

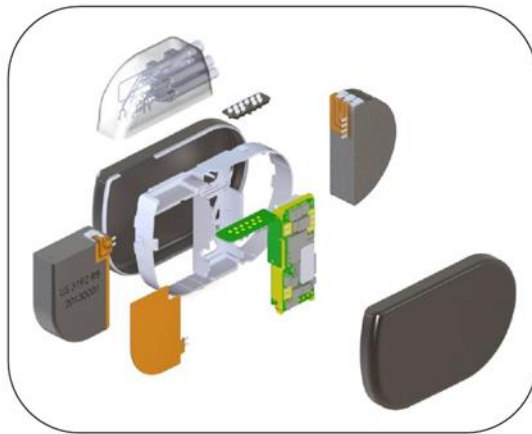
# Sensor Technology Integration and Hermetic Module Fabrication Using Liquid Crystal Polymer

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1. Motivation
2. Liquid Crystal Polymer (LCP)  
- a Thermoplastic Material for Flexible,  
Multi-Layer Laminated Substrates
3. Encapsulation of Components in LCP  
Substrates
4. Test Results from Temperature Accelerated  
Soak Testing of Embedded Silicon Dies

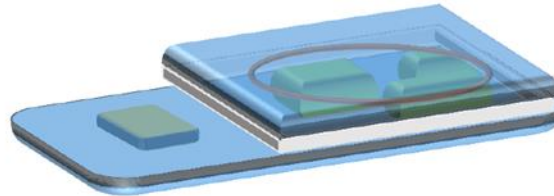


# MOTIVATION



**Today**

**Vision:  
Full Organic Module**

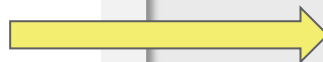


**With substantially  
reduced size and  
application  
appropriate form  
factor**

# LIQUID CRYSTAL POLYMER (LCP)

## MATERIAL PROPERTIES

- Flexible thermoplastic base material
- **Chemically Inert** under most conditions
- Temperature stable up to 190°C (T<sub>g</sub> > 280°C, T<sub>d</sub> > 320°C)
- **Very low water absorption** (0.04 %) & diffusion rates
- Low weight (1.4 g/cm<sup>3</sup>)
- Excellent high frequency properties (ε<sub>R</sub> = 2.9, tan θ = 0.0025)
- For multilayer, lamination forms one homogeneous dielectric material



### BUILD-UP WITH ADHESIVE



Pi
Adhesive
Pi

No homogenous material > adhesive is needed

### ADHESIVE FREE

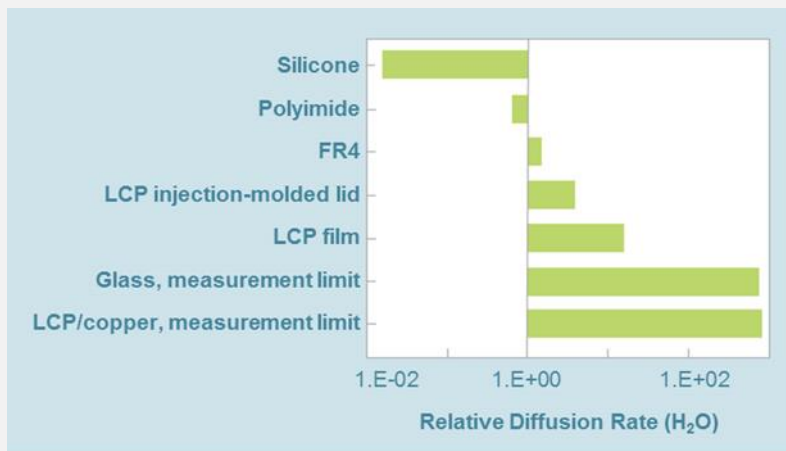


**Only LCP**

Only one homogenous LCP thermoplastic material

# LCP NEAR-HERMETIC & BIOCOMPATIBLE

## MOISTURE DIFFUSION



Source: <http://electroiq.com/blog/2006/10/lcp-pcb-based-packaging/>

Test	Test Duration	No Animals	Result
USP Systemic Toxicity in the Mouse of Saline Extracts	4, 24, 48 an 72 Hours	10	Pass
USP Systemic Toxicity in the Mouse of Cottonseed Oil Extracts	4, 24, 48 an 72 Hours	10	Pass
USP Intracutaneous Toxicity in the Rabbit of Saline Extracts	4, 24, 48 an 72 Hours	2	Pass
USP Intracutaneous Toxicity in the Rabbit of Cottonseed Extracts	4, 24, 48 an 72 Hours	2	Pass

