Market Drivers for Embedded Components Packaging

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Materials are added to the printed circuit structure to create the passive element.

The component is placed on an internal layer then buried as additional layers are added.

Source: JISSO International Council, May 2004
Embedded in Substrates: A Look Back

- Companies embedding discrete passives into modules
  - Module size reduction
  - Improved performance
  - Driven by trends in portable products
  - Examples in production include products from Taiyo Yuden, DNP, etc.
  - PCB with 250 components (0603s) embedded
- Many research projects and roadmaps
  - European Hiding Dies project
  - Fraunhofer “Chip in Polymer” process
  - Casio and CMK EWLB consortium
  - Motorola’s embedded passives demonstration vehicle
- Examples of embedded active components
  - Casio watch modules (2006)
  - Digital TV tuner modules (2006-2007)
  - Ericsson mobile phone with RF device embedded in Clover’s PCB (200?)
  - AT&S test vehicles (various)
  - TI switching regulator (2010)
  - Many demonstration vehicles
Casio, CMK, and Imbera Embedded Structures

- Casio embedded WLP in production in watch modules
- Casio, CMK, others in Japanese consortium—expect some standards to emerge
- Imbera technology licensing agreements, but Imbera no longer exists as a company developing technology

Source: Casio, CMK, and Imbera
Casio EWLP

No Solder Ball!

- Copper Bump (Post)
- Encapsulation Material (Epoxy Resin)
- LSI Chip
- Copper Redistribution
- Passivation Layer (Polyimide)

Subtractive Method
Electroless Cu Plating

Electro Cu Plating

Circuit Generation

Solder Mask

Terminal Finish (Solder Ball Attach)

Diecing

Source: Casio Computer

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Formed Thick Film Capacitors

Motorola Mezzanine in GSM SOM

- 2+4+2 HDI EP PWB
  - Microvias on Filled Core Vias
  - Stacked microvias
- 26 embedded Gen 2 caps on layers 2 and 9

Source: Motorola
BossB2it and B2itPWB with Embedded Active

- Buried Bump Interconnection Technology Offered by DNP

Source: Dr. Fukuoka, Weisti, Surtech 2006  Cross Section
Clover’s Embedded Active Device

- > 1 millions PCBs with embedded RF device for Ericsson mobile phone
- Clover (Japan) was purchase by Unimicron (Taiwan)
Printed Circuit Board Trends with Embedded
Why Embedded Components Today?

• Small form factor (reduced Z-height), enables reduced board thickness
  – Provides low profile SiP for mobile applications
  – Embedded die in bottom of PoP substrate
  – Alternative until 3D IC with TSV ready for HVM
  – Includes fan-out WLP packages

• Improved performance
  – Shorter electrical path, EMI reduction,
  – Passive devices (capacitors today, high capacitance material in future)

• Shielding advantages for RF components

Source: TI
Fan-Out Wafer Level Packages

- Fan-out WLP can be considered an embedded package
- Fan-out WLP from ADL Engineering, Amkor, ASE, Deca Technologies, Freescale Semiconductor, FCI/Fujikura, J-Devices, NANIUM, Nepes, STATS ChipPAC, YOUR NAME HERE
- Infineon eWLB (wireless operation acquired by Intel)
  - Technology licensed by ASE, STATS ChipPAC, NANIUM
  - Companies have installed production lines

Source: Infineon

- Achieved by conventional back-grinding process
- Thinner profile results in more compliant structure
- Better BLR, DT & TCoB performance

Source: STATSChipPAC
Projected Demand for Fan-Out WLPs in Units

- Unit shipments increased from 513 million units in 2011 to 616 million units in 2012
- Growth continues
- Multiple die can be packaged in fan-out, some panel configurations are used and can be considered embedded die packages (EDPs)
- Demand for fan-out will increase if cost, reliability, and supply targets can be met
Embedded Devices Today

- **Embedded actives:**
  - Driver—package thinness
  - Secondary advantages are improved robustness and security
  - First applications—ultra-thin PoP for mobile products
  - Technology—thin-film, laminated or build-up
  - Companies with embedded die PoP activities ASE, AT&S, DNP, FlipChip International/Fujikura, J-Devices, NANIUM, Shinko Electric, STATS ChipPAC

