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

RELIABILITY & TRUST

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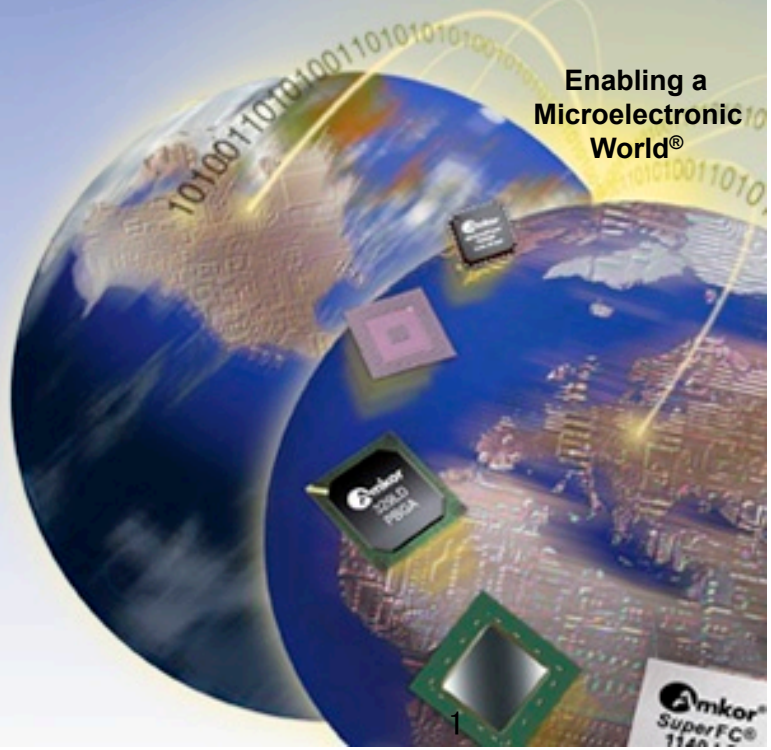
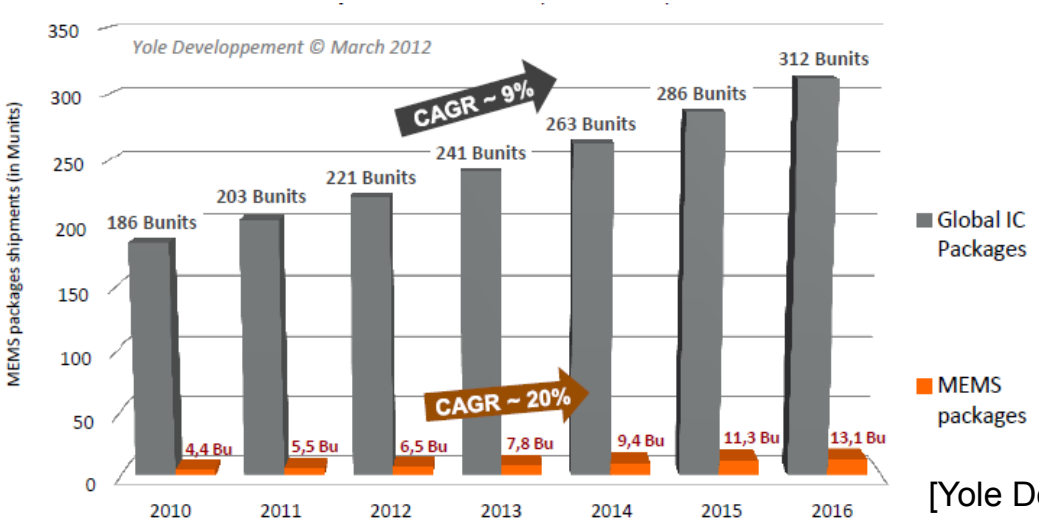


Amkor Technology®

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



[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

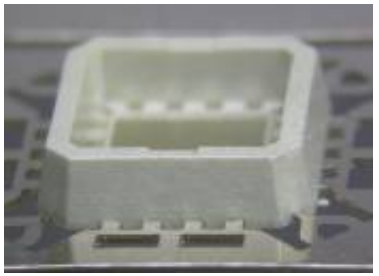


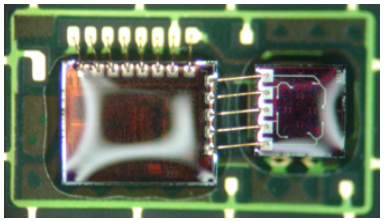


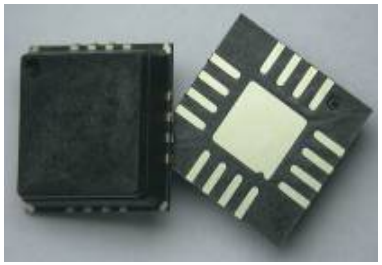

  - Diversity in application and requirements is driving many unique packaging solutions through combinations of:
    - Design
    - Materials
    - Processing

