Packaging of Miniaturized Sensor Modules with LCP (Liquid Crystal Polymer)

Eckardt Bihler, September 2021

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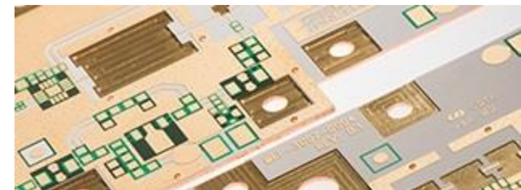
Content

- Introduction – Where we come from
- Liquid Crystal Polymer (LCP)
- Substrate Technology
- Encapsulation



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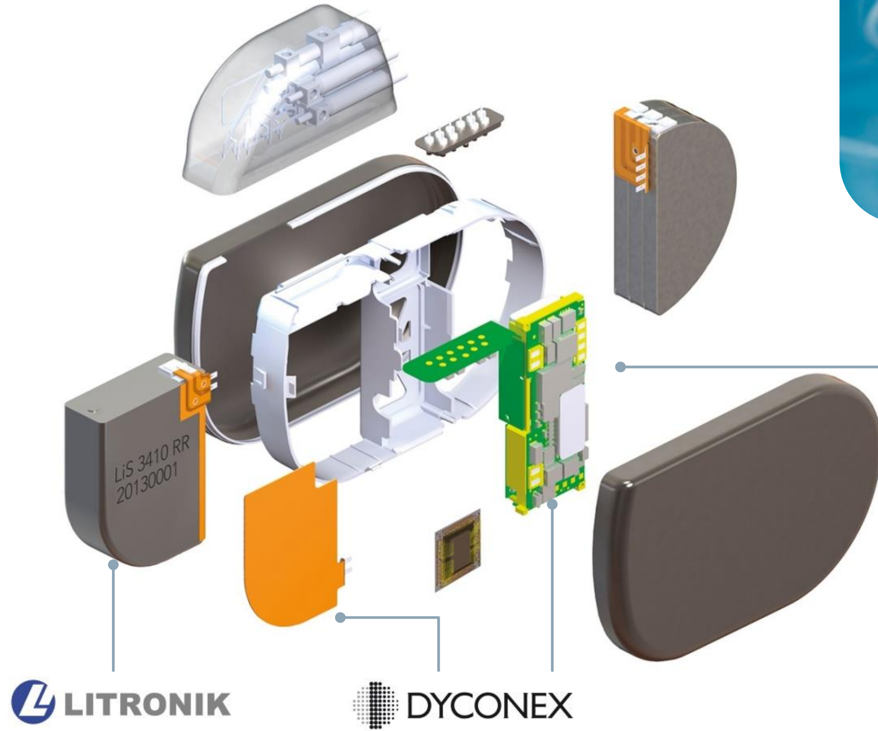
MST

Where we come from

Bio-electronic implants



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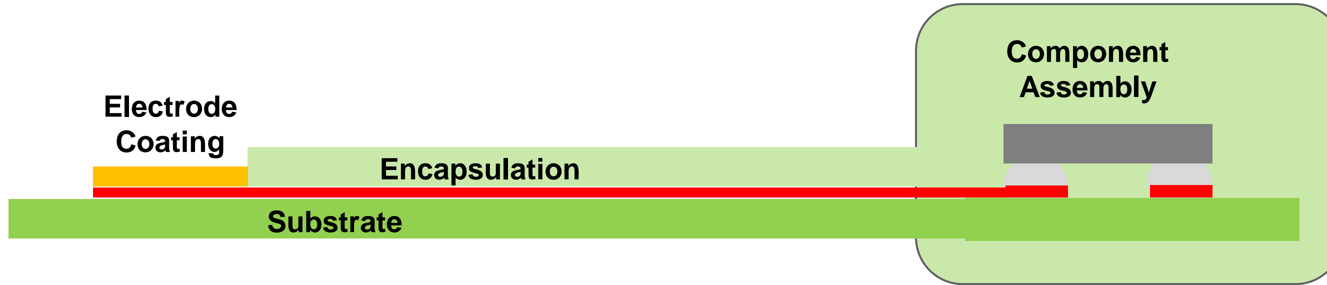
Our vision: All-in-one substrate concept

Bio-compatible substrate technology



✓Paper-thin
✓Flexible
✓Soft
✓Bio-stable functionality for > 25 years

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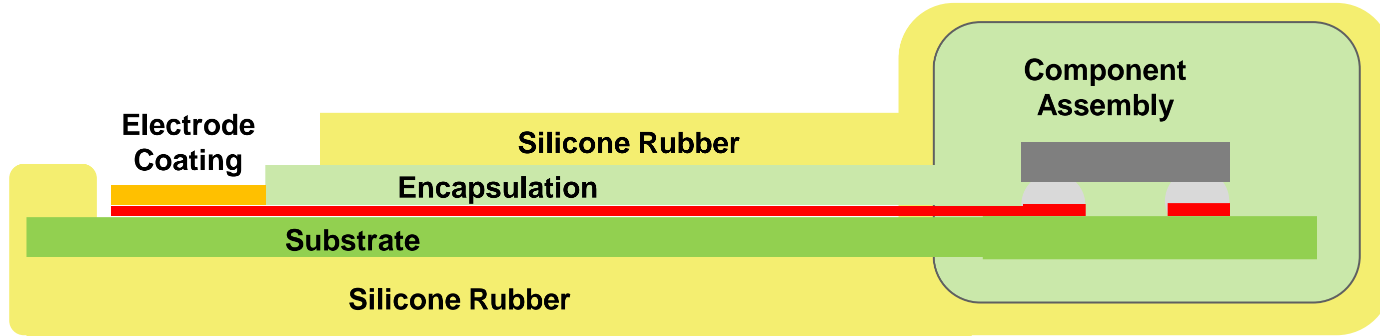
Our vision: All-in-one substrate concept

