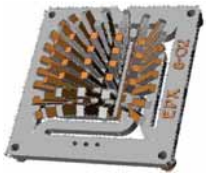


Bridging The Gap Between "Nano" And "Just-Plain-Miniature"

High Volume Print Forming (HVPF™)

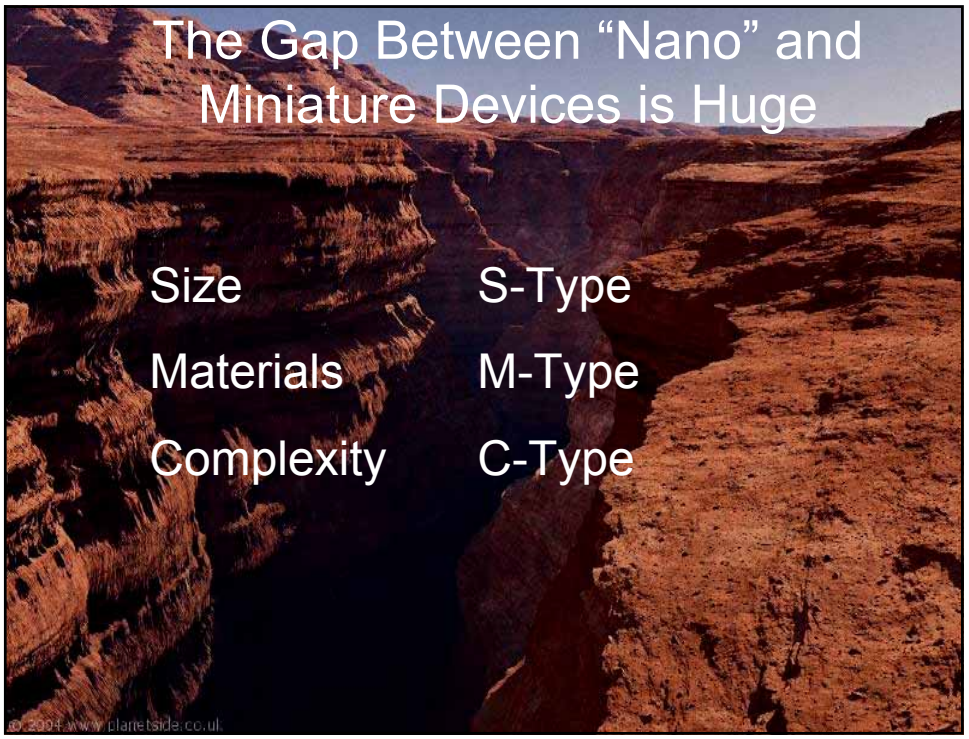
Arthur L. Chait
President & CEO
EoPlex Inc.
Redwood City, CA
www.eoplex.com

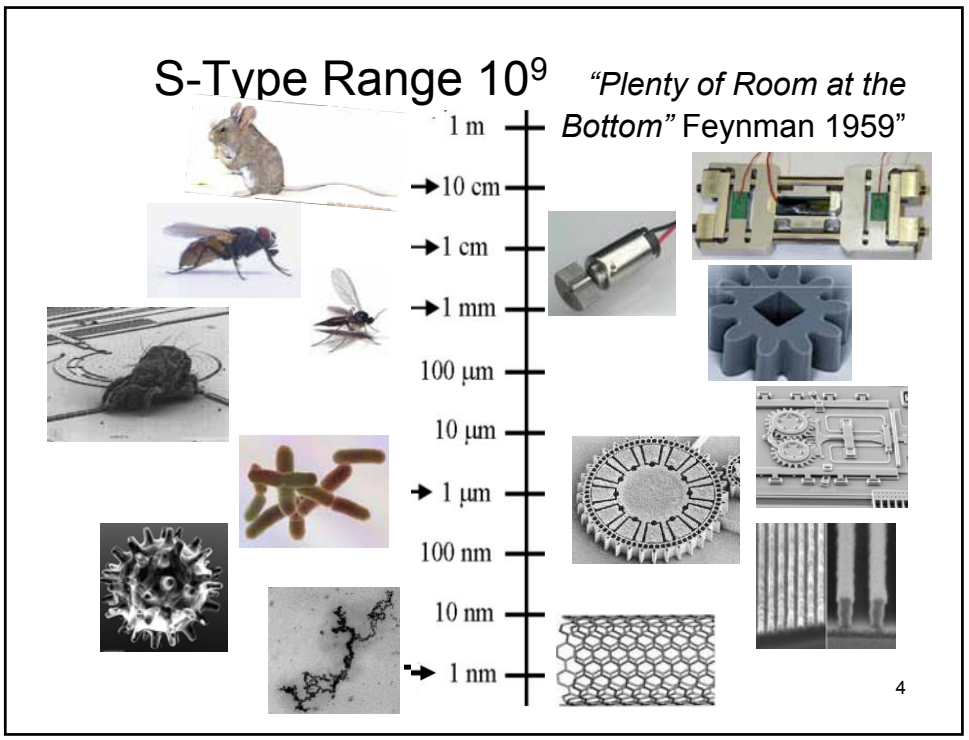
1

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

2


The Gap Between "Nano" and Miniature Devices is Huge
Size
S-Type
Materials
M-Type
Complexity
C-Type
© 2004 www.planetside.co.uk


S-Type Range 10^9
"Plenty of Room at the Bottom" Feynman 1959"
1 m
10 cm
1 cm
1 mm
100 µm
10 µm
1 µm
100 nm
10 nm
1 nm
4