Test	Test Duration	No. Animals	Result
USP Elution Cytotoxicity Study	48 Hours	N/A (L-929 mouse fibroblast cells)	Pass
ISO Muscle Implantation in the Rabbit with Hispathology	12 Weeks	3	Pass
ISO Muscle Implantation in the Rabbit with Hispathology	26 Weeks	4	Pass

Source:  
LCP Printed Circuits Board Based Packaging and Microfabrication for Implantable Electronic Devices,  
Linus Jauniskis, Foster Miller Inc, Meptec 2008

## PVD PROCESS FOR FLEXIBLE SUBSTRATES

- PVD process allows use almost any metal and inorganic dielectrics and a few semiconductors
- Large format: 36x36 inch
- High throughput: 10'000 Panels per year
- Up to four different materials can be sputtered in the same run
- Substrate materials include polyimide and LCP flexible substrate
- Double sided sputtering possible
- PVD process fully integrated into flexible substrate process – can be combined with standard copper structures on same surface

### LARGE FORMAT PVD EQUIPMENT

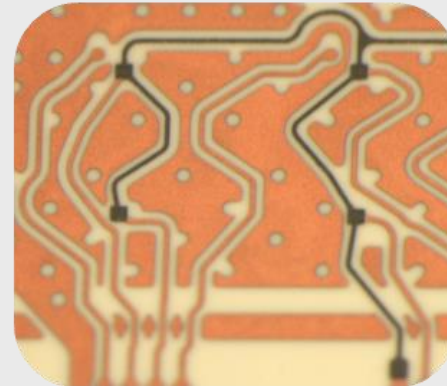
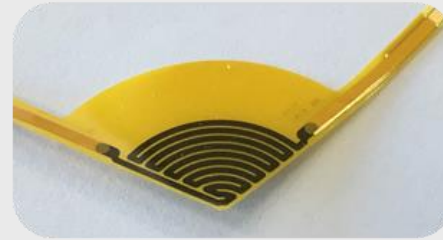




# THIN FILM SENSORS

## INTEGRAL SENSORS

- LCP with non Cu conductors
  - Noble Metal conductors
    - Au, Pt for inert electrodes
    - Pt-Ir fractal surface for low impedance
  - Constantan
    - Thermocouples
    - Temperature invariant Resistors
  - Titanium
    - Thermistors



## 3D SHAPING

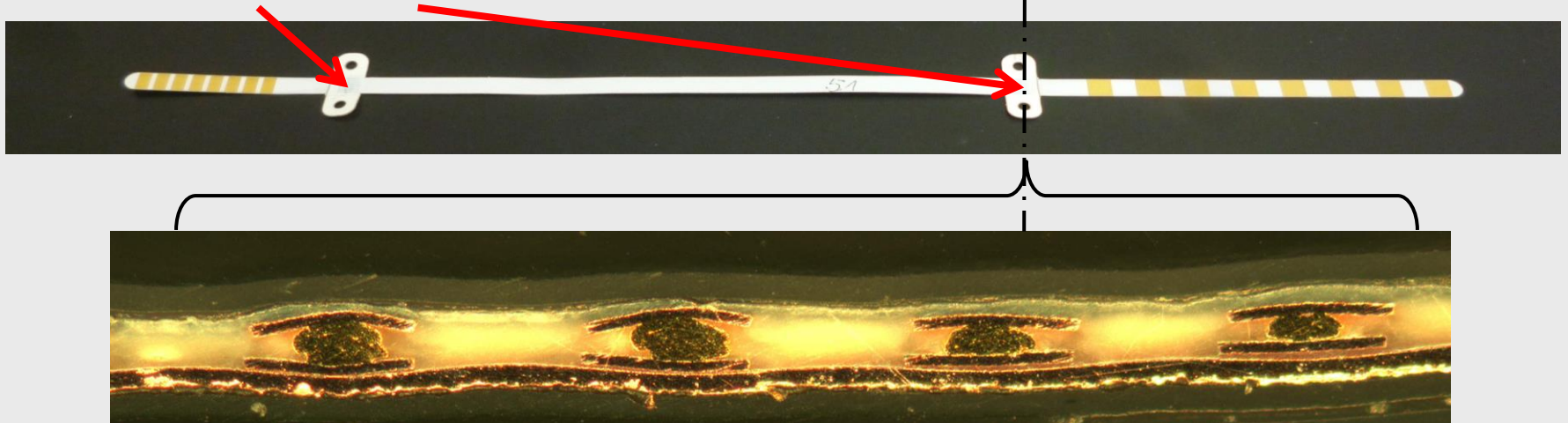
- Thermoplastic polymer properties
  - Define shape
  - Apply Heat
  - Cool Down
- Defined, flexible 3d Shape
- 3d Structures
  - Fit in small spaces
  - Enable stretching





