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3D High Volume Print Forming

3D Printing for Volume Manufacturing

MEPEC, May 13, 2015

Advanced Layered Deposition Technology

Featuring:

⇒Real engineering materials (Ceramics and Metals)

⇒Multiple materials in each device

⇒Exceptional design flexibility

⇒Highly scalable through panel processing

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Works for a Wide range of Applications with a Wide range of Materials

EoPlex HVPF™ Fills the Gap Between Macro and Micro Fabrication

of Materials

5+

4

3

2

1

- The GAP -

meso scale,
multiple materials

Discrete Assembly | MEMS | Nano

Largest | Size: Log Scale | Smallest

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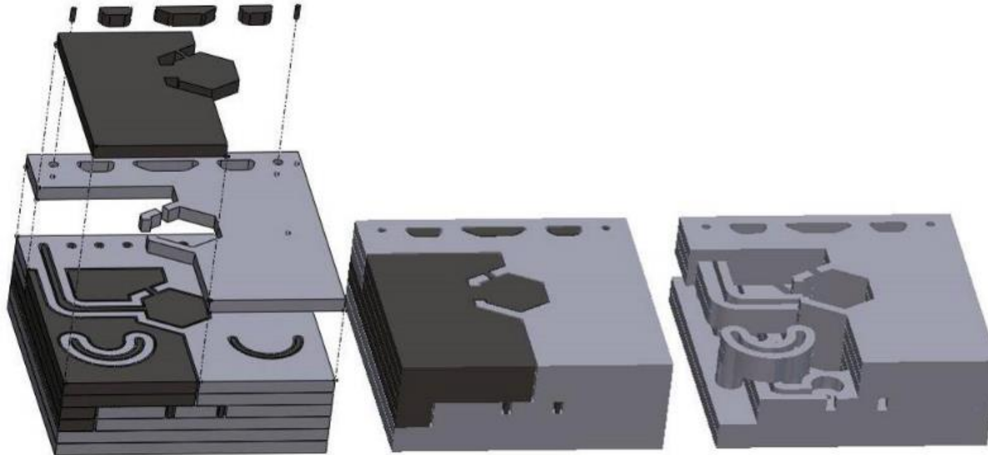
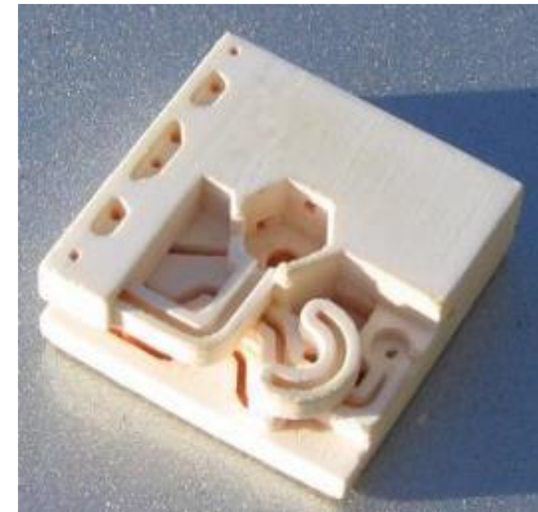
High Volume Print Forming

- Sequential deposition of layers





  - Ceramic or metal loaded paste for final structure
  - Fugitive material to create precision internal voids
- Fugitive removal/sintering yields complex structure composed of high performance materials
- Panel processing makes it cost effective

Keys to High Volume Print Forming

Basic Elements Must Work Together

Materials

Paste properties work with chosen deposition technique

Materials plus maturation step determine final materials properties

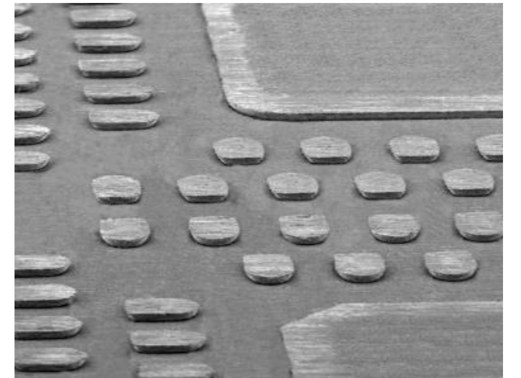
Deposition

Maturation

Deposition technique and maturation technique influence final properties

Precursor Materials that Enable Processing and Final Properties

- Pastes are precursors in "printable" format
  - Ceramics & metals w/wide range of properties
  - Fugitives to create precise & clean void spaces



- Physical properties of paste must be compatible with deposition method
  - Rheology — Particle size distribution
  - Solids loading — Particle Morphology

- Final materials properties result from precursors and maturation process

Materials Demonstrated So Far

Ceramics:

- Glass-ceramics: Sintering temp. from 700ºC to 1,000ºC
- Piezoelectric materials (PZT)
- Refractory oxides: Alumina (Al_2O_3), silica,(SiO_2), zirconia (Zr_2O_3)

Metals:

- Structural metals: Nickel alloys, stainless steel
- Conductors: Palladium, silver, gold, platinum

Passive component materials:

- Custom low loss dielectrics
- Buried and surface resistors

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Fugitives: Key to design flexibility

- Space holders that burn away without a trace and without damaging the structure
- Create void spaces within a structure, with or without communication to the outside
- Enables a true multi-material 3D printer

