What is needed to Successfully Introduce "Device Embedding Technology" in Design and Manufacturing of PCBs and PCBAs to Add Value to Your Products?"

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Abstract
The embedding of components in electronic interconnection structures has been carried out for more than 30 years. It is regarded as the "poor men's silicon device". Different technologies have been developed and were technically successful, but history has shown that these embedding developments did not result in a sustainable success over a longer period of time. Replacement technologies have been developed after a short period of time by the so-called "Not in Kind" (NiK) technologies often called disruptive technology. (e.g. From the viewpoint of a PCB fabricator the use of an "Inorganic ceramic material is a = "Not in Kind", while a standard FR4.0 or FR4.1 is considered as an Organic = "In Kind" technology). The paper will explain what is needed to avoid technology pitfalls that will lead to business failures in future. In addition, opportunities are discussed that enable development managers, design engineers and specialists to use the full benefits of embedding devices in automotive, medical and industrial applications. These 'enabling' manufacturing technologies will offer the opportunity to develop innovative product solutions in critical technical, environmental and business situations.

Introduction
The number of PCB fabricators in Europe has declined over the last 20 years to less than 25% of what it was at the end of the '80s. Today, Europe has little more than 250 PCB fabricators with a turnover of about 2.7 billion US$ [1]. Large companies, like Siemens, Philips, Alcatel and IBM closed their in-house PCB manufacturing plants a long time ago. For the remaining PCB companies in Europe the strategy is more on survival, with growth as a near-goal objective. Under these circumstances, innovation is a major part of the survival strategy. To stay in business today, it is important to understand what field of business the company is operating in and what are the means necessary to differentiate your company from other suppliers, wherever they may be. The PCB fabrication market was a 'suppliers market' in the '80s. The supplier (i.e. the PCB fabricator) could set the prices for his products and the customer had to agree on it to get the products. Today, the PCB market is a "buyer or purchasing agent market". The product buyer in many instances, defines the prices for PCBs. Often, the PCB fabricator has no option but to agree to the offered price or he will not get the order. Furthermore, in longer term contracts, price reductions are included; often between 5 to 10% p.a. Purchasing agents are using the well written IPC standards to define the workmanship and the quality of the finished PCBs. On many occasions these requirements are over-specified and do not reflect the required manufacturing technology and tolerances needed for a given application. PCB fabricators have to learn again that they are in the business to make money and that the PCBs are the tools to achieve this task. In addition, the PCB purchasing agents or buyers have to learn that only a PCB fabricator that makes money will be able to stay in business and will have the financial resources to invest in future technology, innovation, manpower and equipment.

Embedded technology in Europe
Why use device embedding in PCBs?
Device embedding technology in Europe is used to add electronic, mechanical, thermal management and environmental function to PCBs as well as increasing the value to the basic PCB. For PCB fabricators component embedding means leading integration in the supply chain. It will also shift the focus away from the PCB assembler to the bare board PCB fabricator who embeds the devices in the PCB.

Historical development of device embedding in PCBs
Embedded passive components have been used in large quantities in ceramic hybrid circuit fabrication since the '70s. Active components have been wire bonded, soldered or glued to such modules. In the late '90s, component embedded technologies using organic PCB materials have been patented by Hofmann Leiterplatten GmbH for the AML technology [2] and by SIEMENS AG in Germany for the SIMOVE technology.

The SIMOVE (Fig. 1) technology was very successful for a period of 2 to 3 years [3]. Licenses have been given to the PCB fabricator industry in Europe, necessary to overcome the issue of a single source supply chain. At the end of the '90s, the PCB industry was anticipating a growing business from this newly-developed technology [3]. So it was a big surprise that this investment did not result in additional business: indeed, quite the opposite. At the moment the technology was ready for industrialization, it was no longer needed. The reason was that the integration on silicon was so much advanced in functionality and cost-reduction that the embedding design - using PCB technology - did not offer any packaging or cost benefits.

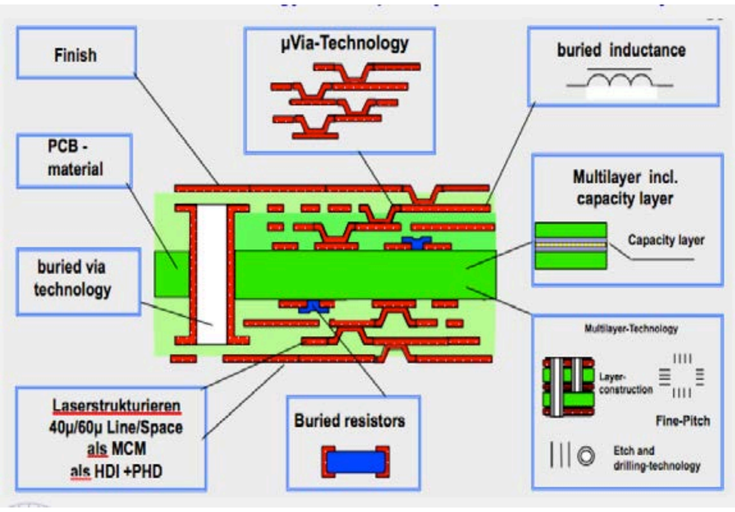

Fig. 1. **Technology options used in the SIMOVE technology developed by SIEMENS AG in Germany [3]**

The questions that need to be answered are:

- Is there a market for embedded devices in PCBs in Europe or in the market world-wide?
- Under what circumstances could the PCB fabricator benefit from these markets or market niches?

To answer this question we have to look at the changes in the market and in the demand by key OEMs and industry segments.

Semiconductors are driving the electronic design

In the electronic business it is important to understand that the semiconductor suppliers are much larger than PCB suppliers. The top 25 semiconductor fabricators (Fig.2) have a turnover of about 4 times the total global PCB market with more then 1500 fabricators worldwide.

As can be seen, the semiconductor market is no longer a fast growing market. The semiconductor industry is looking into opportunities in forward integration in packaging, like SiP (system in package) or even in SiPCB (system in printed circuit boards). When the quantities are large, the design on silicon is one option to expand the business.

2012 Worldwide Semiconductor Sales Leaders

(US$ millions, including Foundries)

Rank Maker 2012 (2012 vs. 2011)

Total Top 25 represent 234,232 -1%

Rank	Maker	2012	2012/2011
1	Intel	49,114	-1%
2	Samsung Electronics	32,251	-4%
3	TSMC	17,167	18%
4	Qualcomm	13,177	34%
5	Texas Instruments	12,147	-6%
6	Toshiba	11,217	-12%
7	Renesas	9,314	-13%
8	SK Hynix	9,057	-4%
9	STMicroelectronics	8,364	-13%
10	Micron	8,002	-7%
11	Broadcom	7,793	9%
12	Sony	5,709	-6%
13	AMD	5,422	-17%

Rank	Maker	2012	2012/2011
14	Infineon	4,993	-11%
15	GlobalFoundries	4,560	31%
16	Nvidia	4,229	7%
17	Fujitsu	4,162	-6%
18	NXP	4,157	0%
19	Freescale	3,735	-15%
20	UMC	3,730	-1%
21	MediaTek	3,366	13%
22	Sharp	3,304	14%
23	Marvell	3,157	-8%
24	Elpida	3,075	-21%
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Source: IC Insights 3/2013

The global top 25 Semiconductor leaders represent 4 times the total global production of PCBs

Fig. 2. **The top global 25 Semiconductor leaders represent 4x the total global production of PCBs [4]**

An additional example was experienced at the beginning of the smartphone era. Flip phones with many PCBs and flex rigid board combinations with integrated key boards were acclaimed as the solution for the future. Optimisation technologies with special rigid-flex PCB designs offered an excellent technical solution and generated more business for the PCB industry.

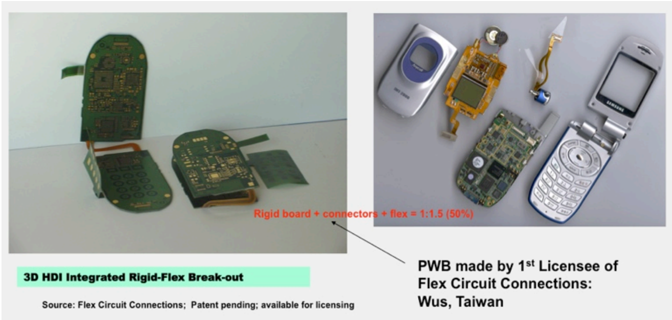

Fig. 3. **Traditional Flex vs. 3D HDI Integrated Rigid-Flex Break-out V 1.1[5]**

At this point, the semiconductor fabricators recognized the quantities needed in future for these advanced mobile communication tools. In addition, smartphones become even smarter and more electronic functions were essential to meet the growing consumer hunger for new features. Video phoning, video games and television became standard requirements, besides making phone calls and sending e-mail, SMS and MMS messages.

Fig. 4. **Smartphone technology evolution. No keypad, no flip screen. 3 keys but a high definition touch screen that offers many more benefits compared to a conventional keyboard. [6]**

Today, smartphones without keyboards fulfill the function of communication tool, television, video player and videophone as well as a radio and music center and, in some cases, they even replace computers.

When manufacturing such electronic devices, intelligent component packaging is the solution. Semiconductor fabricators can integrate these functions into a semiconductor package or even design it direct on to silicon. For the mobile 'phone, where the quantities are in the tens of millions, the required investment for these electronic devices can be easily justified. In the field of automotive applications, where quantities are smaller (< 10 million) the design on silicon may not be the solution. Here, the fixed costs of designing a customized chip, including the interfaces and the related software, are very high in relation to the quantities needed. However, when "system in package" and "system in PCBs" are more widely designed and accepted, this situation is more cost-effective and this will change how car electronics are designed and manufactured in future. New opportunities for interfaces between devices may apply in near field communication (NFC) protocols, may replace connectors and flexible PCBs, and may even change the automotive assembly technology. In addition, RFID components have become cost-effective alternatives to store important information about the assembly processes and environmental requirements and other unique device information. This technology will offer even more options for the software developers and system designers of the future.

Advanced Projects in Europe.

Europe is strong in automotive, industrial, medical, photovoltaic, avionics and space electronics. In addition, power electronic devices are needed in many of the new electronic automotive application. As indicated in the beginning of the report, the PCB market is at present a 'buyers' market and the purchasing managers and/or agents define where the order is placed. For them, cost reduction is one of the key objectives, but will, in many cases, not go in line with innovation, reliability, traceability and environmental requirements.

The European industry depends on leadership through innovation in electronics. Compromises between cost-reduction and innovation are key drivers for the PCB fabricators and OEM / EMS industry in Europe. Today, PCB costs are calculated on a square meter or square decimeter level. The smaller the PC board, the lower the selling price for it will be.

One example is the EU-sponsored consortium project "HERMES" The name stands for – "**H**igh density integration by **E**mbedding chips for **R**educed size **M**odules and **E**lectronic **S**ystems". The following companies have cooperated as partners: AT&S Austria Technologie & Systemtechnik AG, Atotech, Bosch, Circuit Foil, Fraunhofer IMZ, IMec, Infineon, Rood Microtec, Siemens A&D, Thales Communications France (Thales TCF) and Thales Corporate Services. This project resulted in a successful product development for a new technology, which is now used in Europe to manufacture several million units per month. In this project, the benefits of PCB technology have been modified in a way that it is fully functional in the area of cost-effective chip packaging fabrication.

In this project, the "Chip in Polymer" process has been developed and industrialised, which offers a reliable and cost-effective embedding technology for the realisation of modules and SiP development. This technology is applied in several projects with industry and R&D centers.

The industrialization of the technology within the "HERMES" project was a great achievement for the electronics industry in Europe. Without funding from the EU the partners would not have seen sufficient benefits and incentives to develop these new packaging technologies. The package realization resulted in single and multi-die packages and provided a reliable and cost-effective solution compared in compared to conventional IC packages.