## SEALED INTERCONNECTS BETWEEN CABLES

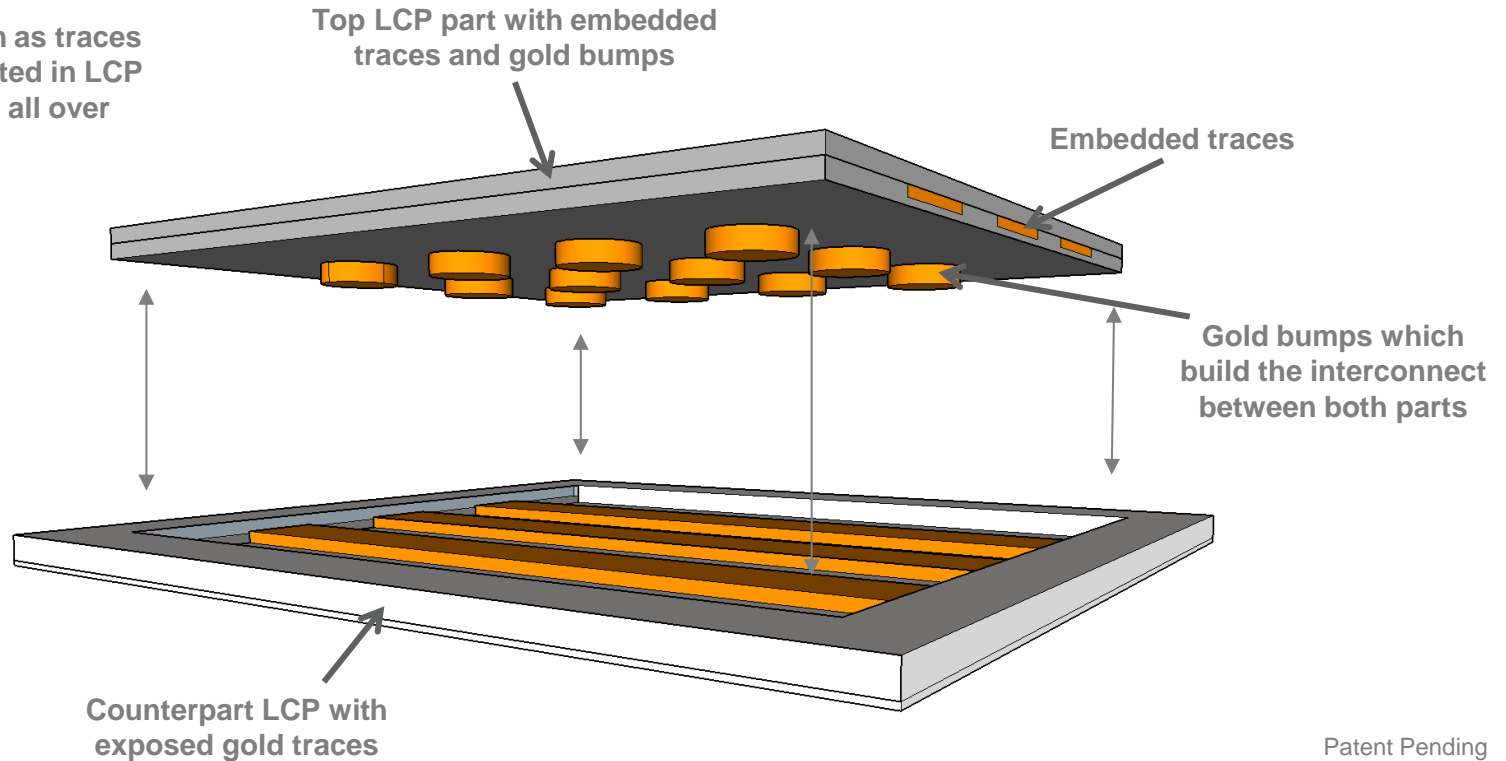
- Fully encapsulated interconnect technology for LCP flat cables.
- Extension of maximum lead length (> 1 m)
- No solder or adhesive used
- Local applied heat pulse under pressure melts LCP and seals contacts
- Pull strength 20 N/mm - same as lead body
- No signal attenuation at interconnect (measured up to 10 GHz)