Unique Capabilities Depend on Materials Formulations

- Carefully engineered materials and processes work together - protected by patents and trade secrets
- Multi-Material system that can be fired together to yield a stable end product
- Fugitives that burn away without residue and don't damage the surrounding structure

Various "Printing" Techniques

Chosen to match objectives of the application

- Screen printing is the standard
  - Greatest flexibility with layer thickness, materials
  - Cost effective
- Transfer printing for finer feature size
- Ink Jetting – Computer controlled but slow
- Photolithography – Best of both worlds
  - Best possible resolution with thin layers
  - Very thick layers w/screen print type resolution
- Patent Pending on true multi-materials 3D printer

Cost Effective Volume Production by “Panel Processing”

- Large panels w/many units in ea. panel
  - Panels very from 100 mm to ~450 mm
  - Hundreds to thousands of units per panel

- Multi-material 3D printer is capable of creating a 3 dimensional matrix of parts

So, What's it Good For

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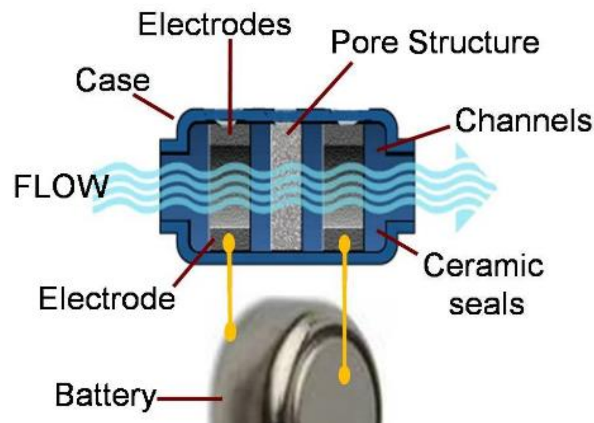
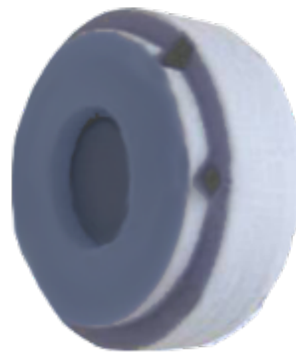
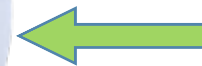
Fluidics are a Perfect Fit