M-Type
Materials>1 Increase Difficulty^{n}

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

5

C-Type
Complexity Makes Everything Harder

- Constant cross section
- Z-Axis Variation
- Overhangs & Undercuts
- Internal channels and pathways
- Circuits, Sensors, Components
- Encapsulated moving parts
- Hermetically sealed chambers

Easy

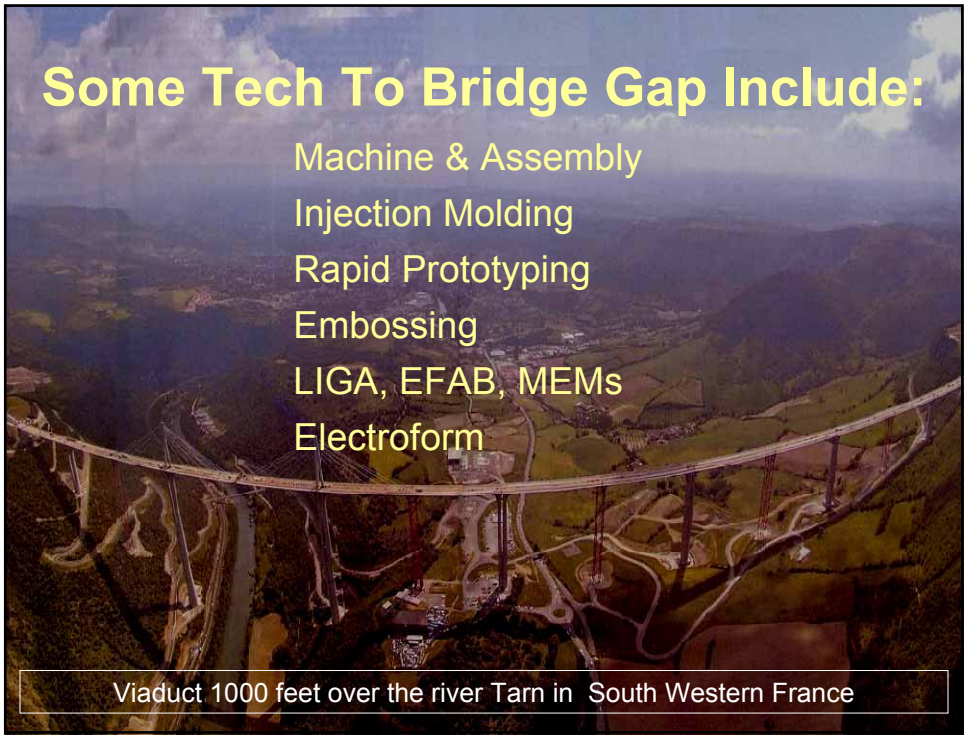
Very Hard

6

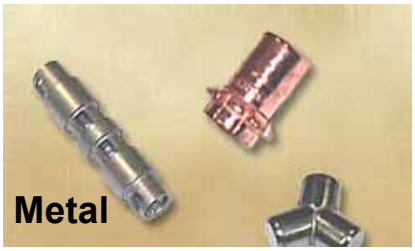
S+M+C Type Combinations Expensive or Even Impossible

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

7



Injection Molding: Good With Simple Parts & 1-2 Materials



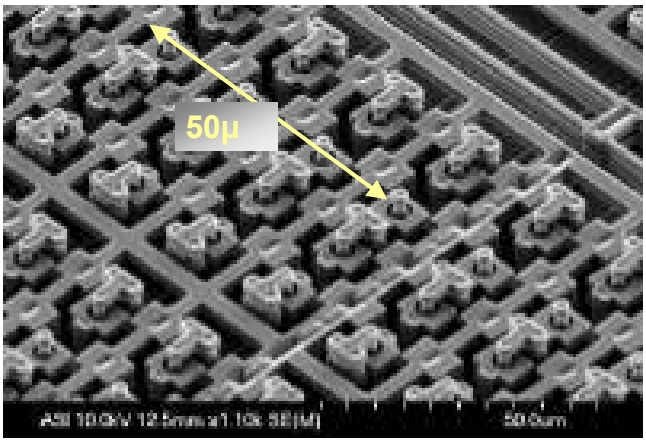
Rapid Prototype (RP): Models & Small Runs With One Material

Source: Stratasys, Inc.

Source: ProtoNow Engineering

10

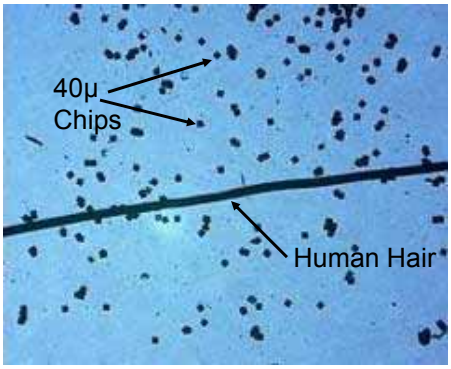
MEMs: Semi-Technology, Produces Amazing Devices From Silicon