- **Embedded passives in IC packages and PCBs:**
  - Driver—decoupling capacitance close to the processor to enable higher operating frequencies
  - First applications—application processors for mobile phones with embedded capacitors in production
  - Mother board with MLCC/resistor
  - Follow-on applications—high-end networking and communications
  - Technology—primarily capacitors in build-up or laminated substrates
  - Companies including Ibiden, DNP, Fujikura, Fuji Print, KOA, Meiko Electronics, Oki Print, Samsung Electro-Mechanics (SEMCO), Shinko Electric, Taiyo Yuden, TI, etc.
Application Processors for Smartphones

- Increasing number of examples of application processors with embedded capacitors in package substrate
  - Example of Exynos processor in Samsung smartphones
- Thinner package and smaller footprint
  - Goal of less than 1.0mm thick packages
  - Improved performance

Source: TPSS
DNP’s e-B2it™ Substrate with Embedded Active

- Coreless substrate with random or stacked vias
- WLP connected with solder attach or Au bump bare die
- Under evaluation for Near Field Communication/Radio Frequency (NCF/RF) modules, CMOS image sensors, and baseband processor modules

Source: Renesas
Shinko Electric’s MCeP Structure

- Chip Capacitor
- Memory Device Package
- Upper Substrate
- Copper Core Solder Ball
- Embedded Layer
- Base Substrate
- Flip Chip Attach (Au bump + Sn-Ag solder)
- Bare IC

Source: Shinko Electric
ASE’s a-EASI Embedded Chip Package

• Single package with one embedded or 2 to 3 side-by-side embedded chips or passives
• Embedded thin chips in build-up substrate
  – Electrical contacts to chip by laser drilling and metallization of microvias
  – Known Good Substrate provides yield enhancement
  – Prefabricated substrate, embed die or component, substrate interconnection and build-up process
  – Reliability test reported good (no cracking)
• Customer evaluations underway
FlipChip International’s Chiplet™

- Partnership with Fujikura (Japan)
- WLP embedded using Fujikura’s flex-based laminate processes
- Examples of both actives and passives
### J-Devices WFOP™ Roadmap

- J-Devices (Japan) OSAT (Amkor/Toshiba ownership) developed embedded solution
- Die sits on metal plate (acts as heat spreader)
- RDL to fan-out die based on PCB technology
- Processed in panel

<table>
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<tr>
<th>Fiscal Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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<tr>
<td>High Density</td>
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<td>3D</td>
<td>Package Stack (PoP)</td>
<td>Die Stack (Embedded)</td>
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Source: J-Devices
Taiyo Yuden’s EOMIN® Embedded Substrate
Texas Instruments MicroSIP™ DC/CD Converter

- PCB (substrate)
- Embedded PicoStar™ DC/DC converter
- Integrated passives (L, CIN, COUT)
- Released to market


0402 Caps, 2012 Inductor

Source: Texas Instruments
Embedded Components Challenges

• Deviation from Traditional Assembly Model: OSAT needs substrate capability or close partner

• Assembly Yield
  – Typical assembly process die are connect to known good substrates and assembly yield is typically greater than 99%
  – Good die may be lost to substrate build-up process yield
  – Companies working on strategies to minimize effect of substrate yield loss

• Cycle Time
  – Substrate fabrication becomes a serial event in packaging flow so assembly cycle time similar to laminate substrate cycle time
  – Laminate substrate cycle time is longer than traditional assembly cycle time
  – Thin-film type process requires serial processing

• Functional testing of embedded die substrate in strip form

• Embedded die technologies appropriate for
  – Embedding lower value, high yielding die where high interconnect density is required on both sides of the substrate
  – RF modules where embedding tested die allows high density SMT on top
  – Some analog parts
  – Capacitors for improved performance
Conclusions

• Embedded device market has arrived
  – Driven by form factor and performance
• Solutions in the market today, more to arrive
  – Embedded actives for PoP and other packages
  – Embedded passives for application processor and other packages
  – Embedded actives
• Issues with previous generation products being solved
  – Thin die handling
  – Use of high yielding die
  – Assembly method improvements
  – Cost reduction