Advanced Embedding Technologies – Core Process for Panel Level Packaging

Klaus-Dieter Lang
Outline

- Introduction
- Future System Integration
- Embedding Technologies of Actives and Passives
- Modular Electronics based on Embedding Technologies
- Conclusions
Characteristics of Smart Systems

Integration of Different Functionalities
- such as sensors, actuators, photonics, signal processing, data transmission, power supply
- with a high degree of miniaturization
- and flexibility
- at reasonable costs

in a Package, that
- bridges the Gap between Nano-Electronics and Application
- is adopted to the application environments
Technology Background for Smart System Integration

Application Environments

System Integration

Heterogenous Integration

Requirements

Technology

Macro Systems

SoC

Micro Systems

More Moore
Nanoelectronics

Nanoelectronics

Microelectronics

More than Moore
(Nano) Electronics + Sensors & Actuators (e.g. Opto-/Biotechnology)

3D Integration

Application Integration

Single Chip Integration

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Today’s System Integration Value Chain

Elektronics
- Mikroelektronics
- Components
- Actuators
- Sensors
- Radio
- Power
- Controller

+ Packaging
- Subsystem
- Package (SiP, PoP,...)
- Reliability
- System Design

= Stand Alone System

Research Center of Microperipheric Technologies
Package form factor

<table>
<thead>
<tr>
<th>Package</th>
<th>Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QFP</td>
<td>~ 5,5</td>
</tr>
<tr>
<td>BGA</td>
<td>~ 2</td>
</tr>
<tr>
<td>CSP</td>
<td>&lt; 1,2</td>
</tr>
<tr>
<td>FCoB/WLP fan in</td>
<td>= 1</td>
</tr>
</tbody>
</table>

Stacks: could become <1 and external I/O no may be reduced

3D allows further density increase

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Example: Package size of accelerometers

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Challenges for Future System Packaging

- Miniaturization
- Multifunctionality
- System Reliability
- Integration into final product
System Integration Strategies

MEMS
Passives
IC

Monolithic
• highest integration density
• low flexibility
• limited functionality

On Top Techn.
• high integration density
• average flexibility
• average functionality

Polym.
Si

3D Integration
• average integration density
• high flexibility
• highest functionality

polymer-, ceramic-, III-V- and Si-technologies

H. Reichl, K.-D. Lang, (IZM Berlin)
Panellevel Roadmap

Embedded die package PANEL infrastructure Roadmap

- OSAT players
  - 4”x20” – 102x508mm / PCB laminate substrate
- 1/2 PANEL
  - RF & MIXED SIGNAL
    - SIP module applications:
      - PMU / PMIC
      - RFEM
      - RF connectivity (WLAN/BT/RF)
      - Audio/Video Codes
- 16”x20” – 400x505mm / PCB laminate substrate
- Full PANEL
  - Digital thin-Pin module applications
  - RF / APE

Substrate players

- DNP
- AT&S
- TDK-FPC
- HighTech
- Fujikura Ltd.

POWER & ANALOG
- small SIP module applications:
  - DC/DC converter
  - IPD
  - AF driver
  - Small ASICs
  - MOSFET
  - BIST
  - RFID

RF & MIXED SIGNAL
- large SIP module applications:
  - PMU / PMIC
  - RFEM (SAW, PA, etc.)
  - RF connectivity (WLAN/BT/RF)
  - Audio/Video Codes

Source: Yole

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Chip Embedding – Chances & Challenges

Advantages
- thin planar packaging, enabling 3D stacking
- improved electrical performance by low inductances
- high reliability by direct Cu to chip interconnects
- cost saving by large area process

Challenges
- improvement of process yield
- new supply chain structure has to be established
**Process – System of Embedding**

Embedding
- bare chips
- packaged chips
- passive components

connection to inner layer by solder or adhesive

mounting on inner layer / foil
embedding
connection by drilling + Cu plating

**solder / adhesive interconnects**

**direct Cu interconnects**

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**Process - Variants for Chip Embedding**

**face up**
- Chip attach
- Embedding by lamination
- Via drilling
- Cu plating and structuring

**face down**

- Electrical and thermal backside contact
- Better fine pitch capability

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Chip Embedding –
Substrate Line at Fraunhofer IZM