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

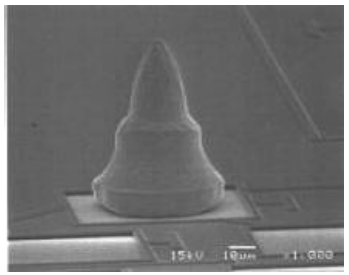


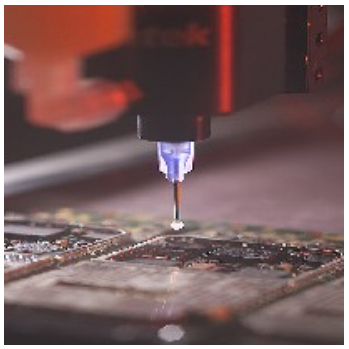


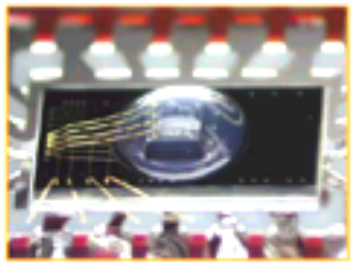


MEMS Diversity of Assembly Processing

- **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

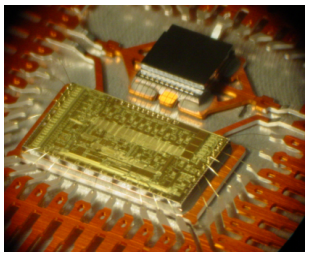




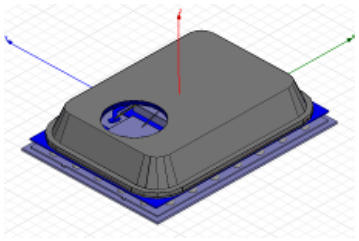


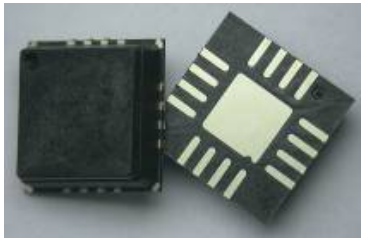
MEMS Diversity of Assembly Processing

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

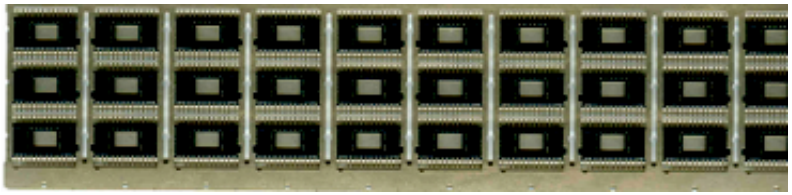


- **Lid attach of Cavity Packages**
  - Array or individual attach
    - Solder
    - Epoxy
    - Swage
    - Laser
    - Ultrasonic



