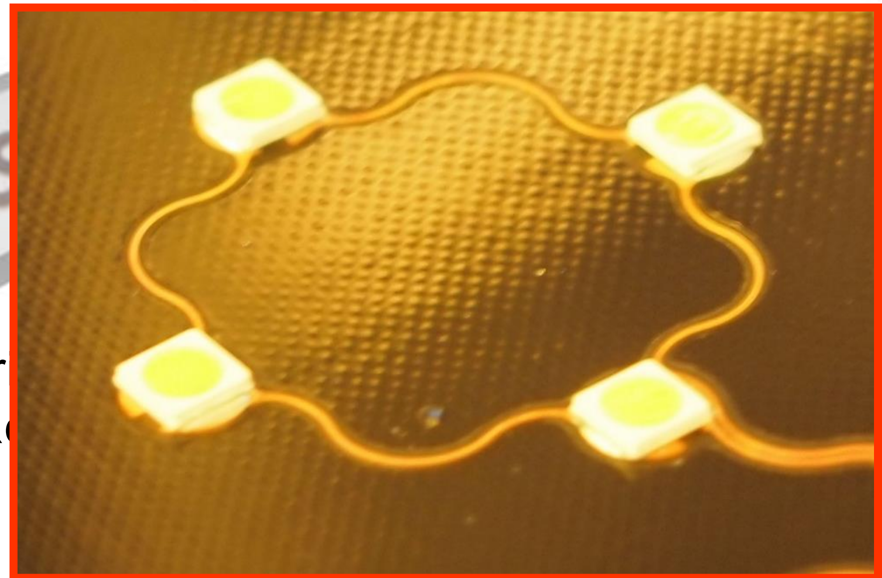
Island & Meander Structuring

Residue Removal

Component Assembly







Topside Lamination

Carr
R

Process Flow

Component Assembly

- Conventional assembly method:
  - Stencil print solder paste,
  - Pick-and-place component placement,
  - Reflow soldering
  - Inspection/Testing
- Compatible with SAC305 if FCB material is.
- Double sided assembly possible:
  - Custom tooling of carrier boards required,
  - Necessary for very few applications.

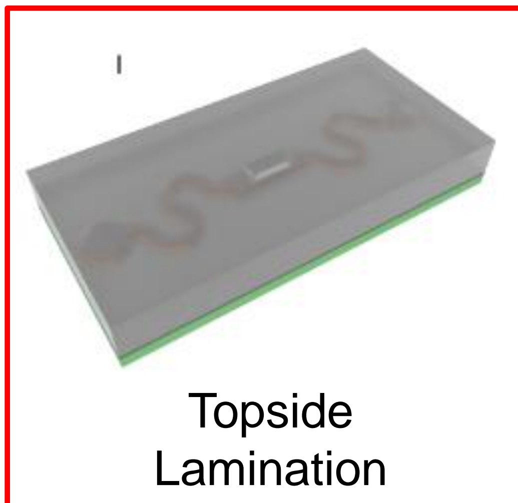
Process Flow

Island & Meander Structuring

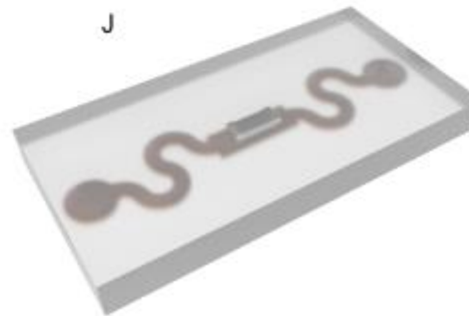
Residue Removal

Component Assembly

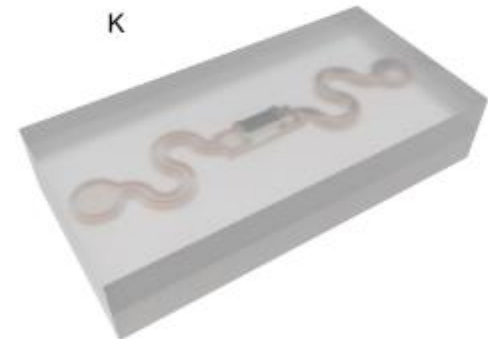
- Standard industrial vacuum press.
- Press book modified to protect components.
- Encapsulation in thermoplastic elastomers (TPEs).
- Mechanical properties provided by other thermoplastics.



