Passive Wireless Sensor Technology Workshop

June 6-7, 2012

Hyatt Regency, La Jolla, CA

Passive Direct Print Sensors

Mike Newton
mnewton@nscrypt.com

nScrypt Inc.
Orlando, Florida

University of Texas at El Paso

University of South Florida

Digital Fabrication Technology

- Printed Electronics
- 3D Additive manufacturing

Convergent Technologies

Direct Print Additive Manufacturing

The Economist

*** The third industrial revolution**
The digitization of manufacturing will transform the way goods are made—and change the politics of jobs too

Direct Print Equipment

3Dn-Tabletop

- Printing heads/pump
  - Smartpump™
  - Positive displacement pump
  - Mixer
  - Sprayer
- Vision
  - Processing camera
  - Automatic guidance/alignment
  - Post process inspection
- Others
  - Laser machining/curing
  - Rotary as 4th axis
  - Heat option for stage and pump
  - Pic and Place
  - UV Cure

3Dn-450 Series

3Dn-300 Series

3Dn-600 Series

Direct Print Equipment

Conventional Dispensing:

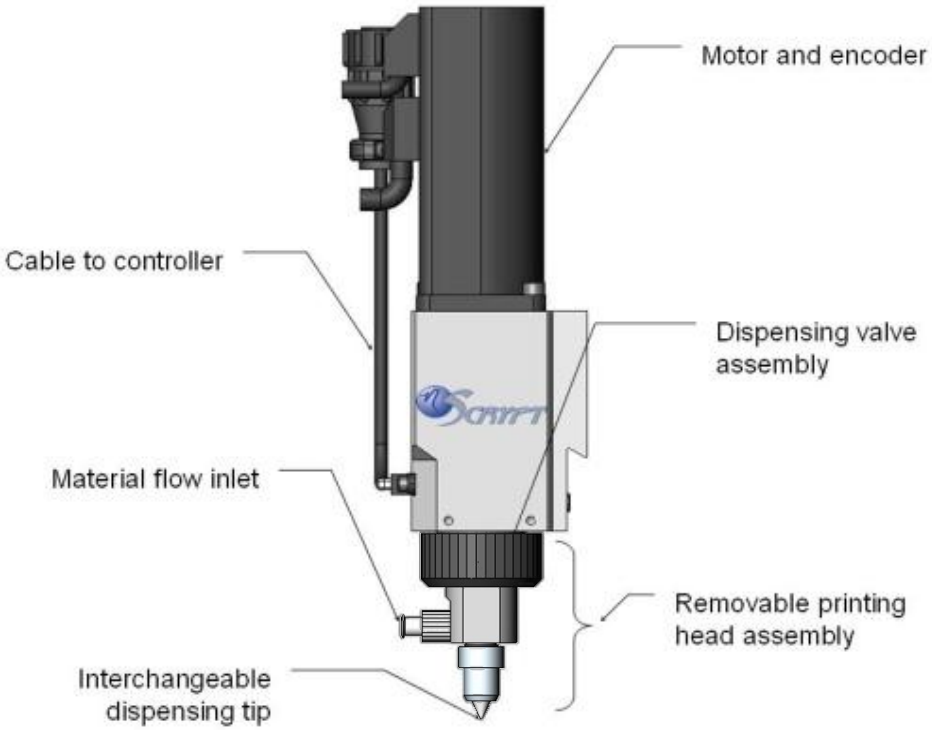
- Pros
  - Direct material deposition
  - Low cost & easy setup
  - Relatively flexible on Material choice
- Cons
  - Slow
  - Lack of accuracy
  - Limited consistency
  - Limited feature size

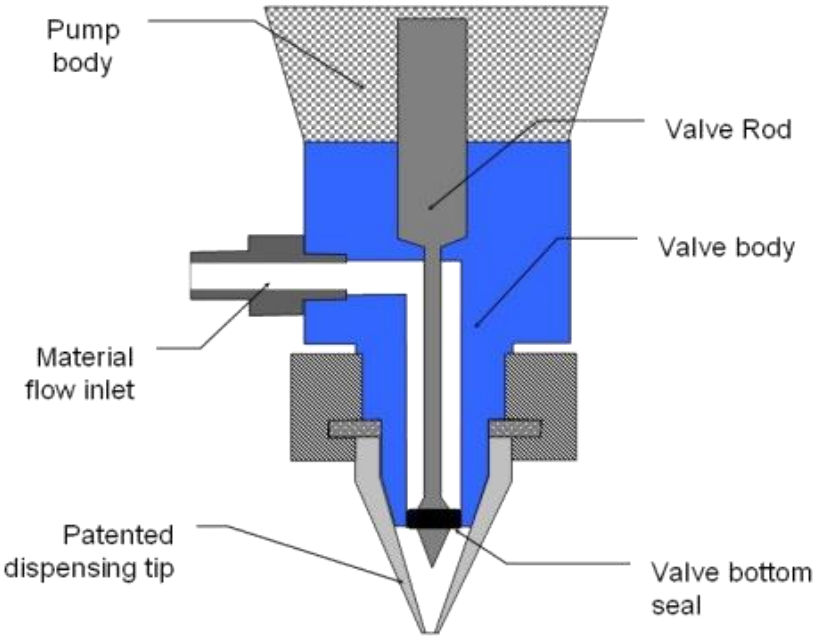
Micro-Dispensing/direct printing:

- High speed
  - As fast as 500mm/sec.
- Wide range of material choice:
  - viscosity from 1cps to >1 million cps.
  - Type of materials can be processed but not limited to conductive, dielectric, adhesive, solder, epoxy, encapsulate, hot melt, silicone oil, biological chemicals, live cells and etc.
- Capability of high resolution and accuracy
  - Pico-liter level column control
  - Line as small as 20um, dot as small as 75um.

