High End PCBs
Empowering your products with new integration concepts and novel applications

Markus Leitgeb
Programme Manager, R&D
Driving Trends in Electronic Industries

Our Environment Changes

- Changing geographic markets
- Growing population, changing age structure
- New application areas arise (e.g. Intelligent environment, E-mobility)
- Increasing demand for raw materials

Trends in Electronics

- Eco Impact
  - Shortage of resources
- Miniaturization
  - Smaller; Faster; Smarter
- Total connectivity
  - People, Machine 2 Machine, etc.
Long Term Developments

2012

“Shy Tech”
Electronic modules are “ready to use” integrated in the surrounding.

“High Tech”
Electronic devices are stuffed with components

2020`s

Personal Computers will achieve one human brain capacity by about 2020. By the 2030s, the non-biological portion of our intelligence will predominate.

(Ray Kurzweil)
Modular Concepts drive Miniaturisation and Integration

"Electronics becomes part of the device rather than being the device"

Yesterday

Today

Tomorrow

Major Impact on Design Chain:

Sequential Design

Concurrent Design
## Development in AT&S

### AT&S PCB Technology Road Map

<table>
<thead>
<tr>
<th>Year</th>
<th>PCB</th>
<th>Technical Development</th>
<th>min. L/S [µm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Multi Layer</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>1998</td>
<td>Micro Via</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>2005</td>
<td>Any Layer</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>2010</td>
<td>Advanced Packaging</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>2014</td>
<td>Anylayer +</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>2016</td>
<td>Substrate</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Future</td>
<td>All in one Package</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Development in AT&S: Based on strategic targets and driven in 4 Key Development Areas

New Products

Key Development Areas

Interconnect Density
Mechanical Integration
Functionality Integration
Printed Solutions

Strategic Targets

Miniaturization
Integration Concepts
Eco-Friendly Products
AT&S Innovation

Miniaturization by
2.5D®C and ECP®

Novel Component Packaging Concepts for Various Applications
Miniaturization – 25D®C

© Registered Trademark AT 257759

2.5DC Cavity
- No limitations in base materials (e.g., High Frequency, High Tg, halogen-reduced, …)
- No limitations in shape and depth of cavity
- Surface finishes in cavities (e.g., ENIG, OSP, …)
- Several depths can be achieved in 1 card
- Solder mask in cavity
- Fan out of assembled layer with vias
- Excellent reliability performance

2.5D® Pipe
- Lateral non-conductive connection
- Transport of gas through the PCB

2.5DR Rigid-Flexible
- Combination of FR4 and/or Polyimide materials
- No baking process prior to assembly needed for FR4 build up
- High miniaturization potential for Polyimide build ups
- Symmetrical build ups
- Proven reliability for Flex-to-install applications
- HDI Design guidelines
Miniaturization - 2.5DC - Cavity Formation

Motivation for Cavities

Reduced thickness of an assembled device by recessing “thick” components

Advantages of 2.5DC

- No limitations in base materials (e.g., High Frequency, High Tg, …)
- No limitations in shape and depth of cavity, different depths in one cavity
- Surface finishes in cavities (e.g., ENiG, OSP, …)
- Solder mask in cavity
- Fan out of assembled layer with vias
- Excellent reliability performance
2.5D®C – Cavity Formation

Samples

12 Layer anylayer PCB
6 different cavity depths
Soldermask in cavity
Why embedding?

Trends and challenges in electronics

- More functions
- Smaller devices
- Short cycles design-to-market
- Increased component population
- Fragile components
- Supply chain complexity
- Increased cost of high-end IC design
- Less power
- Increased clock frequency
- Thermal management
Why embedding?

Advantages of embedding offer a solid solution

- More functions
- Smaller devices
- Short cycles design-to-market
- Increased component population
- Fragile components
- Increased cost of high-end IC design
- Supply chain complexity
- Less power
- Increased clock frequency
- Thermal management
- Reliability
- Miniaturization
- Ease-of-use
- Performance

High End PCBs / Markus Leitgeb
What is Embedded Component?