Topside Lamination



Carrier Board Release



Backside Lamination

Process Flow

Topside Lamination

- Vacuum press is available at every board house:
  - Encapsulation using vacuum lamination.
  - Low-cost compared to custom injection moulding approaches.
  - Long cycle times but large quantity of devices per cycle.
- Thermoplastic elastomers as encapsulating material:
  - Large variety of materials available. (e.g. TPU, EVA, …)
  - Good adhesion to most FCCL base materials.
  - Adhesion to copper is limited! (Use soldermask or coverlay.)
  - Incredibly cheap.

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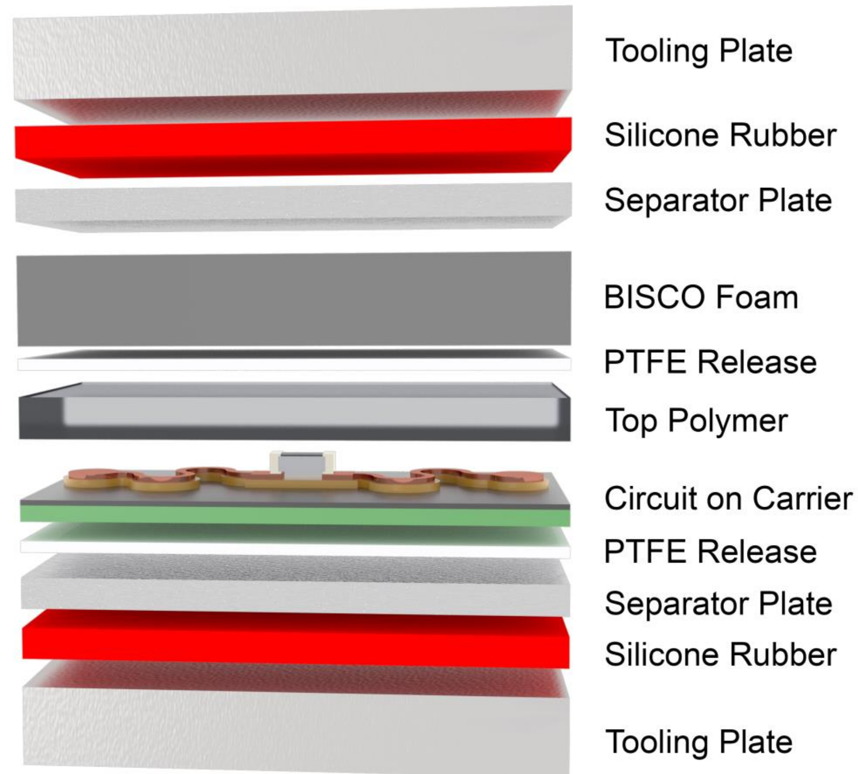
Process Flow
Topside Lamination

- Components are fragile:
  - Components are the highest feature on the substrate.
  - Modern low profile packages are sensitive to pressure.
- Modified press book to distribute pressure equally:
  - Silicone foam rubber press pad (Rogers BISCO Foam HT-870),
    - Able to conform to high aspect ratio features,
    - Stable up to 200 °C.
  - Press pad thickness is a critical factor,
  - Relatively high lamination temperature (180 °C) ensures high flow of thermoplastic material around components.