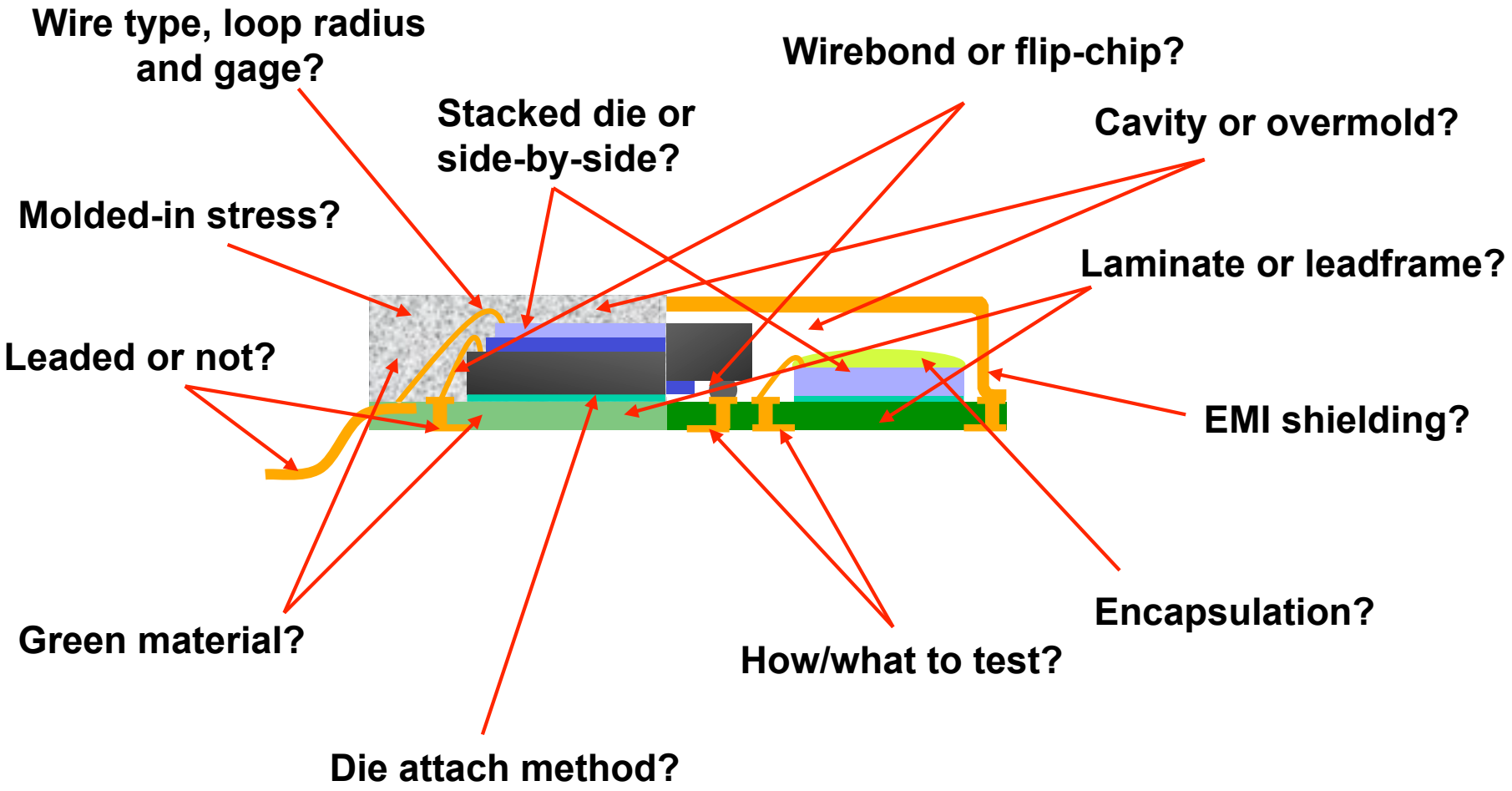


- **Test**
  - Strip Test
  - In-Situ Stimulus
    - Acoustical ports
    - Inertial Shakers with Axis Alignment
    - Magnetic Field
    - Pressure



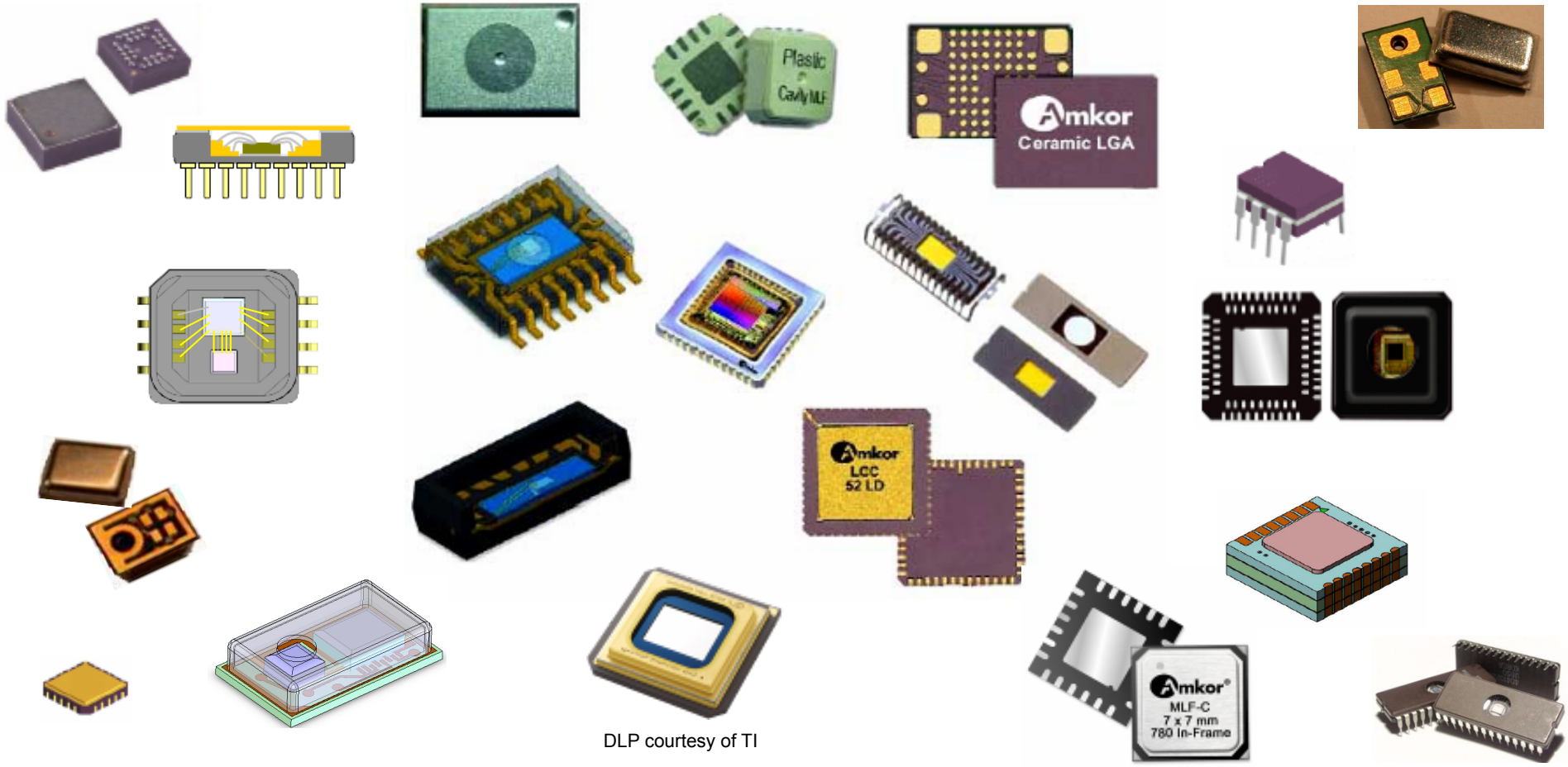
MEMS Packaging Complexity

Many options and cost / performance considerations



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!