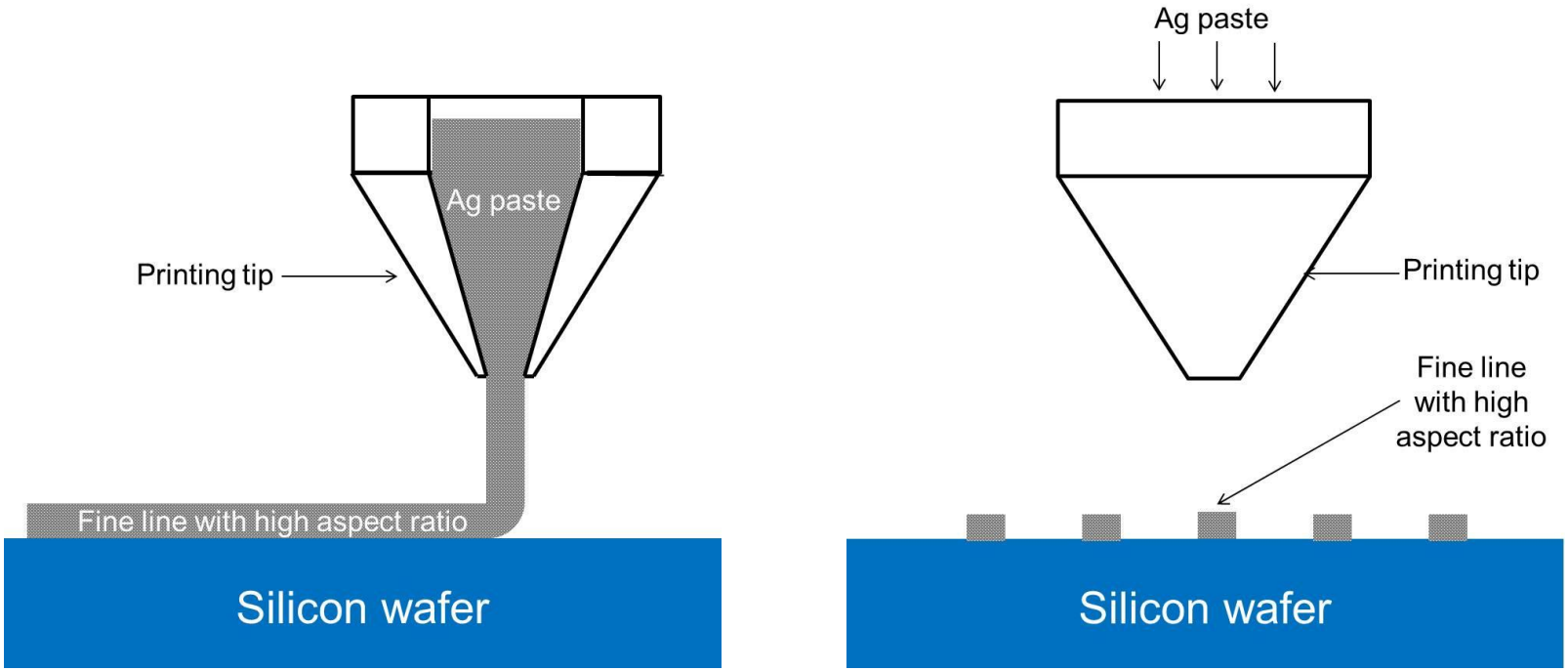
Direct Print Equipment

Standard SmartPump™





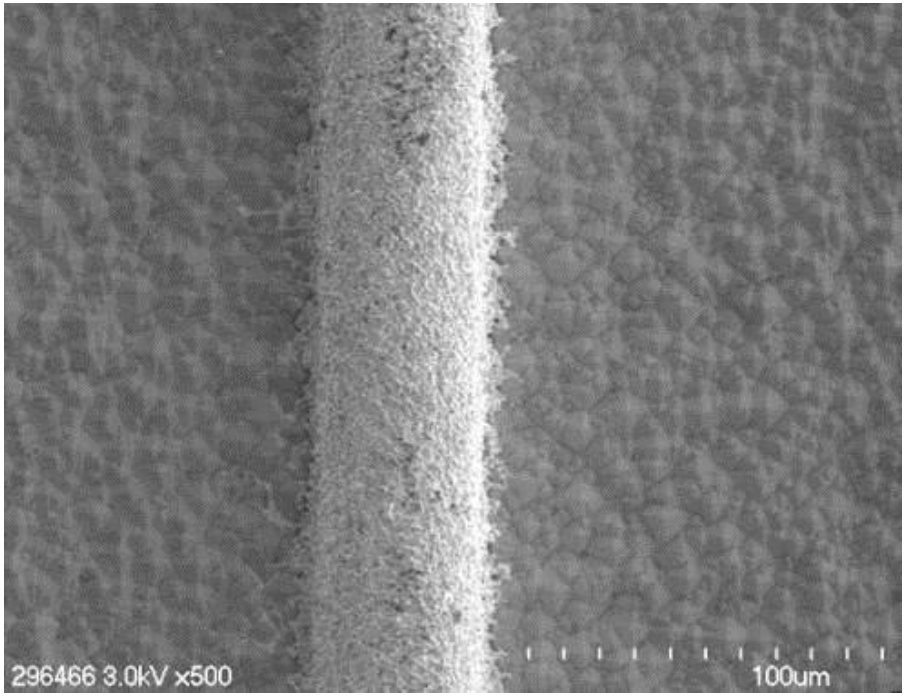
Direct Print Process

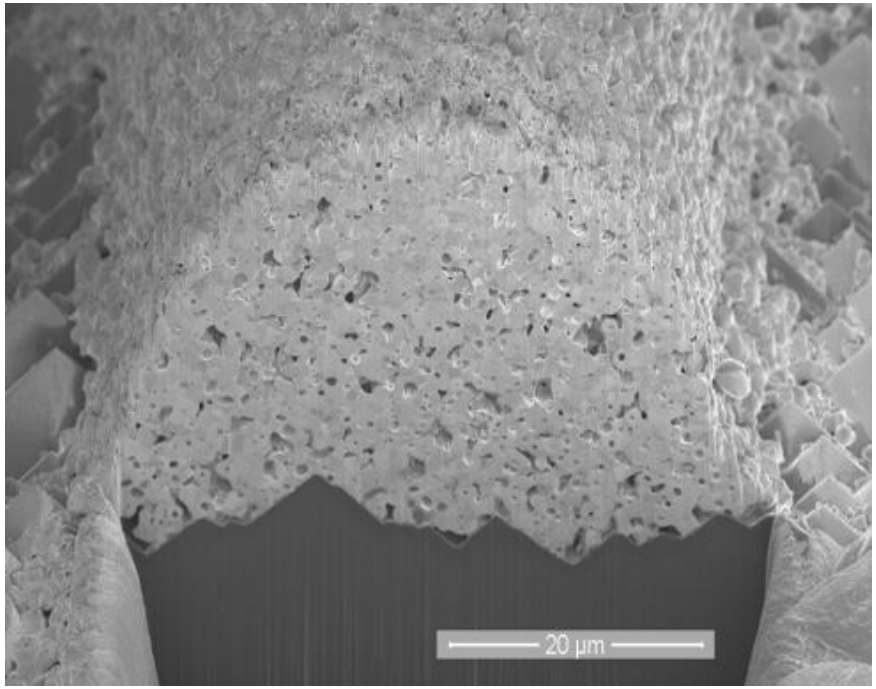


- It is possible to print fine lines with exceptional start/stop.
- If there surface is not completely flat, it is possible to accommodate that without scanning.
- It is possible to utilize a layering approach to build structures if the material is viscous.
- There are number of issues that must be resolved, but one of the biggest issues ….. Software.

Direct Printed Gridline

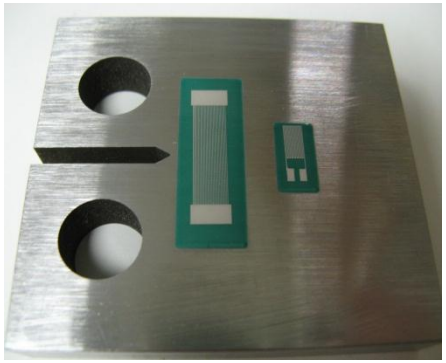
Representative SEM images of direct printed gridline*





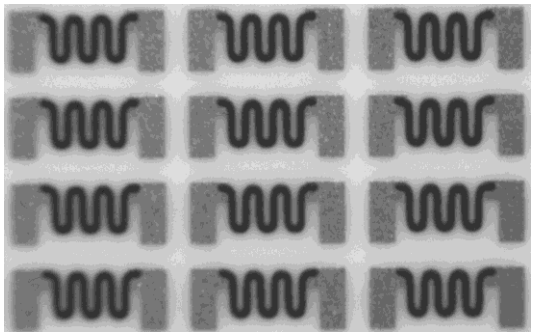
*X. Chen, K. Church, H. Yang, 35th IEEE PVSC (2010).