Bio-compatible substrate technology



✓Paper-thin
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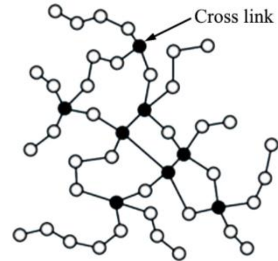
Polymer Categories

Thermoplastic resins

Thermoplastic Polymers	Thermosetting Polymers
❑ Melting point	❑ Cured ❑ No melting point
Examples: ❑ Polyethylene ❑ PTFE ❑ LCP ❑ TPU (Pellethane) ❑ Polycarbonate ❑ PET ❑ PMMA	***Examples:*** ❑ Silicone Rubber ❑ Glass Fiber Epoxy ❑ Polyimide ❑ Polyurethane Foam ❑ Bakelite



Thermosetting resins

Remark: *most polymers used in electronics are thermoset polymers*

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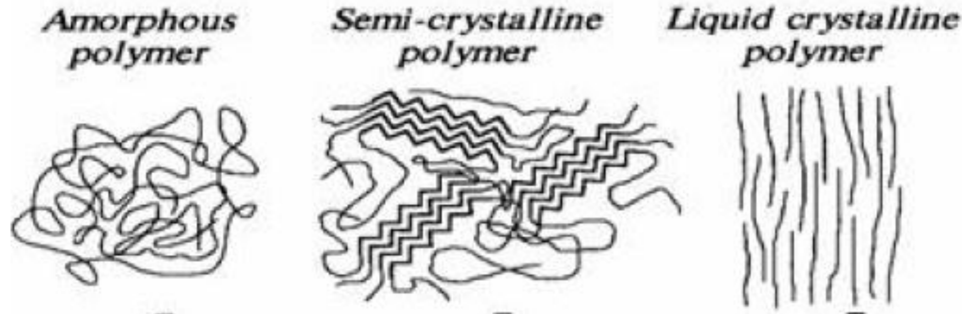
Thermoplastic Polymers

Amorphous Polymers	Semi-Crystalline Polymers	Liquid Crystal Polymers
No sharp melting point	Relatively sharp melting point	Sharp melting point; depends on thermal history
Random chain orientation in both melt and solid phase	Ordered chain structure only in solid phase	Ordered chain structure in both melt and solid phase
Does not flow as easy in melting stage	Flows easily above melting point	Flows extremely easy under shear within melting range
Examples: ABS, PS, PC,	Examples: PTFE, TPU, Polyamide, PE	Examples: LCP



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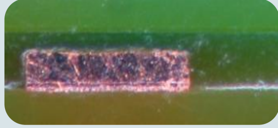
Liquid Crystal Polymer

High performance organic polymer

BUILD-UP WITH ADHESIVE



	Pi
	Adhesive
	Pi

No homogenous material > adhesive is needed

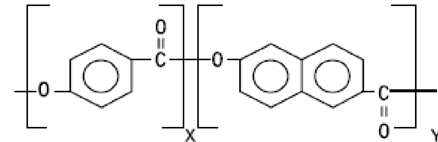
ADHESIVE FREE

Only LCP

Only one homogenous LCP thermoplastic material

LCP (LIQUID CRYSTAL POLYMER)

- Flexible thermoplastic base material
- Chemically inert under most conditions
- Operational stable up to 190 °C; Solderable 260 °C
- Melting temperature Tm > 280 °C < 340 °C
- **Very low water absorption (0.04 %) & diffusion rates**
- Low weight (1.4 g/cm^3)
- Excellent high frequency properties (ε_R= 2.9, tan θ = 0.0025)
- **For multilayer one homogeneous material (no adhesives needed)**
- polycondensation of 4-hydroxybenzoic acid and 6-hydroxynaphthalene-2-carboxylic acid



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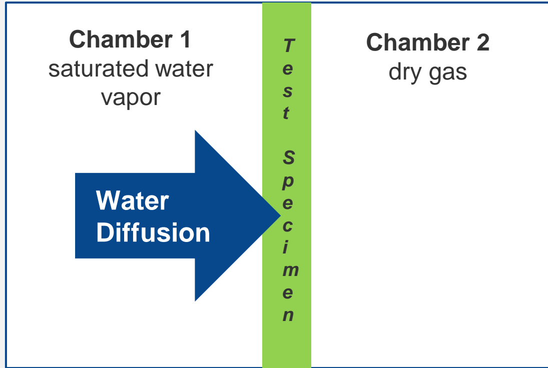
Permeability of polymers for water vapor

TEST SETUP



WATER VAPOR TRANSMISSION RATE

Layer	Total thickness (µm)	WVTR (g/(m2/Day))	Remark
Parylene C (Rerference 1)	30-35	0.6	
Polyimide (Kapton) (Rerference 2)	80/35*	3.9/5.5*	Values for 35µm extrapolated, indicated with a *.
LCP (Dycoplast) (single layer LCP sheet)	50/35*	<0.01	Values for 35µm extrapolated, indicated with a *. *Sensitivity limit reached for WVTR*