- Methanol reformer for micro fuel cells

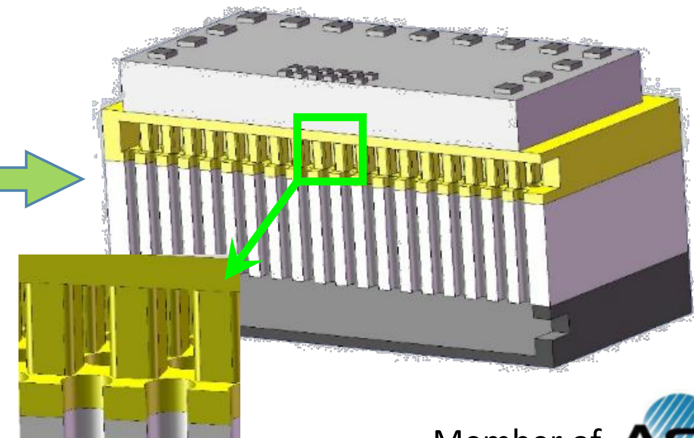




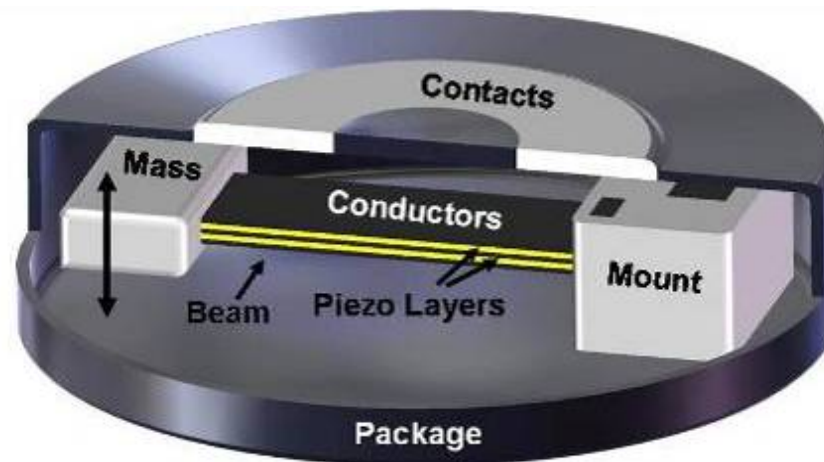


- Electro osmotic pump for micro fuel cells

- Loop heat pipe to cool high power semiconductors



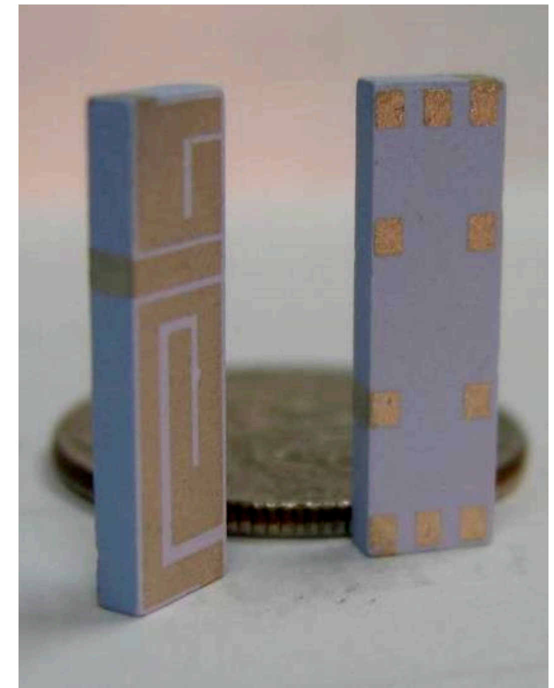
Piezo Energy Harvester Leverage EoPlex's Advanced Materials Capabilities



- PZT and metals in small complex structures
- Fugitive materials create space for moving parts
- Building a complete system in situ

Electronic Wiring Structures
Like Chip Ceramic Antennas

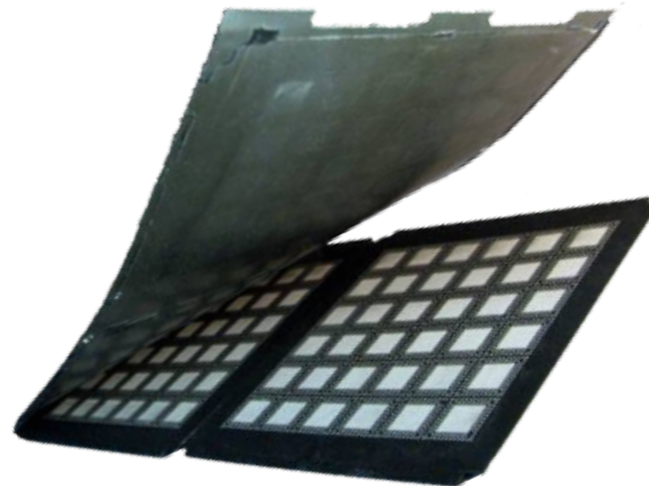
Conceptually simple, EoPlex processes reduce cost and enhance performance.



- Greater design freedom
- Materials optimized for the app. cut cost & maximize performance
- Novel panel processing reduces labor, materials & equipment cost.

Many Opportunities But One Had An Immediate Multi Billion $ Market

EoPlex Configurable Sintered Interconnect – CSI™



A More Capable Replacement for QFN leadframes

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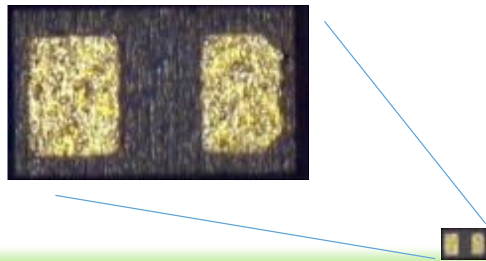
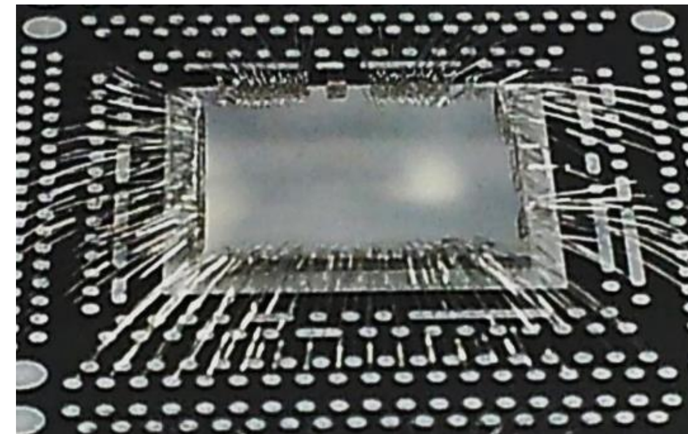
CSI™ is a Vehicle for QFN Packages with Lead Counts from 2 to 500 +

01005 (.4mm X .2mm), 2 lead



12mm X 12mm, 224 Leads, 437 wires



CSI™ Package Benefits

- ✓ Multi-row, lead counts to >500
- ✓ Min. metal = higher performance
- ✓ Improved thermals & electricals
- ✓ Finished package to ≤ 250µ thin
- ✓ Design flexibility