Directly Printed Electronics

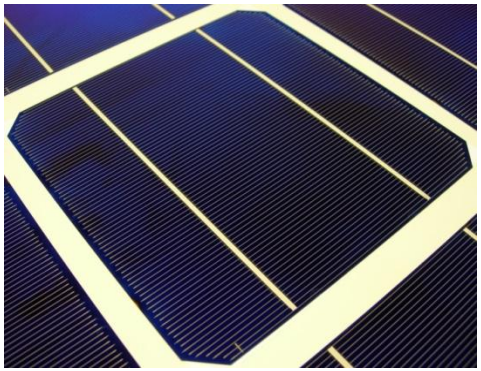


sensors

3D scaffold

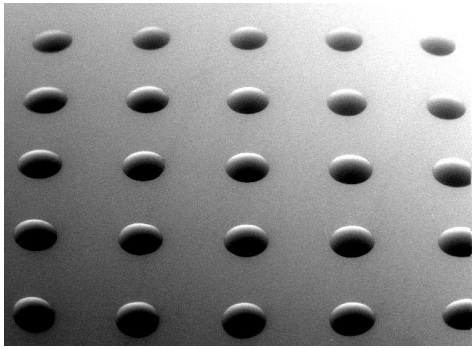


resistors

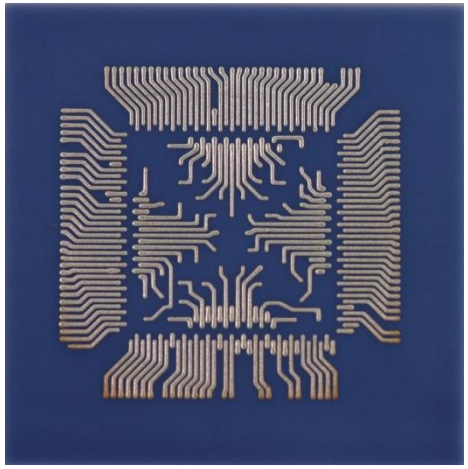


solar cell

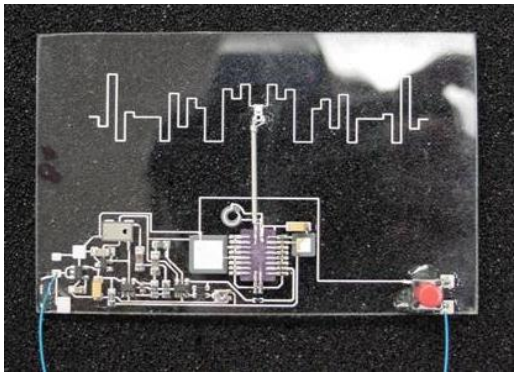
solder and via



micro lens



breakout pattern



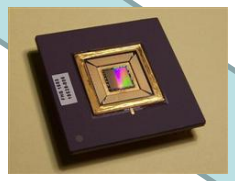
working device

A Hierarchy of System Packaging

$  Bare Die

Package of Packages

$

$  Packaged Die

$ 

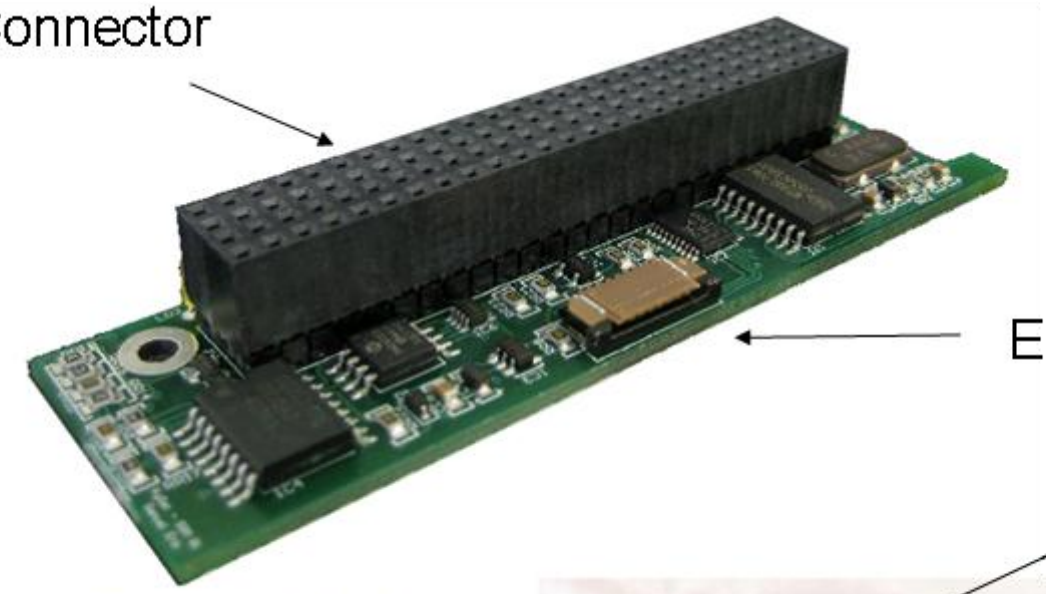
Packaged Circuit Board Sub Assembly

$ 

Packaged Chassis Assembly

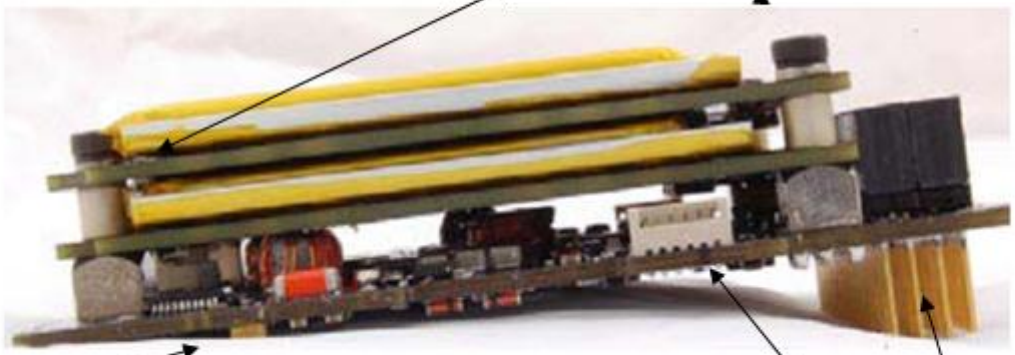
$ 

Volumetric Inefficient Packaging



Size, Weight and Power

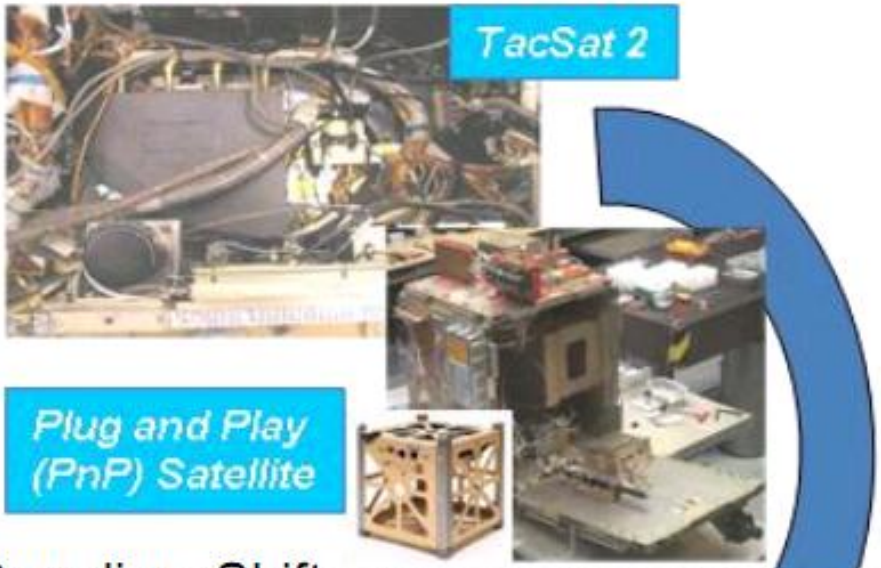
System Support Module



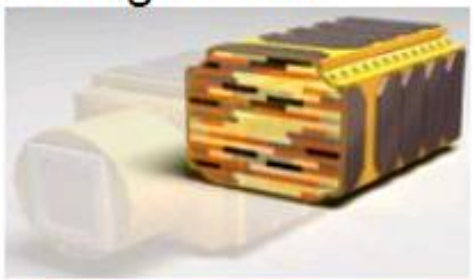
Hardware/Fasteners/Connectors drive SWaP in the wrong direction