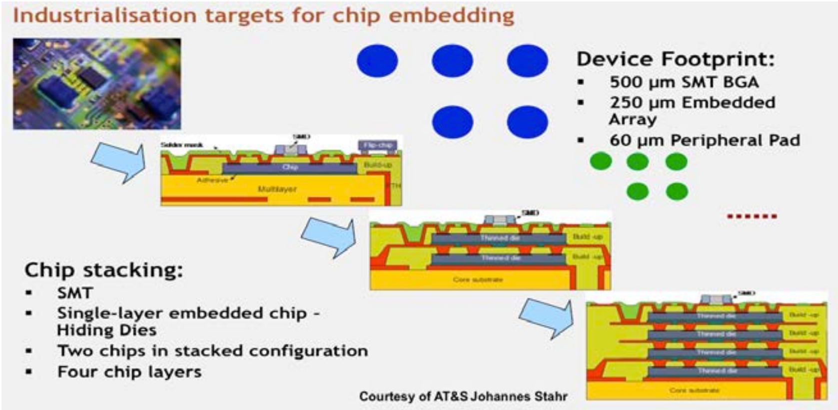

Fig. 5. **Project supported by the European Commission under the name "HERMES" – Industrialisation was carried out at AT&S in Austria together with the Fraunhofer IZM in Berlin. The Project Partners came from the fields of acadæmia, OEMs, silicon fabricators, and the chemical, electro-plating and paxkaging industries [7]**

The HERMES project was direct application-related and resulted in multiple levels of embedded chips, multiple lamination cycles, embedding of ultra-thin chips in flex, power modules and radar applications of 77 GHz

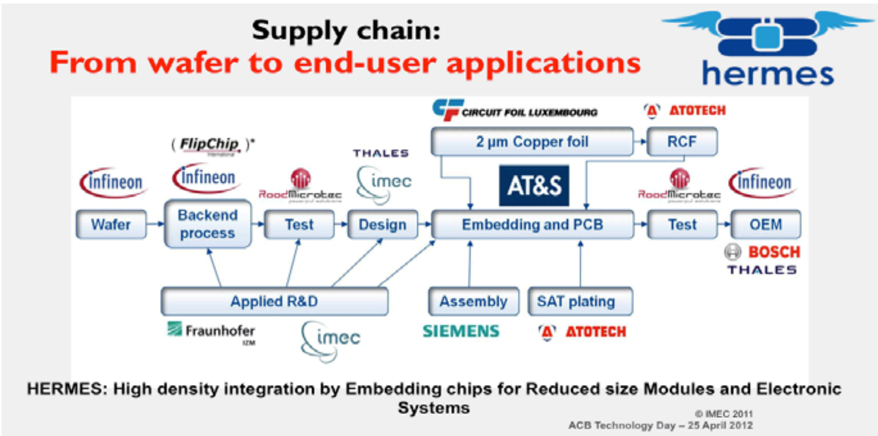

Fig. 6. **The success of the "HERMES" project was based on the involvement of the total supply chain for electronic devices. Representatives from silicon wafer fabrication, materials and process suppliers, to packaging to end-users with specific applications proved the need for this form of package and product** [8]

The products that have been developed under this project are not easy to copy. Special investments are needed to perform the required technologies and co-operation between PCB fabricator, assemblers and chip fabricators are needed to get the required unpackaged components. At present, most of these products are manufactured in Europe.

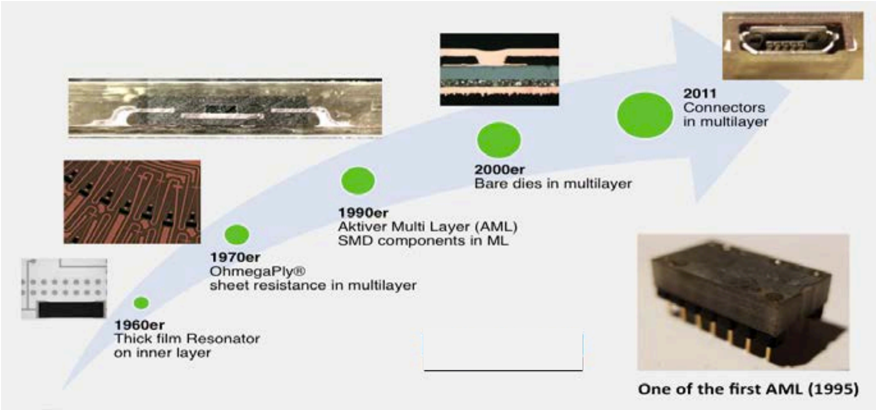

Fig. 7. **Device Embedded Technology in PCBs using standard packaged components. Active Multi Layer (AML) technology developed by Hofmann Leiterplatten in Germany can use standard components including connectors inside the PCB. Miniaturisation, reliability and improved thermal management are achieved simultaneously [2]**

Experience has proved that the European electronics industry very much depends on innovation. Based on such by the electronics industry, the "Active Multi Layer" technology was developed by Hofmann Leiterplatten GmbH in Germany. The goal was to combine the benefits of the standard copper clad laminate, prepregs and epoxy resin as well as standard placement and soldering technology into one embedded device with an advanced thermal conductivity of these materials in one package. The key to success is based on using standard materials (Fig. 9), assembly attachment and soldering processes in conjunction with some modified standard manufacturing PCB processes. Key in the success of this technology is the control of the design, the PCB fabrication and assembly processes. Today, standard PCB fabricators do not have these capabilities. However, for future high added value PCB products and innovative solutions, forward integration will be important for PCB fabricators.

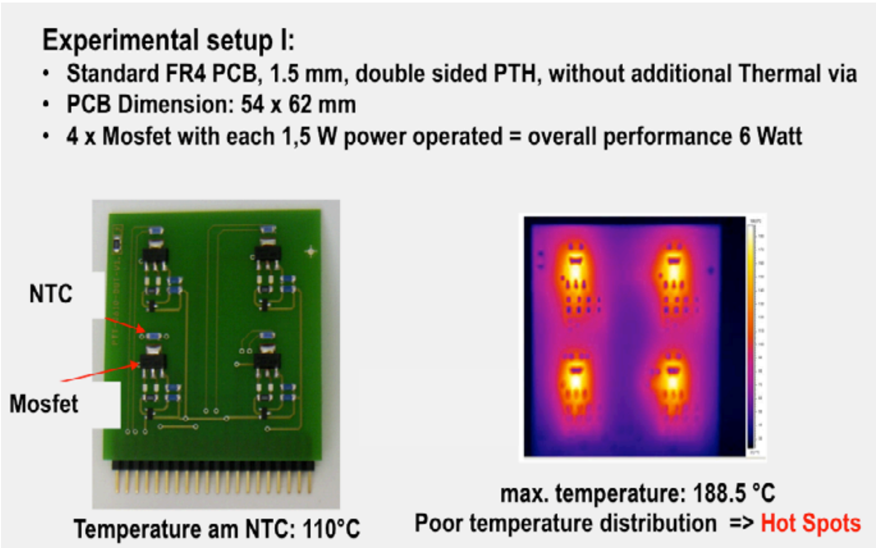

Fig. 8. **Mosfet components on standard assembled PCBs can generate high temperature, as cooling is only by ambient air which has low thermal conductivity [2]**

In the experiment, standard PCBs where assembled with 4 Mosfet components powered with 1.5 W. The PCBAs were operated for some time and then the surface temperature was measured. Using thermography measurement methods, the temperature showed hot spots of >188°C at the components. Even the thermo-sensor still showed a temperature of 110°C. Life expectation of electronic devices depends on the operating temperature of the components and the co-efficient of thermal expansion in X-Y and Z direction. Operating an electronic device at a lower temperature will increase the life expectancy or the "Mean Time Between Failures" (MTBF)

Thermal Conductivity of Materials used in Electronics

Material	Thermal Conductivity in W(m/K)
Acrylic	0.2
Air	0.024
Aluminum	250
Copper	400
Epoxy	0.35
Glass	1.05
PTFE	0.25
Silicon	149
Water	0.58

Source: Alun Morgan, ISOLA. Presented at the EIPC Conference on May 3-4, 2011

Fig. 9. **The thermal conductivity of different materials used in PCBs indicate that air is not the prefered media when thermal disipation is required. Epoxy resin has a 0.35 W(m/K) thermal conductivity and Glass has 1.05 W(m/K) [9]**

Repeating this experiment with the same layout, the same type of components and same manufacturing technology was used to embed the components inside the PCBs. In this process, the components are completely surrounded by epoxy resin and glass fibers used in copper clad laminate and prepregs. A dramatic temperature drop at the component was achieved. As shown in Fig. 10, the thermal conductivity of the base material indicated no hot spots on the PCB. The total PCB temperature is lower, not only at the components.

It is expected that the PCB with embedded components are operated at a lower temperature. This will result in an extended operating life of the electronic device. An OEM and or EMS company can use this benefit to show a larger number of hours for the MTBF. This will be a reliability argument when it comes to product life expectation and will be, in many cases, a strong sales argument and it indicates a commitment to quality.

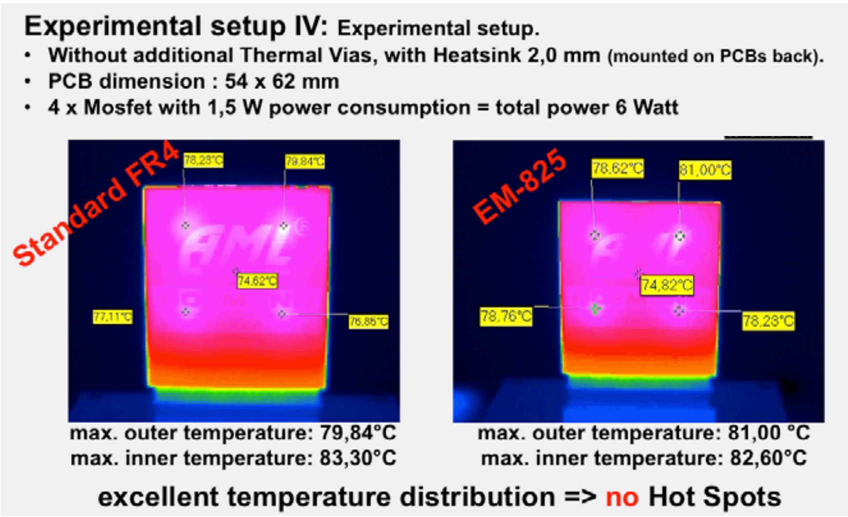

Fig. 10. **Components embedded inside the PCB assembly have shown much lower temperatures based on better thermal conductivity of CCL compaired to air [2].**

Fig. 11. **LEDs embedded in CCL are surviving exposure to chemicals and water / humidity very well. In this sample, the illuminated LED strips are partially in water for more than 5 years and without any damage. [2]**

The component embedding technology offers an additional benefit in protection against environmental contamination, dust, humidity, gases and various chemicals. Encapsulating in epoxy resin can, under certain circumstances, replace housing, improve EMC shielding, help in miniaturization and improve the thermal properties of the electronic devices.

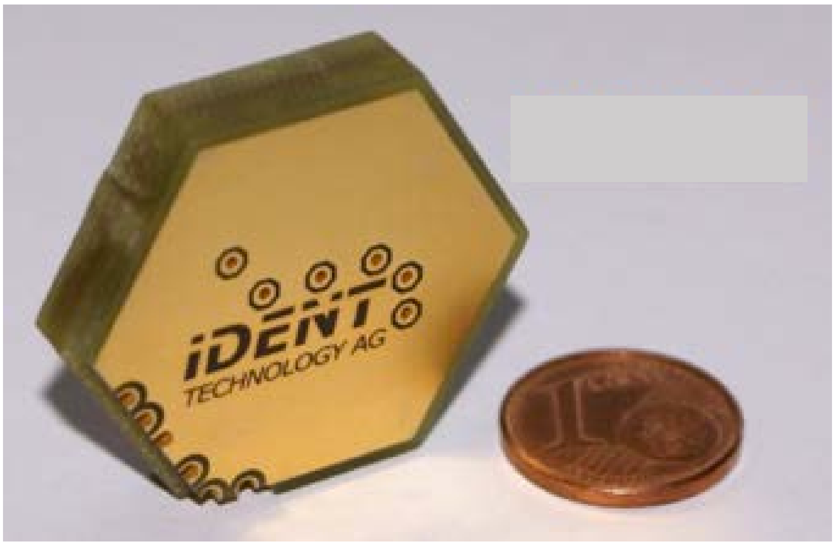

Fig. 12. **Proximity Sensor with 2 assembled inner layers and 90 integrated SMDs. All of the parts were made using PCB manufacturing technology and materials and the applied process is called AML developed by Hofmann Leiterplatten in Germany [2].**

The impact on innovation and embedding by the European Commission in Europe

To understand the opportunity for technical innovation, it is important to consider the markets the European industry in operating in. As countries operating under EU legal administration, it is important to adapt to the legal changes in Europe since the European Union was, in its present form, implemented in 1992. [11]

The 24 official languages in the EU can make communication difficult, but although about 20% of the population in Europe speak German, it is widely recognized that English is the language of business.[12].

