High Volume Assembly & Test Solutions To Meet The Rapidly Growing MEMS Market

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MEMS & IC Package Comparison

• MEMS Package Relative Growth
  – MEMS package market is now growing at an accelerated rate (~20% CAGR) of more than twice the overall IC package market (~9% CAGR), in unit shipments

  ![Graph showing MEMS and IC package shipments from 2010 to 2016]

  [Yole Development, March 2012]

• Commonalities between MEMS & IC Packaging
  – Driven by miniaturization
  – Driven by cost reduction
  – Driven by integration

• Differences between MEMS & IC Packaging
  – MEMS early adoption into high grade applications bred great diversity
  – The rapid adoption and growth is in a very early stage without standardization
Growth and Diversity

• Explosive growth of MEMS Opportunities
  – Enabled by creative application of known wafer fabrication techniques to create Si-based transducers
  – Form factors are as diverse as the applications they serve

  – Diversity in application and requirements is driving many unique packaging solutions through combinations of:
    ▪ Design
    ▪ Materials
    ▪ Processing
MEMS Diversity of Assembly Materials

- **Substrate**
  - Low CTE thin core
  - Pre-molded and in-frame cavity lead frame
  - Cavity in laminate substrate
  - Ceramic

- **Die attach**
  - Low stress epoxy
  - Silicone gel
  - Die Attach Film (DAF)

- **Die coat Encapsulation**
  - Silicone Gel
  - Epoxy

- **Lid**
  - Flat or formed metal
  - Molded plastic

- **Molding compound**
  - Low stress EMC
MEMS Diversity of Assembly Processing

- **Wafer handling**
  - Wafer Thinning
  - Cavity protection
  - Vacuum Chuck
  - Wafer Expansion (Laser Stealth Dicing)

- **FC/WLP**
  - Solder Bump, Au stud, or Cu Pillar
  - Wafer level RDL
  - Silicon TSV

- **Die attach**
  - Low Stress
  - Multi-Die (stack, flip, vertical mount, side-by-side)
  - Precise placement control (positional, rotational, tilt)
  - Transducer protection (vacuum damage)

- **Die coat**
  - Coverage
  - Selective dispense
  - Transducer protection
MEMS Diversity of Assembly Processing

• **Interconnect**
  – Ultrasonic wedge-bond
  – Thermosonic ball-bond (Au or Cu)
  – Micro Bump (TSV)
  – FC (Thermo-compression, Reflow)

• **Lid attach of Cavity Packages**
  – Array or individual attach
    ▪ Solder
    ▪ Epoxy
    ▪ Swage
    ▪ Laser
    ▪ Ultrasonic

• **Test**
  – Strip Test
  – In-Situ Stimulus
    ▪ Acoustical ports
    ▪ Inertial Shakers with Axis Alignment
    ▪ Magnetic Field
    ▪ Pressure
MEMS Packaging Complexity

Many options and cost / performance considerations

Wire type, loop radius and gage?
Molded-in stress?
Leaded or not?
Green material?
Die attach method?
Stacked die or side-by-side?
Wirebond or flip-chip?
Cavity or overmold?
Laminate or leadframe?
EMI shielding?
Encapsulation?
How/what to test?
MEMS Packaging at Amkor

- First 20+yrs: Broad range of packages & numerous new, complex applications
- Next 10 to 20yrs – will there be more standardization? YES!

DLP courtesy of TI
Standardization in MEMS Fab, Assembly & Test

• Early adoption bred diversity but rapid growth now creates a need for standardization to:
  – Increase cycle time-to-market for new applications & products
  – Support cost erosion

• MEMS Wafer Fabrication
  – Adopting standard processes to support MEMS
    ▪ DRIE Etching, Wafer Bonding, TSV

• MEMS Packaging
  – Driving standard materials & strengthening supply base
  – Integrating MEMS processes & handling into mature product lines
  – Selecting Platforms that allow flexibility to support design variation
    ▪ Cavities, Ports, Multi-die, Optical windows etc…

• MEMS Test
  – Multiple insertions & mechanical stimuli integration for combo sensors
  – Strip based or Carrier based handling of various form factors for reuse & higher parallelism and lower total cost
Amkor MEMS & Sensor Packaging Evolution

20+yr Experience and Evolution in MEMS & Sensor Packaging

Transition from Custom Packaging to High Volume Manufacturing

Broad range of point solutions

Focused platforms

MLF® -Cavity (in-line or FAM)
ChipArray® -Cavity
LF-Cavity (pre-mold or FAM)
MLF® -Molded
ChipArray® -Molded
WLCSP