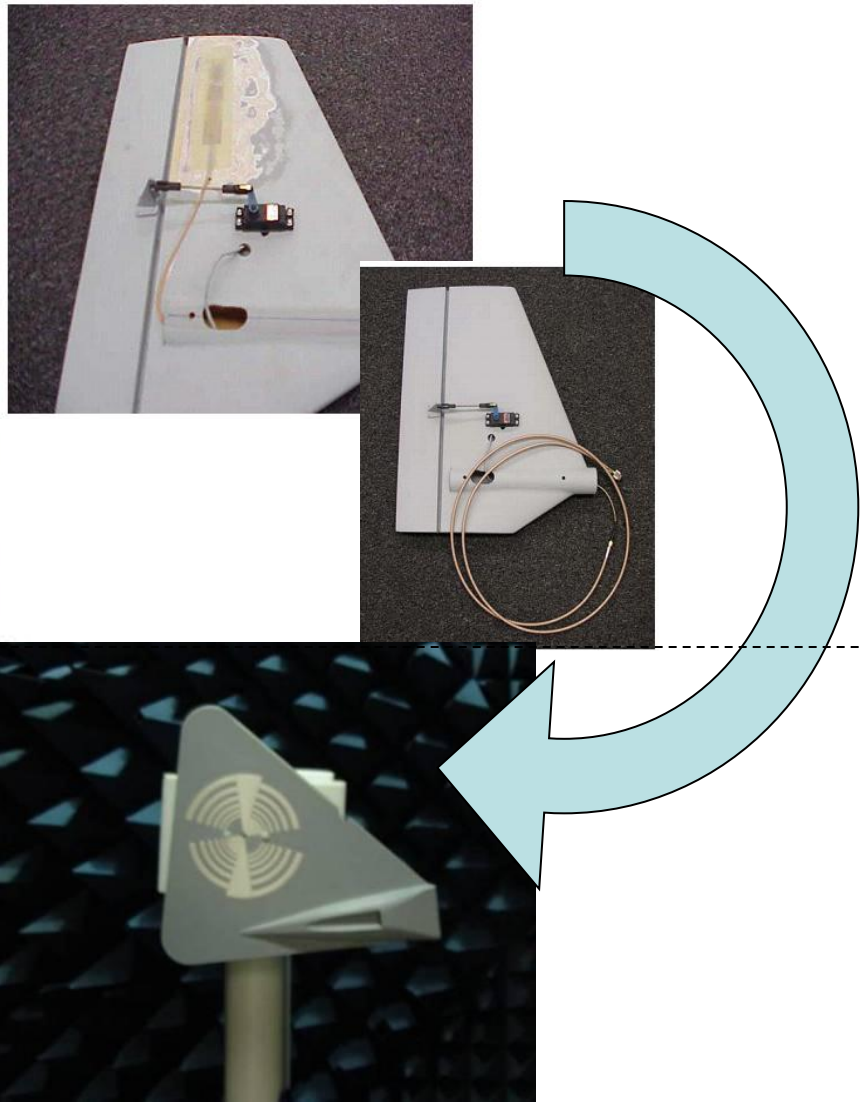
Shifting the Packaging Paradigm

Evolution of Integration Technology



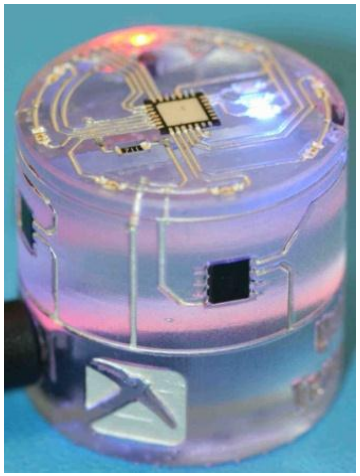
Paradigm Shift



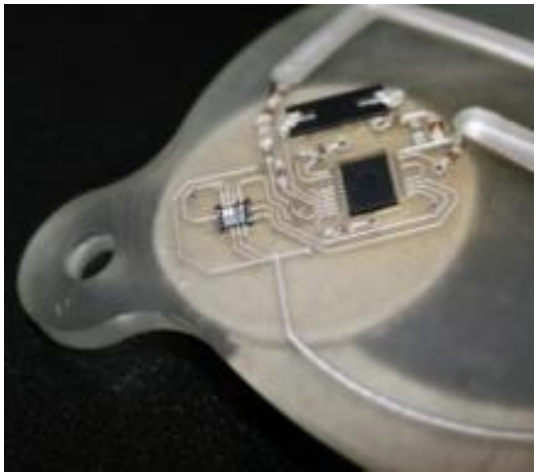


Directly Printed Functional Structures

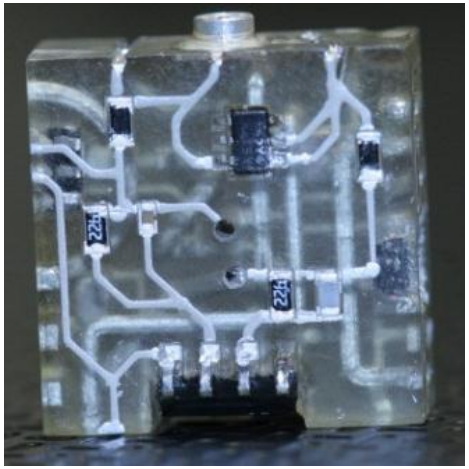
UAV wing with strain sensor



Magnetometer

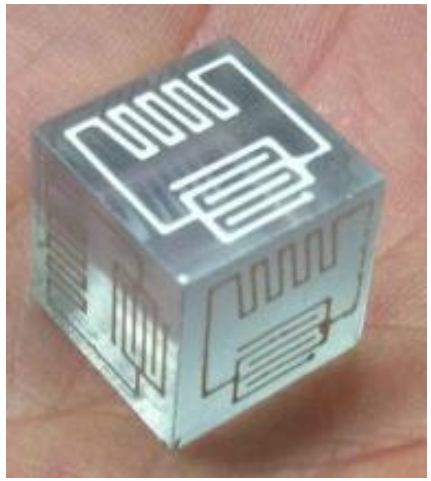


Vibration sensor



Electronic circuits

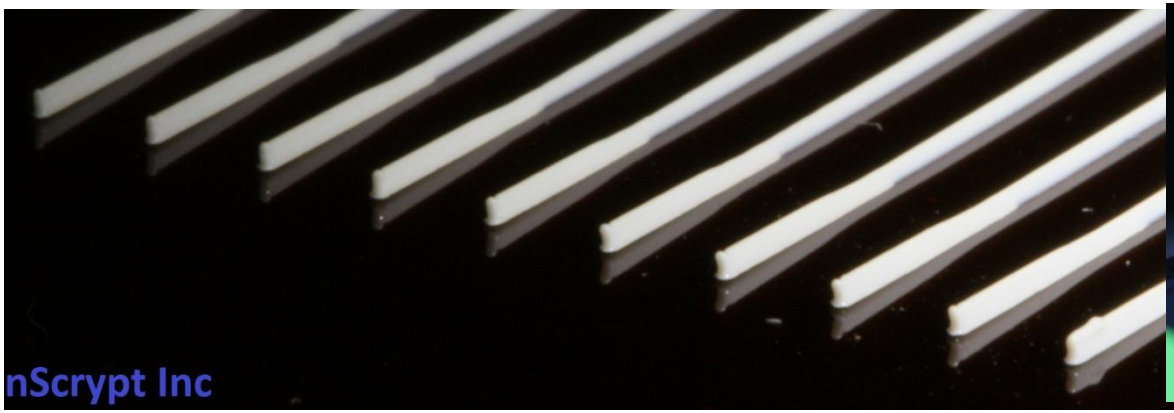
Monolithic dice



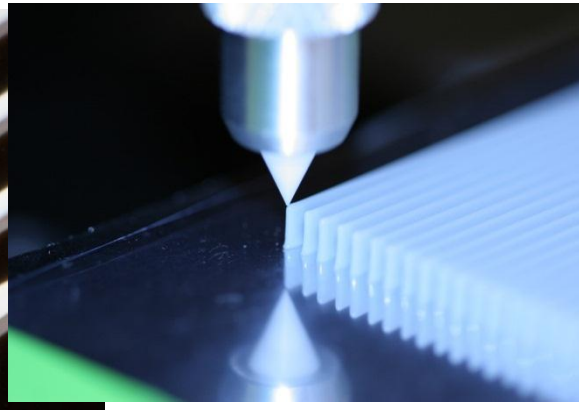
Loaded metamaterial cube

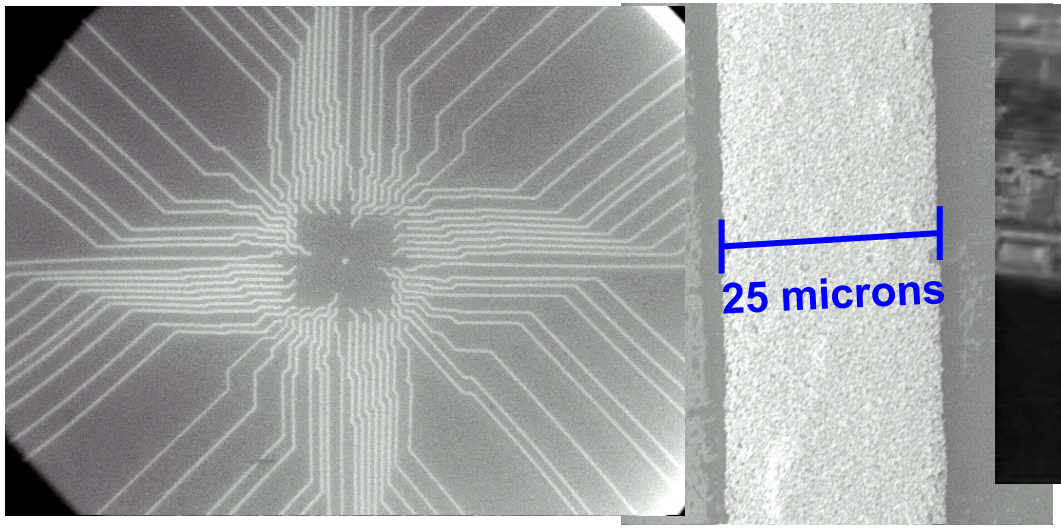
Direct Print Material Selection …very wide

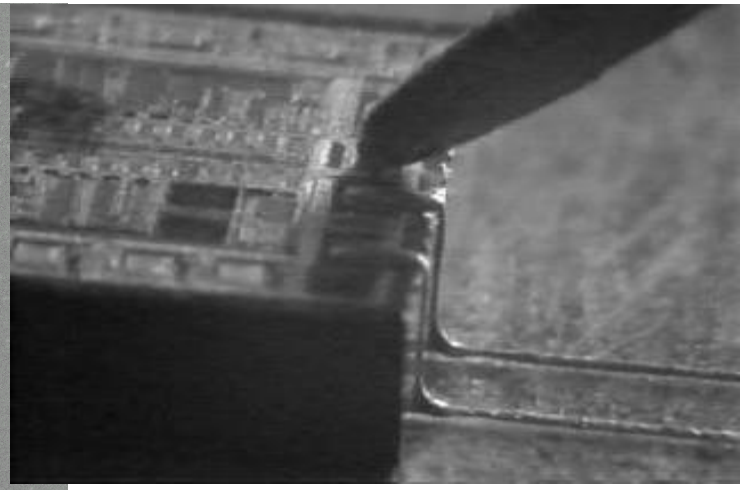
Ceramic loaded UV curable mixture



Metal loaded silicone







Breakout patterns from 25 micron wide lines to hundreds of microns wide.