Source: Fraunhofer IZM

Electrode Coating

Encapsulation – Parylene, PI, LCP

Substrate – PI, Si, LCP

Traces

Water ingress can cause electrochemical corrosion / resolution of trace material and delamination of layers

Water ingress can deteriorate impedance and longterm functionality

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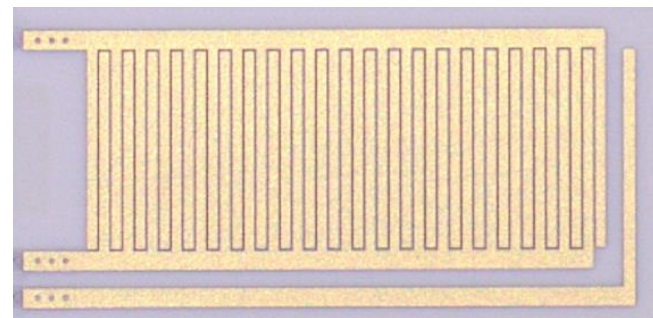
Soak test at elevated temperature

Soaking Liquid	Temperature	Duration
Saline solution	67, 77 °C	> 18 months
Sulphuric acid	50 °C	> 12 months
Hydrogen peroxide	67 °C	> 6 months

Soak test in liquids at elevated temperature

Test structure: Interdigitated capacitor for electrochemical impedance spectroscopy



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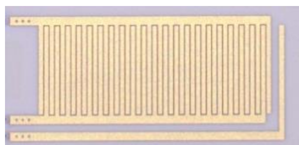
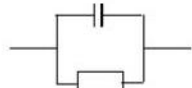
Soak Test

Electrochemical Impedance Spectroscopy (EIS)

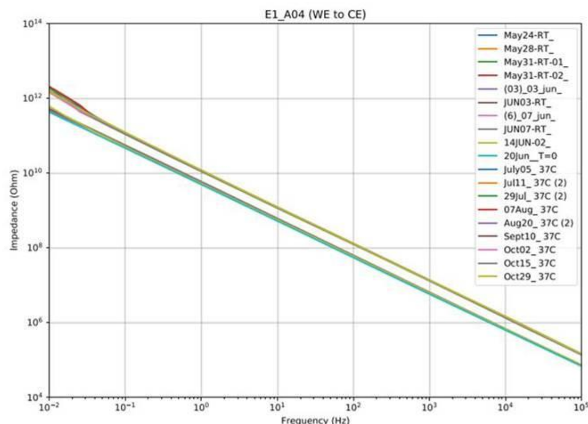
Embedded
Inter-Digitated-Capacitor (IDC)

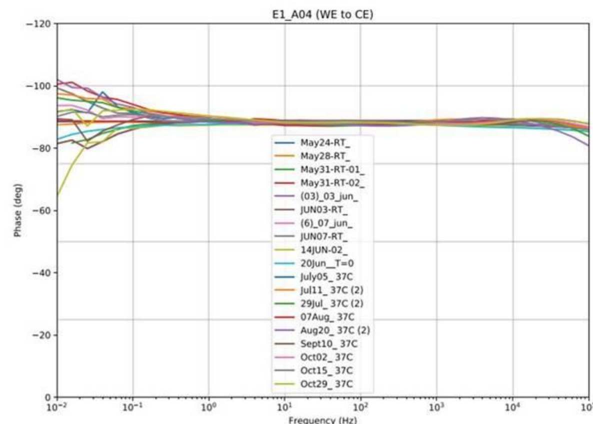


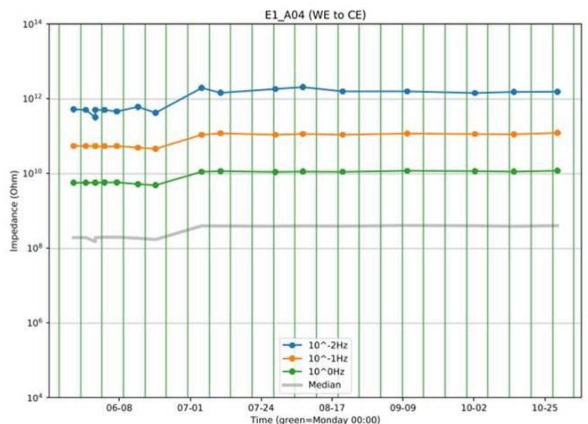


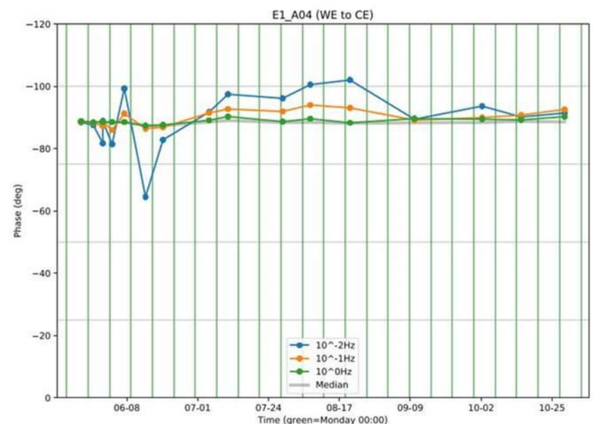
$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{i\omega C}$$

Bode Plots
Impedance $10^{12}\ \Omega$ …. $10^{4}\ \Omega$
Frequency 10^{-2} Hz … 10^{5} Hz