# ENCAPSULATED FLAT CABLE INTERCONNECTS

## Benefits:

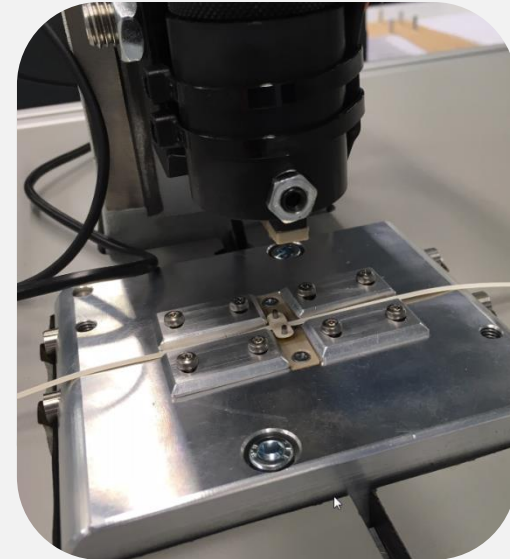
- Same resolution as traces
- Fully encapsulated in LCP
- Same thickness all over



Patent Pending

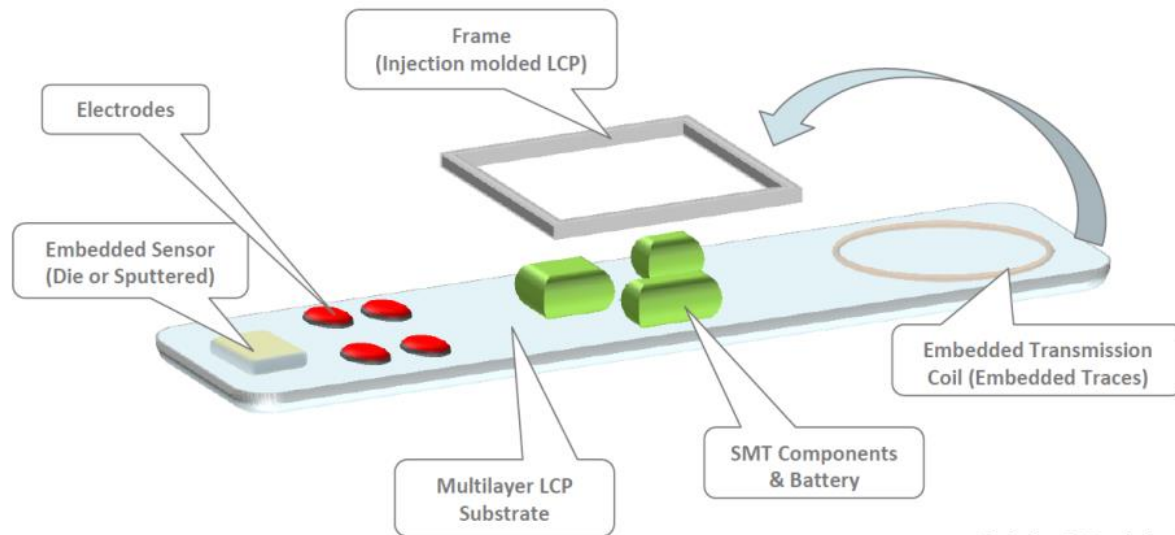
- Fully encapsulated interconnect technology for LCP flat cables
- Extension of maximum cable length up to more than 1.5 m
- No solder or adhesive used
- Local applied heat pulse under pressure melts LCP and seals contacts
- Pull strength 20 N/mm - same as lead body
- No thickness increase at interconnect
- No signal attenuation at interconnect (measured up to 10 GHz)
- Process cycle time for welding: < 5 s