Robotic and dispense precision for bare die (when performance is needed)

Print what you can….place what you can't.

Material and Test Structure

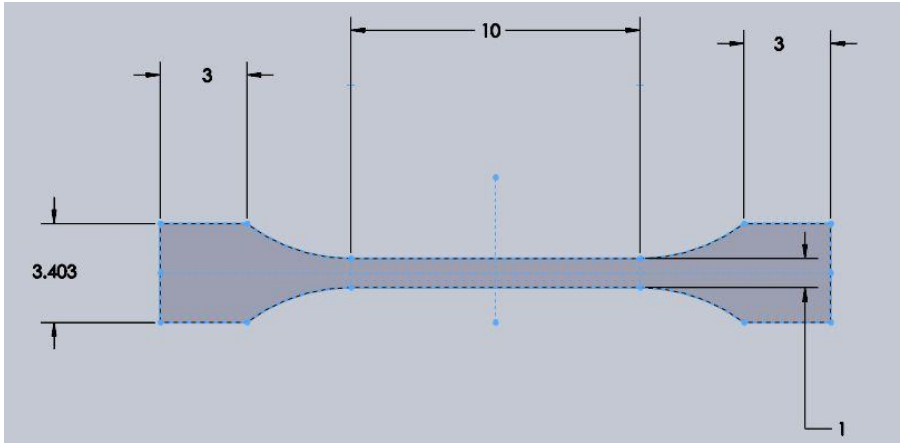
Mix UV curable material with ceramic powder

25% DSM Somos 11122 by volume

Viscosity	~260 cps @ 30 C
Density	1.12 g/cm3 @ 25C

75% Ceramic Powder by volume

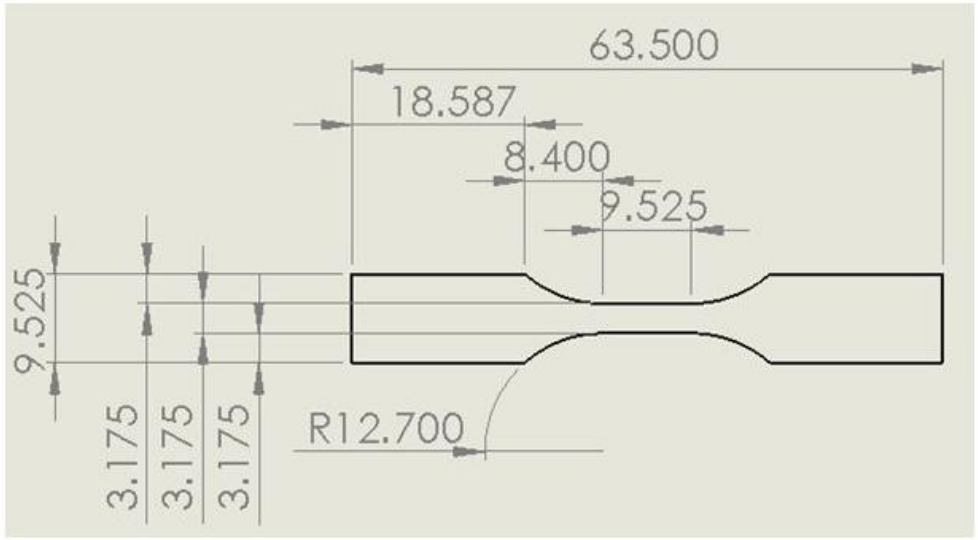
Melting Point	2050 C
Specific Gravity	3.6-3.98
Specific Surface Area	13.5 m2/g
Avg Particle Size	.17 µm



Standard structure for mechanical testing

Loaded and mixed material can be stored and used in a syringe. This allows for easier storage and reduced waste. From the syringe it is printed directly onto a substrate or a structure.

Direct Print Additive Manufacturing DPAM



DPAM is being used to build 3D structures: "Dog Bones"

A standard size is being utilized to build a data base for a variety of materials to include loaded and unloaded UV curable polymers. The loading can be carbon micro or nano strings, ceramic, titanium, iron particles that can be micro or nano in size.

Diverse loadings create a unique ability to vary and control the material properties and the concept of multiple pens enables heterogeneous properties in a homogeneous build.

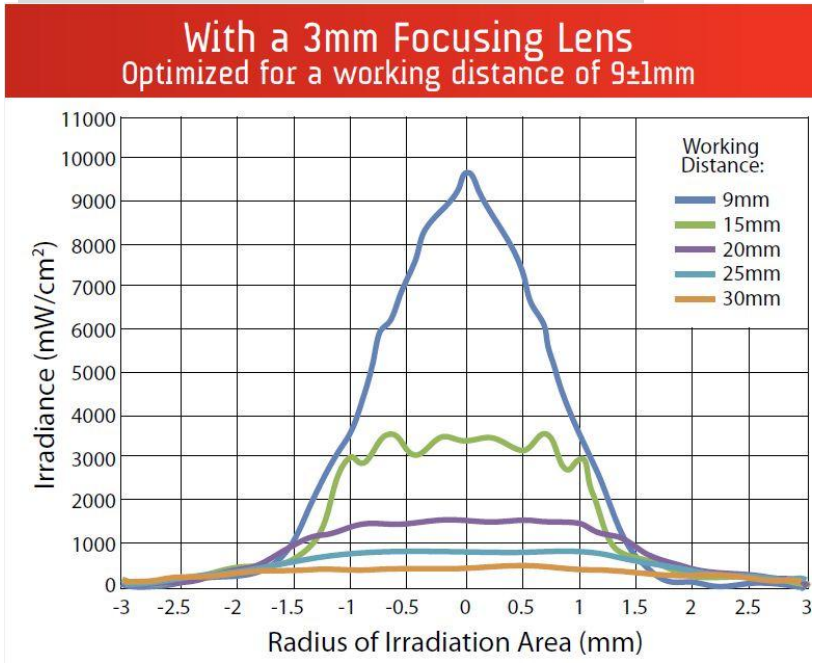
ASTM D 638 Type V 2.5 inch

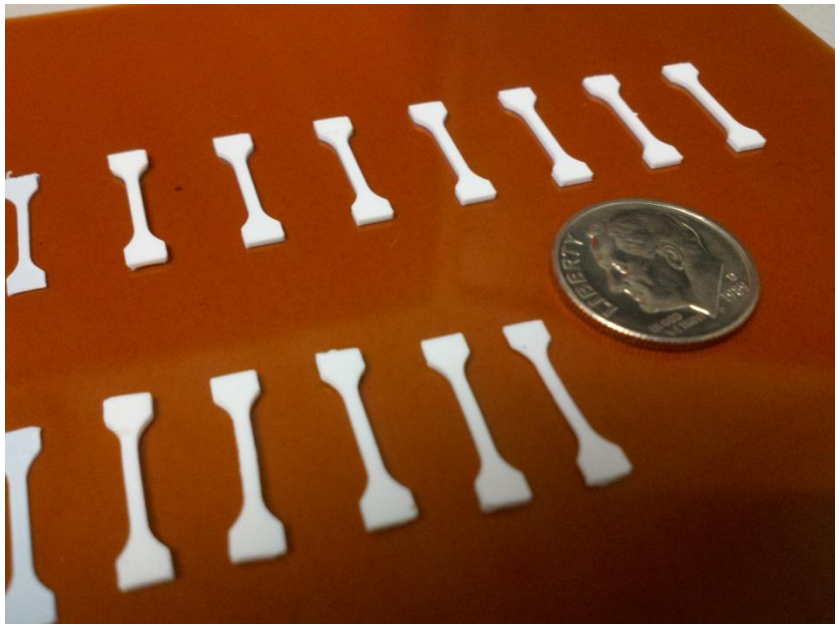
Print and Post Cure Process

DPAM was used to print “dog bones” and after each layer was printed, UV curing was done.

