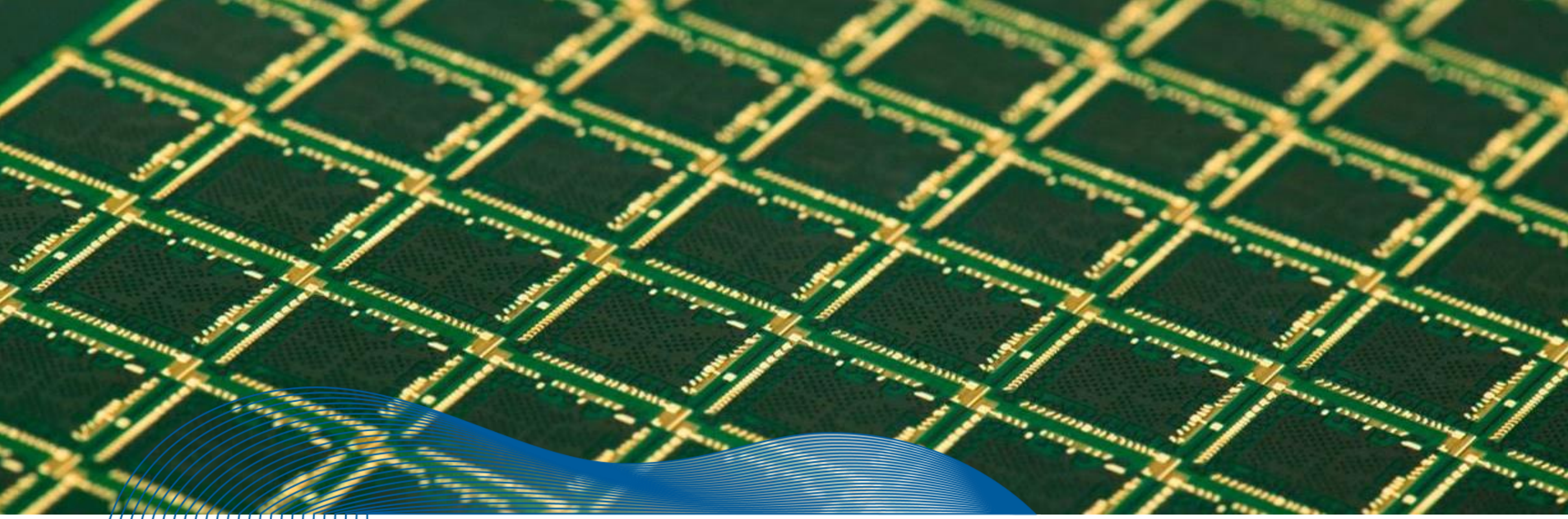

Ultra-thin base materials take PCB miniaturisation to the next level

Flexible and rigid ultra-thin base materials enable highly reliable, thinner PCBs

AUTORS Daniel Schulze

SUMMARY

New approaches are needed to meet the increasing demand for smaller and thinner electronic devices. Both rigid and flexible ultra-thin base materials for PCBs can fill this need by enabling higher-density designs with enhanced miniaturization in the Z direction, leaving more space for other components or reducing the overall thickness of the device. Because these materials require specific design approaches and fabrication technology, it's important to collaborate with a PCB manufacturer that has advanced engineering services to ensure a PCB design that is compact, cost-effective and reliable.

DYCONEX
an MST company

MST
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Almost all markets are experiencing increasing demand for smaller and thinner electronic devices. Today's mobile devices are small enough to fit in a watch, and the aerospace and automotive industries desire smaller and lighter devices to lower fuel costs and reduce emissions. Likewise, the medical industry needs wearable sensors, implantable devices, and handheld instruments that are small and lightweight.
Manufacturers of the printed circuit boards (PCBs) that are at the heart of these electronic devices have been making them more compact and lighter primarily by decreasing the size of the copper features and board materials. Extremely thin base materials are making it possible to take miniaturization beyond what was previously possible without compromising reliability or performance.

Ultra-Thin Multilayer Substrates

Standard PCB equipment and processes can be used to process LCP films. Multilayered substrates can be constructed with LCP films by laminating metallized and structured LCP cores with a lower melting point bond film.