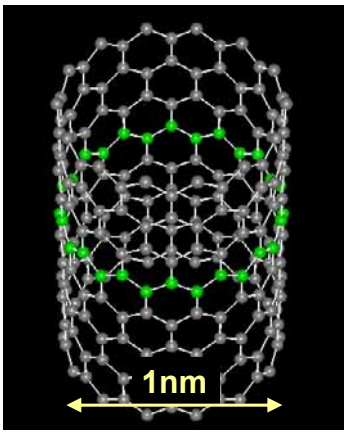
Source: Sandia National Laboratories

11

Self Assembly: RFID to C-Nanotubes



RFID chips source Hitachi



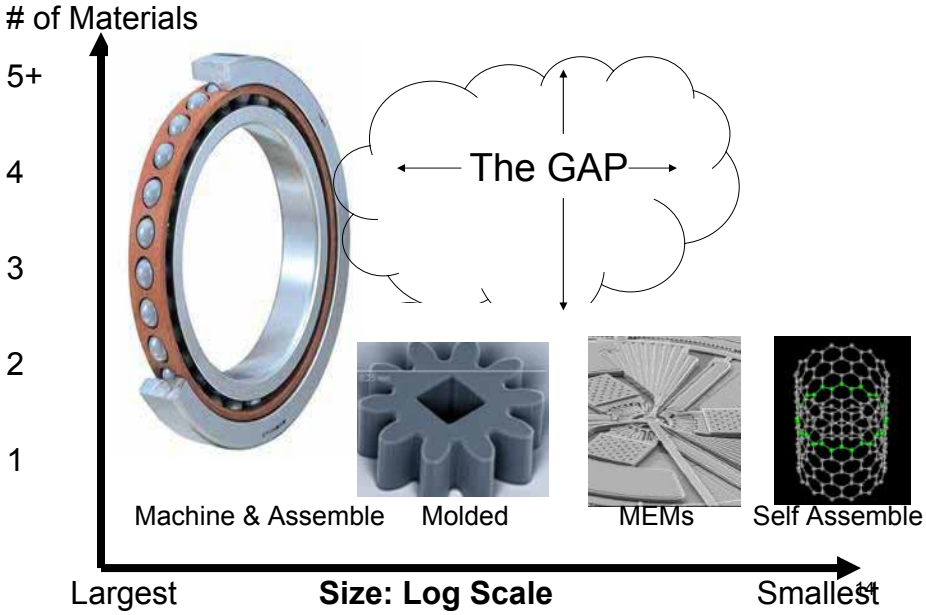
Carbon Nanotube

12

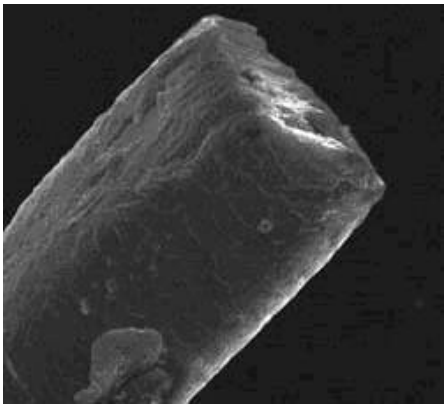
How Small Is A Nanometer?

Gals. to cover 1nm thick?

Today's Focus Is on the mm-µm Not nm



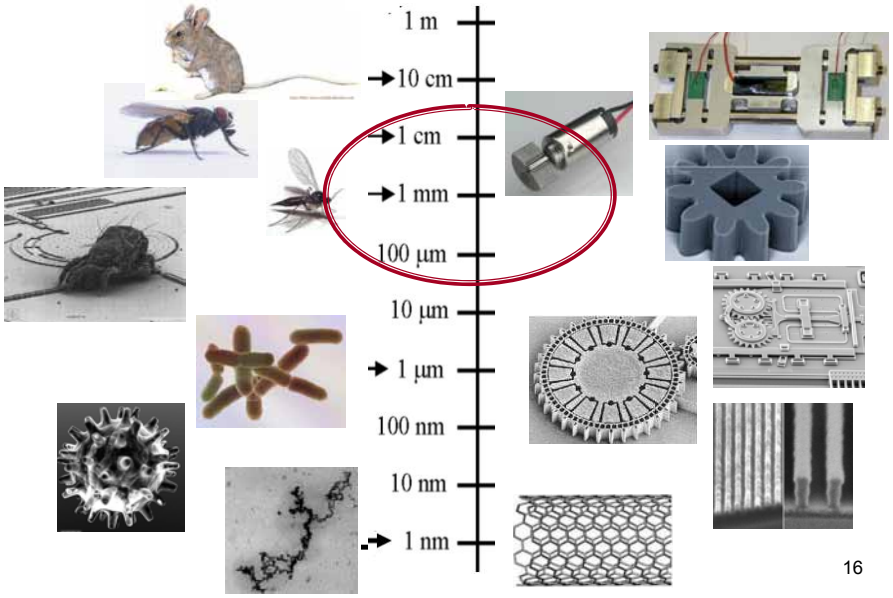
Specifically The Portion Of The Gap From 40μ To 40mm