## LCP FILM WELDING EQUIPMENT

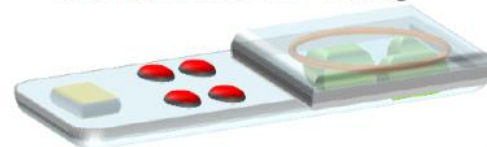


Semi-Automated Welding Machine

# LCP WELDED MODULE

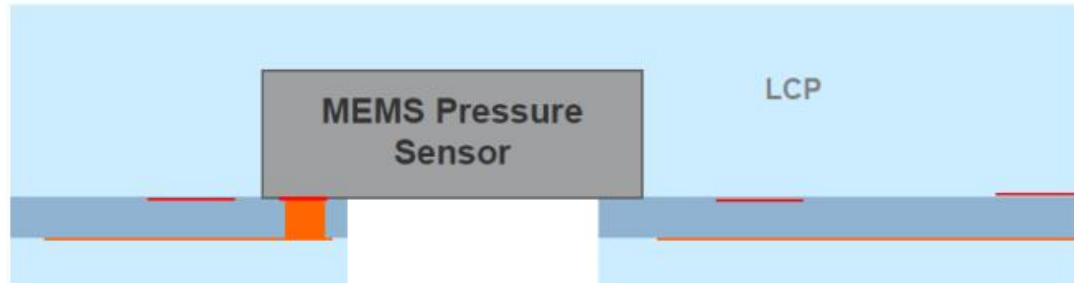


*Finished Module After Welding*



Patented

## EMBEDDED PRESSURE SENSOR



*Embedding of Pressure Sensor with Opening for Membrane*

# TEST CHIP DESIGN

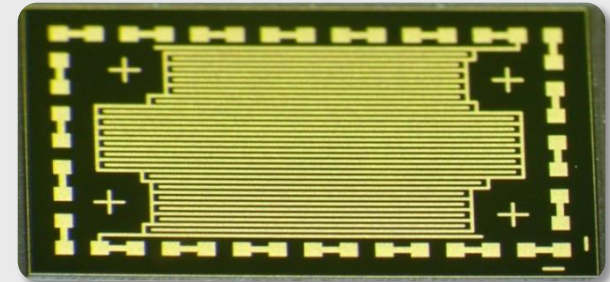
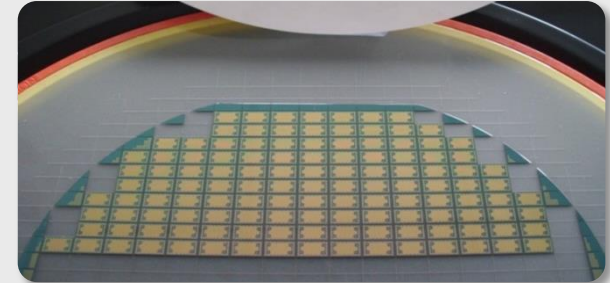
FIGURE 2

## Test chip for embedding

- Manufacturer: TLMI, Austin, Texas
- Wafer diameter: 150 mm
- Active wafer diameter: 147 mm
- Wafer thickness: 100  $\mu\text{m}$  (thinned)
- Die surface: thermal oxide
- Adhesion promoter: TiW (sputtered)
- Metallization: 3  $\mu\text{m}$  copper & gold flash
- Chip dimensions: 5 x 8 mm

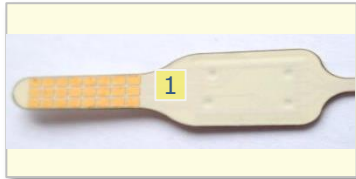
## Artwork on die

- Pad size: 250 x 250  $\mu\text{m}$  (thinned)
- Interdigitized comb structure with 50  $\mu\text{m}$  lines & spaces

