EoPlex™

Member of ASTI

High Volume Print Forming

3D Printing for Volume Manufacturing

IEEE August 25, 2015

Semiconductor Equipment

Semiconductor Manufacturing Services

Semiconductor Packaging Solution

Equipment Contract Manufacturing

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About EoPlex

- Headquarters: San Jose, California
  - R&D, Sales and Marketing
- Subsidiary of ASTI since 2012
- Production Facilities in Penang
- Expanded Manufacturing Capability in Cavite, Philippines – Q2 2016
- Creator of 3D High Volume Print Forming process (HVPF™) for multi material additive products

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3D Printing

- "Money will be made with manufacturing, not with prototypes,"
  Tim Caffrey, Wohlers

3D Printing

- "Money will be made with manufacturing, not with prototypes," *Tim Caffrey, Wohlers*

- "I think the next big innovation that is needed is 3D printing with multi-materials—that is, the ability to print any material at any location in three-dimensional space." *Tim Simpson, Professor, Mechanical and Industrial Engineering at Penn State University and ASME AM3D chair*

Advanced Layered Deposition Technology

Featuring:

⇒Real engineering materials
(Ceramics and Metals)

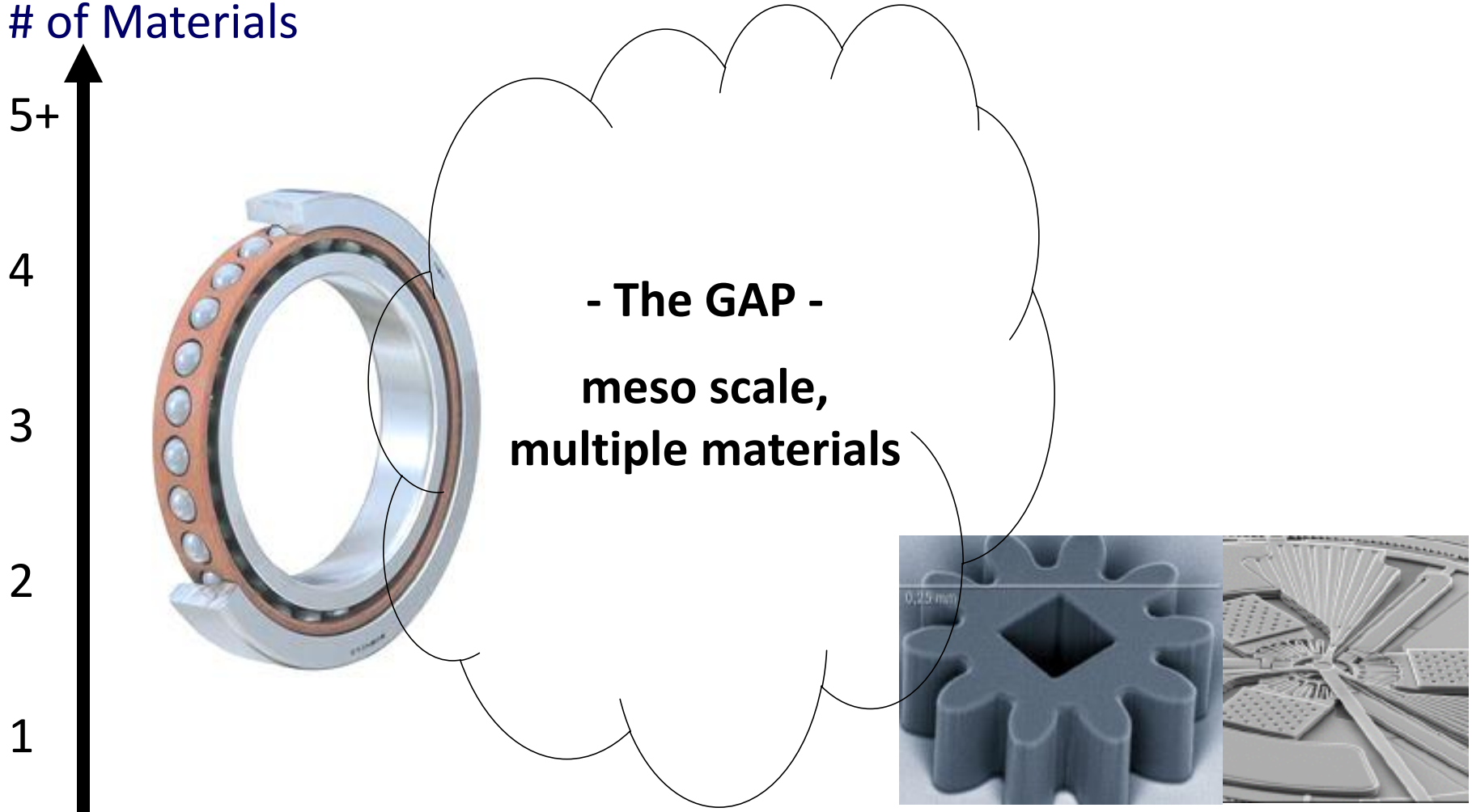
⇒Multiple materials in each device

⇒Exceptional design flexibility

⇒Highly scalable through panel processing

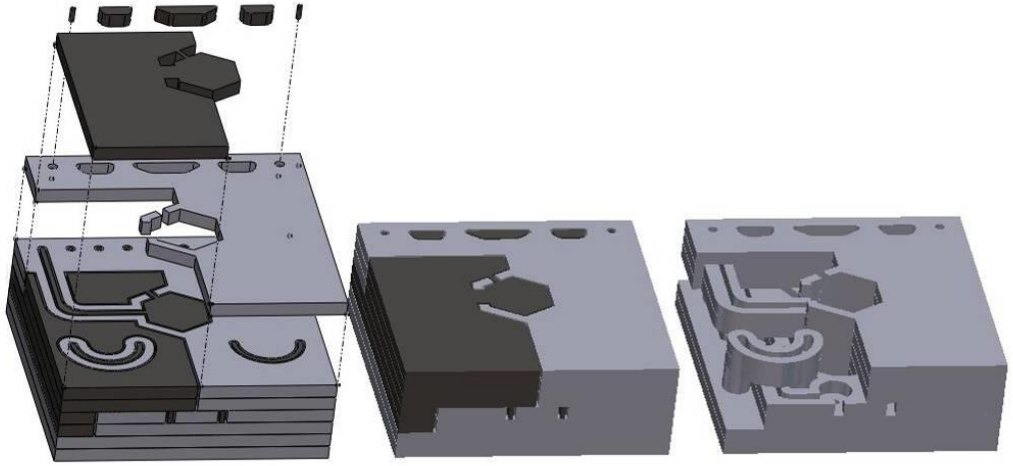
Works for a Wide range of Applications with a Wide range of Materials

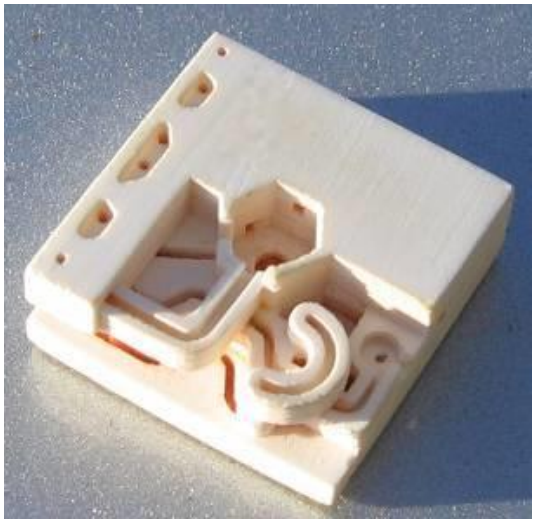
EoPlex 3D HVPF™ Fills the Gap Between Macro and Micro Fabrication