6 months

6 months

Source: Measurements done by Salvia Bioelectronics

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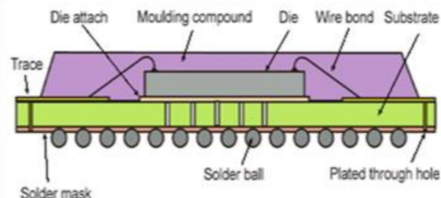
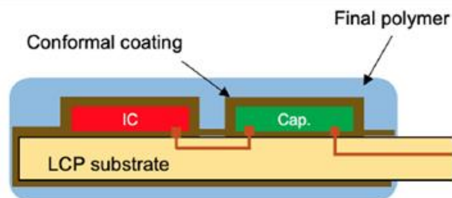
Encapsulation for miniaturized electronic modules

Ball-Grid-Array



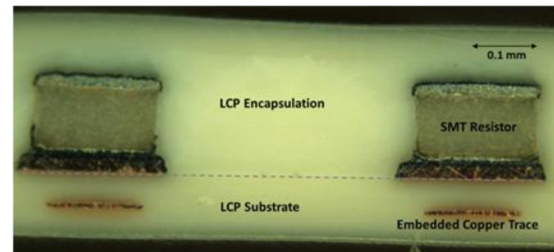
Rigid substrate assembled with wirebonded ASIC and epoxy overmolding

Parylene Coating



Substrate assembled with SMT components encapsulated with conformal coating: Parylene, multi-layered with ALD (Al_2O_3/HfO_2)

LCP Encapsulation



LCP Substrate assembled with SMT components fully encapsulated with LCP

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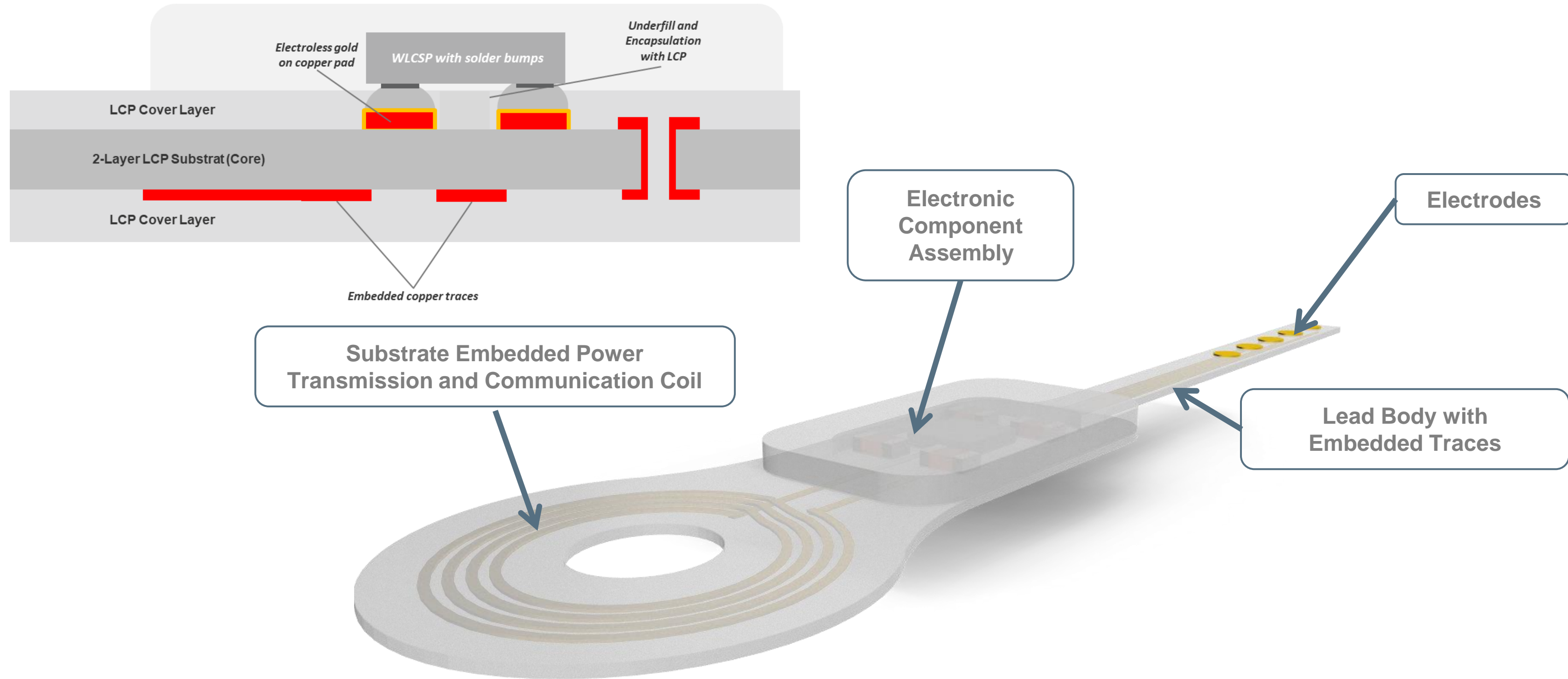
All-in-one Paper-Thin Implant using LCP Substrate