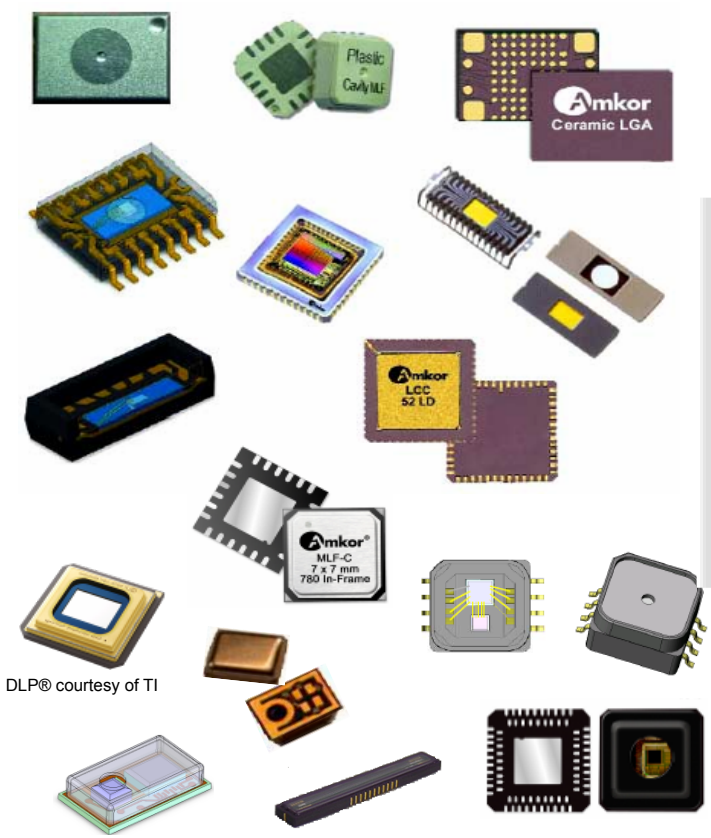
DLP courtesy of TI

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



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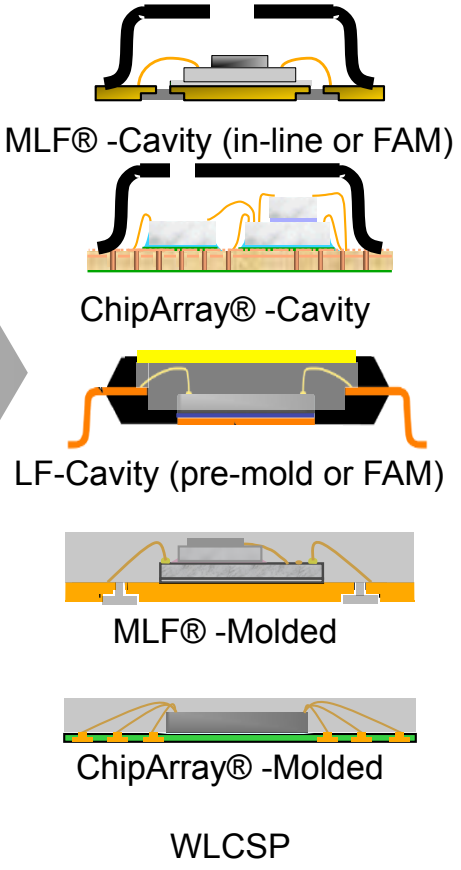
Transition from Custom Packaging to High Volume Manufacturing



