Bridging The Gap Between “Nano”
And “Just-Plain-Miniature”
High Volume Print Forming (HVPF™)

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Overview

• Nature of the gap
• Technologies available
• Challenge remaining
• High Volume Print Forming (HVPF™)
  – An addition to the state-of-art
  – How it works and advantages
• Applications
  – Tire Pressure Sensors
  – Fuel Cell Reformers
  – Cell Phone Antennas
The Gap Between “Nano” and Miniature Devices is Huge

- Size
- Materials
- Complexity

S-Type
M-Type
C-Type

S-Type Range $10^9$

“Plenty of Room at the Bottom” Feynman 1959
### M-Type
**Materials > 1 Increase Difficulty**

- Single material: metal, ceramic, polymer
- Multiple similar materials
- Two or more different materials
- Multiple materials in limited location
- Multiple materials in any location

### C-Type
**Complexity Makes Everything Harder**

- Constant cross section **Easy**
- Z-Axis Variation
- Overhangs & Undercuts
- Internal channels and pathways
- Circuits, Sensors, Components
- Encapsulated moving parts
- Hermetically sealed chambers **Very Hard**
S+M+C Type Combinations
Expensive or Even Impossible

- Small Size
- Multiple ceramic, metal or polymer parts
- Complex internal features
  - Conductors
  - Dielectrics
  - Sensors
  - Capacitors
  - Channels, fluid paths
- Precise dimensions and tolerance

Some Tech To Bridge Gap Include:
- Machine & Assembly
- Injection Molding
- Rapid Prototyping
- Embossing
- LIGA, EFAB, MEMs
- Electroform

Viaduct 1000 feet over the river Tarn in South Western France
Injection Molding: Good With Simple Parts & 1-2 Materials

Rapid Prototype (RP): Models & Small Runs With One Material

Source: Stratasys, Inc.
Source: ProtoNow Engineering
MEMs: Semi-Technology, Produces Amazing Devices From Silicon

Source: Sandia National Laboratories

Self Assembly: RFID to C-Nanotubes

RFID chips source Hitachi

Carbon Nanotube
How Small Is A Nanometer?

Gals. to cover 1nm thick?

Today’s Focus Is on the mm-µm Not nm

# of Materials
5+
4
3
2
1

Largest

Size: Log Scale

Smallest

Machine & Assemble
Molded
MEMs
Self Assemble

The GAP
Specifically The Portion Of The Gap From 40µ To 40mm

L: Fine Hair 40µ dia. R: Silver Dollar, 40mm

Size Neighborhood: Small Mice-Big MEMs
In This Size Range Assembly Is Common For S+M+C Parts

Piezo vibration canceling device

Assembly Has A Lower Size Limit And Requires Cheap Labor

Cell phone vibration motor

4 mm dia. X 8 mm long

Source: Precision Microdrives
Assembly: Not New Tech & Not Scaleable

Modern Cell Phone Vibration Motor

Feynman Prize: working motor
no more than 1/64th in./side
McLellan: Motor - winner

The Challenge
How do you produce large volumes of small, complex ceramic and metal parts, with internal structures, components and connectors at low cost?
The Challenge: High Volume, Complex, Multi-material Parts at Low Cost

H₂ µReformer: Highly Complex Multi-Material Challenge

33 Features
300 Layers
Ceramics
Metals
Catalysts
Fugitives

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EoPlex HVPF™ Fills Key Part of The Gap

How EoPlex Works; A Simplified Example

Simple part with these features:
- Hollow Via
- Dielectric
- Conductors
- Suspended Area
EoPlex Process Builds In Layers

Many Finished Parts Produced At Once
Panels of Parts Processed Together

Heat Treating
EoPlex HVPF™: Low Cost Even With Complex Designs

Device Dimensions
- Min. length: 1 mm
- Max. length: 200 mm

Feature Dimensions
- Min. (standard process): 100 µ
- Min. (extended process): 25 µ
- Feature tolerance: +/- 0.5%

Layer Characteristics
- Max. materials/layer: 7+
- Typical layer thickness: 40 µ
- Min. layer thickness: 5 µ
- Layer thickness variability: 2%
Proprietary “Inks” & Process Are Required

**Material Factors**
- Chemistry and Rheology
- Solids Loading
- Shrinkage
- Particle Size Distribution
- Morphology
- Interface Bonding
- Coefficient Thermal Expansion

**Process Factors**
- Print Quality
- Cure System
- Sintering Profiles
- Atmosphere

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**EoPlex Current Catalog of Materials**

- Cofired Ceramics LTCC (800C), HTCC (1200C)
- Piezoelectric (PZT) ceramics
- Nickel Alloys, Stainless Steel
- Palladium-silver, silver, gold, copper, platinum
- Oxides like Alumina (Al₂O₃), Silica,(SiO₂)
- Glasses like Boro-Silicate
- Polymers with ceramic and metal fillers
Process Summary