Versatile Concept for Subcutaneously Implanted Medical Devices



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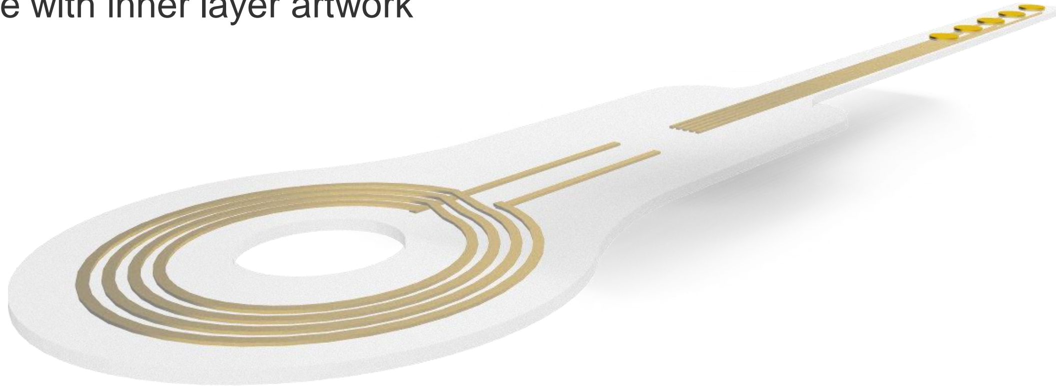
Substrate with inner layer artwork



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Substrate with cover layer applied

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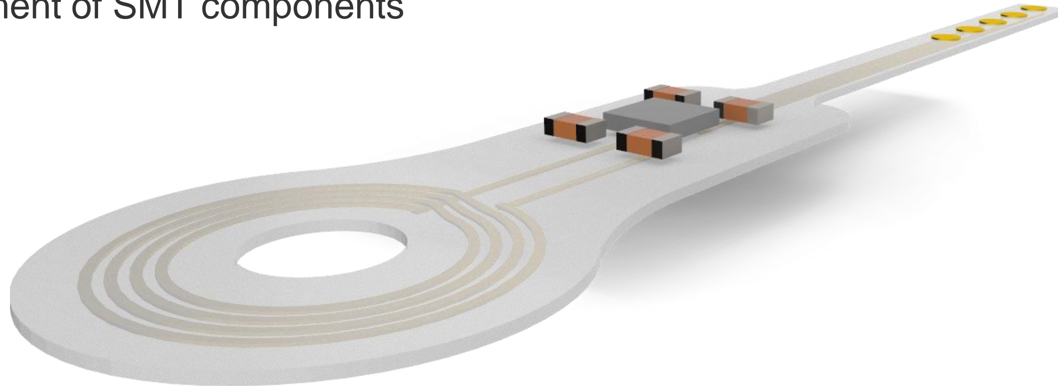
Placement of SMT components



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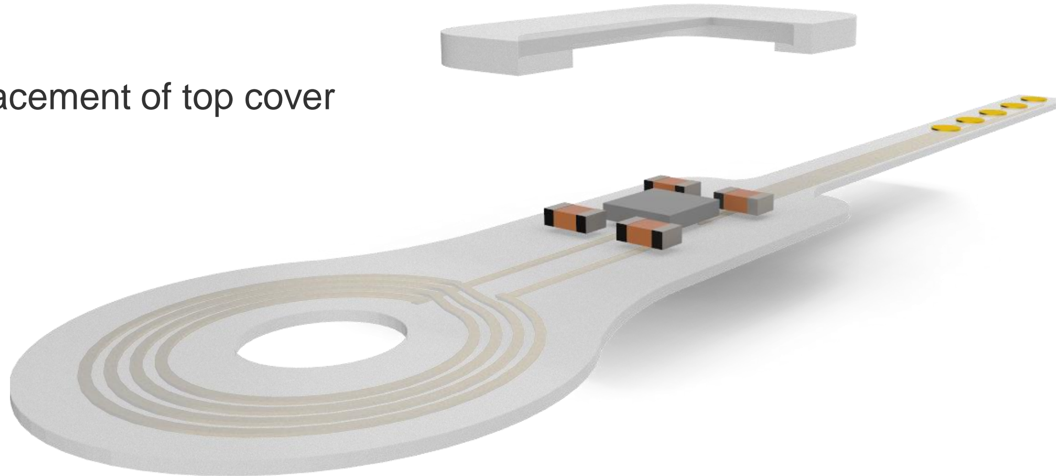
Versatile Concept for Subcutaneously Implanted Medical Devices