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

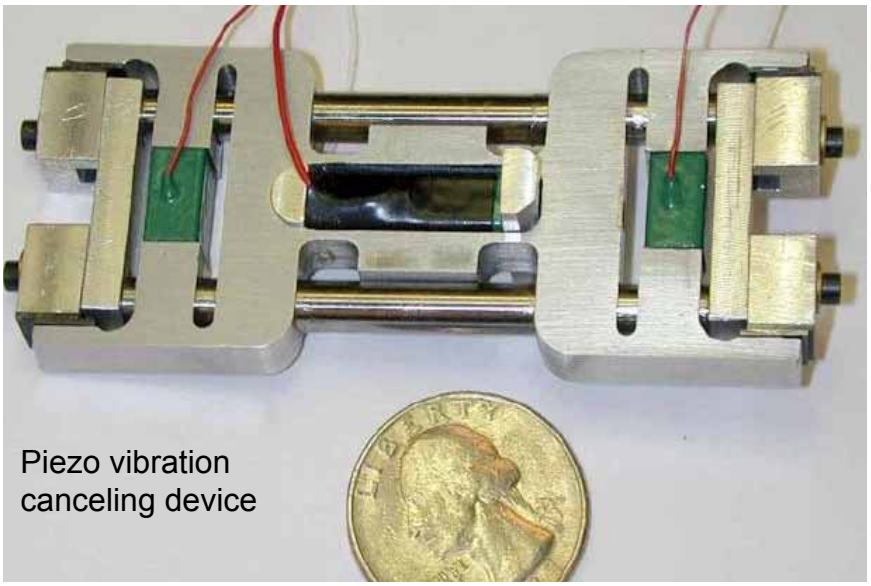
15

Size Neighborhood: Small Mice-Big MEMs



16

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

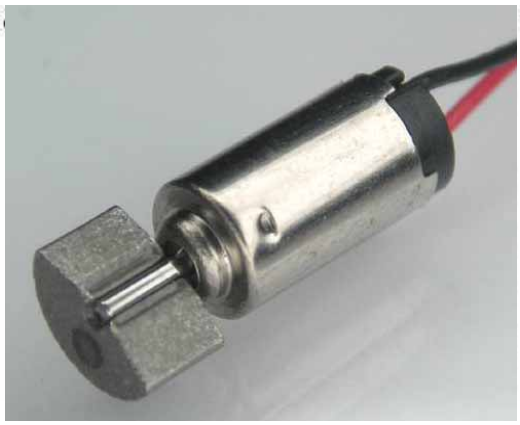
Cell phone vibration motor

4 mm dia. X 8 mm long

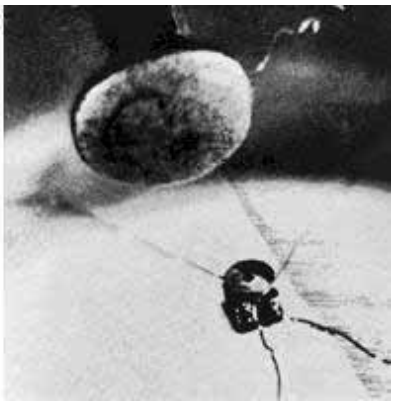
Source: Precision Microdrives

18

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

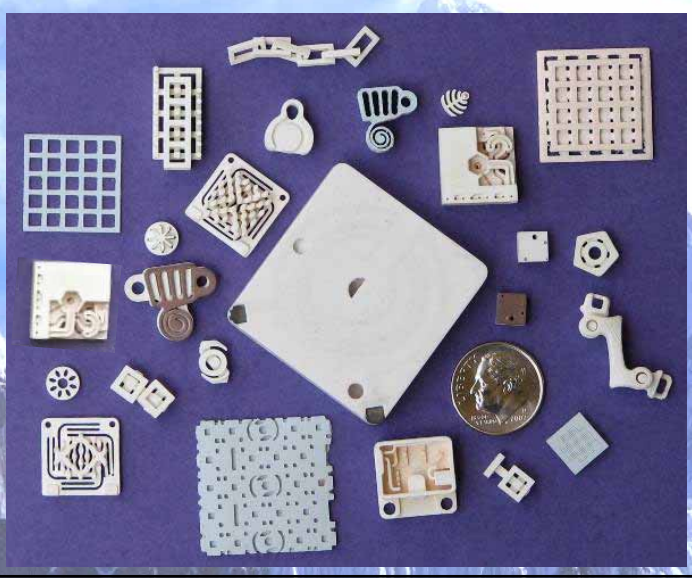
Image: Caltech Archives

19

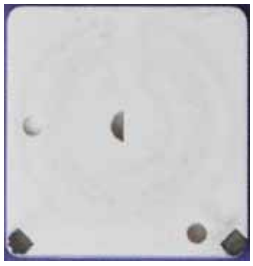