In Europe, the German speaking counties represent a large section of the industrial production and it is recommended to communicate in the local languages. This is very important at the new electronics development stage when new products are being designed. In addition it is important to understand that electronic designers in many cases are not the printed circuit board designers. Printed circuit board designers do not know all the details required to design for manufacturing (DfM) and design for the end-use application where the final electronic device is used. To design for the best technical and most cost-effective solution, close co-operation in the supply chain is a major key for success. Here, a strong impact on cost is given by the fact that PCB solution can be manufactured locally during the development phase.

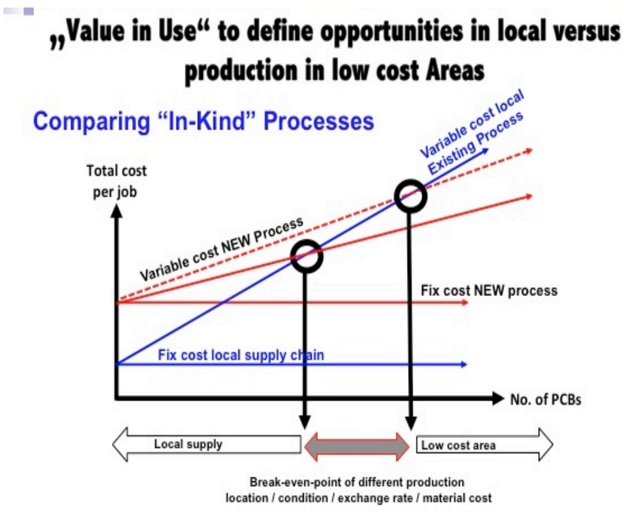

Fig. 13. **Small series of PCBs using an ‘In-Kind’ PCB technology are manufactured locally while large series are often sourced globally [10]**

It is a common practice that prototype and small series of PCBs are sourced usually at local PCB fabricators (Fig 13). Here good communications and technical know-how of the PCB fabricators are needed to manage an effective development cycle and to ensure that the electronic devices are working as specified. These development cycles have sometimes been seen as difficult, when language barriers and technological standards as well as different manufacturing standards are used. In the areas of industrial electronics, medical and avionics and space application, the quantities of PCBs that are required are small to medium. These run lengths can be cost-effectively manufactured in Europe. But when it comes to consumer electronics and automotive, the situation is different.

In the automotive field, much product development takes place in Europe, and therefore the prototype PCBs and the start-up production originates in Europe. When larger quantities of products are needed, and the PCB technical requirements are well covered by standards, low-cost manufacturing countries are chosen.

However, when the demand for the required units gets larger, the “In-Kind” PCB fabrication process may be changed against a “Not-in-Kind” (Fig. 14). Therefore it is important to understand that different technical solutions can adopt different manufacturing technologies. These are the following options:

- **Organic material solution (PCB)**
- **Ceramic material solution (LTCC)**
- **Silicon technology solution (SiS)**

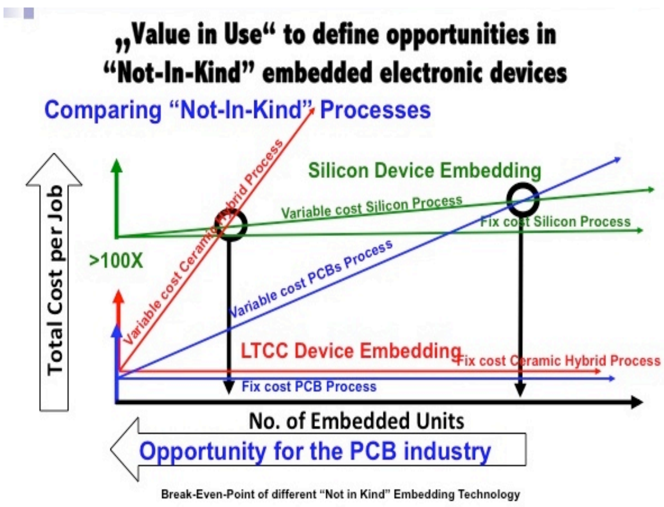

Fig. 14. **For large quantities, a “Not-in-Kind” Technologies may offer technical as well as cost benefits. In addition dimensional changes and miniaturisation are also key drivers for alternative technologies [10]**

Summary and outlook

New product developments require new ways to improve quality, miniaturization, and efficiency, including energy efficiency, and in many cases improved thermal management. **Device Embedding Technology in PCBs has a large potential to meet these future requirements.** However, PCB fabricators have to learn how to absorb and master the technology challenges not only in PCB fabrication and material selection, but also in assembly of devices, electrical and functionality testing, and end use application. In addition, the new IPC-7092 Design and Assembly Process Implementation for Embedded Components will help to develop the industry to get improved products with embedded devices.

In addition, PCB fabricators have to understand that the actual quantities of manufactured boards will determine the market opportunity for the printed circuit board technology. When quantities are large, as in the mobile phone or computer tablet business, the chip and the chip packaging industry will sooner or later work out a solution that takes this market segment away from the PCB technology (Fig 14).

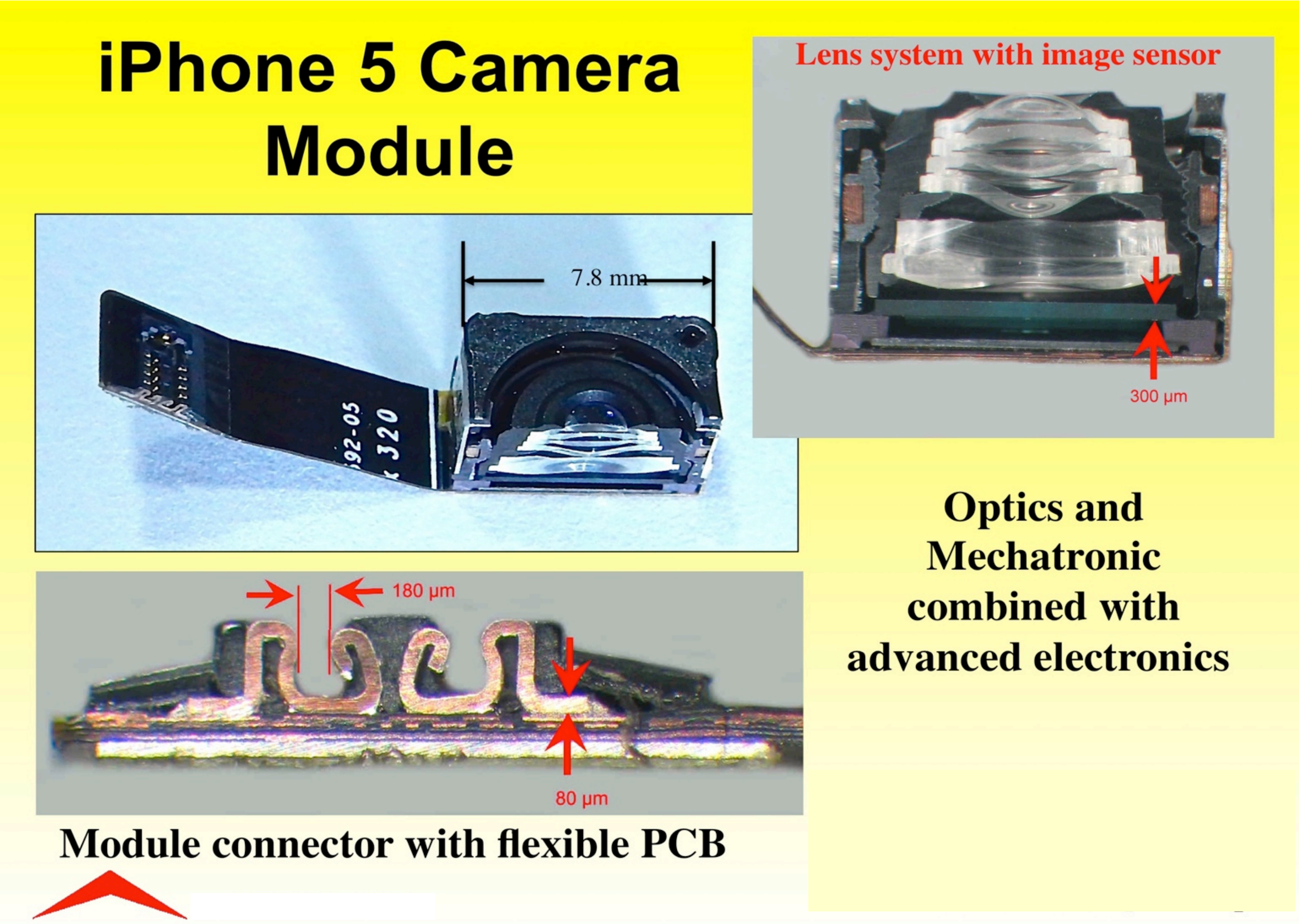

Fig. 15 Device embedding using PCB technology is shown on the iPhone camera module. Many other examples are used in the industry today but not shared for confidentiality reasons [13]

Based on historical information from the hybrid circuits industry in the '80s and from organic embedded device technology (e.g. SIMOV) in the '90s, the PCB industry has to encourage electronic designers to focus on many new developments in technology. This will stimulate demand in the area of small to medium PCB quantities, and, based on the cost structure of the PCB fabrication process, the production of small batch sizes should offer a good return for the PCB fabricators. For the semiconductor industry the start-up fixed costs are too high to focus on a small number of products, and therefore these market segments are of little interest to the chip and the chip packaging industry. In addition, many new designs require good engineering at the PCB fabricator and a good communication between the development engineers. Both must exist to ensure success.

Fig. 16 for new technologies like the embedding of components of devices a cooperation of the total supply chain is needed. Industry 4.0 is an example how this could be achieved. However, before this becomes reality, a cooperation of the partners in the supply chain form material to end customer will help to develop products that are needed by the industry and the consumer. Source: Hofmann Leiterplatten.

The HELP program [14] in Europe was one of the many examples that are ongoing to build sustainable processes for products of the future.

References

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[11] The detailed publication can be found at the internet: http://bookshop.europa.eu/en/agreement-on-the-european-economic-area pbRX7291568/?CatalogCategoryID=wJSep2Ix7TUAAAEwhSwlaWl7The reference number is as follows: Identifier: ISBN: 92-826-3445-0, Reference No.: RX-72-91-568-EN-C, Publication year: 1992.

[12] The European Union (EU) has more than 500 million inhabitants, who represent a large industrial and consumer market. The EU today has the third largest population after China and India.

[13] Mr. Hirotaka Ueda, of SemiConsult E-Mail: hi-ueda@msi.biglobe.ne.jp, Slide generated based on information provided by Michael Weinhold, EIPC and Mr. Hirotaka Ueda..

[14] The HELP project was a German government supported program of 4.9 Million €. See details under: http://www.help-hochtemperaturelektronik.de/

What is needed to Successfully Introduce "Device Embedding Technology" to Add Value to Your Products?"