Placement of top cover



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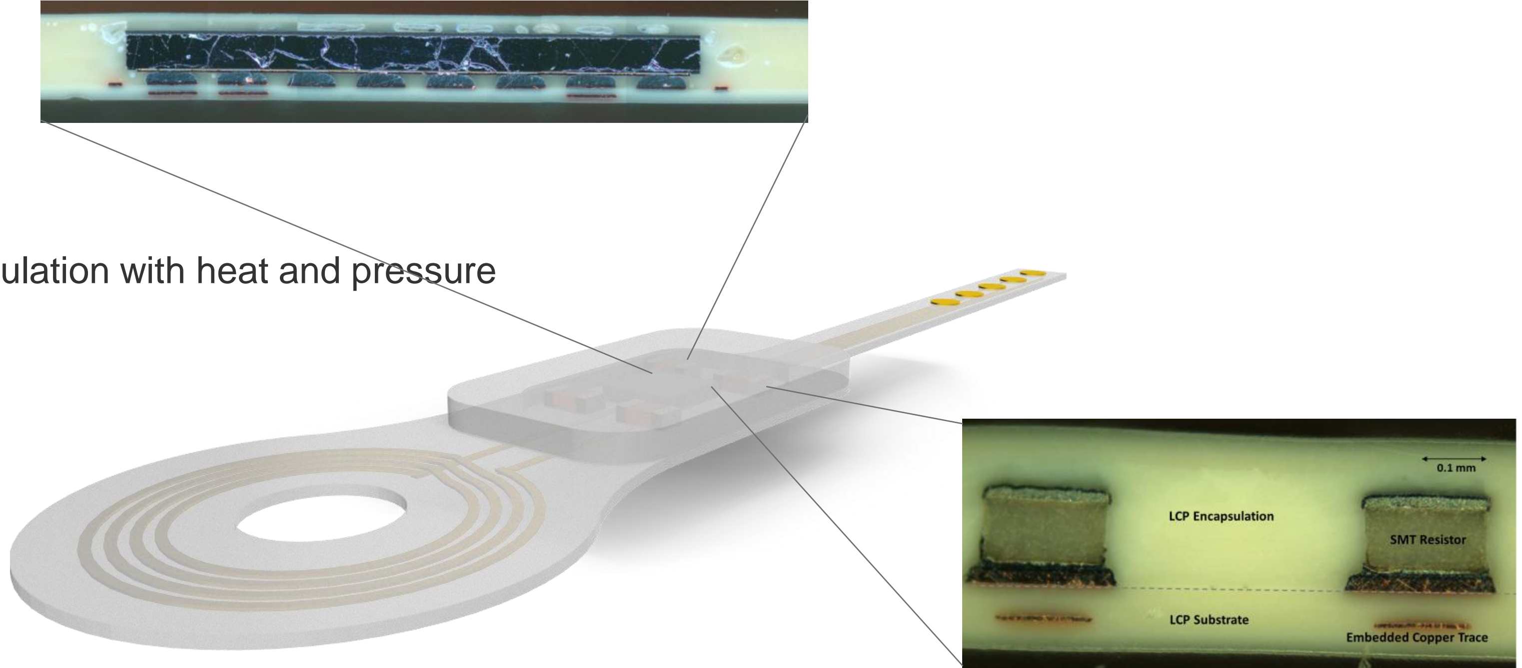
All-in-one Paper-Thin Implant using LCP Substrate

Versatile Concept for Subcutaneously Implanted Medical Devices

Encapsulation with heat and pressure



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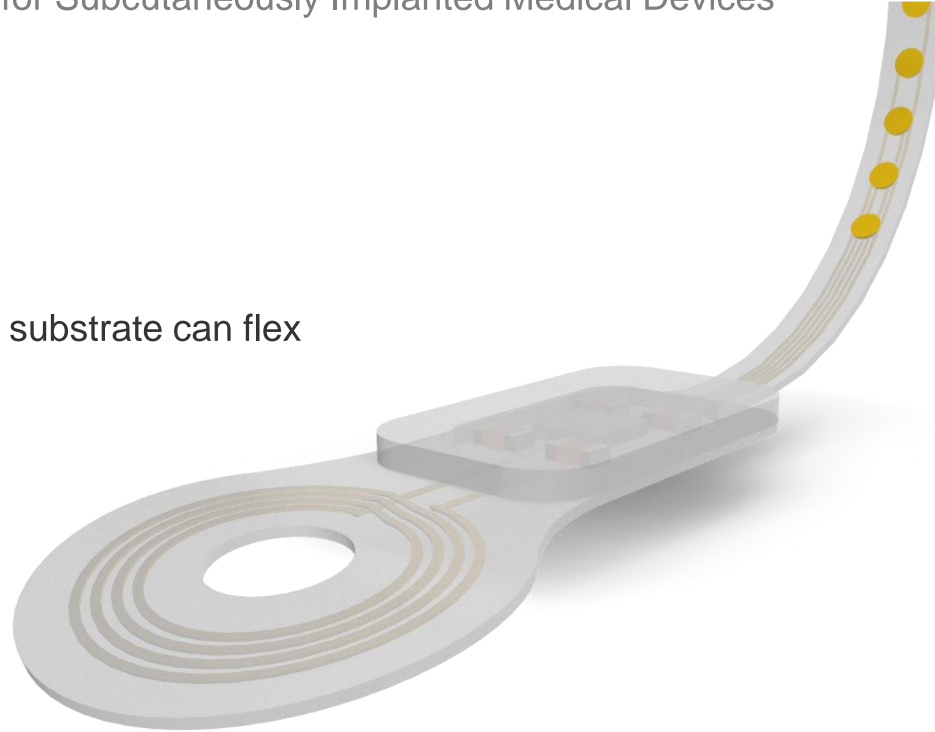
All-in-one Paper-Thin Implant using LCP Substrate

Versatile Concept for Subcutaneously Implanted Medical Devices

Thin substrate can flex



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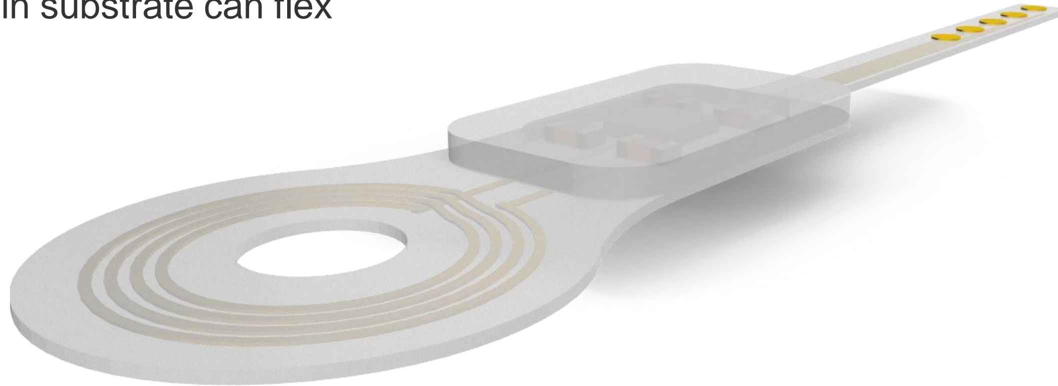