• EoPlex process is a new way to build devices
• Parts are “printed” in layers with proprietary inks
  - Ceramics - Polymers
  - Metals - Fugitives
• Materials react and form complex parts at low cost
• Allows new ways to design existing parts
• Provides opportunity for totally new designs

Since HVPF™ Is Based On Printing, Complex Designs Are Low Cost

Simple

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Complex

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Components Can Be Integrated During Processing, Lowering Cost Further

- Circuits & Passives
- Energy Scavengers
- Reaction Chambers
- Cavities & Channels
- Catalyst Beds
- Heating Elements
- Sensors

Modifications Are Fast & Low Cost

Different Materials

Add new feature with HVPF™
- 2 days
- Low Cost
- No Hard Tool
EoPlex Applications: 3 Current Examples

1. Ceramic Antennas

2. Tire Pressure Sensors

3. Emergency Radio Power

Ancillary Antennas Link To Many Devices

- 2008: 3.8 B ancillary antennas; 0.6 B ceramics
- 2012: forecast 6.9B ancillary antennas; 3.4B ceramics
Ceramic Ancillaries: Highest Performance

Requires integration of complex metal-ceramic structures with voids – **Perfect For EoPlex**

EoPlex: Advantages In Ceramic Antennas

- Low cost
- Metallization on all faces
- Embedded antennas
- Embedded voids
- Via-less conduction paths
- Multiple dielectrics in the same part
- Several antennas in the same part
- Custom dielectrics
- Small size

Different Dielectrics

Voids
EoPlex Controls The Process from Raw Materials To Finished Parts

- Proprietary material formulations
- In-house processing for consistent batches
- In-process testing
- Finished parts testing
- ISO 9001 certification expected Q4 2008

First Plant Scheduled For July 2008

- New VC funding for antenna manufacture
- Facility adjacent to our current site
  - Quadruples manufacturing and test space
  - Staff will double by year end
  - Space for multiple lines
- Installation starts May; production begins Q3
- Ultimate line capacity: 40M units/year
- Additional factories planned for outside USA
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Tire Pressure Sensors All New US Cars

- TREAD Act: response to SUV rollovers in the 1990s
- Under inflated tires dangerous and waste energy
- TPS: wireless unit for each tire
- Sends warning and or data to driver display
Battery Life: The Achilles Heel of TPS

• Battery life is a major concern
• Maintenance est. $1,000/car lifetime
• Major consumer dissatisfaction expected
• Fear is customer will not replace dead batteries
• Both OEMs and regulators want a battery alternative

Piezo Energy Harvester Are Attractive Battery Replacement

• Advantages
  – Lasts the life of vehicle
  – Greener: no battery disposal
  – Not degraded in use
  – No motion sensor needed
• Unfortunately cost is high due to:
  – Size
  – Complexity
  – Number of Materials
Up To Five Materials Are Required

1. Mass
2. Package
3. Mount
4. Conductors
5. PZT Layers
6. Space

How EoPlex Builds EHs

- **Package & Mount**
- **Fugitive**
- **PZT**
- **Conductor**
- **Contact**
HVPF™ Many Parts Made Together & Sintered At Once

EoPlex Designs EHs For Specific Apps

- Poling Bath
- EH Fixture
- Shaker Platform
- Network Analyzer
- Capacitance Meter
- Oscilloscope
EoPlex Typical Design EH: Output

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Mobile Power Is Critical in Emergencies

• 1st responders & military burdened with extra batteries
• Fuel cell can replace the batteries, but must meet 20 watt specs.
• H₂ fuel cell meets specs, but supplying H₂ is a problem
• Solution: H₂ from alcohol, but requires complex micro reformer

Challenge: A Low Cost Micro Reformer
The Size Of A Few Poker Chips

1. Methanol + Water Fuel
2. 1st Catalyst: CH₃OH → CO + 2H₂
3. 2nd Catalyst: H₂O + CO → CO₂ + H₂
4. Gas Conditioning
5. Hydrogen to Fuel Cell
Reformer: Complex Structure: Required 300 Layers, 33 Features And 5 Materials

- Channels
- Chambers
- Ports
- 2 Catalysts
- 1 Metal
- 1 Ceramic
- 1 Fugitive

15% Shrinkage

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A Typical EoPlex Factory Module

- Low cost
- Relatively small
- Can be located anywhere in the world
EoPlex Working With Customers To Apply HVPF™

- Micro Pumps
- Cooling Devices
- Medical Parts
- Micro Reactors
- Energy Harvesters
- RF Parts
- Fuel Cell Parts
- Fluidic Devices

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