CSI™ QFN replaced
4 layer BGA

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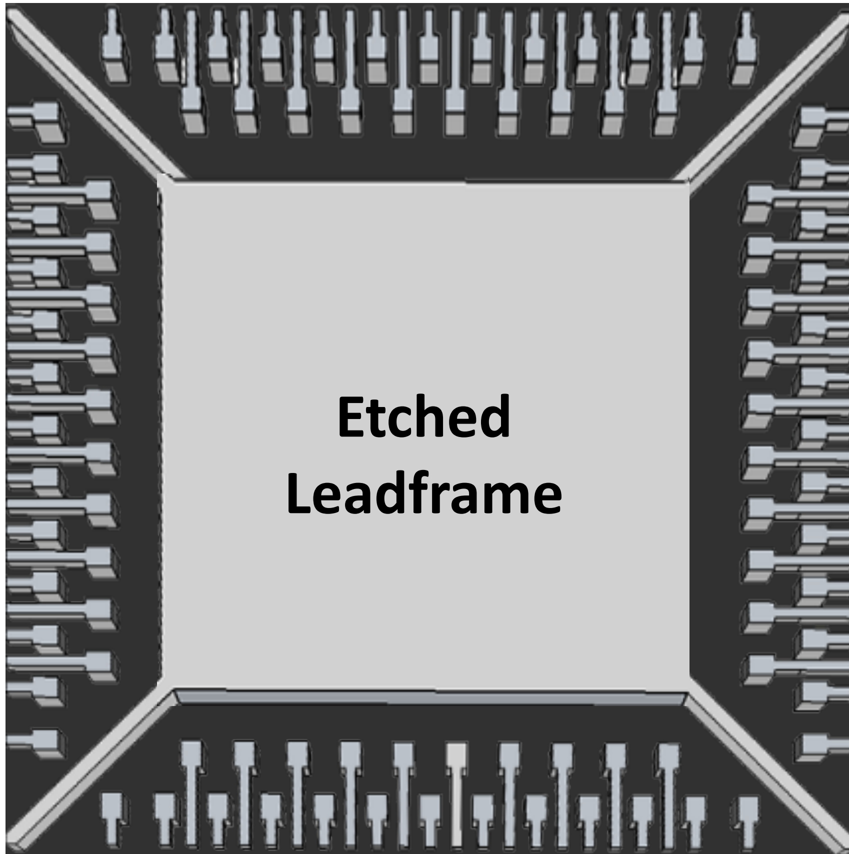
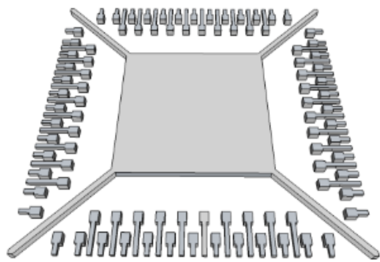
CSI™ Eliminates Tie Bars
Package Shrinks, Electricals Improve



Allows for more complex interconnect

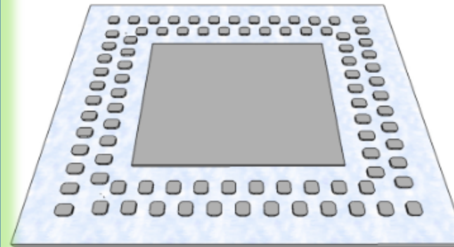
CSI™ - Array of Package Components on a Temporary Carrier

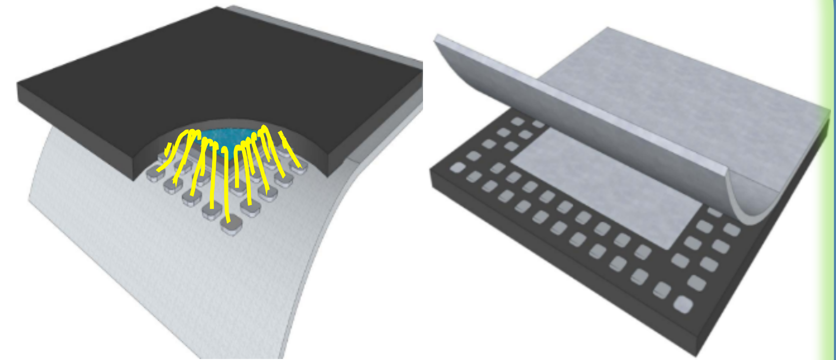
Std Lead Frame



Tie bars stay with finished package: poor signal integrity

CSI™ LeadCarrier





CSI™ : leads on temporary carrier

Carrier removed leaving only metal for interconnect

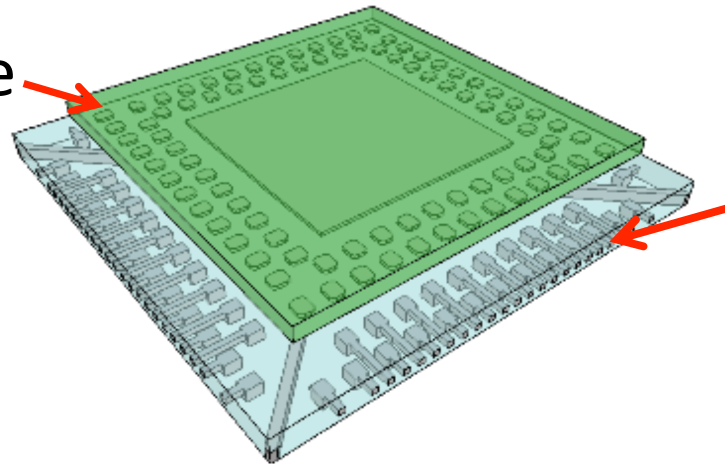
The carrier provides needed mechanical properties,
Leads are only as thick as required – nominally 40µ

Temporary Carrier Improves the Process and the Product

- A Better Process
  - Steel carrier is cheap and robust
  - The carrier eliminated the need for tape
  - Displaced leads is virtually eliminated
  - Pads are securely bonded to the carrier, no deflash
  - Pads are electrically isolated enabling Strip
  - Singulation requires cutting only EMC
- A Better Product
  - Enables packages as thin as .200 mm
  - Residual tie bars are eliminated
  - Greatly expanded design freedom