Broad range of point solutions

Focused platforms

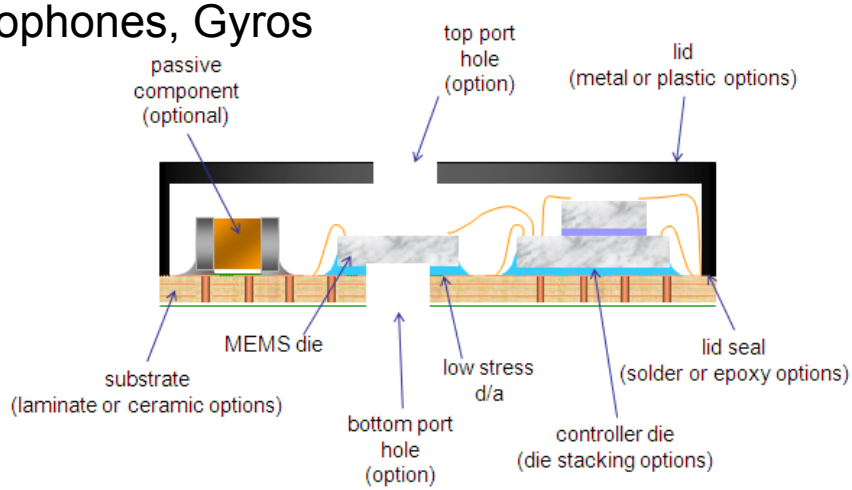
MEMS Package Selection

- **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

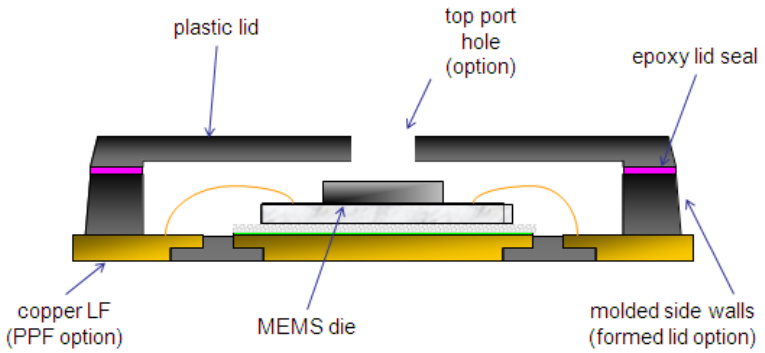
CSP MEMS Packaging

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
      - — or —
    - Low stress ceramic



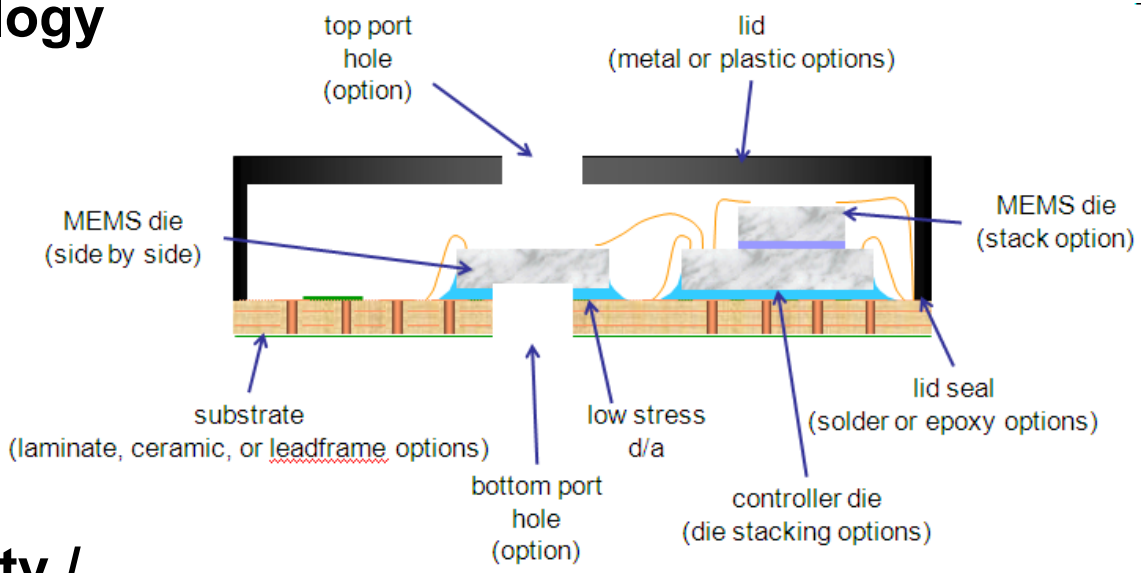
- **MLF-Cavity package structures**
  - Cavity LF and flat lid
    - — or —
  - In-frame molded with formed lid

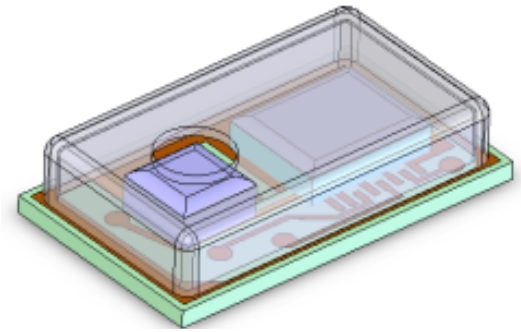


- **Over-molded versions of each are available for MEMS that are more immune from stress effects**