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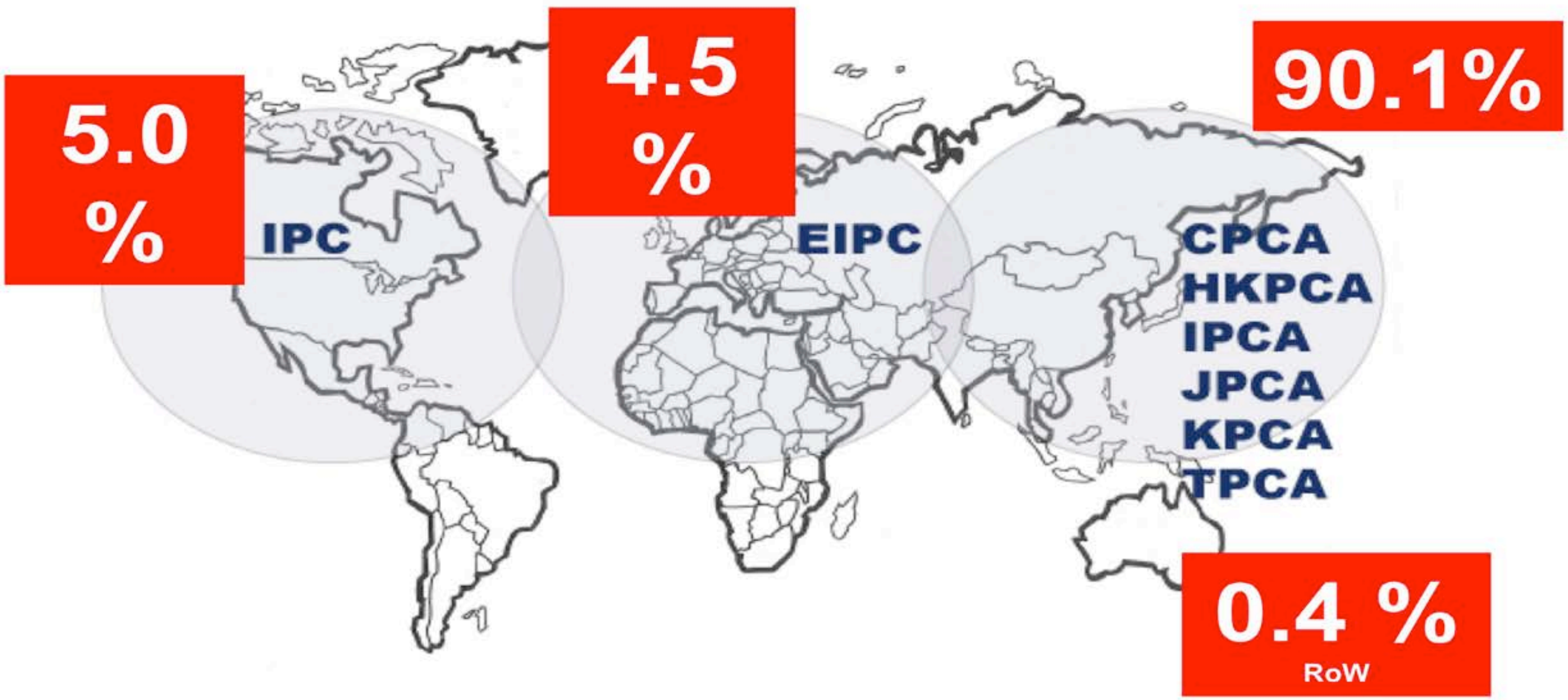
PRESENTATION OVERVIEW

- The global PCB market
- What Business we are in?
- Embedded technology in Europe
- What is the situation today
- What are the future projects?
- Define the route to success

PRESENTATION OVERVIEW

Total Global PCB Production in 2012: $60 Billion IPC 8/2013 / Custer consulting



What are the market drivers?

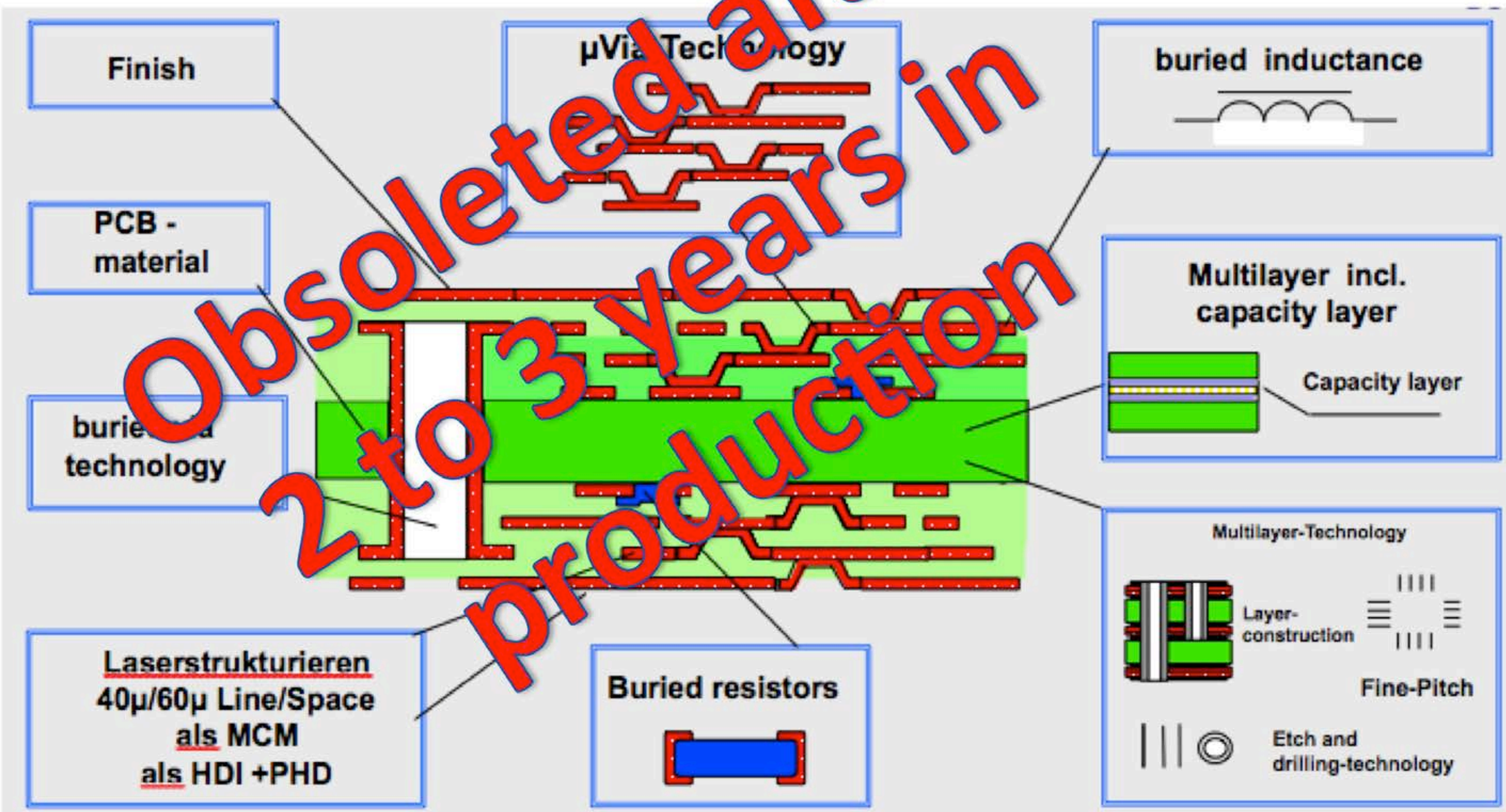
The potential to make money through:

- Innovative new electronic products
- Focused on large volume production
  - Using competence and existing know how
- Investing money and resources in future technologies and
- Target markets with growth opportunities

Device Embedding using LTC-Ceramic Hybrid Technologies

- **Used embedding since more then 30 years**
  - Very reliable in the field of High-Tech
  - Market size: Niche market
- **Reason for niche market application:**
  - Fast Design and Fabrication
  - High Rel product development possible
  - Use of embedding with standard components in small and medium quantities
- **Alternatives: Design on Silicon**
  - Takes longer time in design and tooling
  - Not cost-effective for small volume production (High NRE)

The SIMOV Technology developed by SIEMENS in Germany

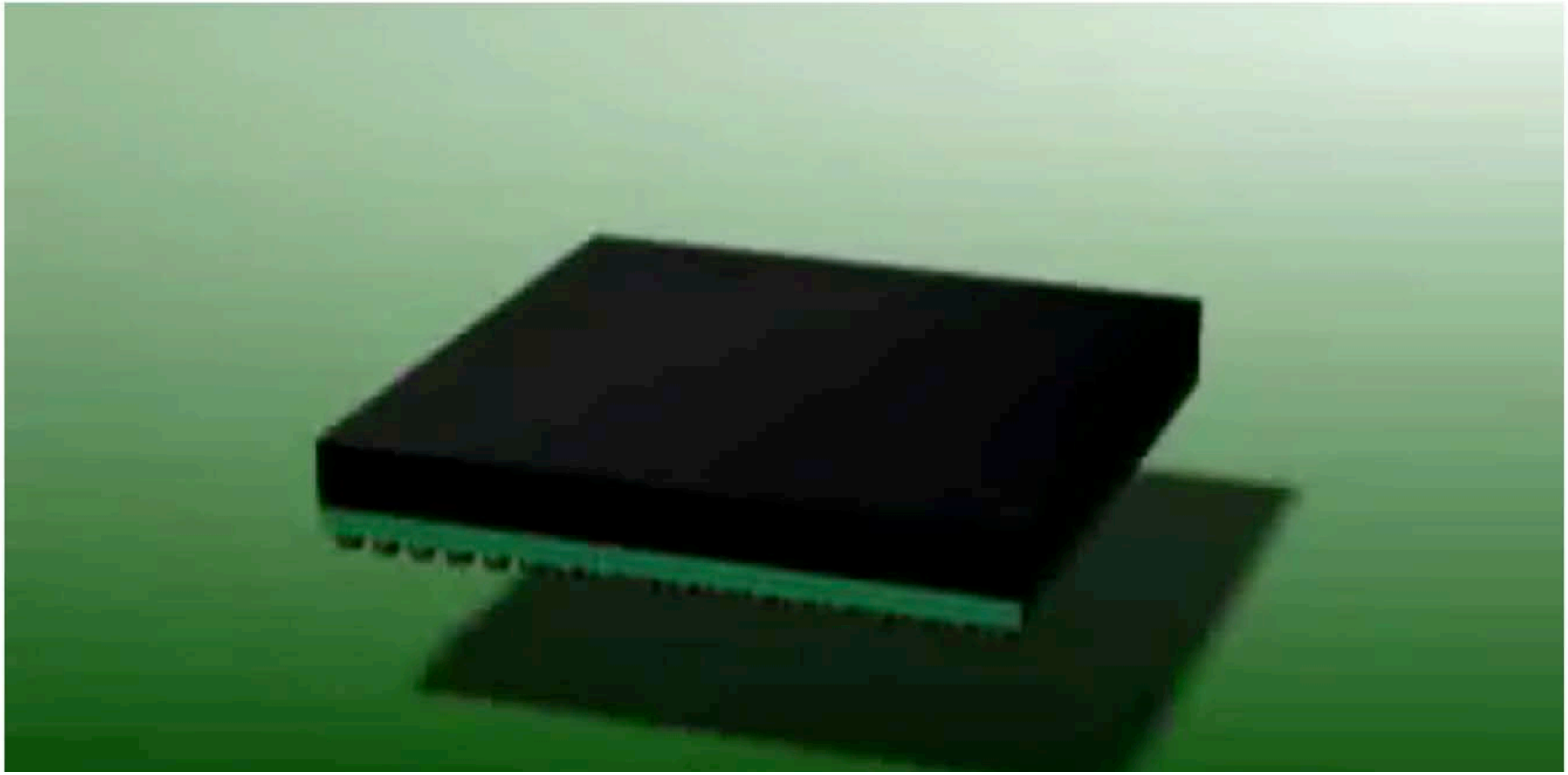


Technology developments

- Integration on silicon as enabling technology to reduce cost
  - Higher packaging density
- Advanced software developments
- Advanced packages
- New hard and software solution