CSI™ Based Packages Have Smaller Footprints and Less Volume/Mass

88 lead package based on CSI™

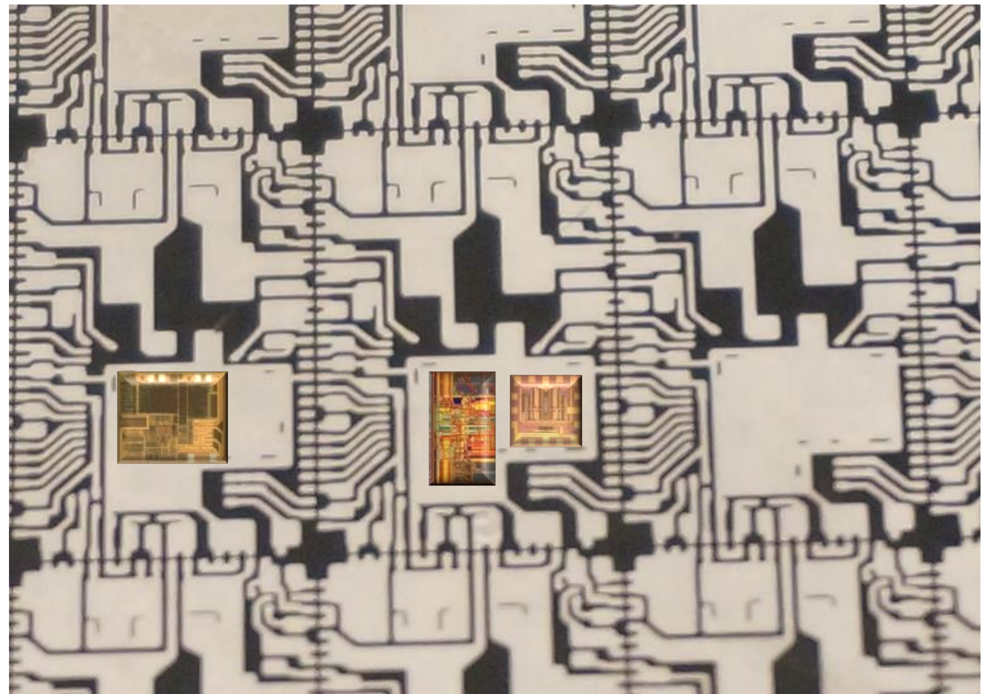


88 lead package based leadframe

- This CSI™ based package example has:
  - 23% smaller footprint
  - 50% less volume
  - 66% less mass

Previously Impossible Design Options On a Single layer

- Multiple rows
- Multiple DAPs
- Floating structures
- More than 500 leads
- 300µ bond pad pitch
- 200µ interconnect pitch
- Wettable flank for solder inspection



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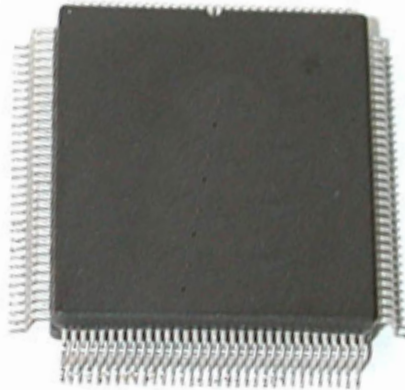
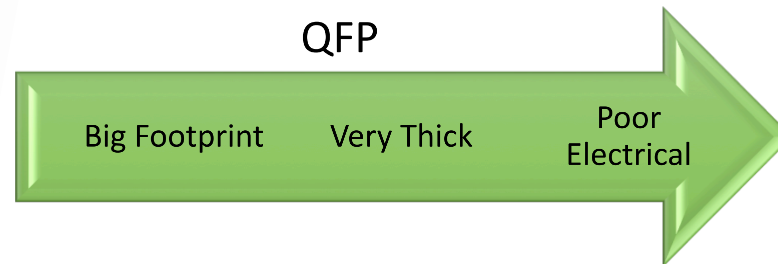
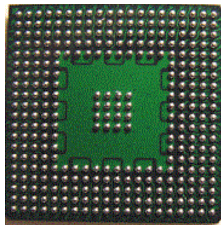
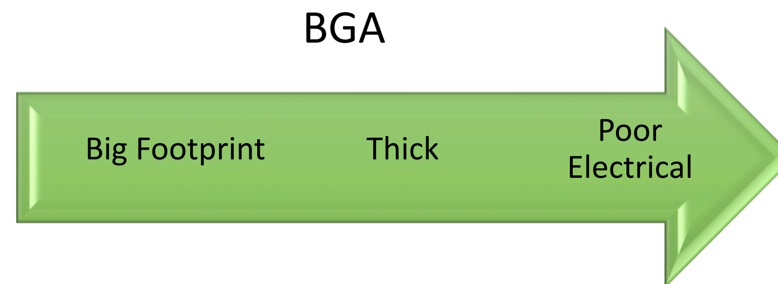
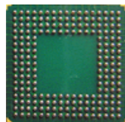
CSI™ Is a Path Forward for Older Packaging Technology