Laminate Cavity MEMS Packages

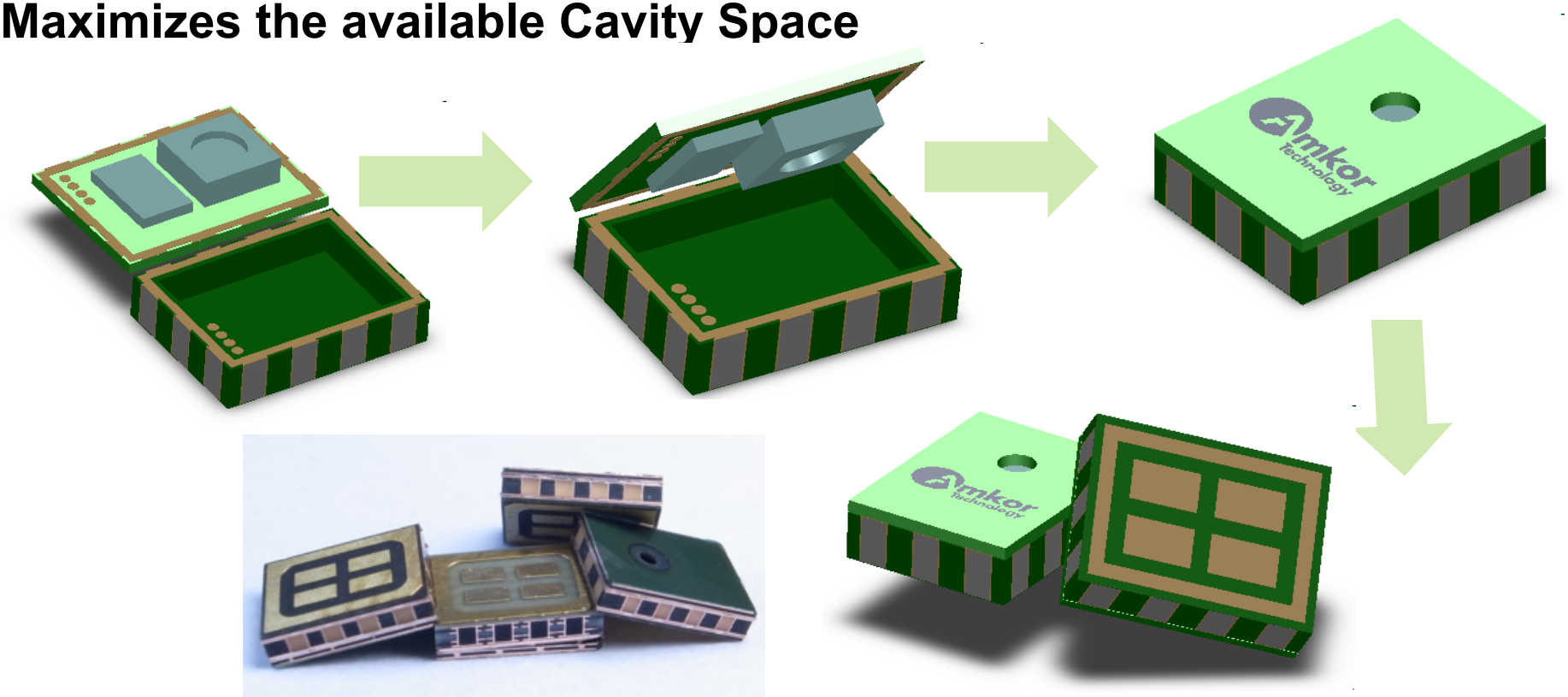
- **Assembled using standard CSP Strip Format, Technology and Infrastructure**
  - Small Die handling
  - 2D Strip Mapping
  - Multi Die and Die Stacking
  - Substrate Supply Base
  - Scalability
- **Matured lid attach capability / technology**
- **Universal approach to MEMS Packaging**
  - Similar package structure can be applied for various MEMS application including Port Hole designs for environment stimulus





Laminate to Laminate Package – L2L

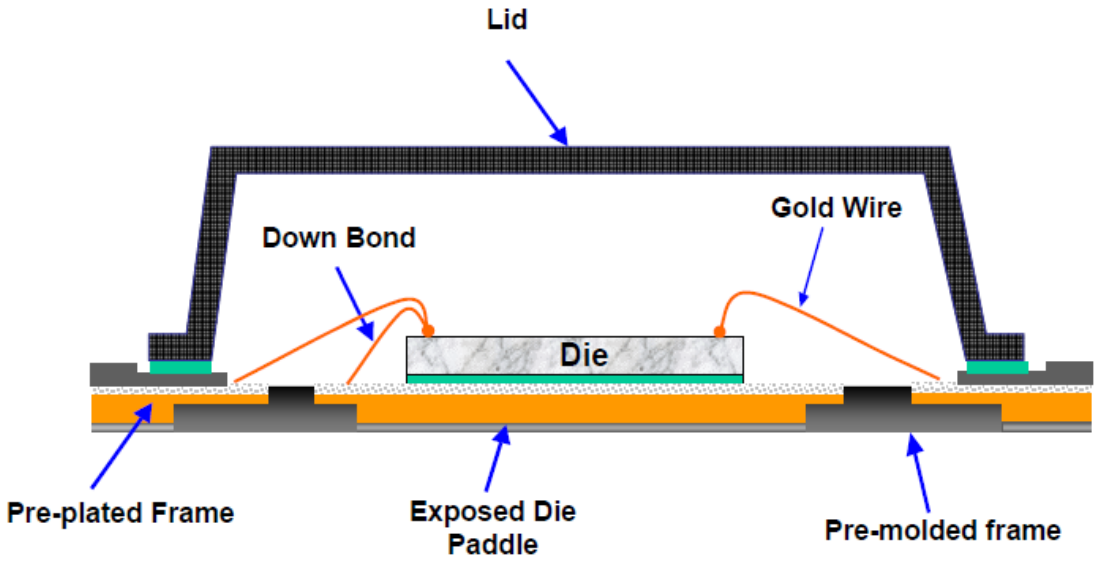
- **Efficient assembly of Cavity packages by joining 2 strips together to create the cavity structure (flat bottom laminate with a cavity top laminate as lid)**
- **Routing is available on both sides of the package which enables a completely reversible design for SMT**
- **Maximizes the available Cavity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