Embedding Components in PCBs

by IMBERRA, means Miniaturization



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11	Broadcom	7,793	9%
12	Sony	5,709	-6%
13	AMD	5,422	-17%
14	Infineon	4,993	-11%
15	GlobalFoundries	4,560	31%
16	Nvidia	4,229	7%
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18	NXP	4,157	0%
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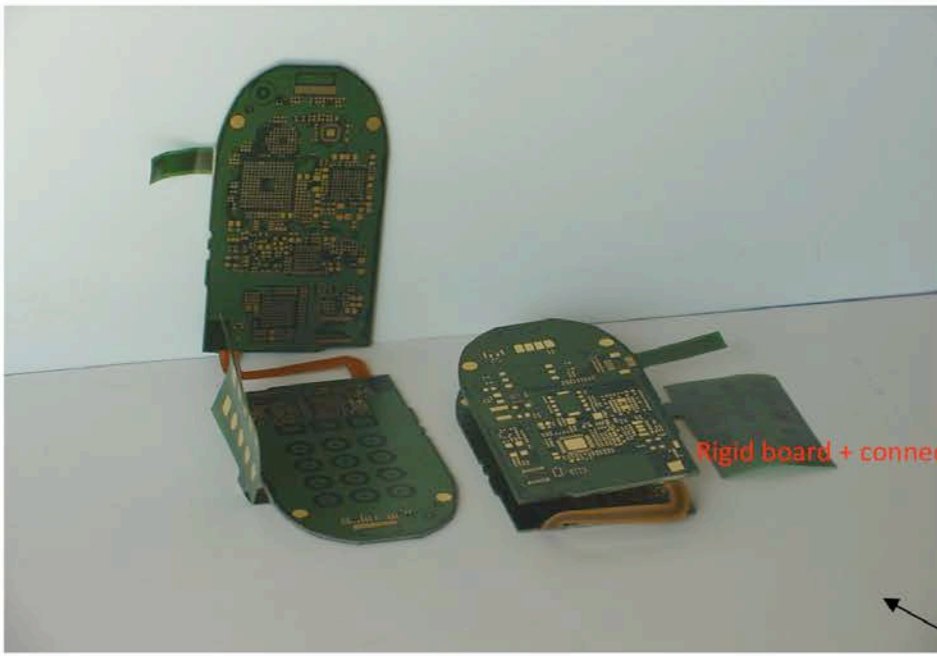
Source: IC Insights 3/2013

Traditional Flex vs. 3D HDI Intergrated Rigid –Flex Break-out V1.11



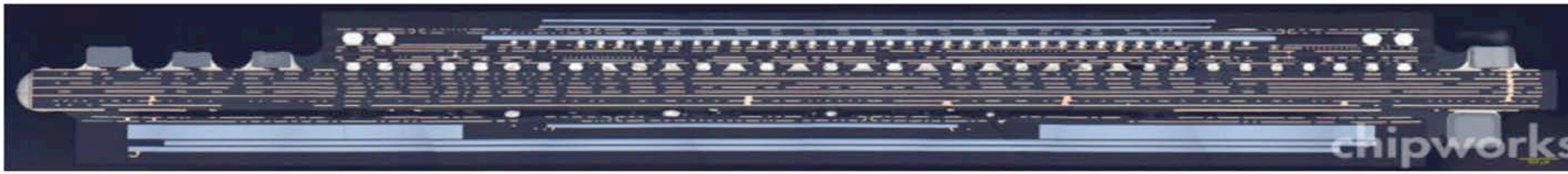
3D HDI Integrated Rigid-Flex Break-out

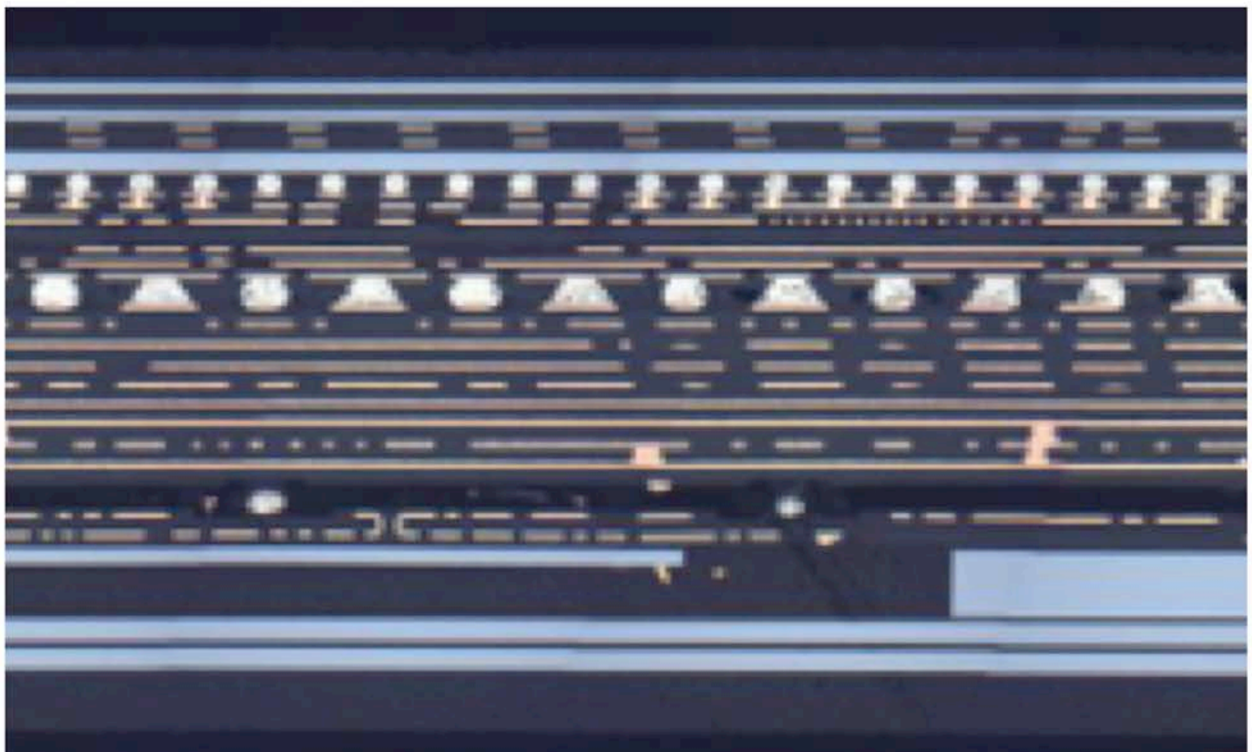
PWB made by 1st Licensee of Flex Circuit Connections: Wus, Taiwan

Source: Flex Circuit Connections; patent pending; available for licensing

Smart-Phone Technology evolution

Cross section of iPhone 5



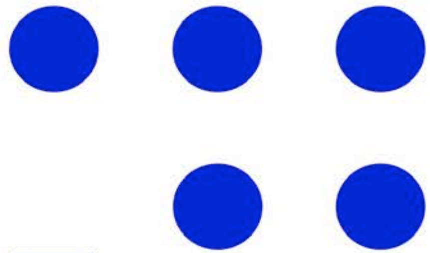


The PCB is the electro-mechanical interconnect of MCM and some discreet components

Is this Embedding Technology?

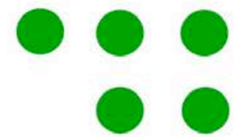
EU supported HERMES - Industrialization

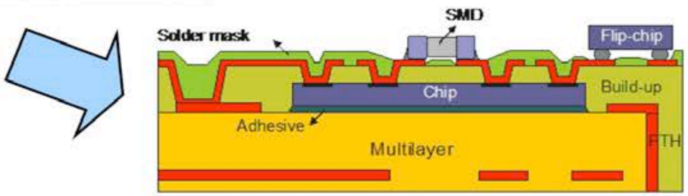
Industrialisation targets for chip embedding

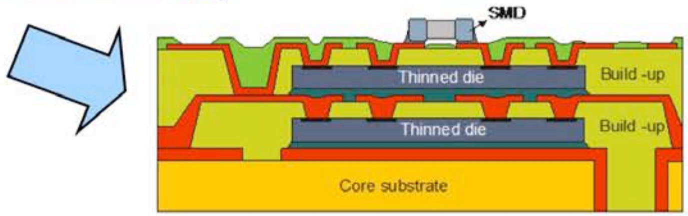


Device Footprint:

- 500um SMT BGA
- 250um Embedded Array
- 60um Peripheral Pad

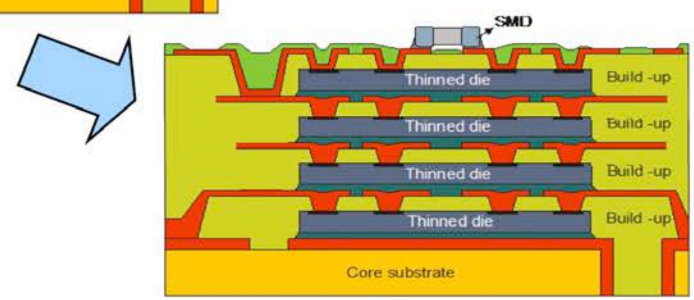






Chip stacking:

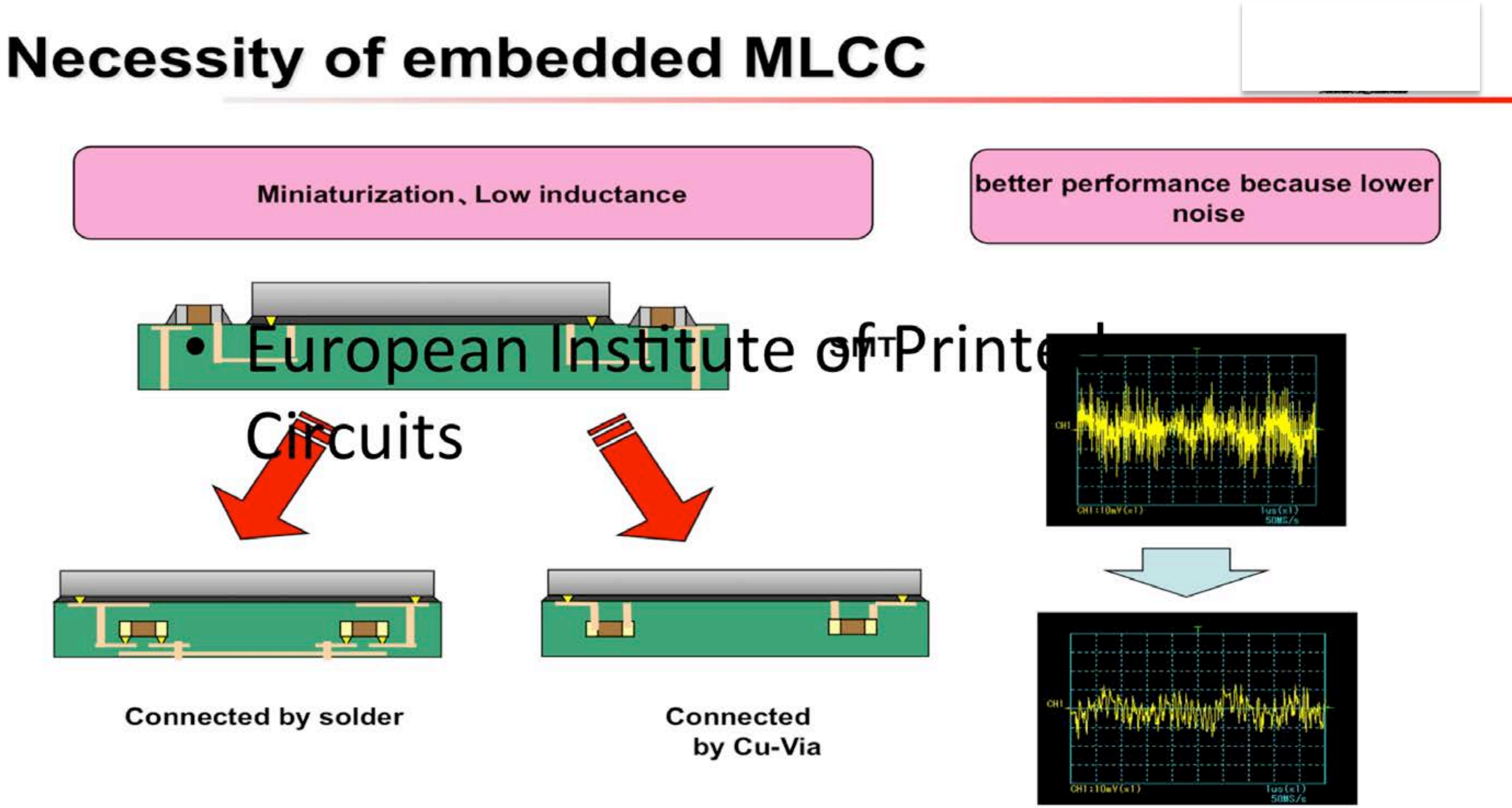
- SMT
- Single-layer embedded chip – Hiding Dies
- Two chips in stacked configuration
- Four chip layers



Courtesy of AT&S Johannes Stahr

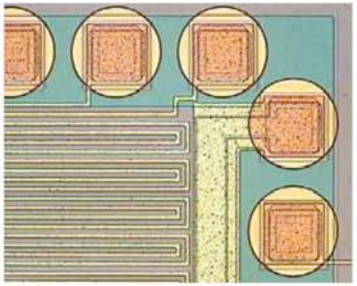
EU Options of capacitor placements

- European Institute of Printed Circuits



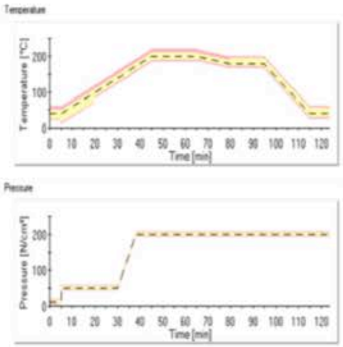
Reference: Murata Manufacturing Co. Ltd.