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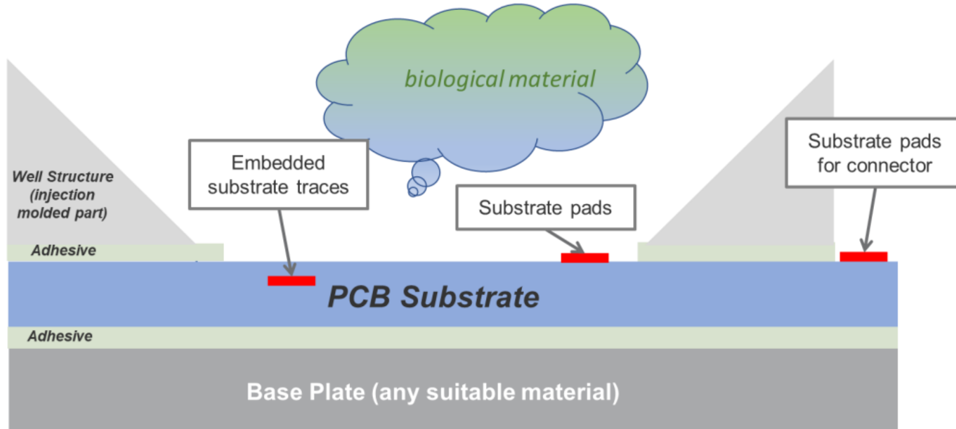
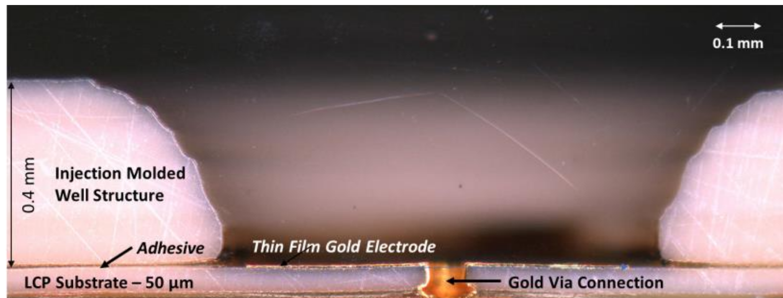
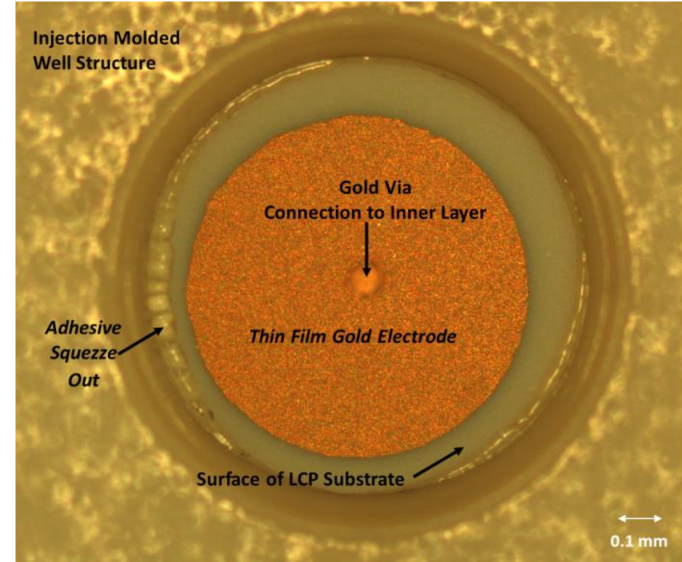
Integration with injection molded parts

Mikrofluidic parts for sensing







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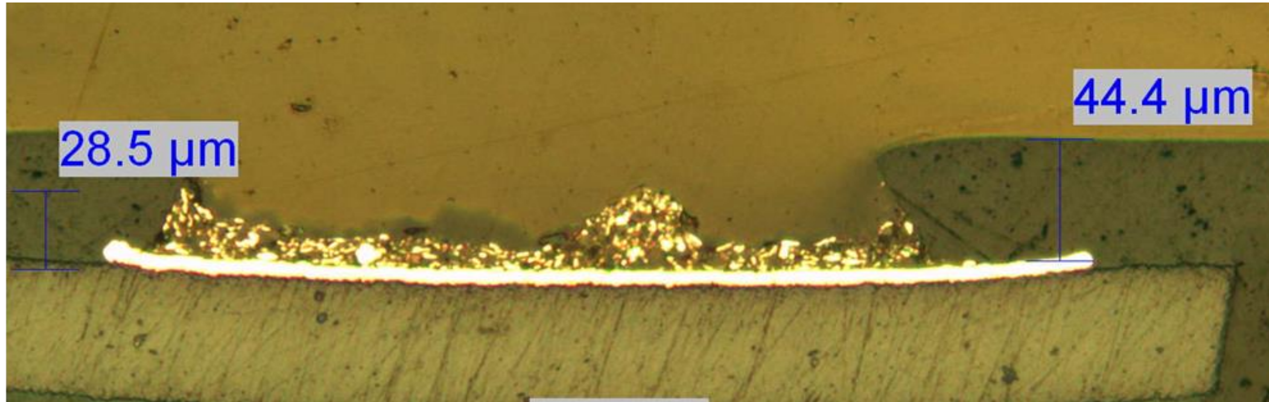
Functionalization for electrochemical sensors