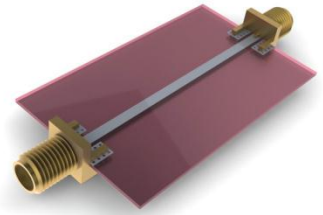
Pen Tip	125/175	µm
Print Speed	3	mm/s
Dispense Gap	100	µm
Number of Layers	7	
Fill Pitch	100	µm

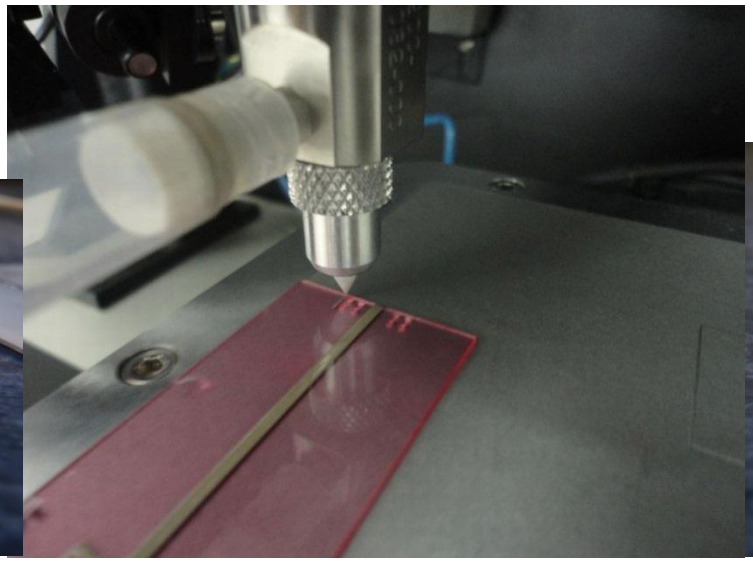
Cure Speed	5	mm/s
Spot Size	3	mm
Max Irradiance	9500	mW/cm2
Cure Height	10	mm

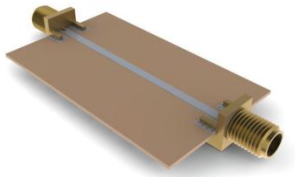


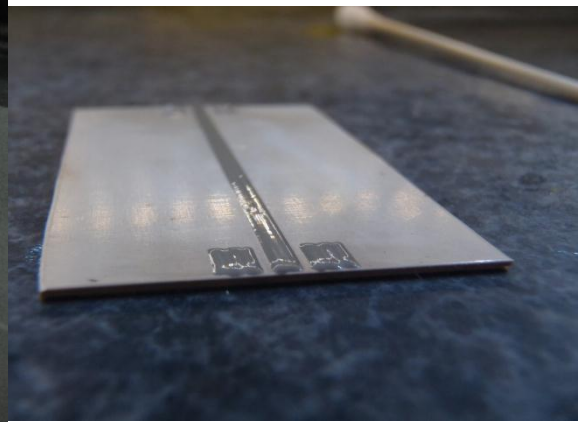


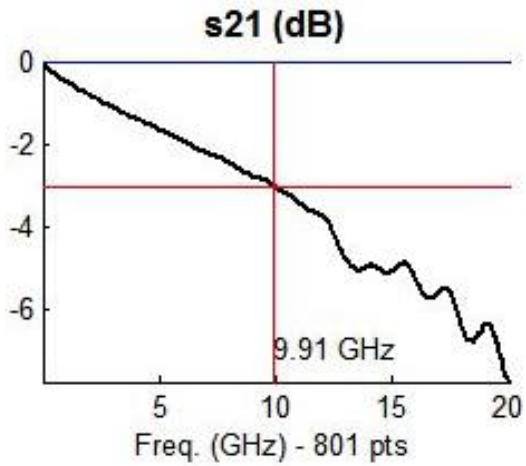
RF microstrip Line Comparison









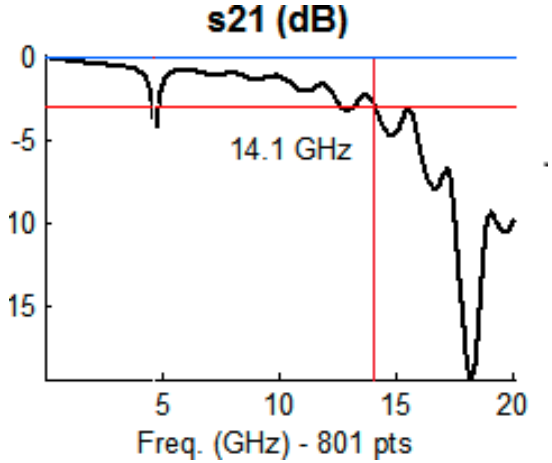


50 mm microstrip on polymer
-3dB at 9.9 GHz

Diverse substrates
Diverse printable materials
Diverse post process parameters

DC is “easy” to get to perform
RF is challenging

Important to open range of materials to include dielectrics, metals, piezoelectric and more.

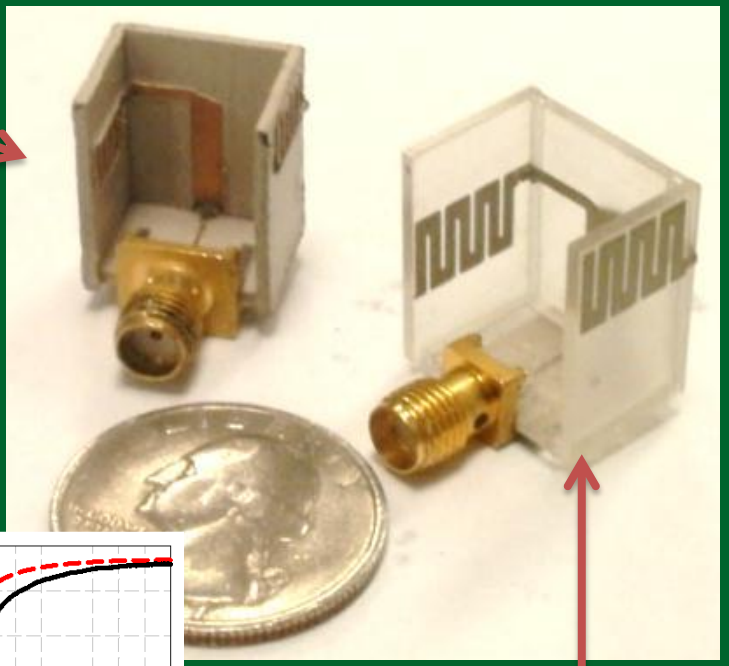


50 mm microstrip on LCP
-3dB at 14.1 GHz

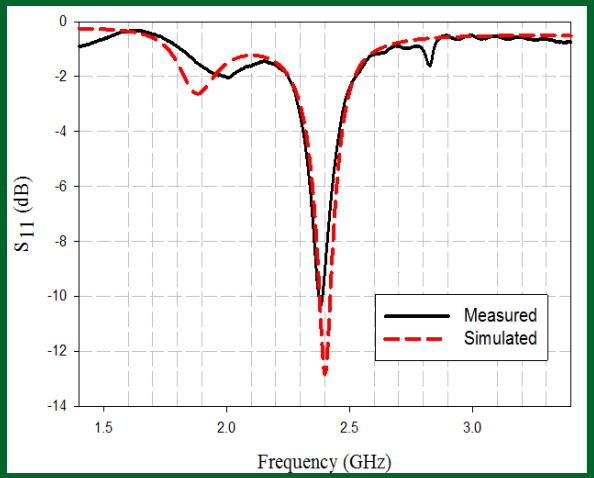
Fabrication

PCB Design

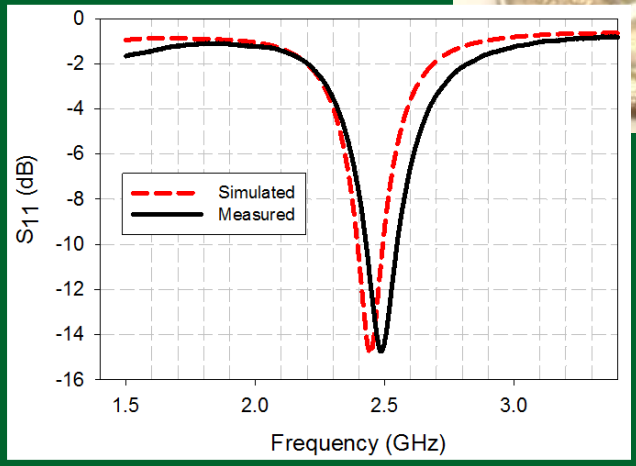
- The data are matched for the PCB design
- Deviation of 40 MHz between predicted and simulated results with the SLA design.
- The SLA bandwidth has increased by a factor of 1.8