- Panel format 610 x 456 mm²
- Die attach (Datacon evo/Siplace CA3)
- Embedding (Lauffer) by RCC lamination (5 µm Cu, 90 µm dielectric)
- UV laser drilling (Siemens Microbeam) of microvias / mechanical drilling (Schmoll MX1)
- Cu electroplating / via filling (Ramgraber automatic plating line)
- Dry film resist application
- Laser Direct Imaging (Orbotec Paragon 9000) of circuitry pattern
- Subtractive Cu etching (Schmid)
- Electrical test (Spea flying probe tester)
Chip Embedding - Evolution

Chip Embedding in organic substrates ➔ use of PCB technology & material

- Production started
  - Japan
  - Korea
  - Europe

First Standards
  - JPCA

- First Patent
  - 1968
- Basic R&D
  - 2000
- Production Demos
  - 2005
- Production
  - 2010

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Chip Embedding - Security Documents

- Integration of ultrathin ICs in Polycarbonate
- Via drilling in Polycarbonate
- Structuring of conductor lines and filling of Vias with electroplated Cu
- „invisible“ electronic structures as security features
Chip Embedding – Volume Manufacturing

MicroSIP Technology - TPS82671, TPS82675

- embedded chips in SIP substrates

- product available since 2010
- manufacturing by AT&S

600-mA, MicroSi STEP-DOWN CONVERTER

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Modular Microelectronics – System Assembly Concept

Traditional electronic system

- \(\mu\text{Controller}\)
- MOSFET
- flash memory
- resistors
- capacitors
- Pt100

Vision

Modular System

- system control / memory
- temperature sensing
- power management
- stacked modules

2D \(\rightarrow\) modules on simple connector

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Module Stacking – Soldering

Evaluation of module stacking
• sizes 4 mm and 10 mm
• 4, 8 and 16 contacts
• SnAg solder caps
• flux dipping, placement, reflow

Assessment of yield and reliability ongoing

modules and stacks with 4, 8 and 16 contacts

cross-section module stack 8 contacts

x-ray image soldered stack of 3 modules
Project – Modular Sensor System
Modular Sensor System – System Concept

Sensor modules connected by I²C bus (4 contacts: SDA, SCL, Vcc, GND)

Functions
sensor functions / modules
- acceleration
- light
- temperature
communication & power module
- USB connection to PC
- power conversion 5V (USB) to 3.3 V
Modular Sensor System – Module Concept

- modules are based on Atmel Atmega168 8-bit microcontroller
- Inside each module the sensor is connected to the μC via I²C
- connection to the system bus via an additional I²C port

Example: Acceleration Sensing Module

Active Components
- microcontroller
  Atmel ATmega168A (QFN32, 5x5x1 mm³)
- 3-axis acceleration sensor
  Freescale MMA7660FC (DFN10, 3x3x0.9 mm³)
- SMD-Resonator
  MURATA CSTCE8M00G55 (4.5x2x1.5 mm³)

=> successful function test of all module types at test board level
Modular Sensor System – Realized Modules

set of sensor system modules

I2C bus contacts

ISP programming contacts

module x-ray image

top side

down side
Modular Sensor System – Advanced Module Stack

- modules were successfully realized
- stack of sensor modules on communication & power module
- basic functional tests passed

Next Steps
- implementation of bootloader software on modules level
- implementation of system control software on stack level
- evaluation of different application scenarios

sensor module stack

x-ray image
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Future Smart System Scenario

- Application
- System integration
- Microelectronics
- Lighting
- Maschinery/Chemistry
- Energy
- Fashion/Life science
- Agriculture/Food
- Medicine
- Sports

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Roadmap towards Modular Electronics

- Embedding technology opens a way over small and robust SiPs towards Modular Microelectronics
- Modular Microelectronics offer much shorter design cycle times
- It can simplify the realisation of complex systems by use of tested functions

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Tasks and Challenges

- Improvement of cooperation between established PCB technologies and Embedding in production areas
- Faster implementation of advanced assembly and packaging (e.g. 3D Integration, Panel Level Packaging)
- Materials development to optimize integration of embedding processes into different application environments (e.g. innovative polymer substrates)
- Known Good Die handling for ICs, MEMS, Optic components, etc
- Interaction of design, technology and reliability at a very early stage of development will be essential for the product success. Especially models and simulations for that have to be allocated.
- Interconnection processes and interfaces at the border from micro to nano have to be understood better
- System test methodologies and new manufacturing standards have to be implemented
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Thank you for your Attention