Process Flow

Topside Lamination



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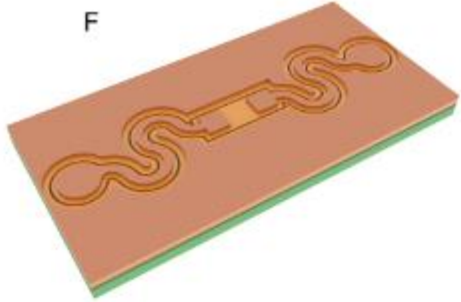
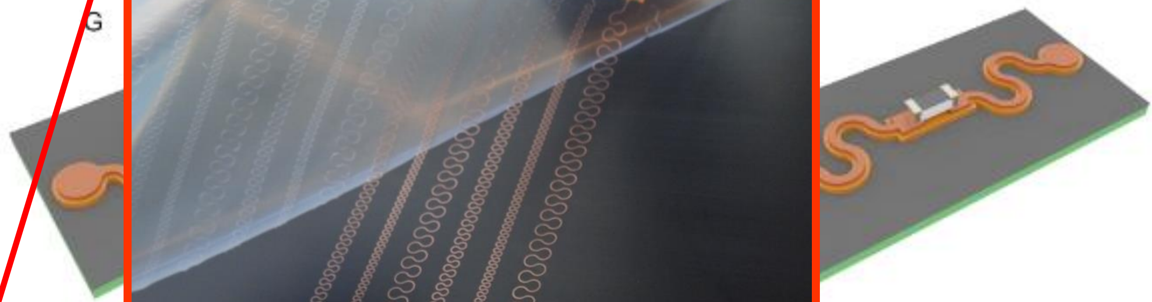
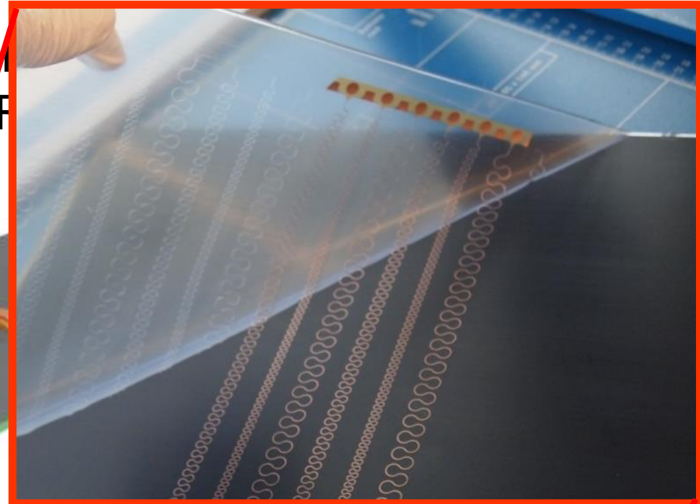
Process Flow