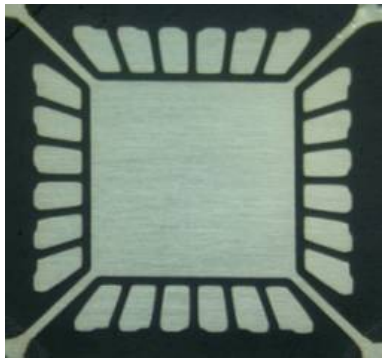


Reversible Package – Top Port♪

What is In-Frame MLF Package?

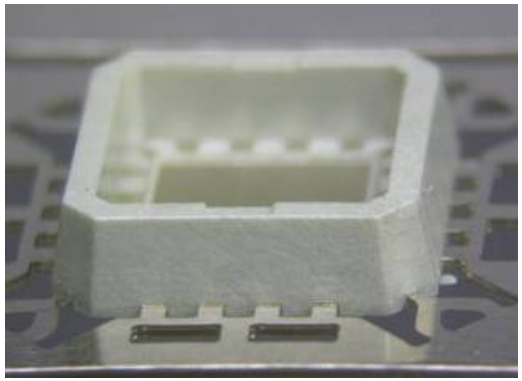
- Leadframe-based Chip Scale Package Platform
- Metal / Plastic Lidded package
- Lid opening options for optical

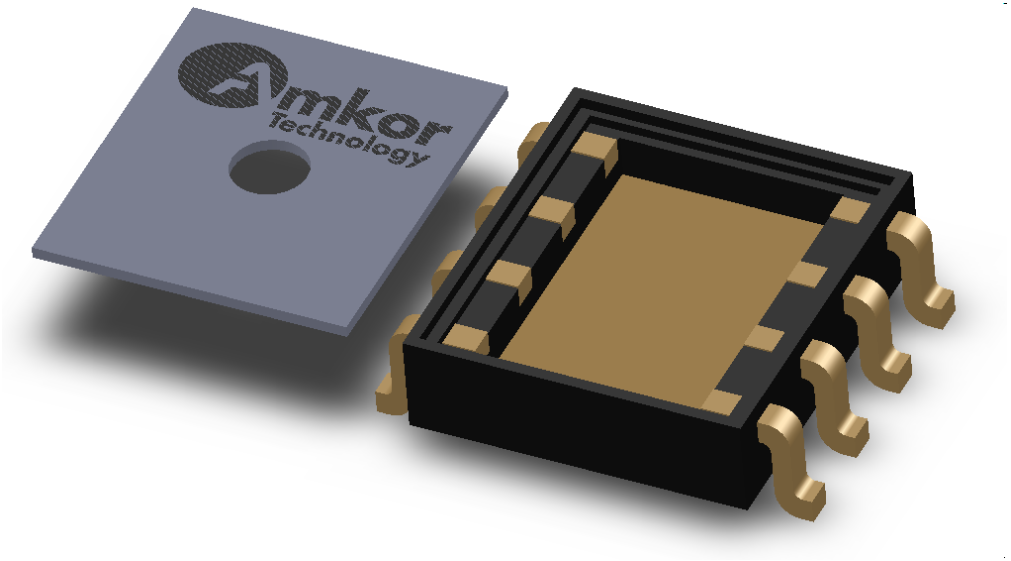




Pre-Molded Leadframe Cavity Package

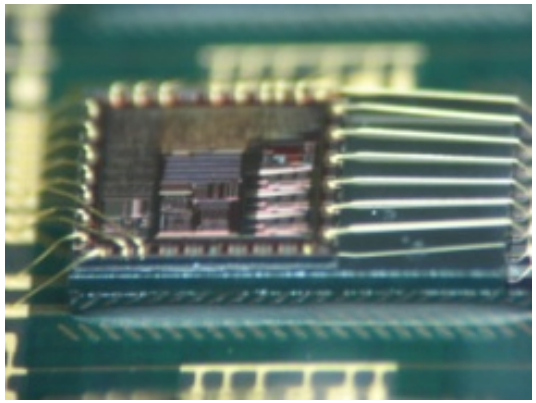
- Pre-plated LF & Pre-molded Polymer Side wall
- Stacked or side by side die configuration
- Multiple lid options based on application (with or without ports)
- Lower cost alternative to ceramic cavity packaging for non hermetic application