SLA Design

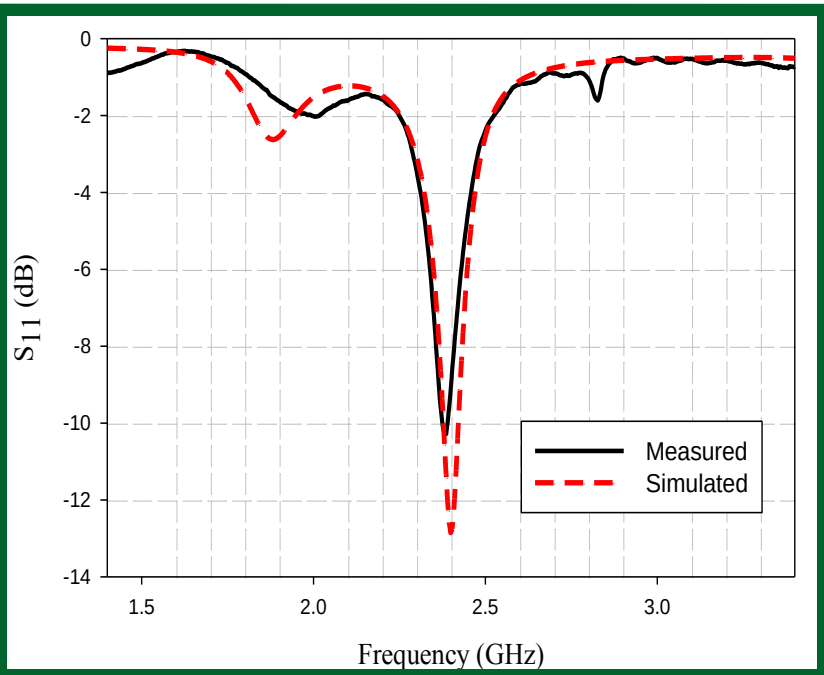


PCB Design

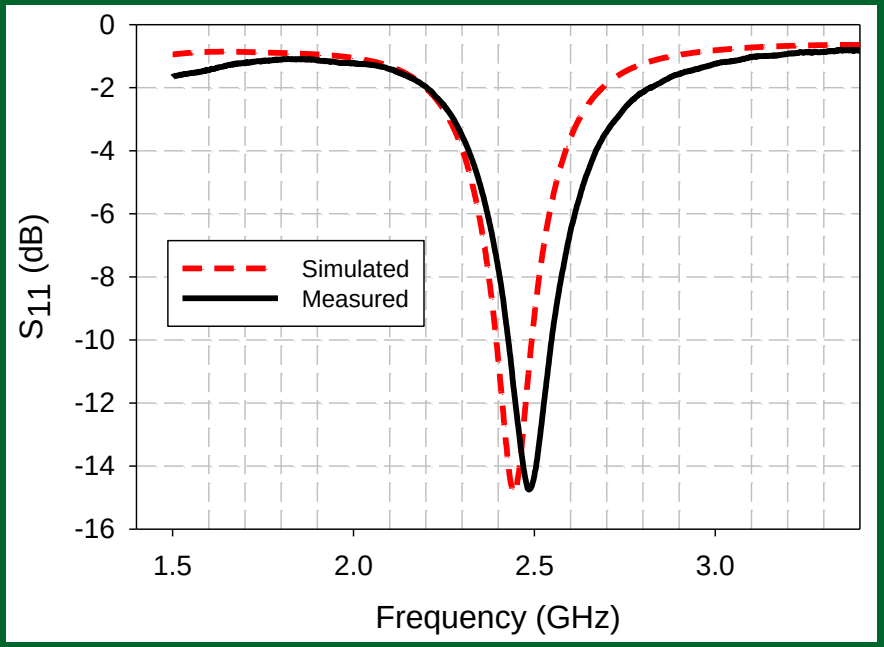


SLA Design

Results



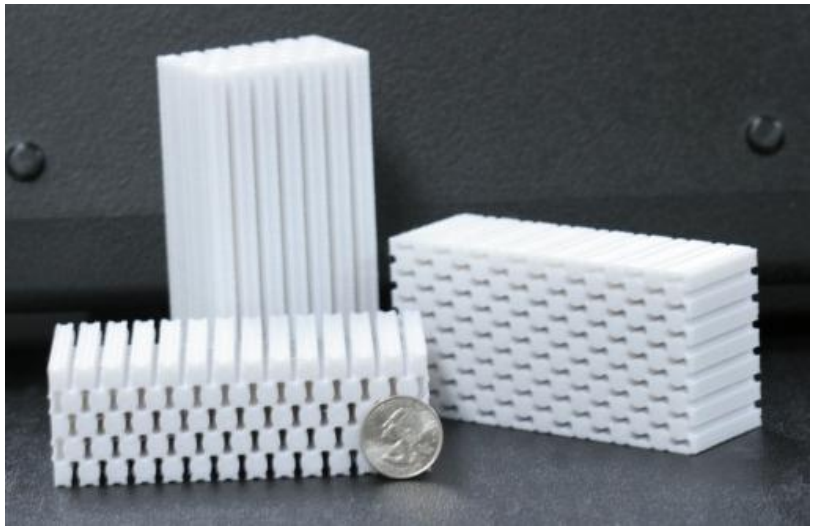
PCB Design



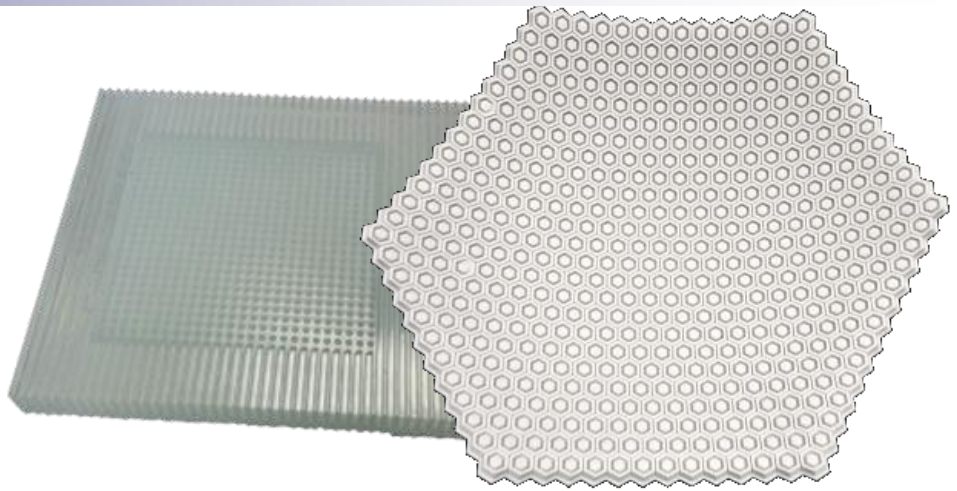
SLA Design

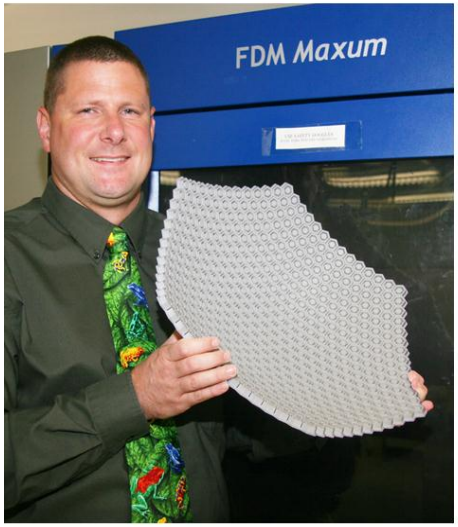
- The data are matched for the PCB design
- Deviation of 40 MHz between predicted and simulated results with the SLA design.
- The SLA bandwidth has increased by a factor of 1.8