The Challenge

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



H_2 µReformer: Highly Complex Multi-Material Challenge



33 Features

300 Layers

Ceramics

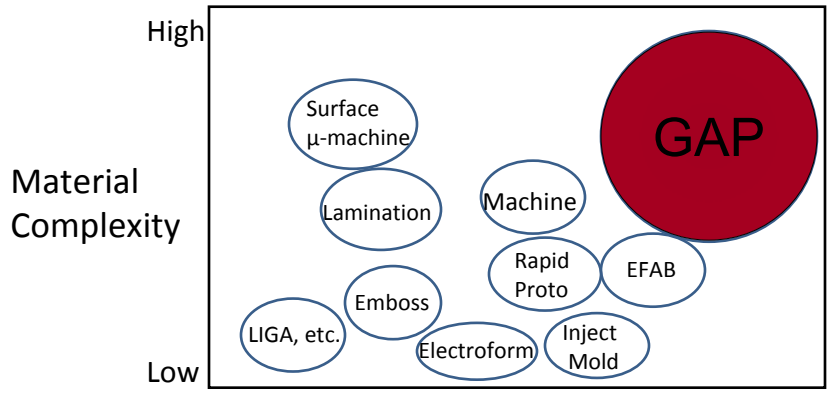
Metals

Catalysts

Fugitives

22

EoPlex HVPF™ Fills Key Part of The Gap



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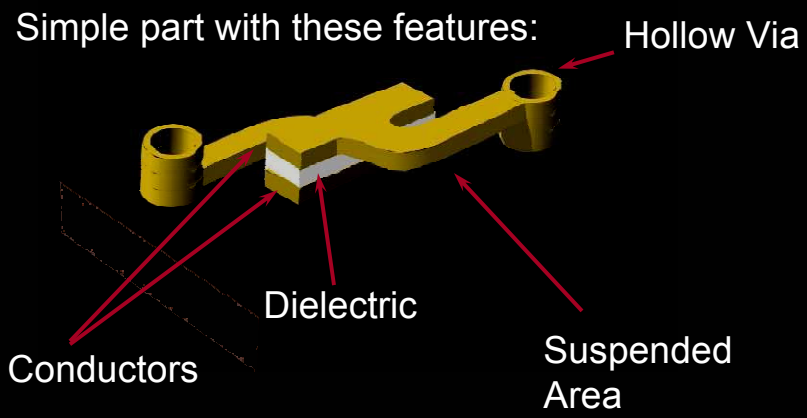
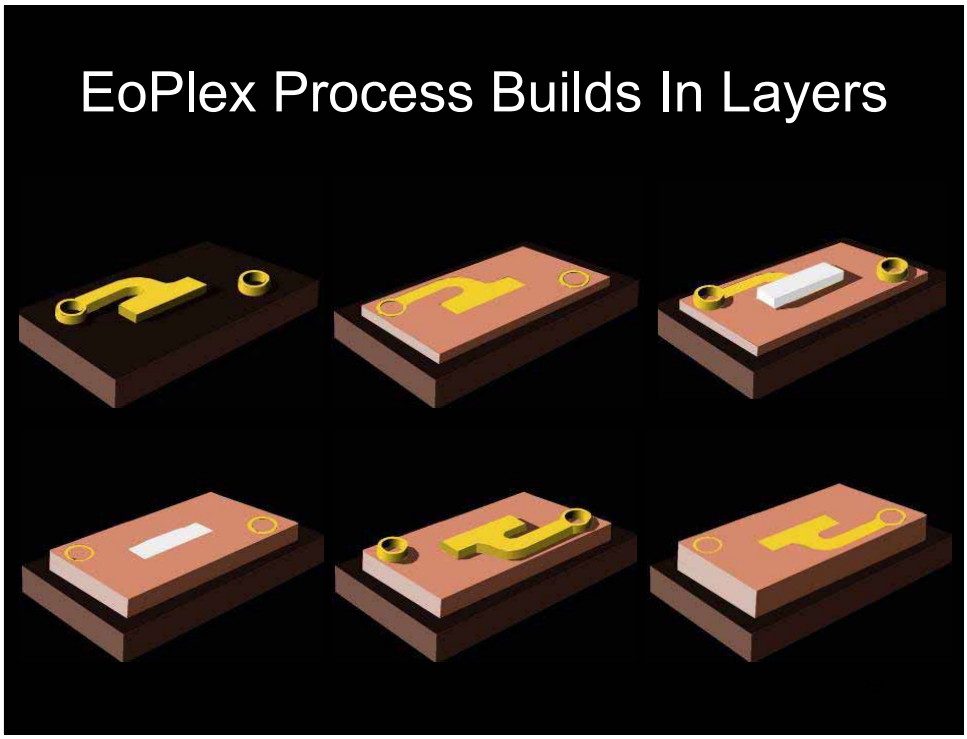
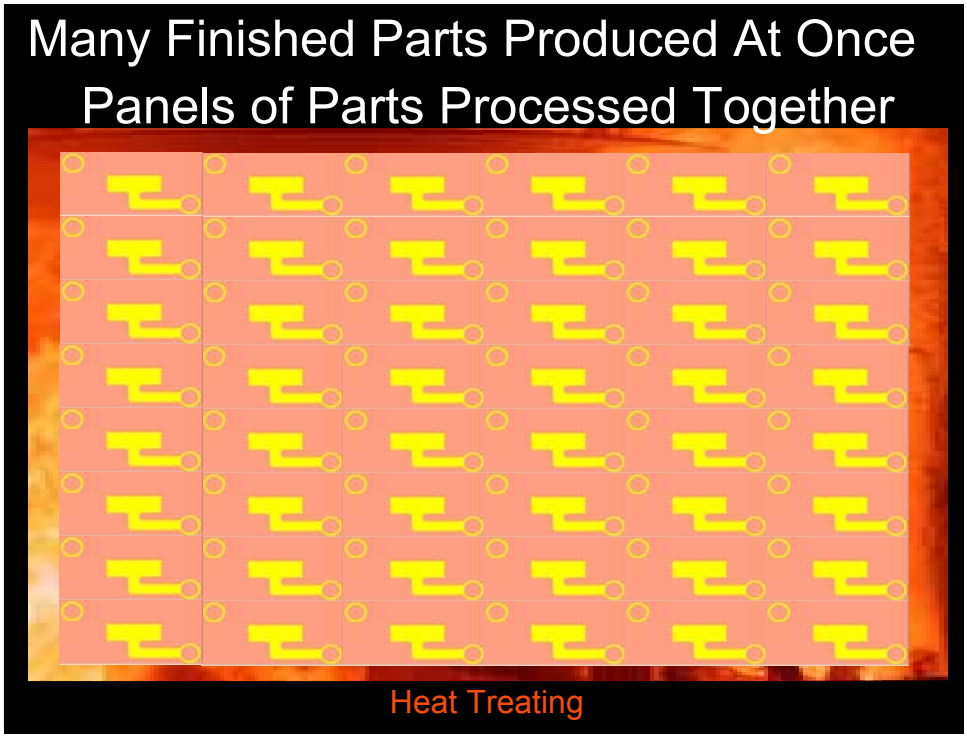
How EoPlex Works; A Simplified Example