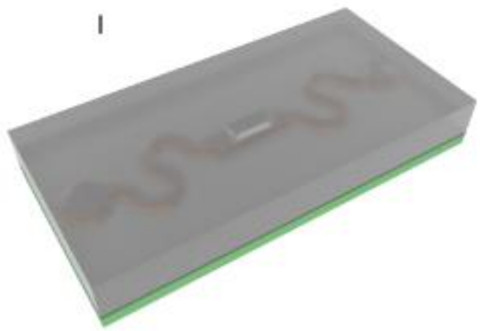
Island & Meander Structuring



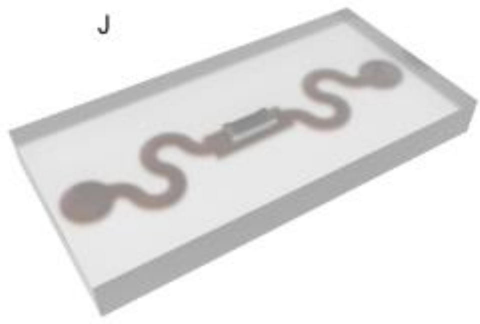




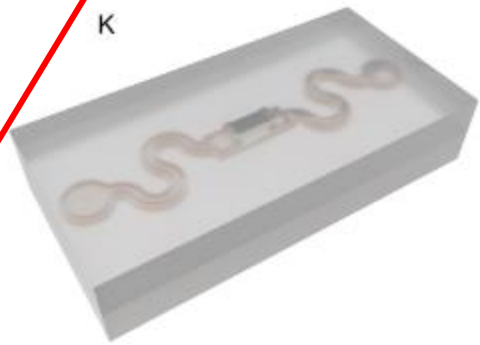
omponent
ssembly



Topside Lamination



Carrier Board Release



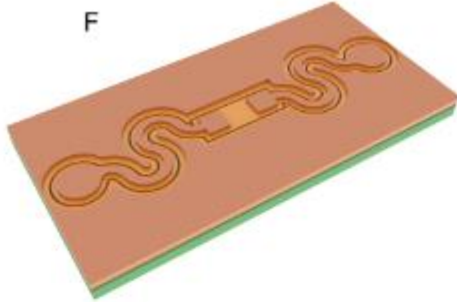
Backside Lamination

Process Flow
Carrier Release

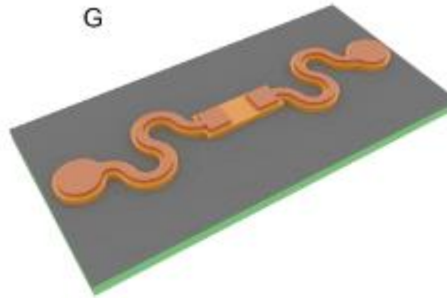
- Release conditions:
  - Adhesion between the elastomer and circuit
    > Adhesion between circuit and carrier.
  - Thermoplastic elastomers have bad adhesion to silicone PSAs. (True for most commercially available TPUs and EVAs.)
- Carrier board peeled away mechanically.
- Correct choice of laminate cause automatic delamination of the carrier due to CTE mismatch.
- Elastomer thickness should exceed circuit thickness!

Process Flow

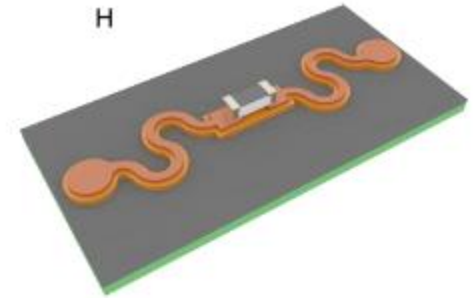
Island & Meander Structuring

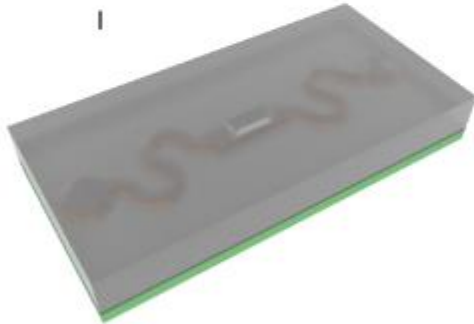


Residue Removal

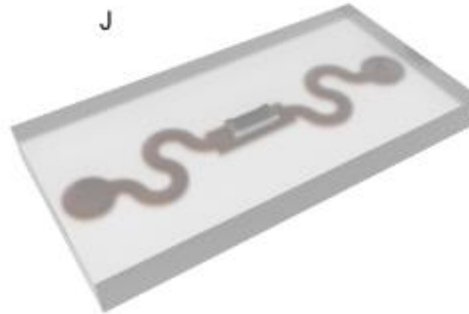


Component Assembly

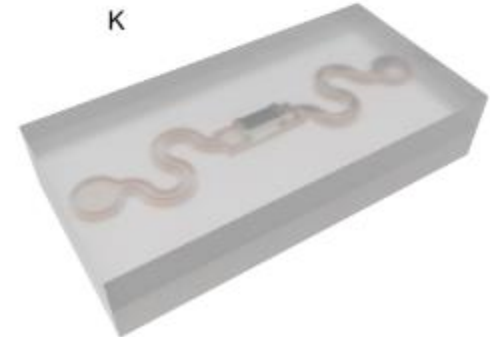




Topside Lamination



Carrier Board Release



Backside Lamination

Process Flow
Backside Lamination

- Symmetric laminates are preferred.
- Limiting material flow is crucial.
  - Reduces repeatability,
  - Causes shift in component locations,
  - Increases trim edges leading to material waste.
- Typically at lower temperature and pressure.
- Custom tooling required at this point for double-sided assembled boards to prevent shearing.
- Press book quasi identical to topside lamination.