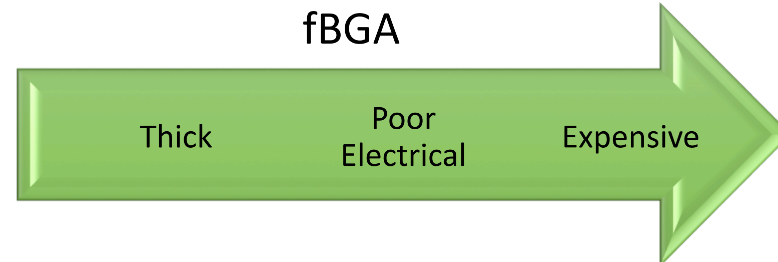


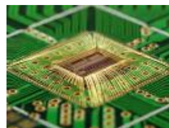


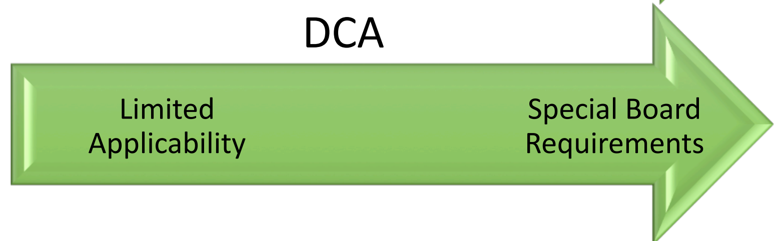




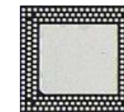








250 microns thin



CSI™

2 to 500+ leads

300 microns solder pad pitch

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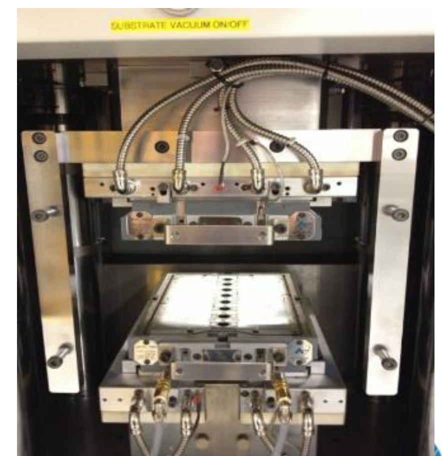
CSI is Fully Compatible with Standard QFN Infrastructure

- Performs well with Cu, Au & Ag automatic wire bonding
- Compatible with common die attach epoxies and die bonders
- Fully functional with mold compound intended for standard QFN leadframes
- No Etching or plating required



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Broadening Our Scope to Leverage the Technology

Multi Materials 3D Printing is a Game Changer

Volume production of real world products using materials optimized for the application, **not** the process

Unique Capabilities Developed

- Print forming complex 3D structures
- Real engineering materials, used in combinations, specifically chosen/developed for the application
- Fugitive materials for cavities within closed structures
- Cofired PZT and conductors for energy harvesters, sensors, actuators
- Controlled adhesion interface for sintered systems
- 2½D direct photolithography

What Are the Best Applications Going Forward

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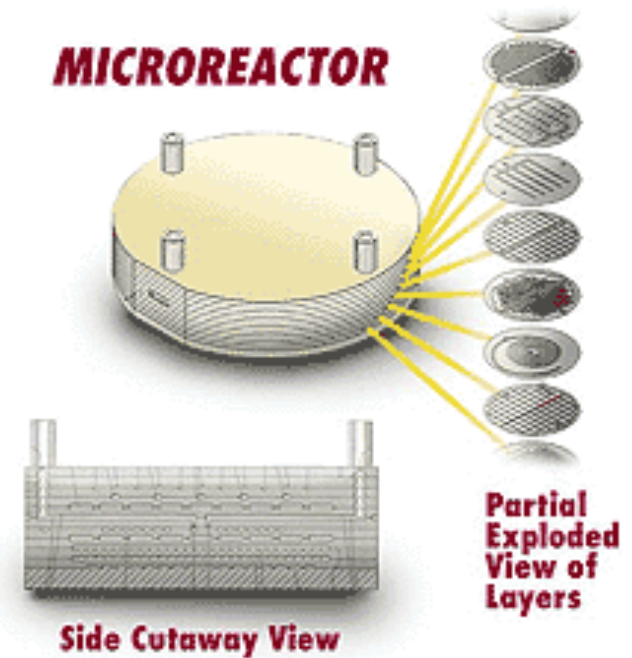
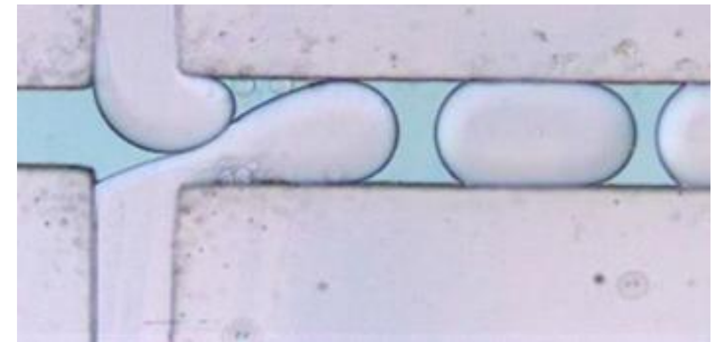
HVPF™ is Ideally Suited for Meso Scale to Micro Scale Fluidic Devices