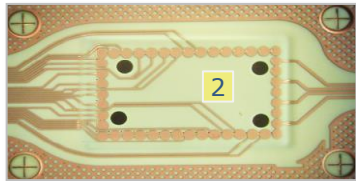




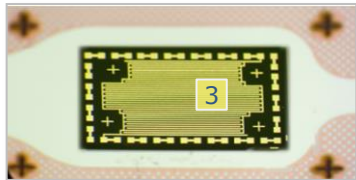
# TEST CHIP EMBEDDED IN LCP



**Electrode layer (1)**



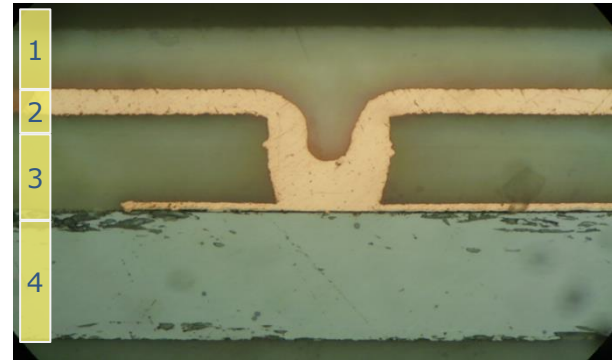
**Redistribution layer (2)**



**Chip pad layer (3)**

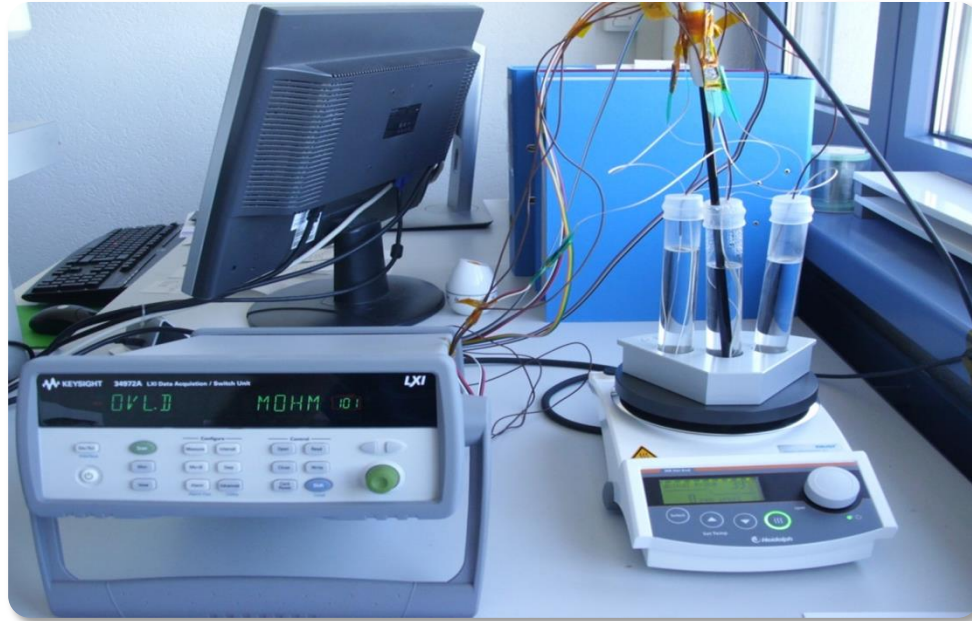
**Backside layer (4)**

## 4-layer LCP multilayer build-up



## SOAK TESTING APPARATUS

FIGURE 7



## RECENT SOAK TEST RESULTS

TEST	LCP STRUCTURE	RESULT
Soak test in PBS at 77° C	LCP with Au traces	> 9 months continuous (equivalent to 15 years implanted in body)
Soak test in PBS at 50° C	LCP with Cu traces, embedded die	Ongoing test (no measureable drop in resistance after >14 months)
Soak test in 40% H <sub>2</sub> SO <sub>4</sub> at 50° C	LCP with Cu traces, embedded die	Ongoing test (no measureable drop in resistance after >14 months)
Soak test in 80% H <sub>2</sub> SO <sub>4</sub> at 50° C	LCP with Cu traces, embedded die	Ongoing test (no measureable drop in resistance after >14 months)

## CONCLUSIONS

### Flexible Thermoplastic Substrate Technology Tool Box - Benefits:

- ❑ Low cost polymer material LCP
- ❑ Thermoplastic substrate material → 3D shaping
- ❑ Encapsulation with same substrate material possible
  - best thermo-mechanical matching and adhesion
  - no additional materials, no adhesives needed
- ❑ Multilayer construction with thin dielectric layers
  - embedding of traces and components
- ❑ Additive thin film metallization: Pd, Au, Cu, Ti, TiW, W, etc.
  - special metals/semiconductors for sensor functionality
- ❑ Module sealing with LCP



**Thank you for your attention.**

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