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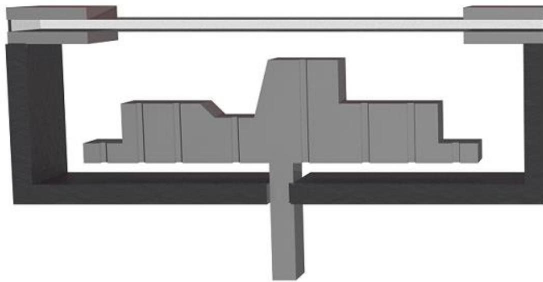
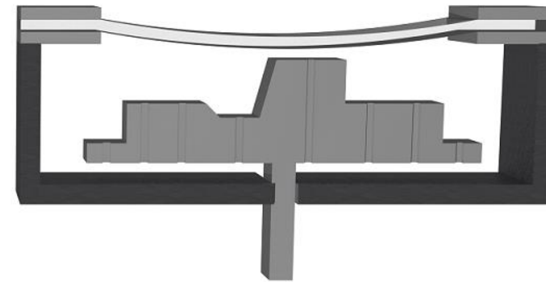
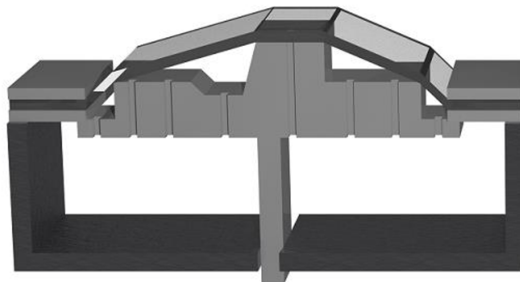
Process Flow

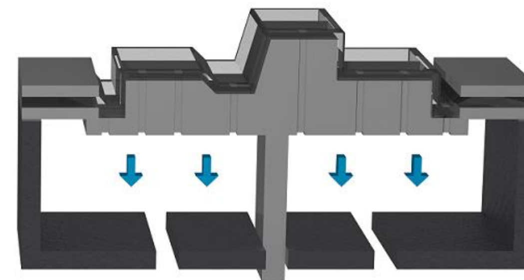
Heat plastic foil past its glass transition temperature.

Remove heater and let plastic sheet sag.









Push forming tool up against the plastic foil.

Draw film against tool using a vacuum and cool down foil.

Process Flow

Forming Process

- Vacuum forming used at lab scale.
- Other methods tested industrially.
- Process temperature window: 120 – 220°C
  - Exact value depends on material glass transition temperature, mould shape, and other factors.
  - SAC305 (high temperature lead-free) solder has an advantage compared to lower temperature alloys!
  - Lower temperatures in case of high pressure forming.

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OUTLINE

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2	PROCESS FLOW
3	DEMONSTRATION DEVICES
4	CONCLUSION
5	QUESTION & ANSWER