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

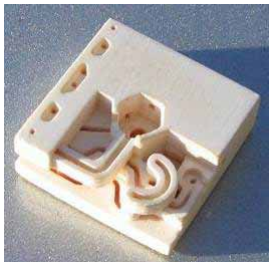
46 cm

Even Moving Parts

27

EoPlex Basic Design Rules

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%



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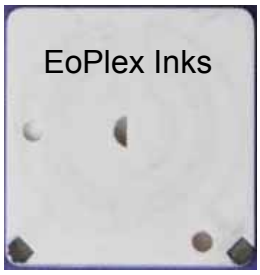
Proprietary "Inks" & Process Are Required

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



EoPlex Current Catalog of Materials

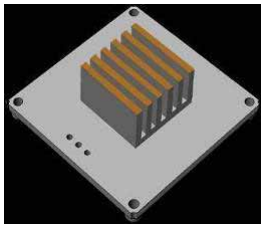
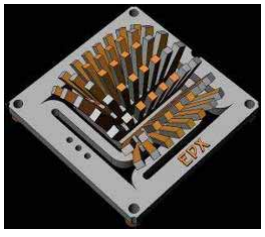
- Cofired Ceramics LTCC (800C), HTCC (1200C)
- Piezoelectric (PZT) ceramics
- Nickel Alloys, Stainless Steel
- Palladium-silver, silver, gold, copper, platinum
- Oxides like Alumina (Al_2O_3), Silica,(SiO_2)
- Glasses like Boro-Silicate
- Polymers with ceramic and metal fillers

Advantages 30

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
- **Advantages include…**

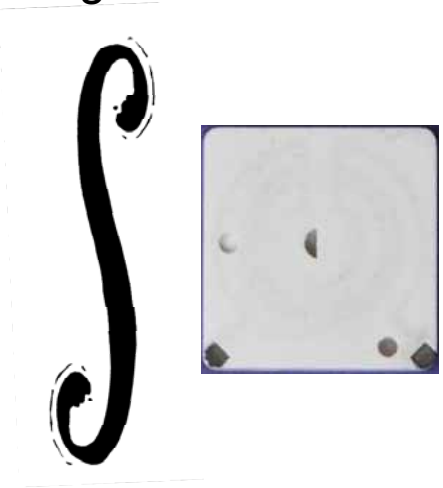
Since HVPF™ Is Based On Printing, Complex Designs Are Low Cost

	Letters		Parts
Simple	A	大	
Complex		武道	

32

Components Can Be Integrated During Processing, Lowering Cost Further

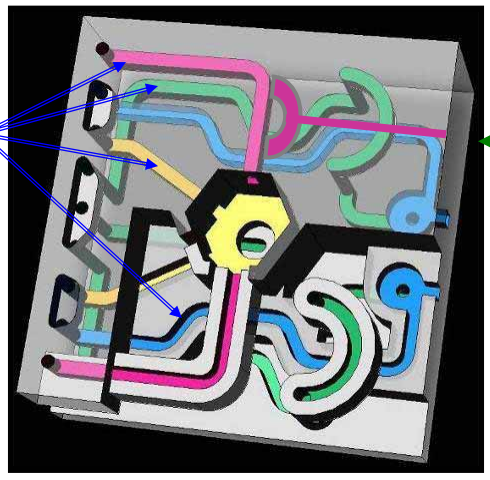
- •Circuits & Passives
- •Energy Scavengers
- •Reaction Chambers
- •Cavities & Channels
- •Catalyst Beds
- •Heating Elements
- •Sensors



33

Modifications Are Fast & Low Cost

Different Materials



Add new feature

With HVPF™

- •2 days
- •Low Cost
- •No Hard Tool

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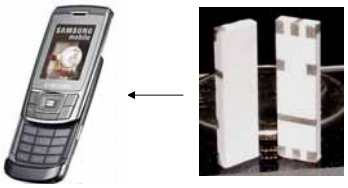
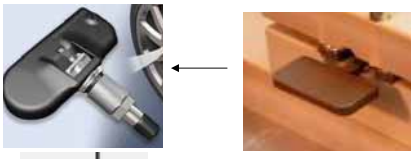
EoPlex Applications: 3 Current Examples

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

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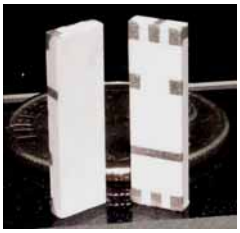
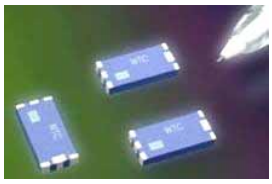
Ceramic Ancillaries: Highest Performance

Sarantel

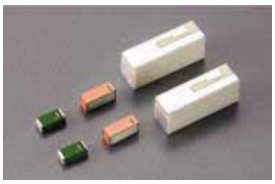


EoPlex



Walsin Technology

Laird Technologies

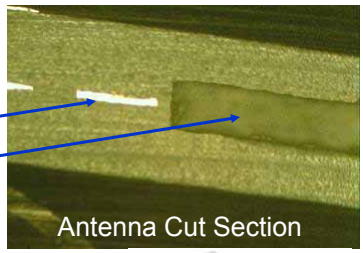


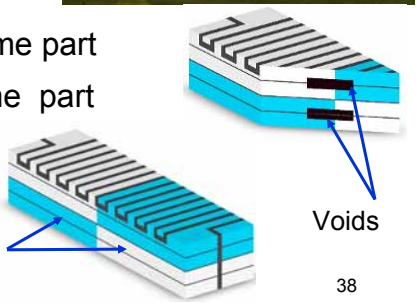
Murata

Requires integration of complex metal-ceramic structures with voids – **Perfect For EoPlex** 37