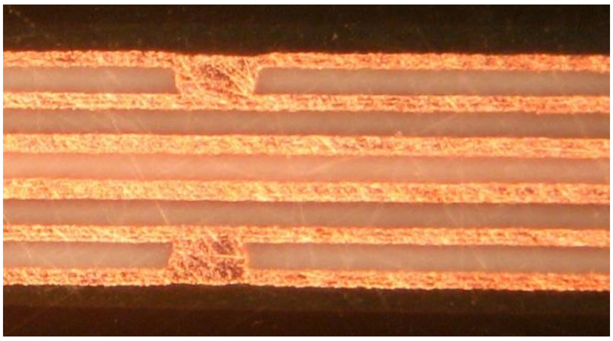

Figure 1. Ultra-thin 6-layer multilayer stackup with 25 µm thick LCP layers. Minimum via diameter: 30 µm. Total thickness: 182 µm.

The LCP substrates can be assembled with SMT components and sealed with heat welded lids or frames from LCP to provide a homogenous, miniaturized and hermetic housing. The big benefit is the combination of standard flexible substrate technology with the thermoplastic material properties. LCP is the only thermoplastic material, which is fully compatible with PCB and thin film technology.

Trace Metallization

The standard metallization of LCP is based on copper and can be copper electro-plated and structured using the same processes known from the PCB industry.

If materials other than copper are required, traces can be deposited by thin film sputtering and are defined by photolithographic methods. All metals, alloys, or dielectric materials available for DC or RF sputtering can be deposited. These materials can be used in combination with copper structures for interconnect.

The copper structures can then receive standard surface finishes suitable for SMT reflow and connector attach. Minimum trace resolution for thin film sputtered traces are about 15 µm, for standard copper traces 25 µm. Thin film thicknesses range from a couple of 10 nm to a few µm. In some cases (i.e. pure Au traces) it can be beneficial to increase the sputtered layer thickness with an electrolytic process to a higher thickness (i.e. up to 15 µm).

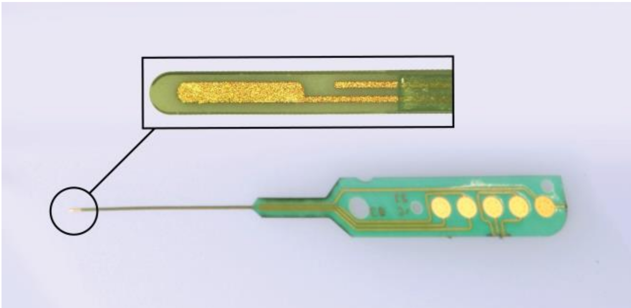

Figure 2. Sensor tip with connector and thin film gold electrodes

Thin Film Resistors and Thermocouples

Thin film resistors are made from sputtered resistive materials with sheet resistances between 1 and 5 Ω/□ with a temperature coefficient of 300 ppm/K.

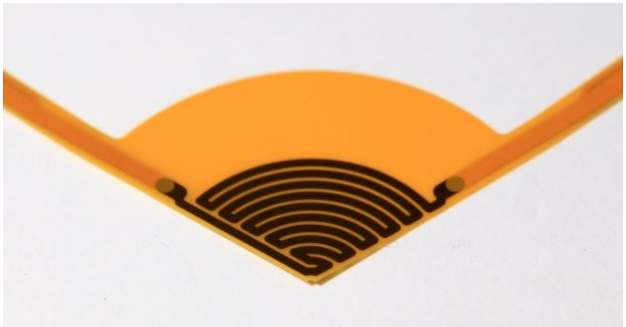

Figure 3. Encapsulated constantan resistor on polyimide for space applications.

While thermistors provide an absolute temperature reading, thermocouples with a Constantan / Copper transition can measure temperature differences with a thermoelectric coefficient of 42 µV/K.

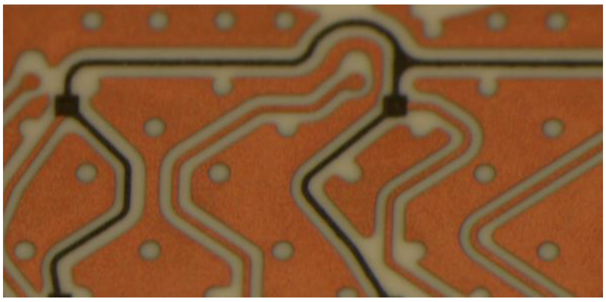

Figure 4. Cu-Constantan (black traces) thermocouples (50 µm x 50 µm) on a LCP substrate. The structure will be covered with another layer of substrate material and can be formed into any desired shape.