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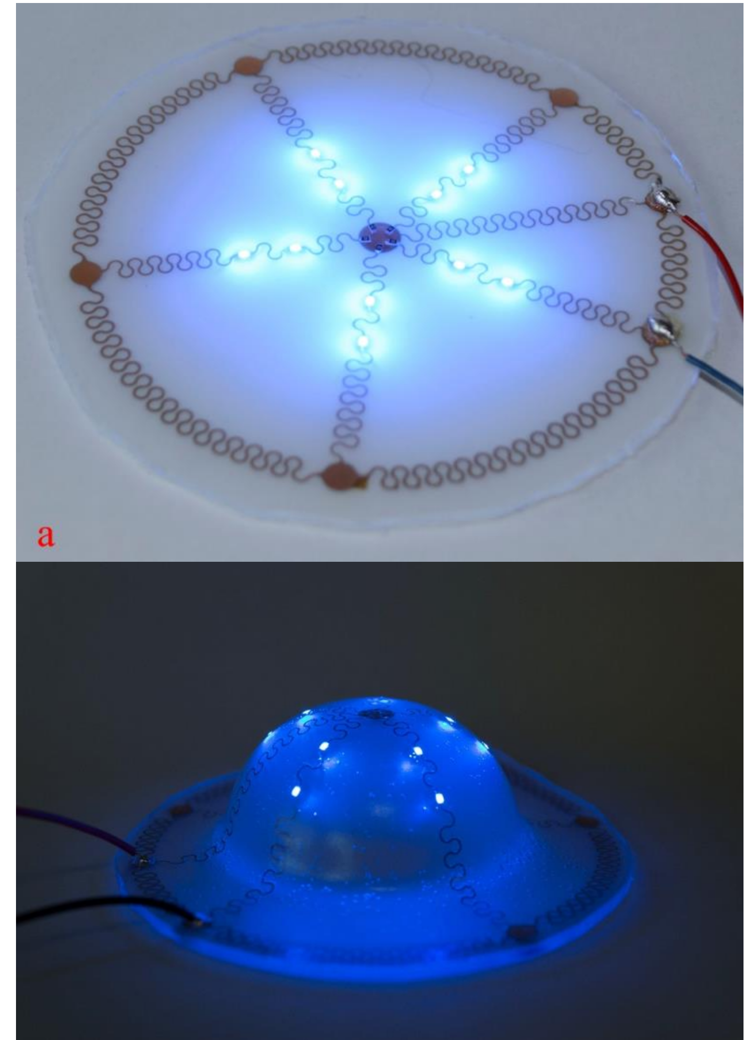
Demonstration Devices
Miniature LED Dome

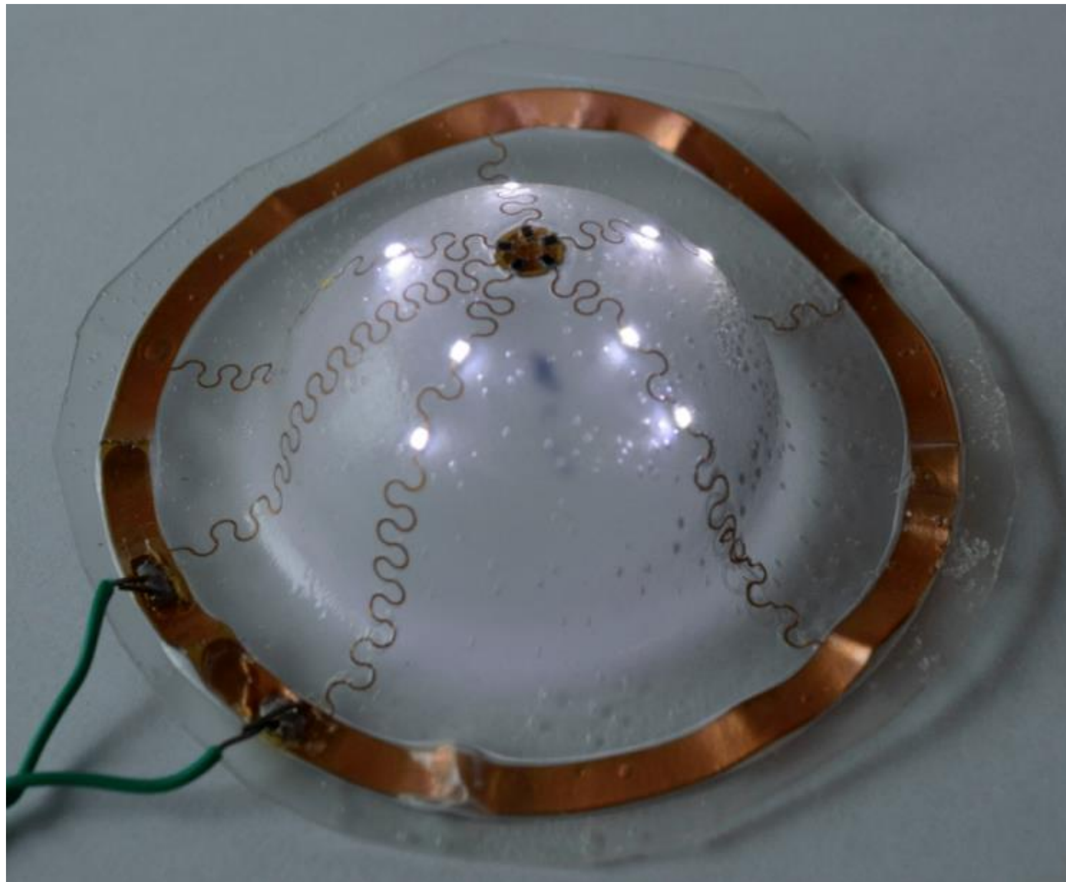
- Ten 0603 SMD LEDs
- In-series 0603 resistor.
- External 9V PP3 battery.
- Laminate:
  - Lexan 9300 – 500 µm
  - Krystalflex PE 429 – 500 µm
  - Circuit
  - Krystalflex PE 429 – 500 µm
  - Lexan 9300 – 500 µm
- UBE UPISEL SR-1220 FCCL