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





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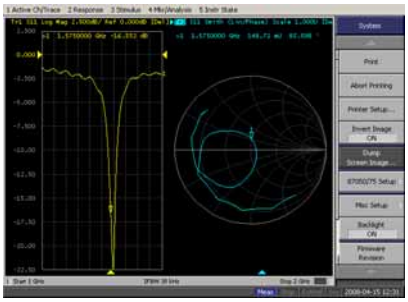
EoPlex Controls The Process from Raw Materials To Finished Parts

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

Typical Return Loss and Smith Plots



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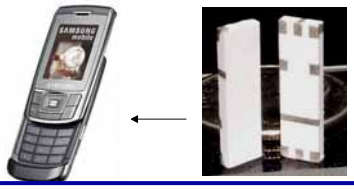
First Plant Scheduled For July 2008

- 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

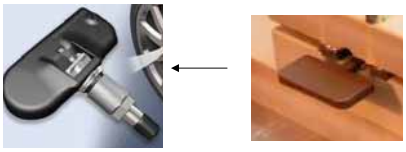
40

EoPlex Applications: 3 Current Examples

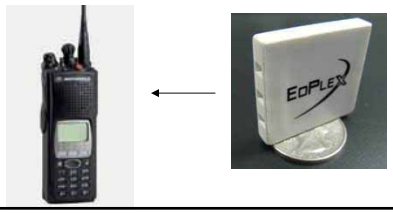
1. Ceramic Antennas



2. Tire Pressure Sensors



3. Emergency Radio Power



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

42

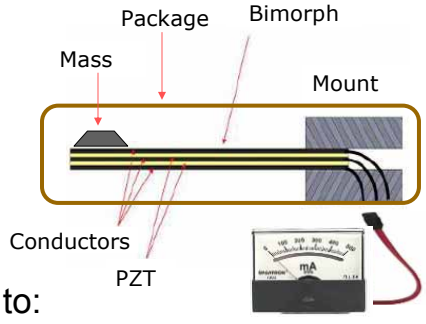
Battery Life: The Achilles Heel of TPS

- 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

43

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



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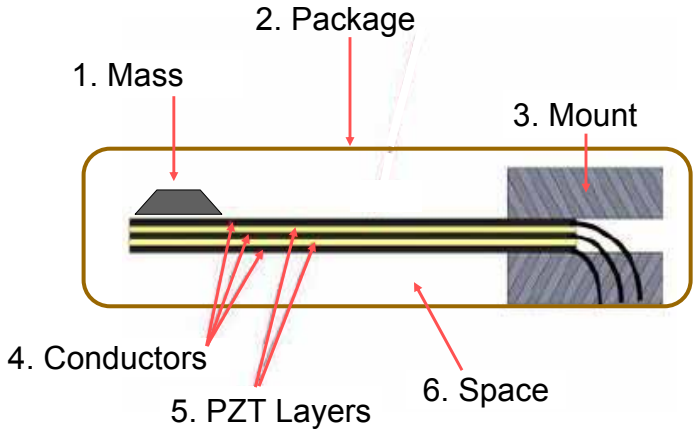
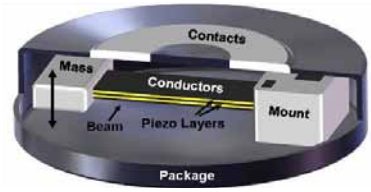
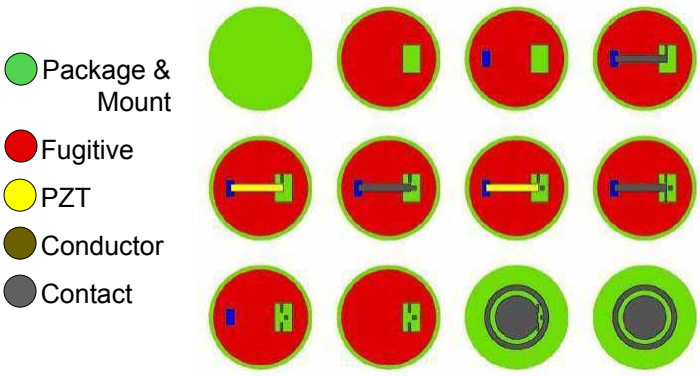
Up To Five Materials Are Required



45

How EoPlex Builds EHs





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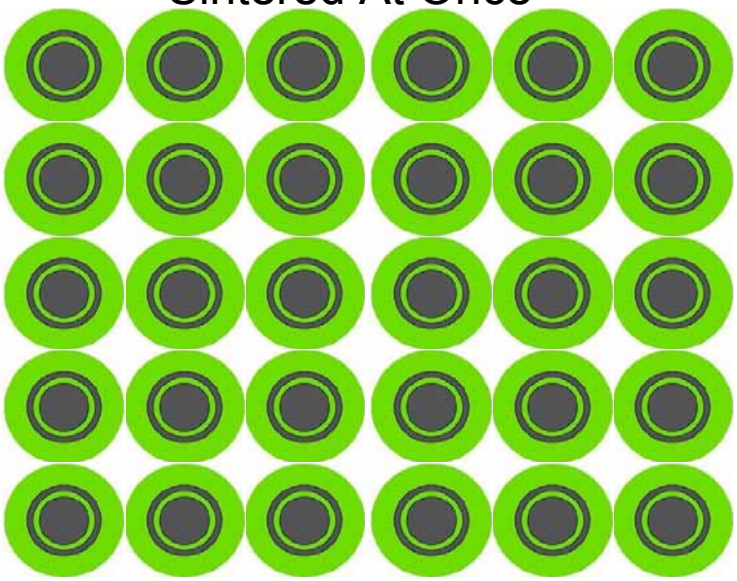
HVPF™ Many Parts Made Together & Sintered At Once