Chip in Polymer - Process

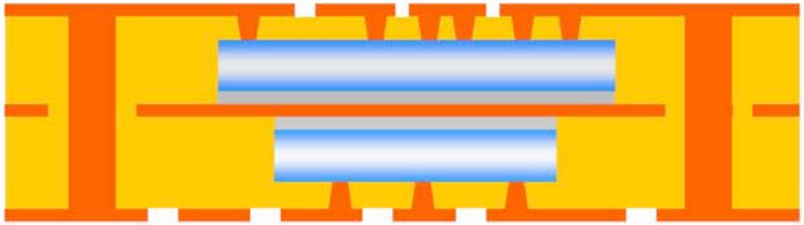


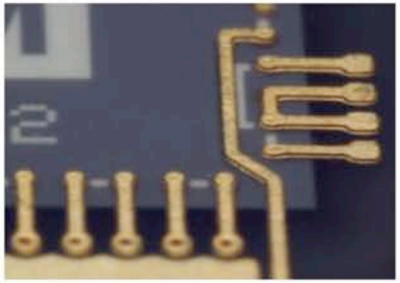
wafer preparation

die bonding

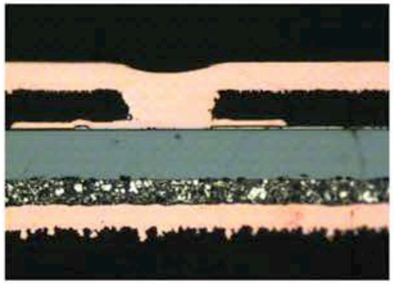


lamination

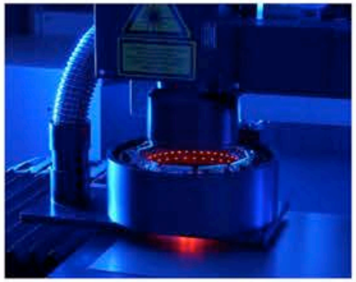




Cu structuring



via metallization



laser drilling

Source: IZM

For KRAFAS Project

Embedding technologies for 77 GHz Radar Module

Project Goal:

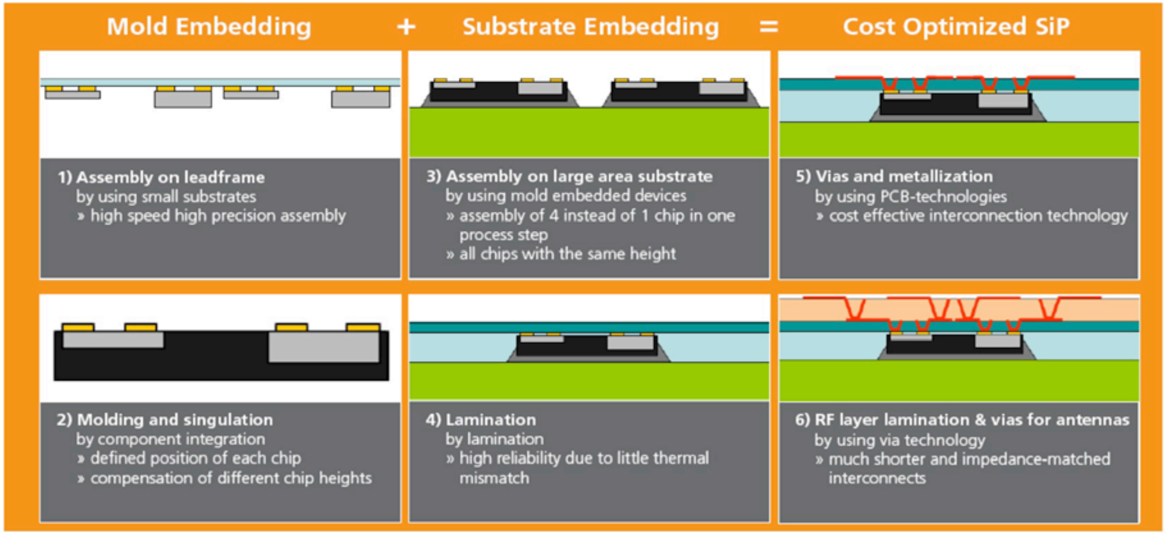
Development of a cost effective assembly technology for highest frequency RADAR applications

Technologies used:

Transfer Molding and Lamination to embed components – PCB processes to interconnect devices

Status:

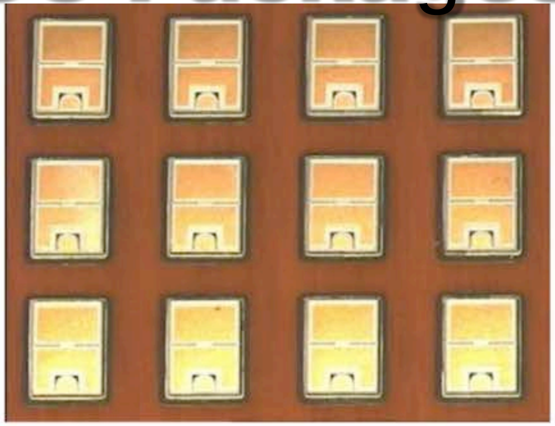
Embedded device achieved excellent performance at 77 GHz, superior to conventional interconnection technologies. Cost estimations show a 30 % cost reduction potential



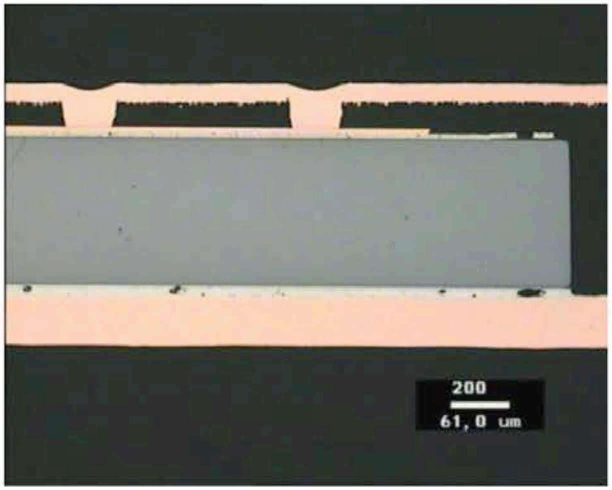
KRAFAS Process Flow

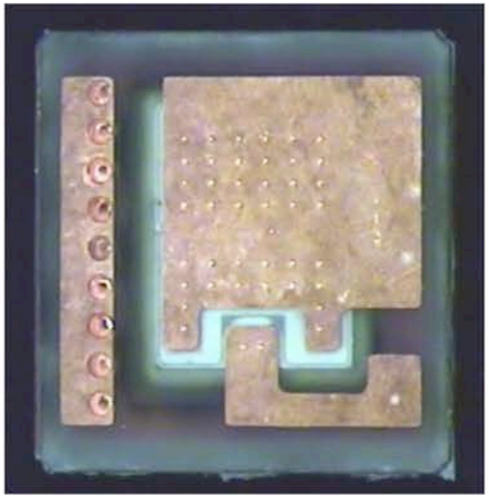
Courtesy of IZM Lars Böttcher

Embedded Power MOS Packages



- 200 µm thick package
- package outline 3.2 x 3.2 mm^2
- assembly like standard SMD

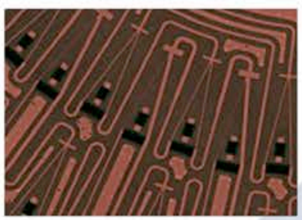


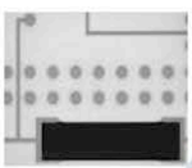


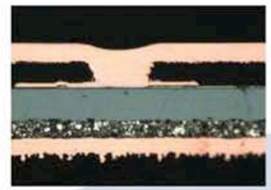
Courtesy of IZM Lars Böttcher

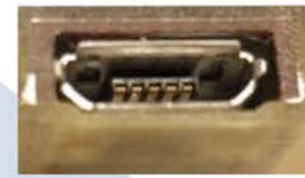
In co-operation with NXP

Development of PCBs with embedded components









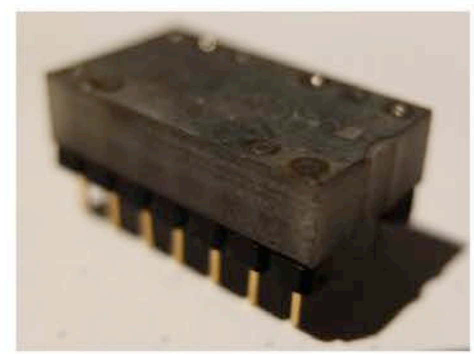
1960er
Thick film Resonator on inner layer

1970er
OhmegaPly®
sheet resistance in multilayer

1990er
Aktiver Multi Layer (AML)
SMD components in ML

2000er
Bare dies in multilayer

2011
Connectors in multilayer



One of the first AML (1995)

Source: Hofmann Leiterplatten.

Thermal Conductivity of Materials used in Electronics

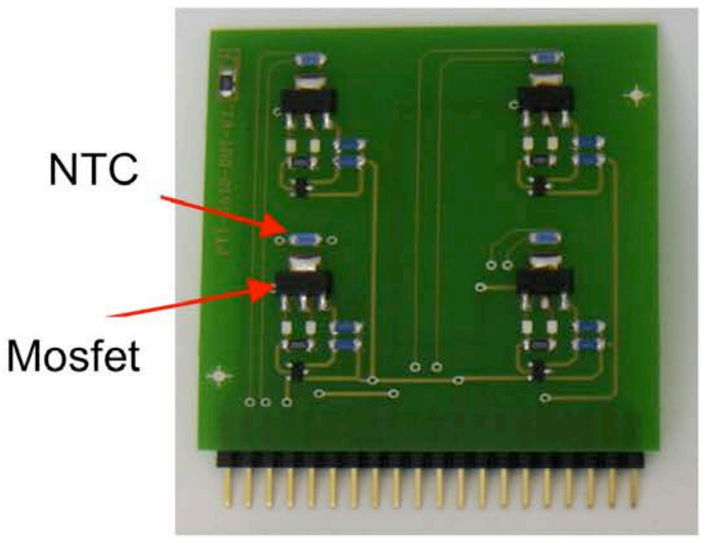
Material	Thermal Conductivity in W(m/K)
Acrylic	0.2
Air	0.024
Aluminum	250
Copper	400
Epoxy	0.35
Glass	1.05
PTFE	0.25
Silicon	149
Water	0.58

Source: Alun Morgan, ISOLA. Presented at the EIPC Conference on May 3-4, 2011

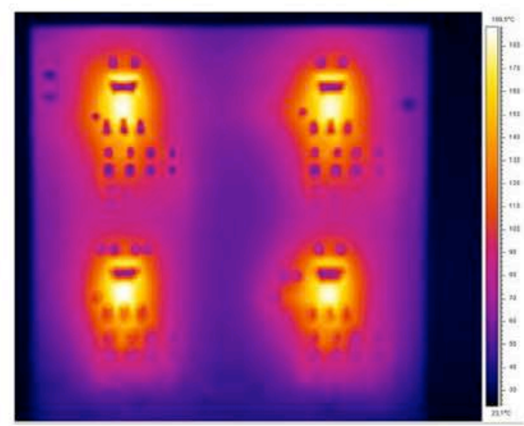
Thermal properties of PCBs with embedded devices