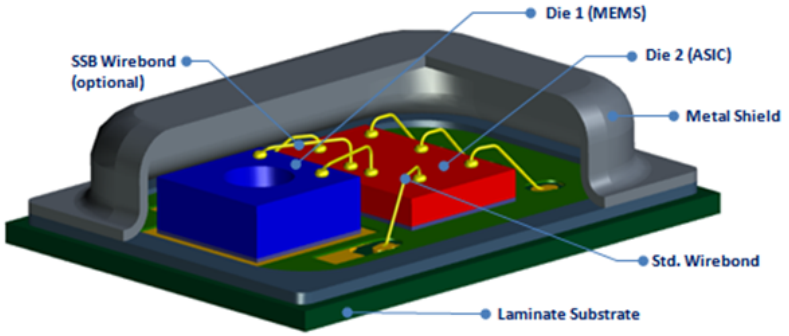


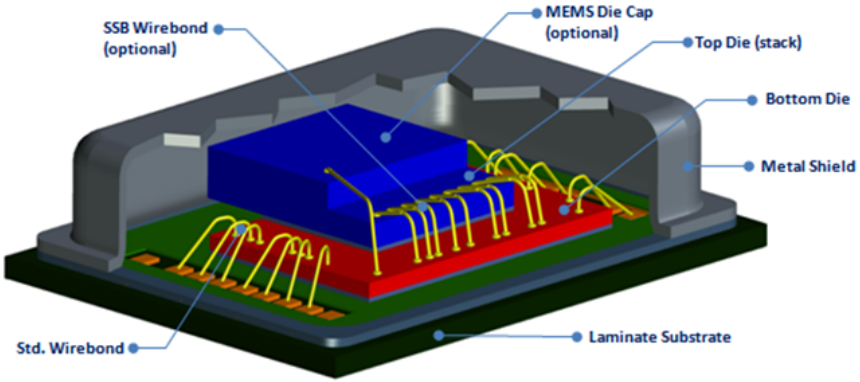


Laminate Cavity MEMS Multi-Die Integration

- **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**

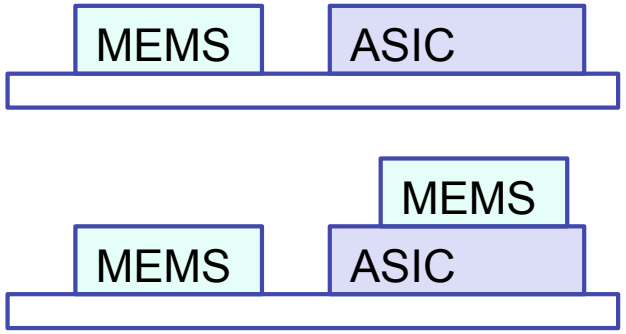




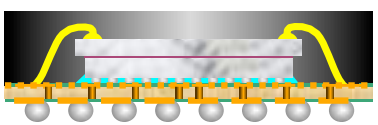


Enabling / Emerging Interconnect Technologies

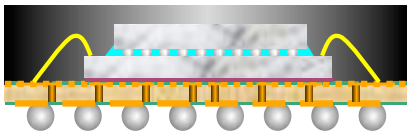
- **Current Interconnect Technologies:**
  - Side-by-side
  - Stacking
  - Wire bond
  - Flip Chip



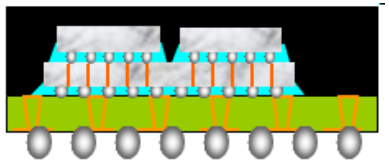
- **3D Package Technologies: non-MEMS today**
  - Face-to-Face (F2F) Flip Stack
  - Through Silicon Via (TSV) Stacks
  - Amkor's Thru-Mold Via Technology (TMV™)
  - Cu pillar FC
  - ASIC as Capping Wafer

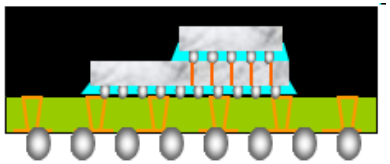


Flip-Stack CSP

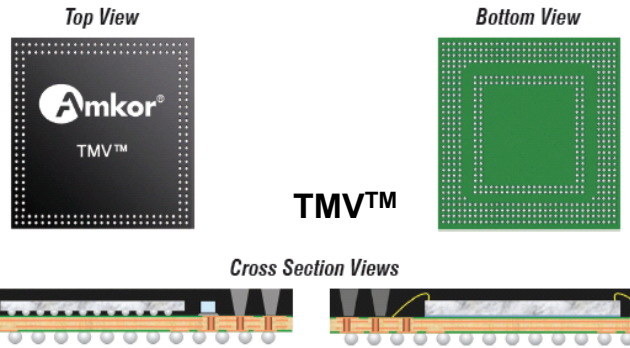


F2F Flip Stack





TSV

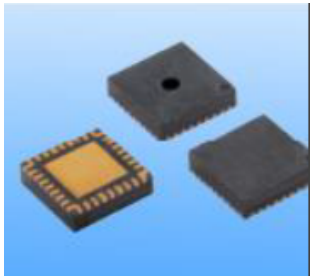


TMV™

Enabling Material & Processing

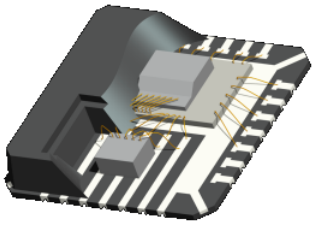
Use of Polymers:

- 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