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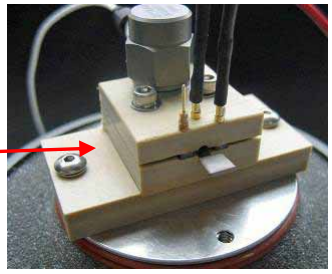
EoPlex Designs EHs For Specific Apps

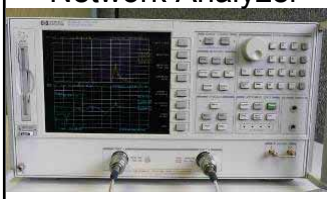
Poling Bath

EH Fixture



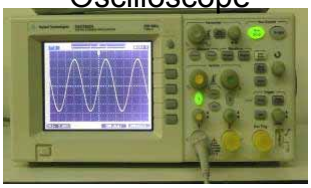
Shaker Platform

Network Analyzer



Capacitance Meter

Oscilloscope



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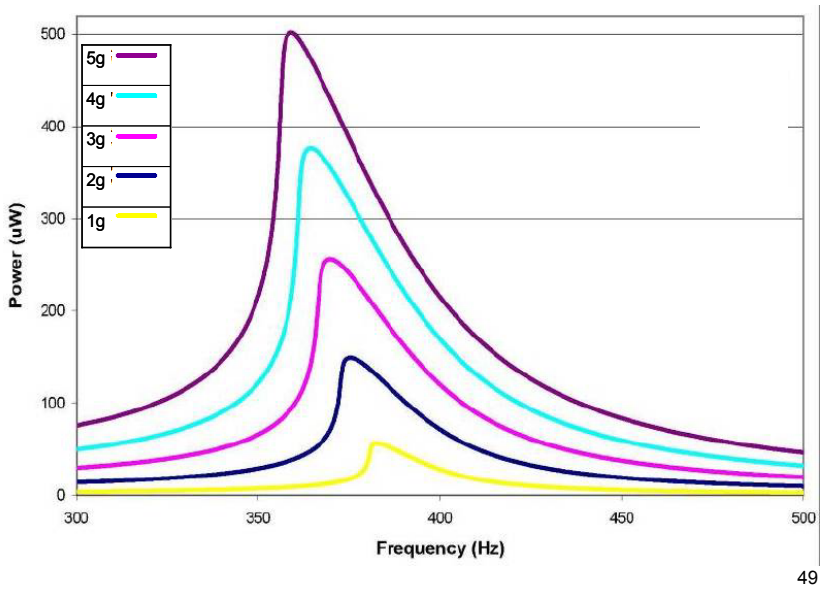
EoPlex Typical Design EH: Output



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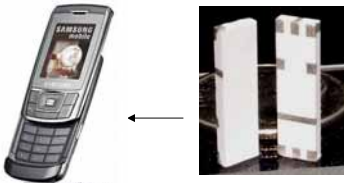
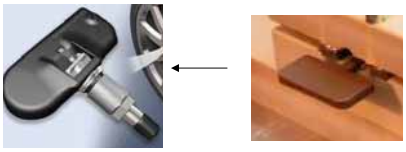
EoPlex Applications: 3 Current Examples

1. Ceramic Antennas



2. Tire Pressure Sensors



3. Emergency Radio Power

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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.
- H_2 fuel cell meets specs, but supplying H_2 is a problem
- Solution: H_2 from alcohol, but requires complex micro reformer

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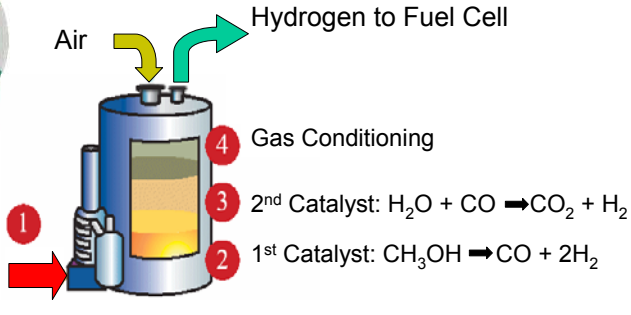
Challenge: A Low Cost Micro Reformer The Size Of A Few Poker Chips



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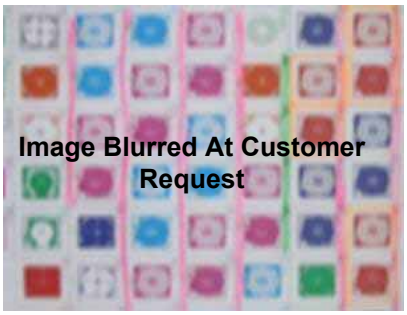
Reformer: Complex Structure: Required 300 Layers, 33 Features And 5 Materials

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



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A Typical EoPlex Factory Module

- Low cost
- Relatively small
- Can be located anywhere in the world

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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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Thank You

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