High Volume Print Forming

- Sequential deposition of layers

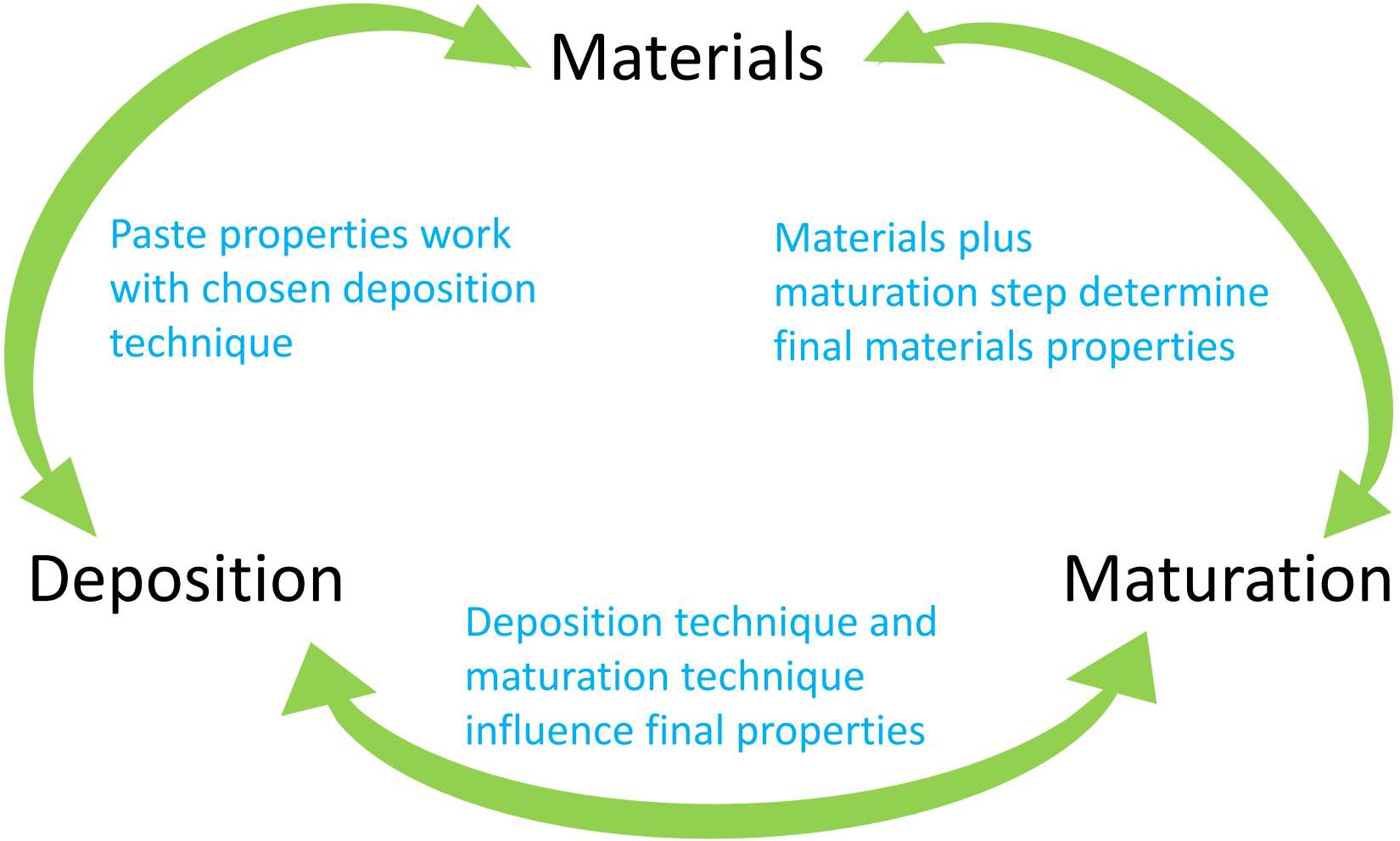




  - Ceramic or metal loaded paste for final structure
  - Fugitive material to create precision internal voids
- Fugitive removal/sintering yields complex structure composed of high performance materials
- Panel processing makes it cost effective

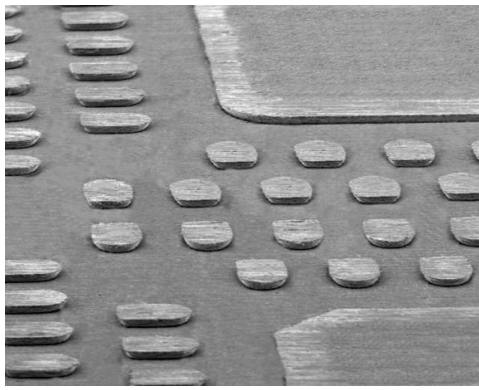
Keys to High Volume Print Forming

Basic Elements Must Work Together



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 700°C to 1,000°C
- 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