Silicon Die Embedding

Semiconductor dies can be embedded between substrate layers to encapsulate them from the environment. The semiconductor pads are connected through laser drilled, electroplated vias to a redistribution and fan-out layer on the next LCP layer. Standard aluminum pads on the silicon die are contacted through a thin sputtered interface layer to the copper vias. Via dimensions and registration tolerances are compatible with typical semiconductor pad layouts and dimensions.

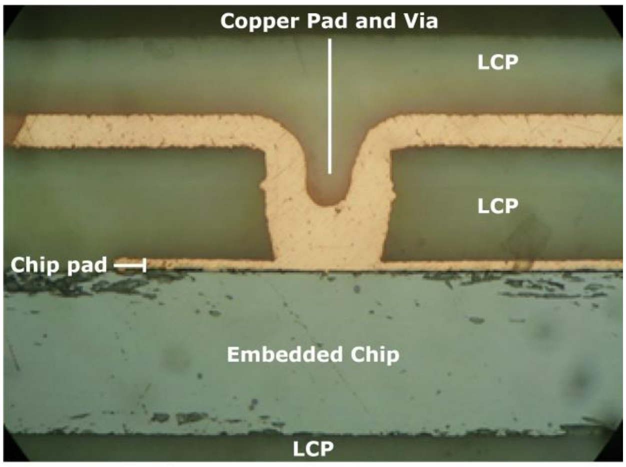

Figure 5. Cross section through embedded die in LCP Substrate

Silicon sensors dies, such as MEMS pressure sensors, laser diodes or photo diodes will need to be exposed to the outside in order to let the medium access the sensor surface. This can be accomplished by removing the LCP material in the area over the sensor surface.

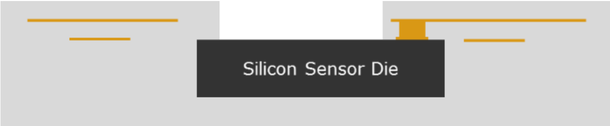

Figure 6. Cross section through embedded sensor die in LCP with opening of the sensor surface to the outside

Module Encapsulation

If more than a few components need to be assembled embedding might not be the most economic option. Solder reflow can be used to assemble SMT components. Leads from temperature sensitive components can be resistance welded to LCP. In order to achieve the smallest possible module size the substrate will be assembled only single sided.

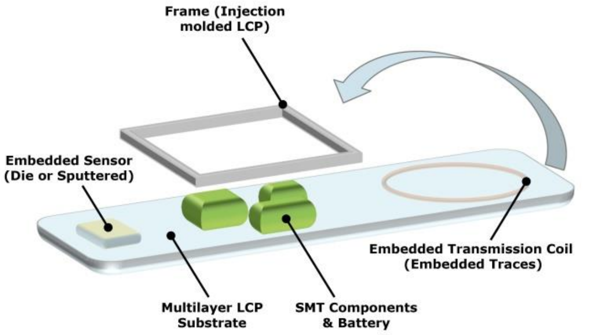

Figure 7. Miniaturized sensor package made from a LCP substrate with embedded sensors, communication coil and other components

The LCP substrate can contain in inner layers embedded, sputtered sensor structures (e.g. the thermocouples of Fig. 3 and 4) or an embedded silicon die (e.g. see Fig. 5). An injection molded frame from LCP will be positioned over the substrate to cover the height of the assembled components. Then the remaining substrate will be bent over the frame to form the cover. In such a configuration the LCP substrate forms the bottom and the cover of the module and the frame the side walls. The thickness of the walls will be as little as only 0.15 mm.