Demonstration Devices

Miniature LED Dome

Importance of stretchable interconnects.



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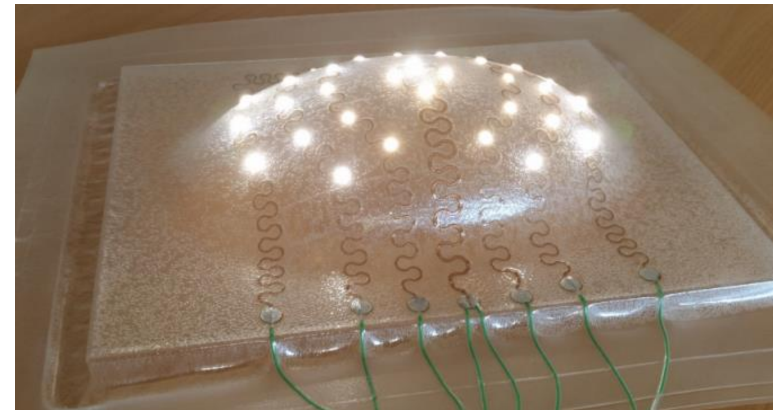
Demonstration Devices
Ghent Light Festival

- 35 Osram DURIS S5 3500K LEDs
- Drive current: 20 – 50 mA
- Laminate:
  - Vikureen polystyrene – 1 mm
  - Krystalflex PE 429 – 500 µm
  - Circuit
  - Krystalflex PE 429 – 500 µm
  - Vikureen polystyrene – 1 mm
- UBE UPISEL SR-1220 FCCL
- Made using other material combinations as well.



Demonstration Devices

Ghent Light Festival

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Demonstration Devices

Ghent Light Festival

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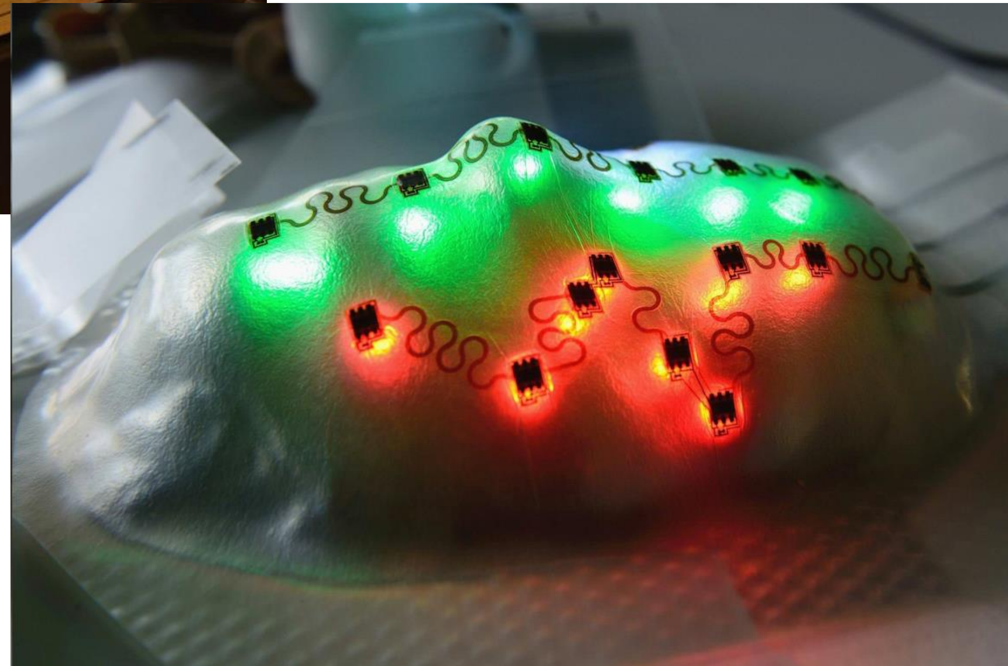
Demonstration Devices
Mask Demonstrator