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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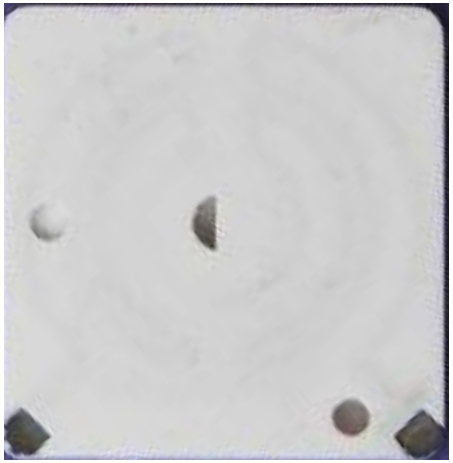
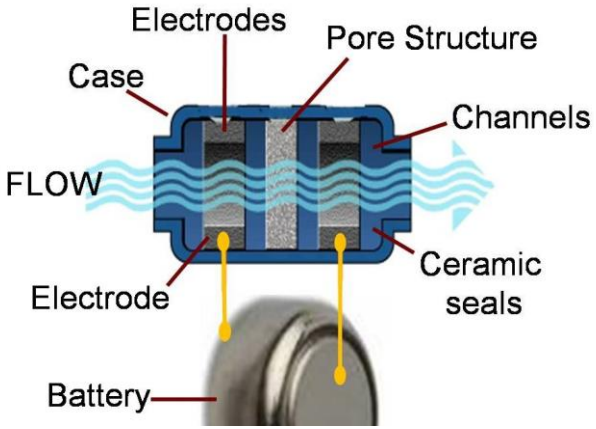
Fluidics are a Perfect Fit

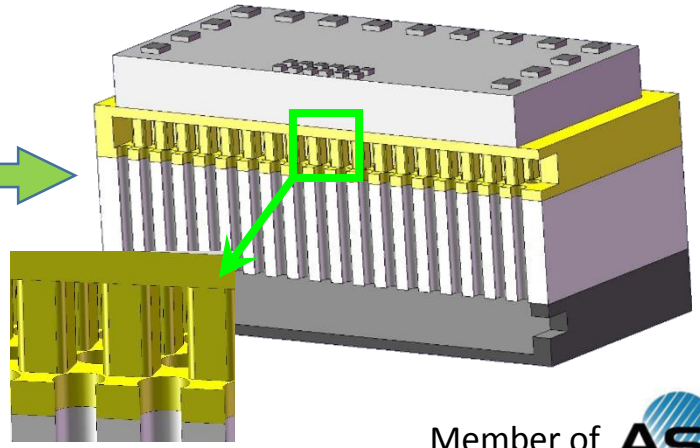
- Methanol reformer for micro fuel cells