Embedding uses the space within a substrate for active and passive components.

ECP® is the leading embedded component technology.

Components are embedded inside an organic substrate / PCB core by a combination of:
- Component Assembly, Component Packaging, PCB Manufacturing

1. Die Placement
2. Lamination
3. Structuring

Subsequent HDI / ML build up optional
What it looks like … #1

1) 0402 resistor, capacitor
2) 0402 resistor
3) Active component
4) 0402 resistor

High End PCBs / Markus Leitgeb
Component requirements

Wafer-based embeddables
- Pad finish: Cu plating needed for contacting with microvias = existing process for WLP components
- Pad pitch: adaptation to organic substrate design rule through RDL
- Wafer thinning: 100-150µm

Passive discrete embeddables
- Use of thin components with copper terminations
- Capacitors and resistors available
- Other discretes (inductors) also in development
- Component thickness 100µm – 220µm
- Case sizes 0201; 0402; above
Production facility

AT&S Advanced Packaging

<table>
<thead>
<tr>
<th></th>
<th>Clean room Class 100K</th>
<th>Clean room Class 10K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Manufacturing</td>
<td>3,000 m²</td>
<td>1,200 m²</td>
</tr>
<tr>
<td></td>
<td>200 m²</td>
<td></td>
</tr>
</tbody>
</table>

- Dedicated Production Facility
- Production area 100% ESD protected
“We are audited and approved to the highest standards. ECP® is ready for your requirements today”

- **Units shipped:** >40Mio
- **AT&S Yield:** >99.5%
- **Field returns:** 0
Automotive Power Module

- Higher current application (30A)
- 4 embedded MOSFETs with double side interconnection
- Logic devices and passives mounted on top
- 50µm dielectric thickness
  - Reduction of thermal resistance
  - High breakdown voltage
  - 50% footprint reduction
Engine Control Module

- High end automotive application
- Embedded processor - 416 I/O
- Stacked copper filled via
- 25µm line/space on all layers
- Active and passive SMDs
- 3D routing from front to back

Fanout over embedded processor using organic substrate redistribution
Radio Frequency
20-80GHz
RF Products

- Automotive Radar / Sensor
- Blind Spot Detection (BSD)
- Commercial Airline Collision Avoidance Systems
- Adaptive Cruise Control (ACC)
- Global Positioning (satellite antennas)
- MM Wave Radio
- W-Lan Network
- Satellite Communication
- Space satellite transceiver
- Airborne and ground based radar systems

GHz:
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
Mixed Microwave and Digital Multilayer PCB for High Density Applications

Innovation:
Integrated Frequency Filters
with organic low Dk/Df materials

- HDI, fine pitch BGA & RF application on same board
- Validation of the structure; assembly and repair process development; electrical tests; reliability estimation.
- Customer oriented development and manufacturing of a cost competitive Product

➢ Challenge: develop a Multilayer organic PCB
  Substrate integrated Waveguide vs. LTCC / PTFE
RF 80 GHz - Material & Process qualification

- HDI, fine pitch BGA & RF application

- Materials with particular RF properties
  - Low Dissipation factor (Dk, Df…)
  - PTFE, LCP, PTFE-PI

- Process Evaluation
  - Plated Through holes
  - Micro Vias
  - Solder mask Adhesion
  - Surface adhesion...

- Validation of electrical & RF performance; reliability estimation.