- Concept by Belgian fashion designer Jasna Rok.
- 22 World Semi WS2812B LEDs in 3 chains.
- Laminate:
  - Lexan 9030 – 250 µm
  - Platilon U4201 AU – 100 µm
  - Circuit
  - Platilon U4201 AU – 100 µm
  - Lexan 9030 – 250 µm
- Shengyi SF305 FCCL

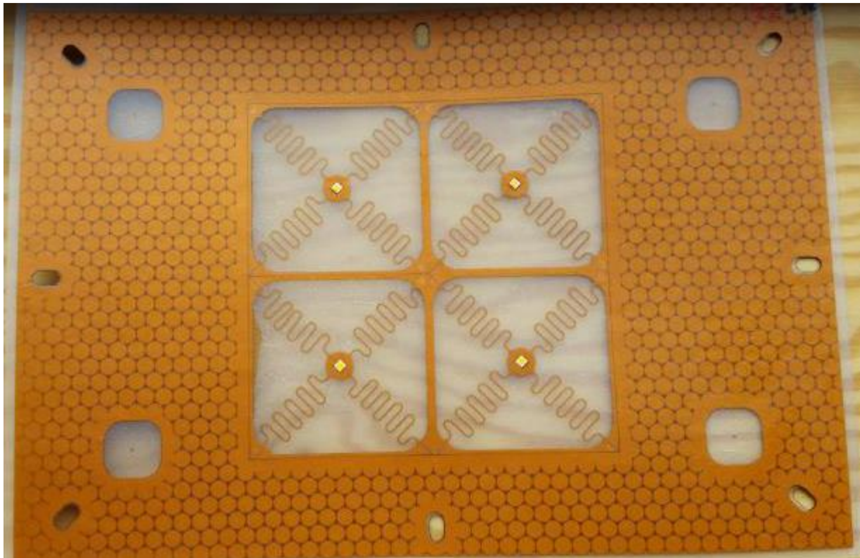
Demonstration Devices

Mask Demonstrator



Demonstration Devices
TERASEL Philips Power Balance

- Executed within frame of the TERASEL project.
- 4 Luxeon 3030 LEDs.
- Shengyi SF305 FCCL



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Demonstration Devices
TERASEL Philips Power Balance

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Conclusion

- Method to fabricate free-form 2.5D smart objects,
- Integration into thermoplastics laminates,
- Need for stretchable interconnects,
- Allows for late stage configuration,
- Based on flexible circuit board technology,
- Using standard industrial equipment,
- Standard SMT components,
- Lead-free high temperature solder,
- Supports multi-layer interconnects.

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The authors wish to thank Rogers Corporation, and Bayer Material Sciences for providing sample materials in the early stages of this research project.

Part of this research was funded by funded by the European Commission's Seventh Framework Programme (FP7 Contract Nr. 611439 - TERASEL).

Q & A

Download slides:

http://users.elis.ugent.be/~bgplovie/IMPACT2016.pdf

The End
Thank you for your listening!

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