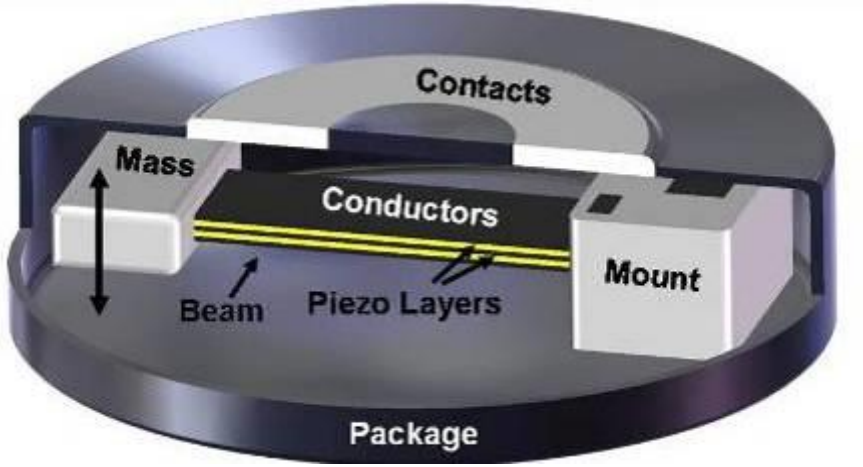


- Electrophoretic pump for micro fuel cells

- Loop heat pipe to cool high power semiconductors



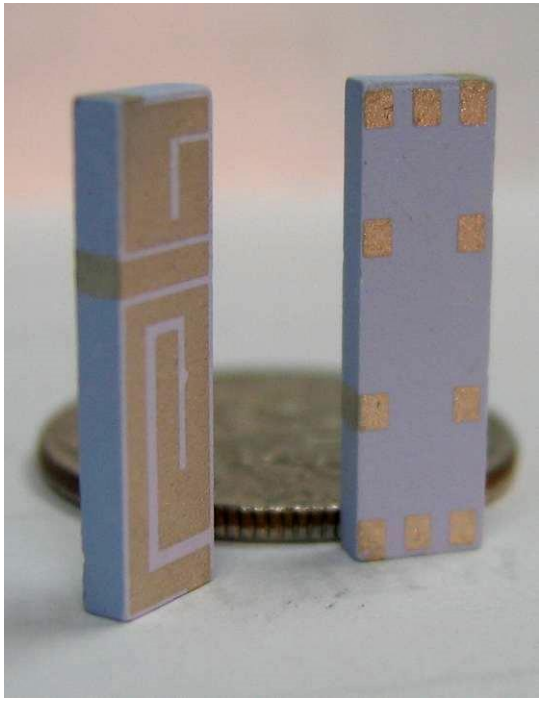
Piezo Materials Enable Sensors, Actuators, Energy Harvesters & more



- 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

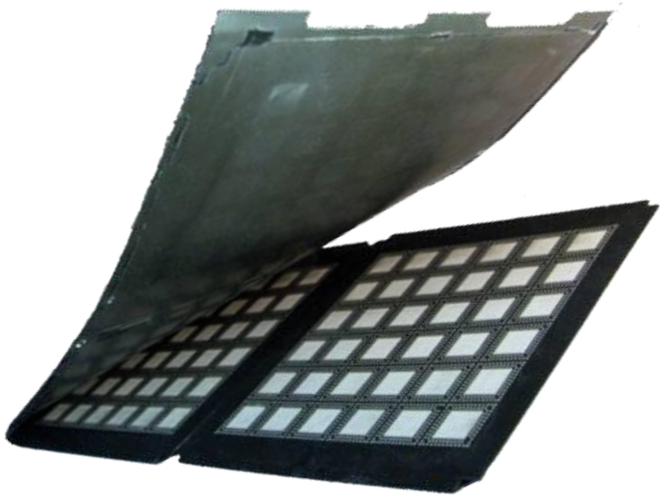
Conceptually simple, EoPlex processes reduce cost and enhance performance.



- 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

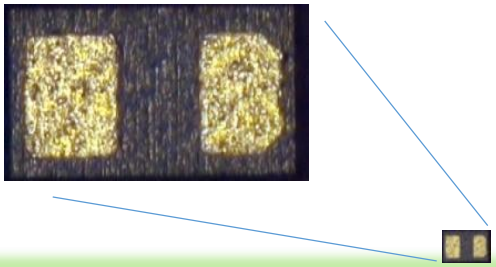
EoPlex Configurable Sintered Interconnect – CSI™



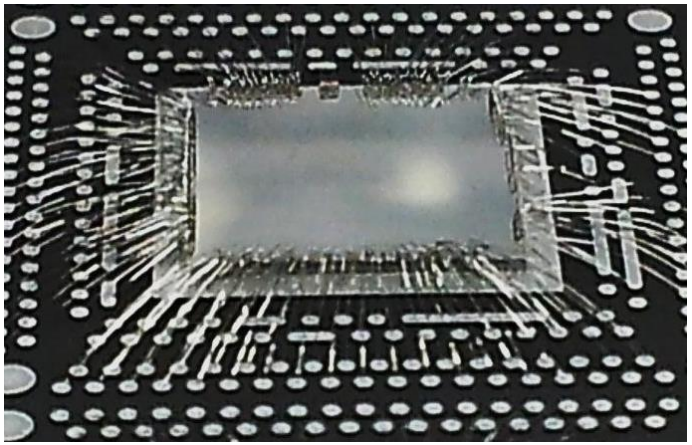
A More Capable Replacement for QFN leadframes