- Customer oriented development and manufacturing of a cost competitive Product

➤ Challenge: Material rules for RF Apps
  Material guideline meets RF application / Frequency area
Radio Frequency from LAB to FAB

Customer requirements
Product application Specifications

1. Material Selection & Characterization
2. Layout Concept
   Stack Up / Design
3. Simulation
4. Manufacturing
5. Test procedure
   Validation
   Reliability Tests
Thermal Management
Enhanced Build-Up Concepts
Thermal Management

MATERIAL

Thermal Vias

Thick Copper

BUILD-UP

Cavities

IMS

DESIGN

HSMtec

Thermal Vias

Thermal path

High End PCBs / Markus Leitgeb
Thermal Vias

Cu-filled Vias

Hole diameter: 100µm - 150µm
Dielectric Thickness: 100µm - 200µm
FR4 with high Thermal Conductivity

Comparison of available Materials

- Panasonic R1577
- Panasonic R1755V
- Panasonic R1755M
- Panasonic R1566W/WN
- Hitachi 679FG(S)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tg [ºC]</th>
<th>T.C. [W/mK]</th>
<th>CTE-xy [ppm]</th>
<th>CTE-z [ppm]</th>
<th>Dk (1 MHz)</th>
<th>Df (1MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panasonic R1577</td>
<td>170</td>
<td>1.0</td>
<td>16-18</td>
<td>20-30</td>
<td>5.3</td>
<td>0.013</td>
</tr>
<tr>
<td>Panasonic R1755V</td>
<td>148</td>
<td>1.3 to 1.5</td>
<td>15-17</td>
<td>24</td>
<td>5.7</td>
<td>0.011</td>
</tr>
<tr>
<td>Panasonic R1755M</td>
<td>No data</td>
<td>1.0</td>
<td>no data</td>
<td>39</td>
<td>5.6</td>
<td>no data</td>
</tr>
<tr>
<td>Panasonic R1566W/WN</td>
<td>140</td>
<td>1.5</td>
<td>no data</td>
<td>39</td>
<td>5.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Hitachi 679FG(S)</td>
<td>120</td>
<td>2.0</td>
<td>no data</td>
<td>39</td>
<td>5.3 (1Ghz)</td>
<td>0.008</td>
</tr>
<tr>
<td>Panasonic R1566W/WN</td>
<td>138</td>
<td>1.0</td>
<td>no data</td>
<td>30</td>
<td>6-7</td>
<td>no data</td>
</tr>
<tr>
<td>Panasonic R1566W/WN</td>
<td>120</td>
<td>2.0</td>
<td>no data</td>
<td>30</td>
<td>5.2</td>
<td>0.015</td>
</tr>
<tr>
<td>Panasonic R1566W/WN</td>
<td>9-13</td>
<td>no data</td>
<td>no data</td>
<td>39</td>
<td>6-7</td>
<td>5.2</td>
</tr>
<tr>
<td>Panasonic R1566W/WN</td>
<td>30-50</td>
<td>no data</td>
<td>no data</td>
<td>39</td>
<td>5.2</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Thermal Conductivity Trends

Thermal Conductivity vs. Dk-Value

High End PCBs / Markus Leitgeb
IMS – Insulated Metal Substrate

IMS at AT&S

- **Base Layer:** Aluminum (1, 1.5, 2, 3 mm)
- **Insulation Layer:** Thermally conductive insulation material (0.5 – 8.0 W/mK)
- **Layout Layer:** Copper (35, 70, 105 μm)

- **DS PTH FR4 pressed on AL**
- **Al Core with Insulation layers and PTH**

High End PCBs / Markus Leitgeb
**Integration of Cu-wires and Cu-profiles** into PCBs for high current and thermal management issues

**Cooperation** between Häusermann GmbH and AT&S AG since Sep. 2009

**Advantages:**
- High current in extremely small spaces
  - Space can be saved
  - Weight can be saved
- Improved thermal management
- Integration in standard FR4 material => standard PCB-production process
- Examined, approved technology
Cavity boards

- Enhanced thermal management
- Protection of components
- Advanced cavity technology
- Combination of different PCB-materials
- Miniaturisation
- Reduced module costs

High performance material

Very high thermal conductivity
AT&S – Well Positioned for the Future