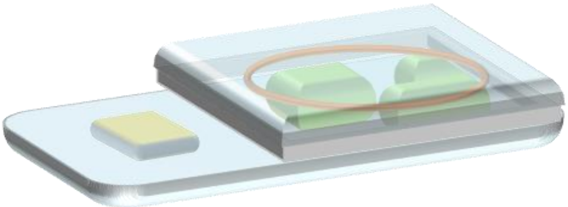

Figure 8. Miniaturized sensor package after folding the substrate over the frame and welding the substrate to the frame

The frame or lid will be locally welded to the LCP substrate. This will be accomplished by placing thin heat conductor traces on the top layer of the LCP substrate. Such heat conductors can be heated precisely with an electric current to melt locally the LCP material of the frame and the substrate. If this is done properly any interface between the different layers of LCP material will be completely removed at the periphery of the module and there are no paths for electro migration remaining, which could limit the hermeticity of the module.

Figure 9: Heat conductor traces between LCP substrate and LCP frame or lid

Long Term Testing for Hermeticity in Liquids

In order to evaluate the long term performance of components embedded into LCP, soak testing in liquids at elevated temperatures was used.
A test chip with a moisture sensitive, interdigitated structure on the silicon surface was embedded into a LCP substrate.

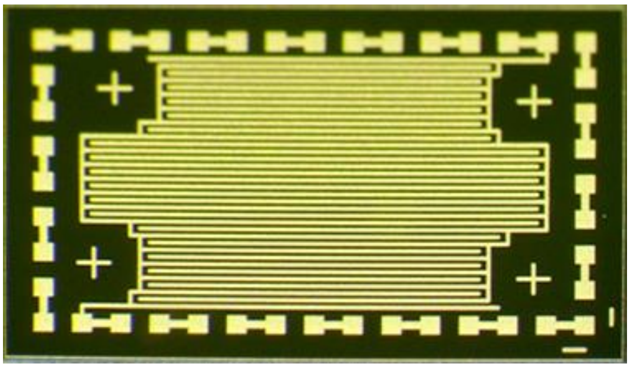

Figure 10: Test chip used for soak tests

The embedded test chip was put into small beakers and soaked with either PBS (phosphate buffered saline solution) or 80% sulphuric acid at 50 °C. The resistance of the interdigitated structure on the test chip was measured over a period of 11 months (still ongoing) to detect any kind of moisture incursion into the LCP package. No resistance below the threshold of the instrument (10 GΩ) could be detected.

Figure 11: Setup for the soak tests

Conclusion

Miniaturized smart sensor modules can be fabricated from LCP substrates using conventional flex circuit, thin film and standard assembly processes and equipment. Passive structures have shown feasibility for long term stability in aggressive environments based on soak testing. Structures with embedded die show promise for stability after > 11 months PBS and sulfuric acid soak testing. These results demonstrate that a new material set comprised of LCP is feasible for producing complex structures for smart sensor modules in medical, food processing, pharmaceutical, chemical or industrial applications.

About the Authors

Dr. Eckardt Bihler graduated with a PhD in solid state physics from the University of Stuttgart. In his more than 25 year career in the microelectronics industry he has collected considerable experience in ceramic and organic packaging, semiconductor design, photovoltaics and printed circuit board processing technologies. He works for DYCONEX as a business development and program manager for sensor applications.

Dr. Marc Hauer is R&D and Engineering Manager at DYCONEX with 13 years of experience in manufacturing of printed circuit boards, sensors and biocompatible substrates. As Engineering Manager he is responsible for medical implantable and high reliability products. In his previous functions he was an application and product engineer. Marc holds a PhD in Laser material processing from the Swiss Federal Institute of Technology in Zürich (ETH) and is author of 18 scientific papers.

Birgit Neubauer (Dipl. Ing.) has graduated as polymer chemist from the University of Applied Science in Reutlingen, Germany. For several years she has gained experience as R&D and application engineer at a German PCB manufacturer and has had the main responsibility for UL qualifications. Since more than 10 years Birgit is working as product engineer at DYCONEX AG and is involved in all major development projects.

Responsible:

DYCONEX AG
Grindelstrasse 40
8303 Bassersdorf / Switzerland

mail.dyconex@mst.com
www.mst.com
Tel. +41 (43) 266 11 00

Micro Systems Technologies Management GmbH
Sieversufer 7-9
12359 Berlin / Germany

info@mst.com
www.mst.com
Tel. +41 (30) 68905-4001