DLP® courtesy of TI
MEMS Package Selection

- **The package selection plays a critical role in**
  - The function and performance of sensor products
  - controlling stresses to the MEMS structure
  - ensuring stability over temperature and time through materials & design
  - allowing the stimuli to reach the MEMS structure
  - protecting the MEMS and ASIC devices

- **Primary Platforms**
  - Ceramic Assembly
  - Laminate Chip Array LGA/BGA
  - Leadframe MLF
  - WLCSP

- **Important factors**
  - Flexibility in design to suit specific sensor type
  - Scalability & flexibility for high volume is very important
CSP MEMS Packaging

Primary MEMS Platforms for Integration

- Two primary package platforms, CA and MLF, are allowing flexibility to accommodate several key MEMS applications
  - Pressure Sensors, Accelerometers, Microphones, Gyros

- CA-Cavity package structures
  - Highly flexible routing for SiP
    - Low cost laminate
    - Low stress ceramic

- MLF-Cavity package structures
  - Cavity LF and flat lid
    - In-frame molded with formed lid

- Over-molded versions of each are available for MEMS that are more immune from stress effects
Laminate Cavity MEMS Packages

- Assembled using standard CSP Strip Format, Technology and Infrastructure
  - Small Die handling
  - 2D Strip Mapping
  - Multi Die and Die Stacking
  - Substrate Supply Base
  - Scalability

- Matured lid attach capability / technology

- Universal approach to MEMS Packaging
  - Similar package structure can be applied for various MEMS application including Port Hole designs for environment stimulus
Laminate to Laminate Package – L2L

- Efficient assembly of Cavity packages by joining 2 strips together to create the cavity structure (flat bottom laminate with a cavity top laminate as lid)
- Routing is available on both sides of the package which enables a completely reversible design for SMT
- Maximizes the available Cavity Space
What is In-Frame MLF Package?

- Leadframe-based Chip Scale Package Platform
- Metal / Plastic Lidded package
- Lid opening options for optical
Pre-Molded Leadframe Cavity Package

- Pre-plated LF & Pre-molded Polymer Side wall
- Stacked or side by side die configuration
- Multiple lid options based on application (with or without ports)
- Lower cost alternative to ceramic cavity packaging for non-hermetic application
Laminate Cavity MEMS Multi-Die Integration

• Integration opportunities through combinations of controller die plus Accelerometers, Gyros, Pressure Sensors, Microphones and Magnetometers.
  – Examples
    ▪ Gaming: Gyros + Accelerometers
    ▪ Smart Phones: Accelerometers + Gyros (or Magnetometer) + Pressure Sensor + Microphone
    ▪ Cable TV Remote Pointers: Accelerometers + Magnetometers

• CA Cavity MEMS Package platform allows flexibility to provide system in package configurations
Enabling / Emerging Interconnect Technologies

• Current Interconnect Technologies:
  – Side-by-side
  – Stacking
  – Wire bond
  – Flip Chip

• 3D Package Technologies: non-MEMS today
  – Face-to-Face (F2F) Flip Stack
  – Through Silicon Via (TSV) Stacks
  – Amkor’s Thru-Mold Via Technology (TMV™)
  – Cu pillar FC
  – ASIC as Capping Wafer
Enabling Material & Processing

Use of Polymers:
• Application:
  • Pre-molded Cavity packages
  • Polymer Lids
  • Bio-compatible thermoplastics
  • Micro-channels or ports for fluidic transport
  • Plated polymer for interconnect or EMI shielding
• Advantage of Injection molding of thermoplastics
  • low cost precision 3D structures especially beneficial to micro-fluidics
  • low cost impact for molding simple to complex structures

Film Assisted Molding
• Applications:
  • Cavity Formation over LF, Laminate or Die Surface
  • Die surface exposure (humidity, temp, light sensors)
  • Wirebond protection (fingerprint sensors)
• Advantage of film assist molding technology
  • Can be applied to backend only of mature production line platforms so the rest of the line efficiencies can be realized
Summary

• There is a broad diversity of MEMS package requirements and form factors.

• Form factors will remain fairly broad due to several types of sensors & package function

• Accelerated MEMS market growth will drive standardization to offer performance and cost demands

• Standardization in package & test can be met by following a platform strategy that brings MEMS-specific materials, handling & processing to mature product lines to benefit from high volume cost & scale efficiency
Thank You