- Micro reactors for flow chemistry – an emerging market
  - Better control of mixtures and conditions greatly increase yields
  - Better control of temperature and smaller "at-risk" volumes increase safety
  - Highly scalable in a smaller footprint than batch chemistry
- Components for micro fuel cells – a promising area of development
  - Reformers
  - Electro osmotic pumps
  - Thermal packaging





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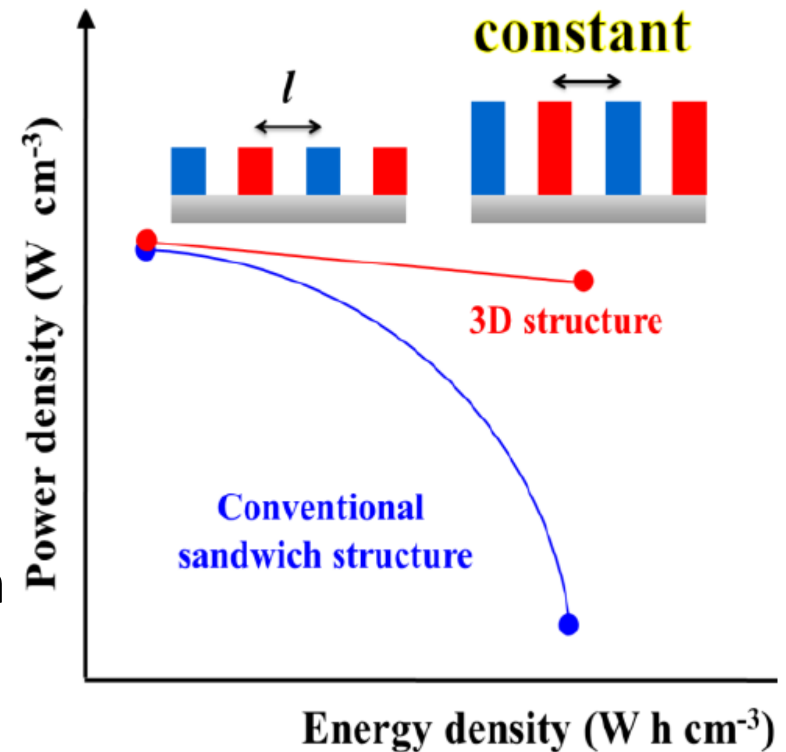
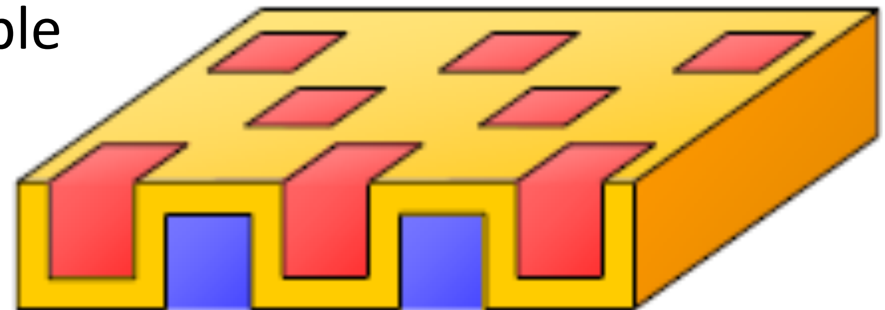
Multi Material 3D Printing Enables Highly Efficient Li Ion Battery

- Conventional sandwich structure sacrifices power for energy
- Multi-materials 3D printing enables solid state battery
  - Solid electrolyte is a game changer but it needs to be thin
  - Improves safety for high energy electrodes
  - Enables Li metal rechargeable
- Scalable from very small to electric vehicle size





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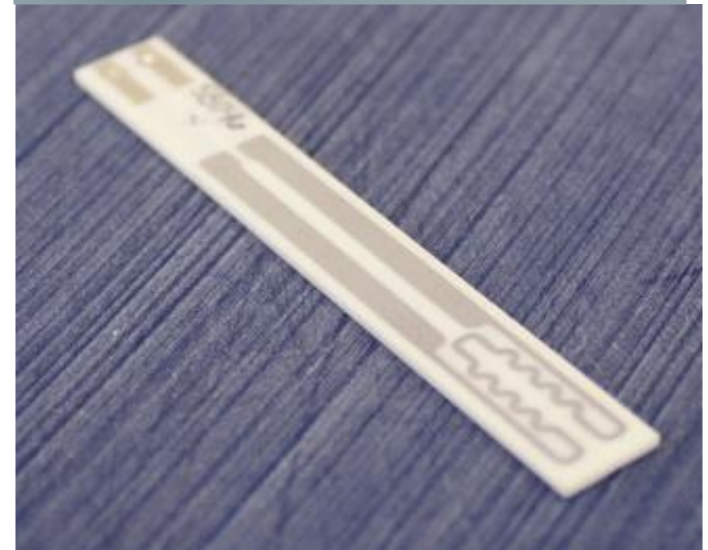
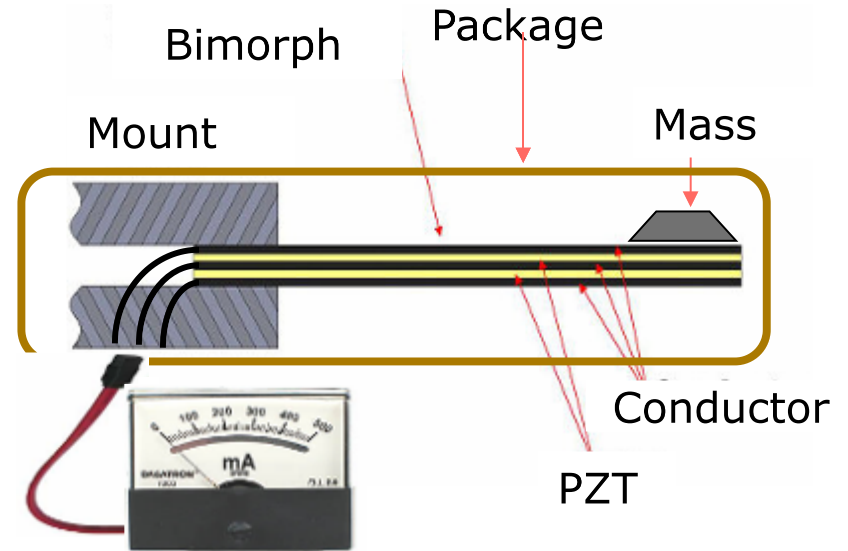
Chemical Sensors