CSI™ is a Vehicle for Expanding QFN Packages Capability

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

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

What Are the Best Applications Going Forward

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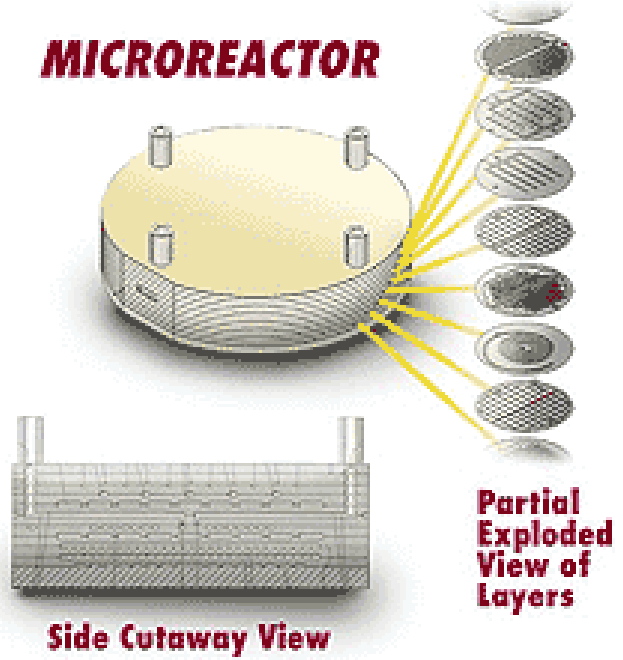
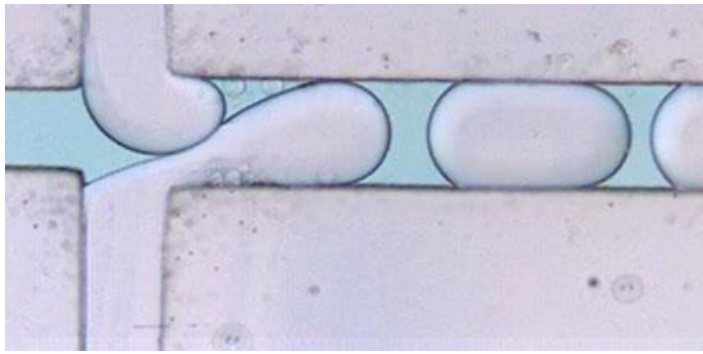
HVPF™ is Ideally Suited for Meso Scale to Micro Scale Fluidic Devices

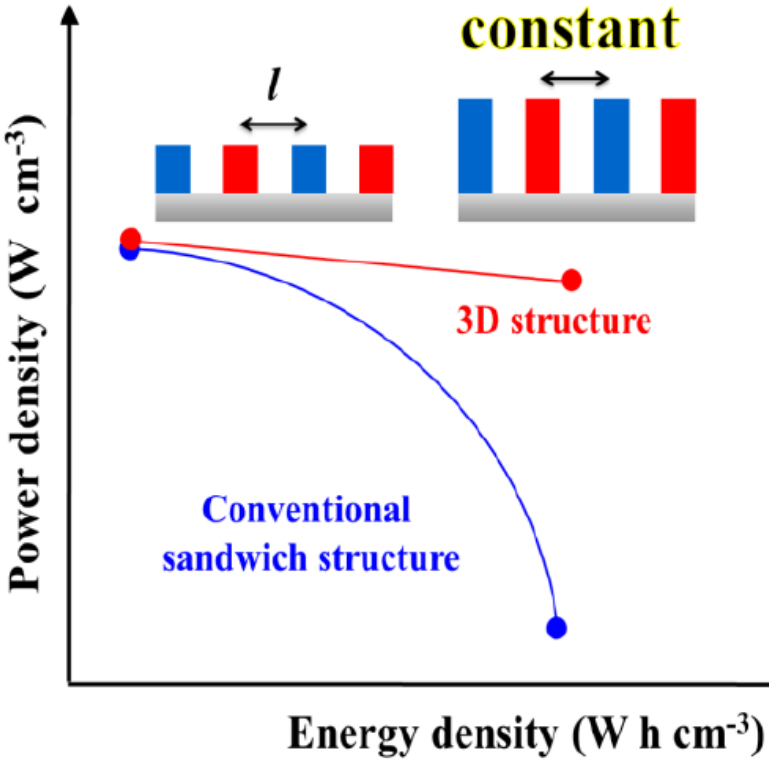
- Micro reactors for flow chemistry
  – an emerging market
    - Better control of mixtures and conditions greatly increase yields
    - Better control of temperature and smaller “at-risk” volumes increase safety
    - Highly scalable in a smaller footprint than batch chemistry
- Components for micro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