Experimental setup I:

Standard FR4 PCB, 1.5 mm, 2s PTH, without additional Thermal via
PCB Dimension: 54 x 62 mm
4 x Mosfet with each 1,5 W power operated = overall performance 6 Watt



Temperature am NTC: 110°C

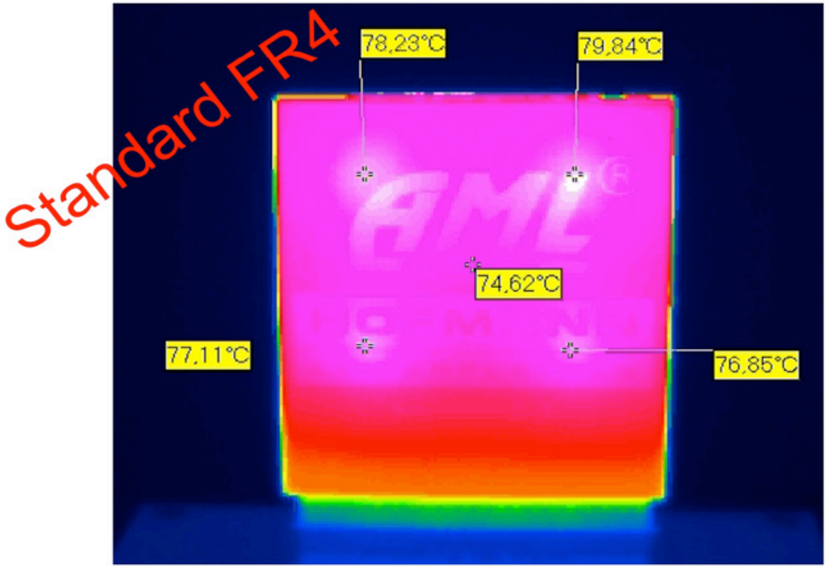


max. temperature: 188.5 °C
Poor temperature distribution => **Hot Spots**

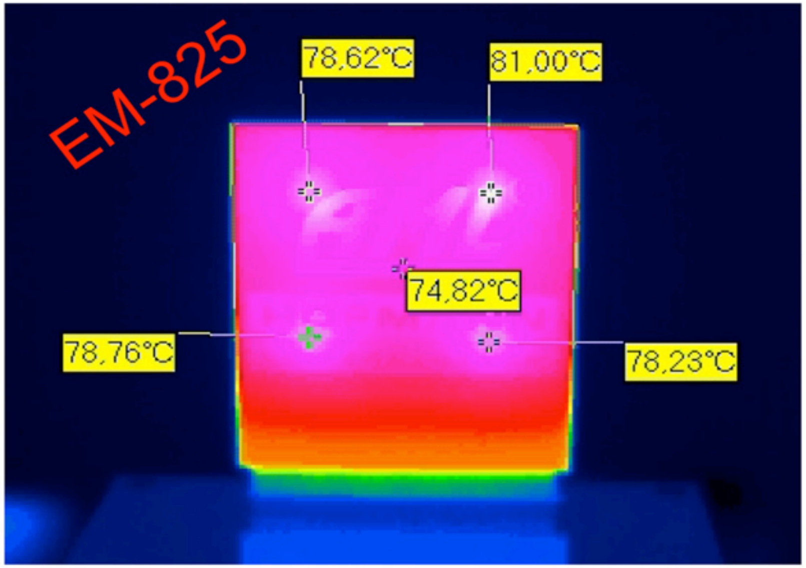
Source: Hofmann Leiterplatten and EIPC.

Thermal properties of PCBs with embedded devices

Experimental setup IV:Experimental setup.
Without additional Thermal Vias, with Heatsink 2,0 mm (mounted on PCBs back).
PCB dimension : 54 x 62 mm
4 x Mosfet with 1,5 W power consumption = total power 6 Watt



max. outer temperature: 79,84°C
max. inner temperature: 83,30°C



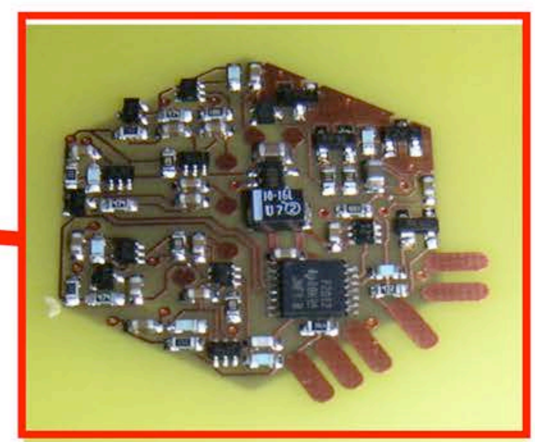
max. outer temperature: 81,00 °C
max. inner temperature: 82,60°C

excellent temperature distribution => no Hot Spots

Source: Hofmann Leiterplatten and EIPC.

Requirements to assemble embedded layers

- Use lead free solder technology and suitable laminate materials
- Gluing with adhesives or low temperature sintering
- Cleaning of assembled inner layer
- Allow for stress free handling of assembled inner layers
- Insure proper testing after placement, soldering of inner layers and cleaning (AOI and functional E-Testing

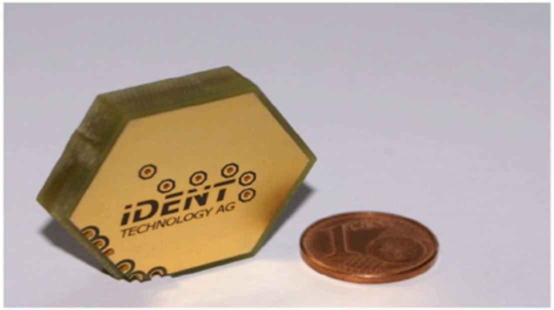


Source: Hofmann Leiterplatten.

Benefits of Embedding

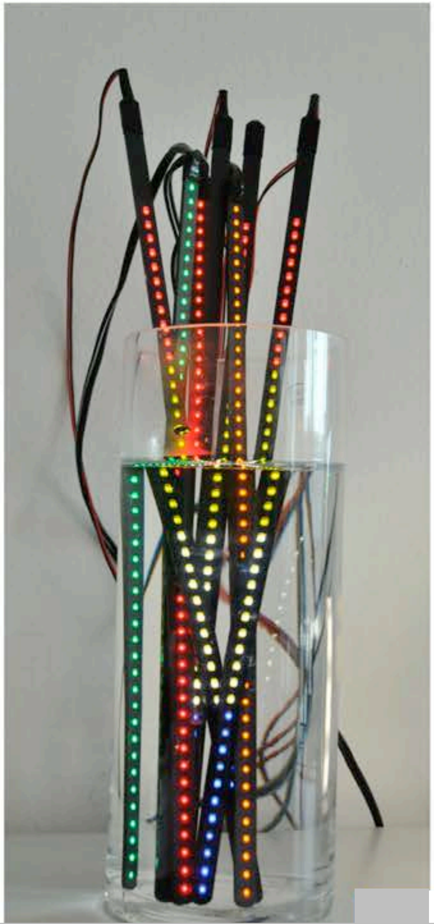
Devices in PCBs as “System in PCBs” = “SiPCB”

- **Standard processes for production SiPC-Boards**
  - Standard SMD assembly process
  - Standard PCB production process
  - Standard and tested PCB materials
- **Improved thermal management of components**
  - Better thermal connection of the components
  - Lower component temperatures
  - Longer lifetime of components
- **Benefits of embedded components**
  - Longer lifetime of electronics
  - Better thermal management of electronics
  - No special device housing (case) needed



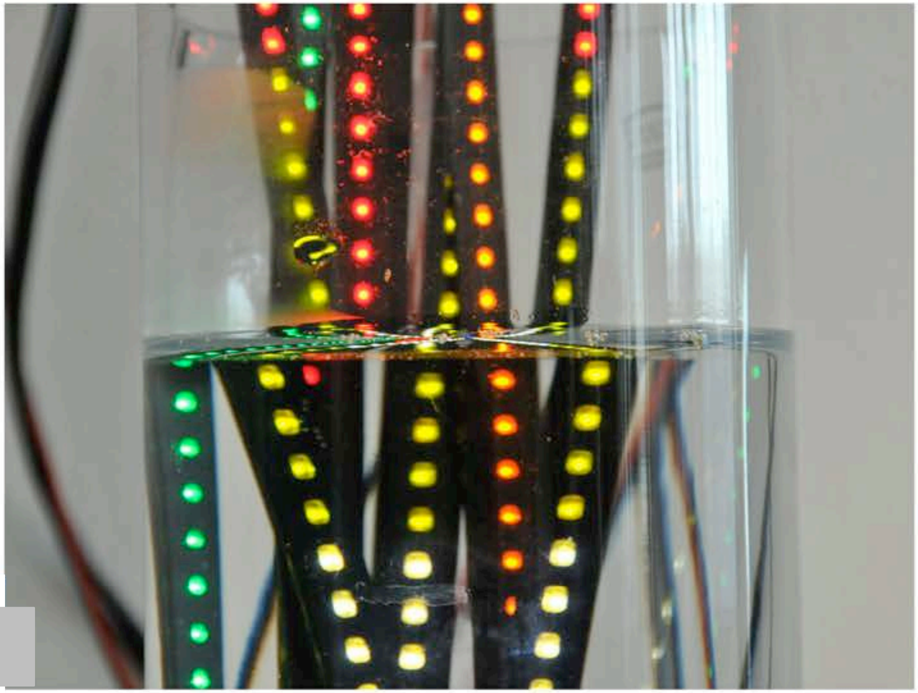
Source: Hofmann Leiterplatten and EIPC.