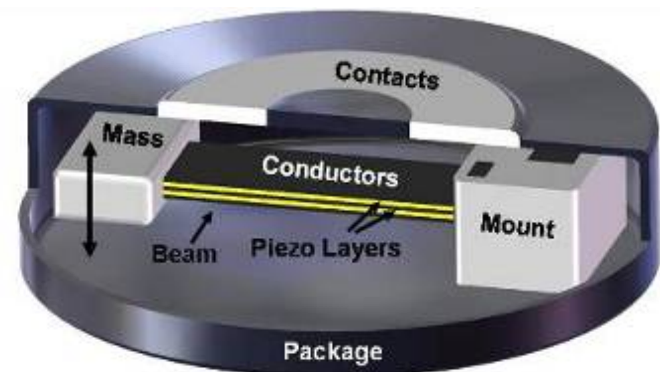
- Automotive emission control sensors for the next generation of cleaner Internal Combustion engines
  - Advanced electrochemical materials technology
  - Precision forming technology to create the low mass measurement cell
- Small low power sensors for CO, CO2 and Hydrocarbon



Piezo Energy Harvester – a Complex Materials & Processing Challange

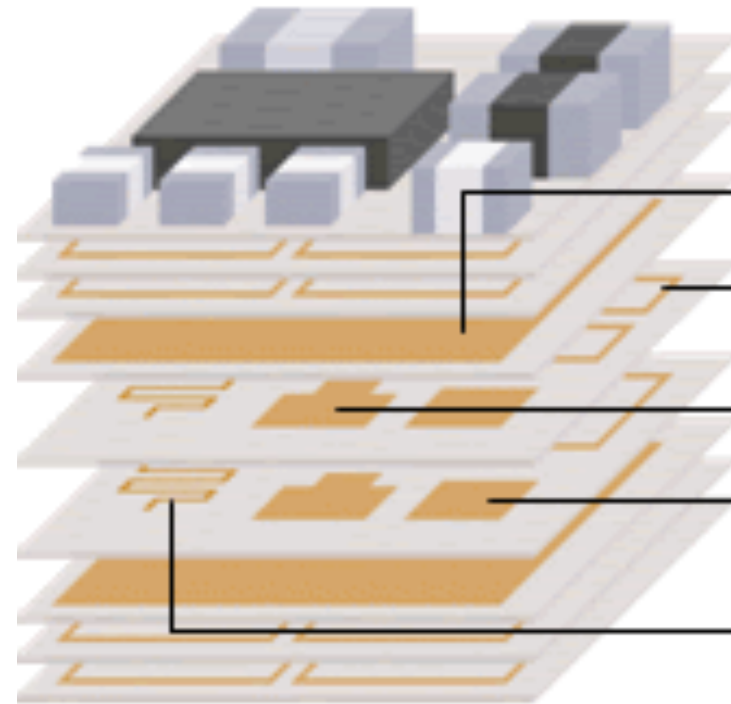
- Energy Harvesters for remote sensors
- PZT and metals in small complex structures
- Fugitive materials create space for moving parts
- Building a complete system in situ
- Applications
    - Tire pressure sensor
    - Wireless medical devices
    - Autonomous wireless networks





Internet of Things Needs Integrated Sensors, Actuators, Radios and Power

- 13 Billion connected devices today; 50 billion by 2020
- Multi-material 3D printing can integrate many basic components – just add chips
  - Interconnect modules
  - Antennas
  - Filters
  - A broad range of sensors
  - Acutators
  - Power sources
    - Li metal batteries
    - Piezo energy harvesters
    - Solar cells



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Features Of the Technology

- Forms thousands of complex parts simultaneously
- Can include 3D components and internal cavities
- Components include one or many materials
- Extremely wide selection of materials
- No hard tooling – simple photo tools or straight from the computer

3D High Volume Print Forming Technology Benefits

- Big design advantages compared to existing methods
  - Wider range of materials to optimize structures
  - Create features that were nearly impossible before
- No hard tooling required
  - Reduces cost
  - Cuts prototyping/manufacturing time substantially
- Highly cost effective with ”panel processing”

Thank You

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