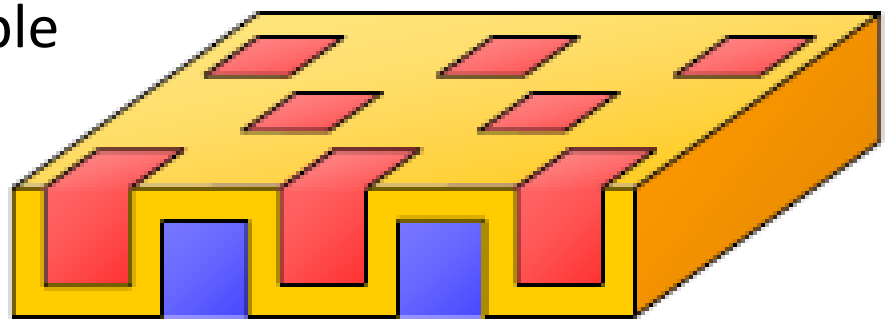




Multi Material 3D Printing Enables Highly Efficient Li Ion Battery

- 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





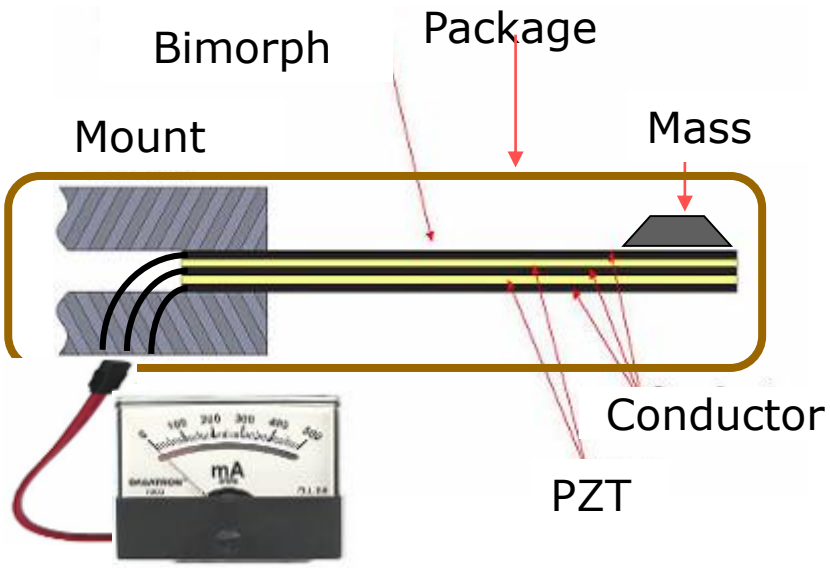
Chemical Sensors

- 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, CO_2 and Hydrocarbon

Piezo Materials are Challenging But Highly Useful

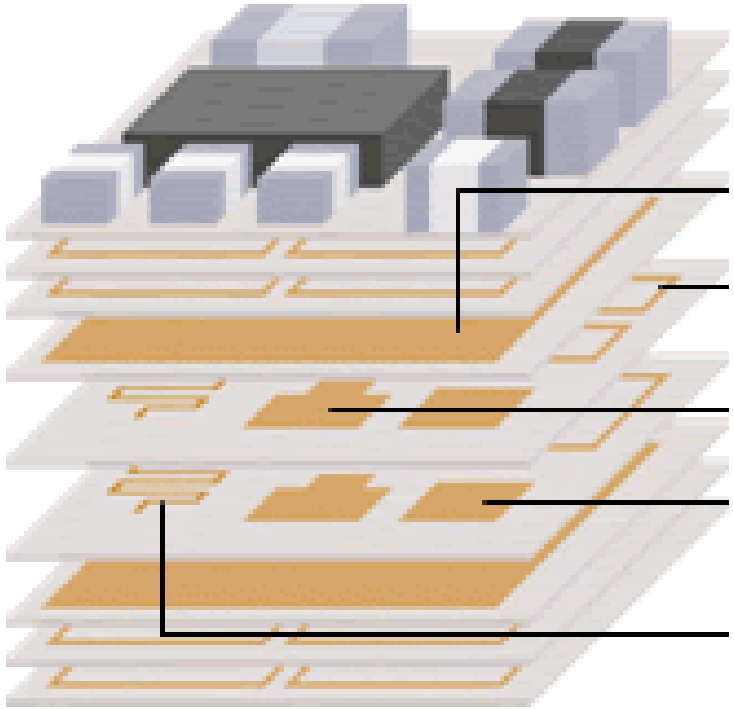
- Cofired PZT and metals in small complex structures
- Fugitive materials create space for moving parts
- Building a complete system in situ enables integration
- Applications
  - Energy Harvesters
  - Sensors
  - Actuators

Piezo Energy Harvester



Internet of Things

- 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



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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