Embedding of Components is not NEW in Germany



Embedding components and LEDs by Hofmann Leiterplatten GmbH, Germany

has patens since the mid 90^{th}



Source: Hofmann Leiterplatten

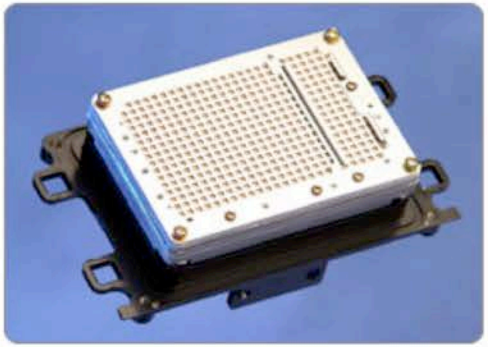
Long Range Sensors

Bosch LRR3

TRW AC100

Hitachi MMW Radar

Delphi RSDS



Denso MMW Radar

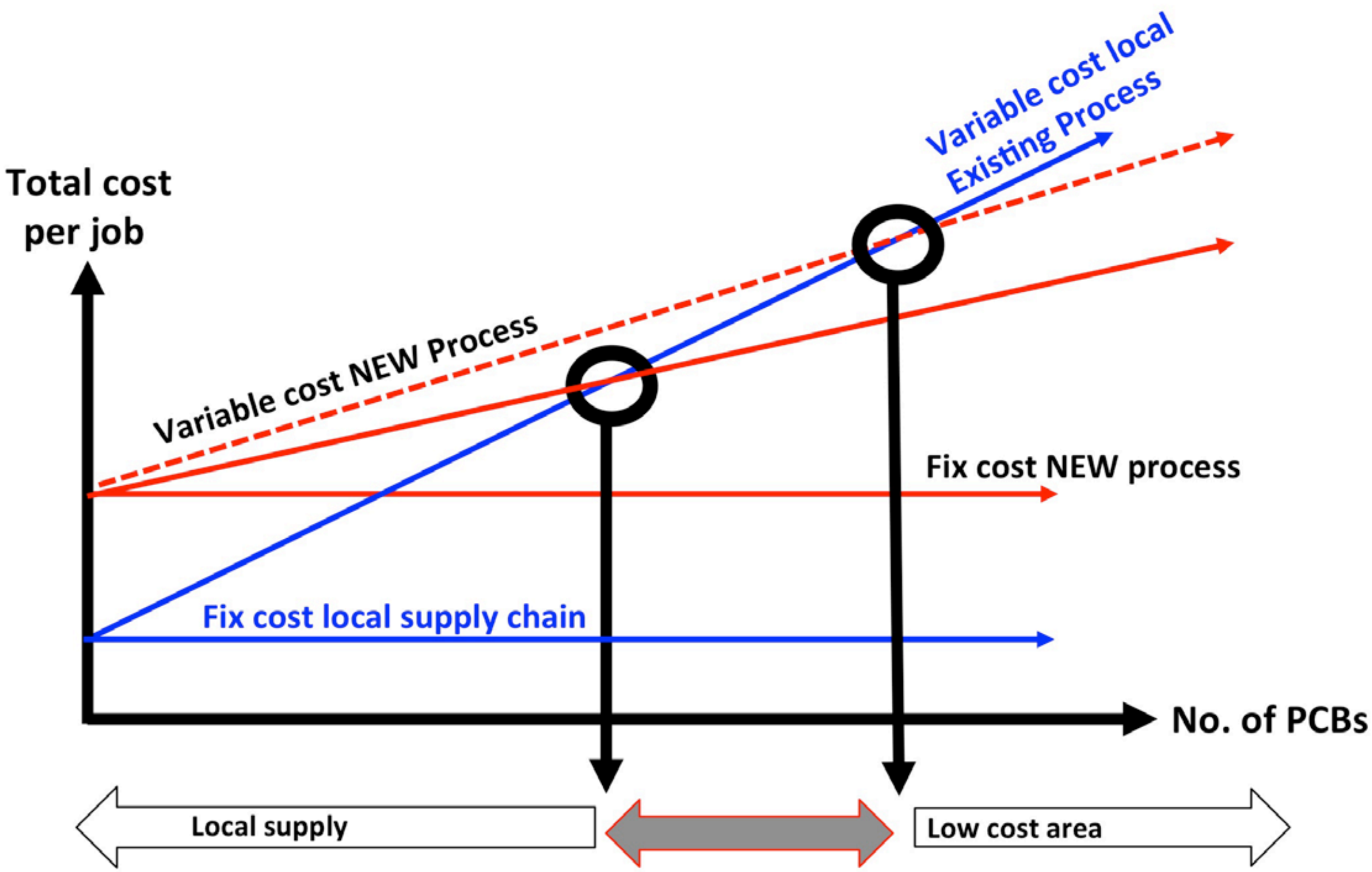
Conti ARS 300

Fujitsu Ten LRR

Mitsubishi Melco Prototype

„Value in Use“

to define opportunities in Device Embedding PCB technology

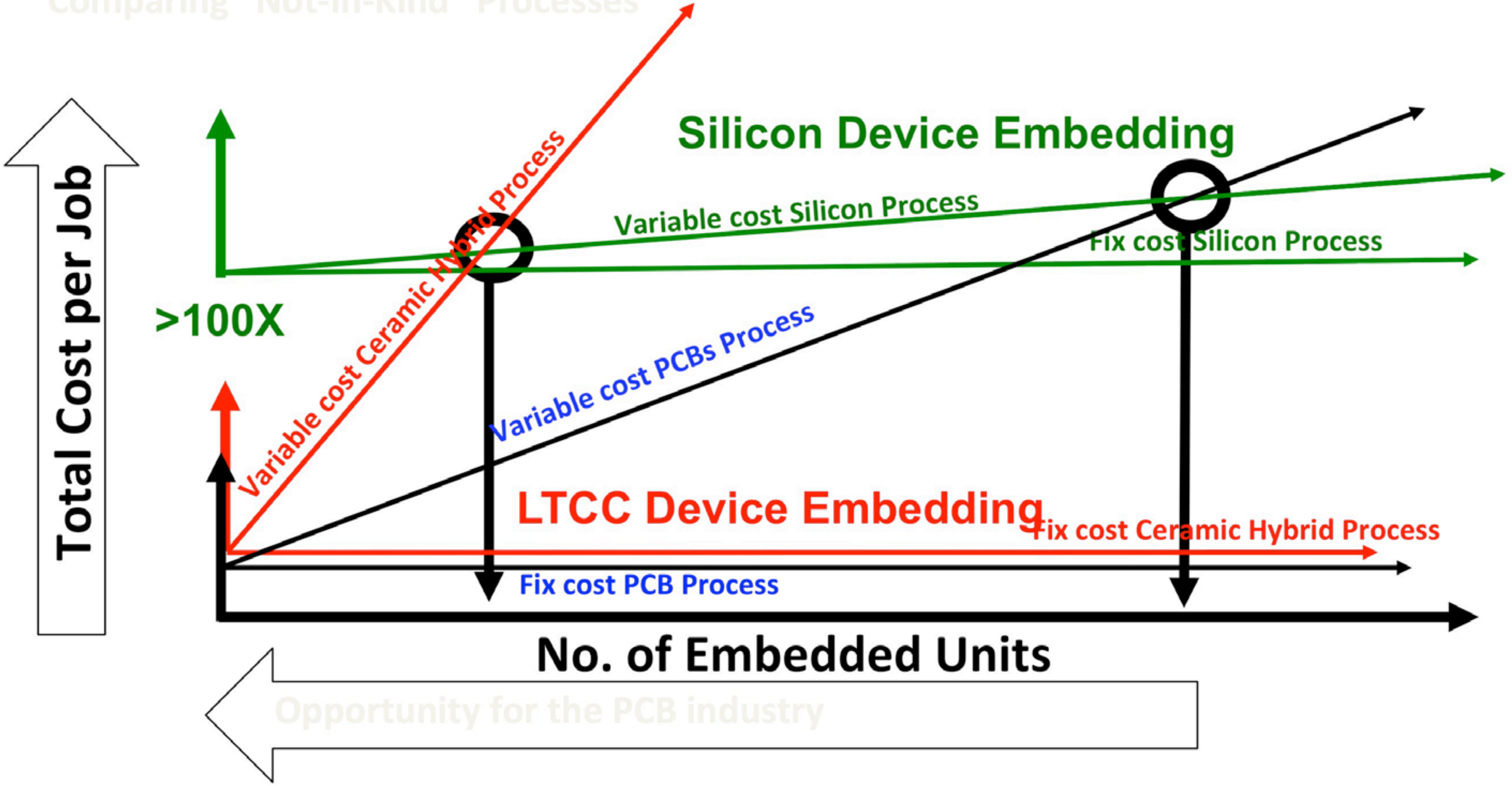


Break-even-point of different production location / condition / exchange rate / material cost

„Value in Use“

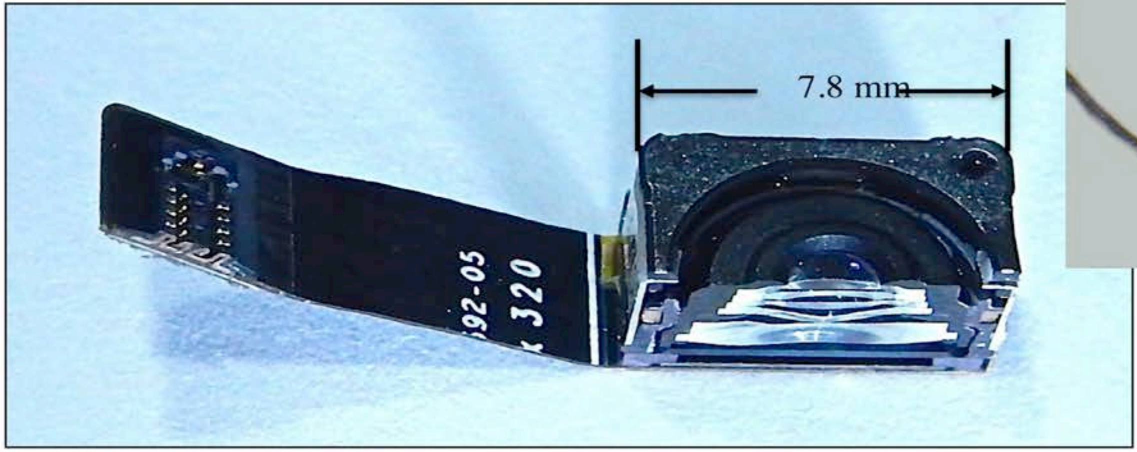
to define opportunities using “Disruptive” Technologies

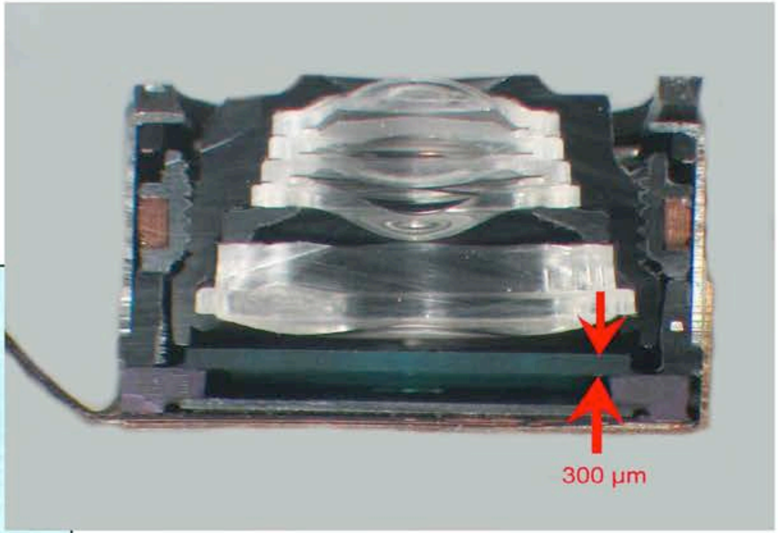
Comparing “Not-In-Kind” Processes

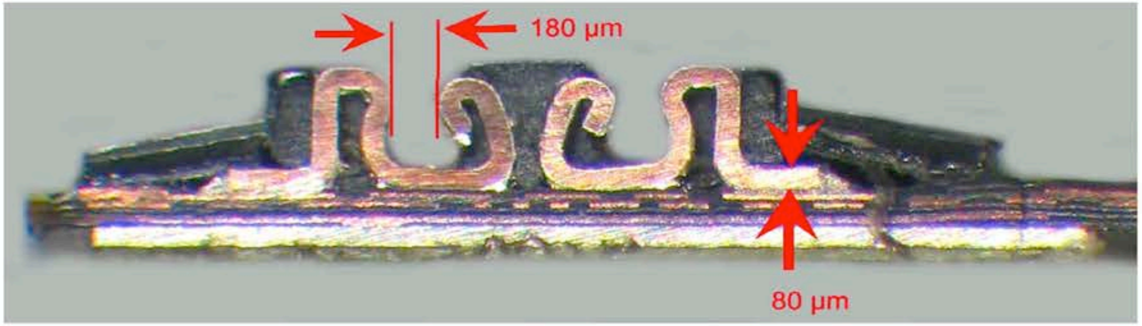


Break-Even-Point of different “Not in Kind” Embedding Technology

iPhone 5 Camera Module







Module connector with flexible PCB

Optics and Mechatronic combined with advanced electronics

Source: Hirotaka Ueda, SemiConsult, Japan.

Outlook and Summary

- **Embedding of passive and active components in PCBs have great potential! Why?**
  - ✧ Enable innovative Mechatronic-Solution through design for manufacturing
    - Reduce cost through miniaturization
    - Improve performance
    - Increase reliability
    - Reduce the BOM for advanced electronics
    - Helps to make electronic devices more environmental acceptable
- **Electronic Designers have to learn how to use the PCB technological benefits for new products**

Outlook and Summary

- **Time to market versus Cost:**
  - PCB design is a very fast way to market
  - It is a cost-effective fabrication technology for embedding components (devices) in PCBs at high first pass yield

Remember: When quantities are large: The silicon solution will be selected and implemented.

Many design changes will keep run length short!!!!! > BUSINESS for PCBs

Thank you for your attention

- **Also Thanks for the support of the electronic industry.**
  - **Thomas Hofmann of Hofmann Leiterplatten GmbH**
  - **Alun Morgan of ISOLA**
  - **Lars Böttcher of IZM, Berlin**
  - **Johannes Stahr of AT&S, Leoben**
  - **Walter Huck of Murata, Germany**
  - **IC Insights 3/2013**
  - **Siemens Karlsruhe,**
  - **WECC for Market data**