Micro-Dispensing



Ag/AgCl Paste on pure gold / platinum pad

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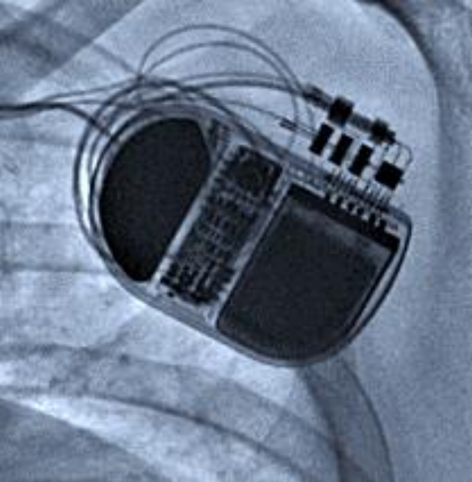

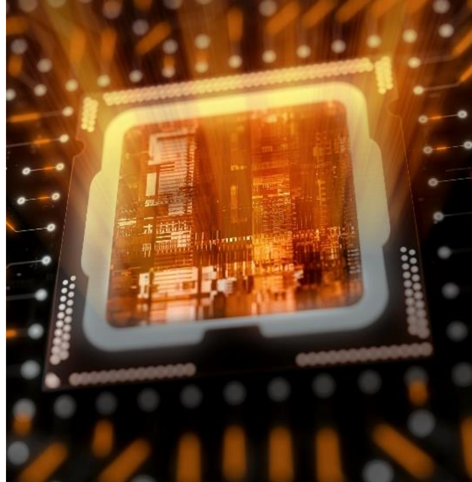

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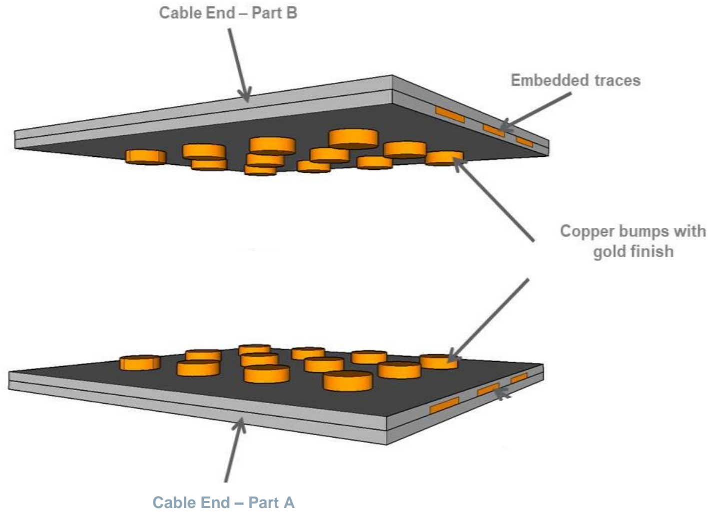
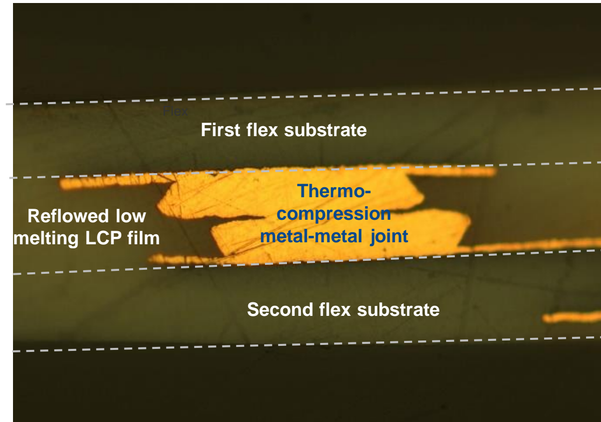
Flex-to-flex interconnect bonding

Micro assembly technique



- Miniaturized flex-to-flex interconnect
- Zero resistance in channel – high impedance between channels
- Fully encapsulated against water ingress
- Extension of maximum cable length up to more than 2 m
- 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)



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Polymer Material Properties

	Copper Film	PI Film	LCP Film	TPU Film	Silicone Rubber
Melting Temperature [°C]	1’085	None	285-330	220	none
Density [g/cm3]	8.9	1.4	1.4	1.2	1.0
Ultimate Tensile Strength [MPa] @ max. Elongation	280 @ 8%	231 @ 72%	282 @ 4%	40 @ 400%	3 @ 600%
Young’s Modulus [MPa] at 23°C	75’000	2’500	4’000	150	0.5-2
Coefficient of Thermal Expansion (CTE) [ppm]	17	20	18	150	900
Thermal Conductivity [W/m*K]	390	0.12	0.2	0.19	0.15
Electric Volume Resistance [Ω*cm] at 23°C	1.7 E-6	1 E17	1 E18	1 E11-E13	1 E15

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