Direct Print 3D Metamaterials

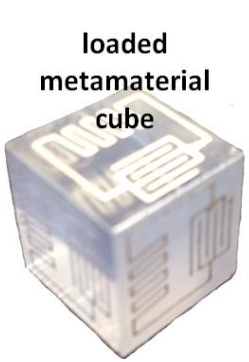


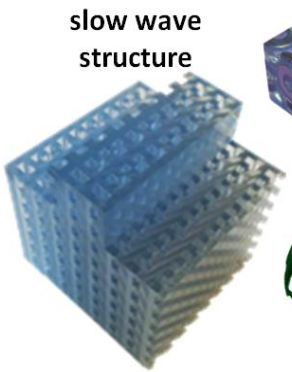
Printed Electromagnetics

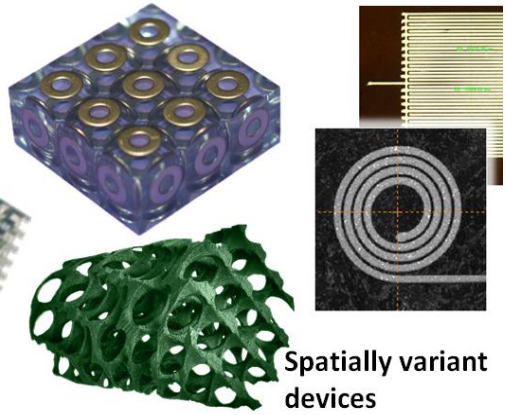


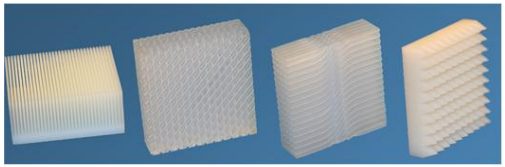


all-dielectric electromagnetics





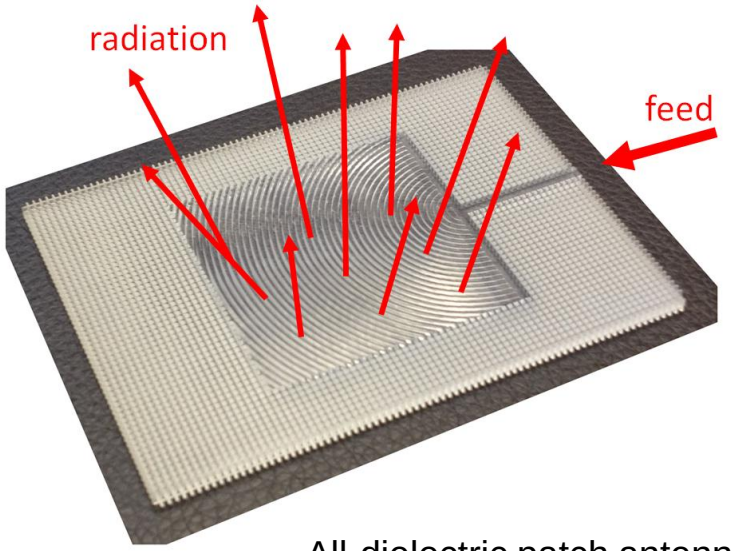




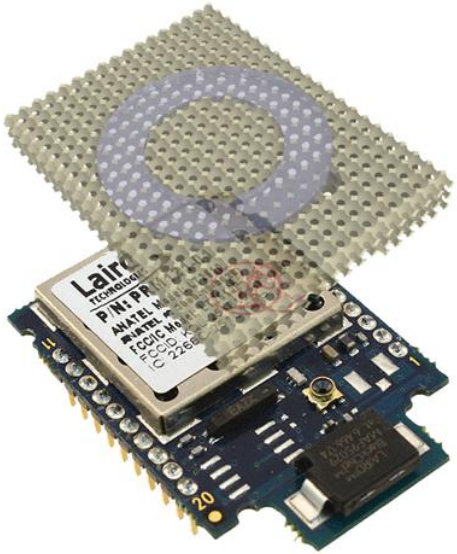
gratings and slow wave metamaterials

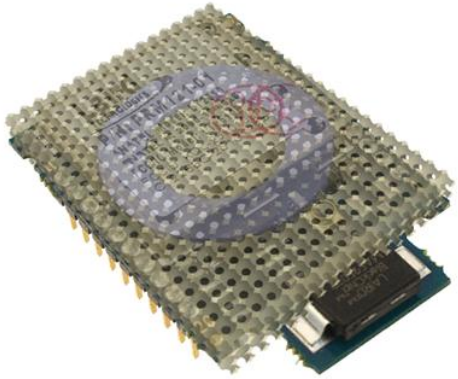
Direct Print 3D All-Dielectric Antennas

- Monolithic
- More options for integration
- Low observable applications
- High power capable
- Extremely low loss
- Photon detection and collection
- An option for processes where multi-materials is still difficult.



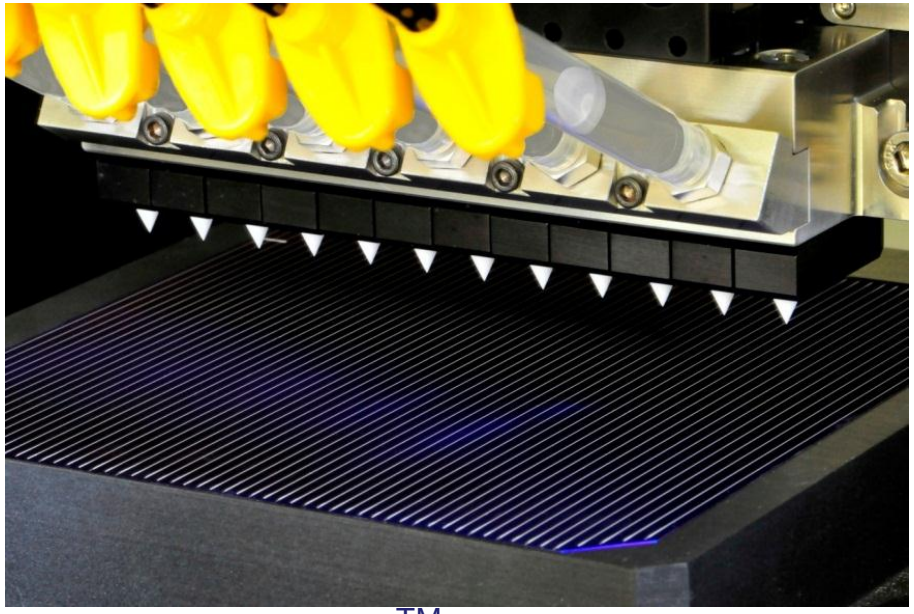
All-dielectric patch antennas





Parallel Printing for Solar Industry

To meet the solar industry throughput requirement, parallel printing by scaling up the number of nozzles is critical.



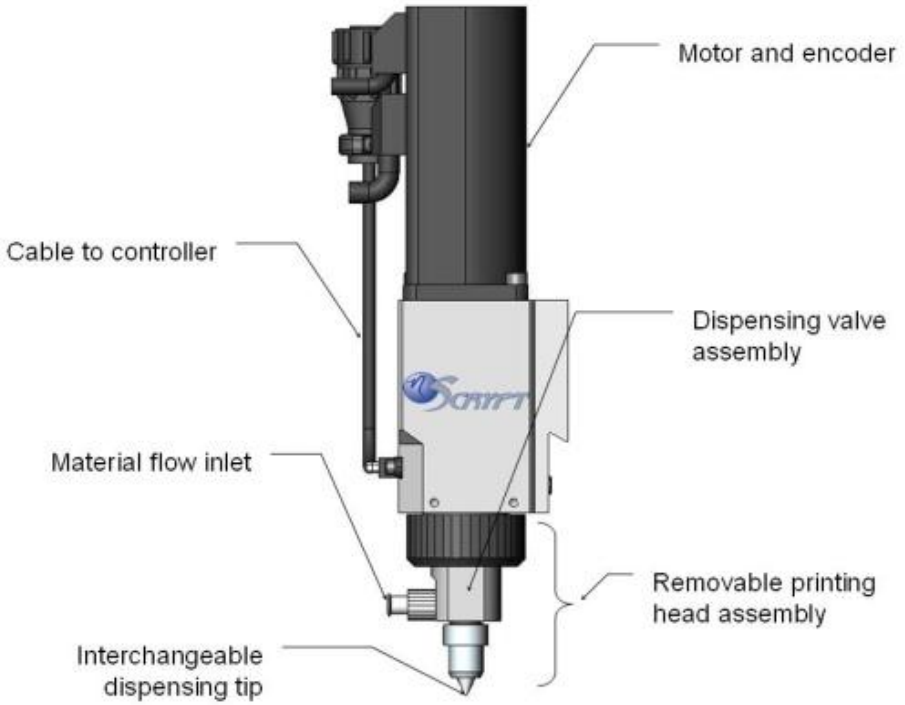
First PV product unit=> Smart Pump PV24™
3 Passes at about 300 mm/s => 72 lines
1200 wafer per hour process

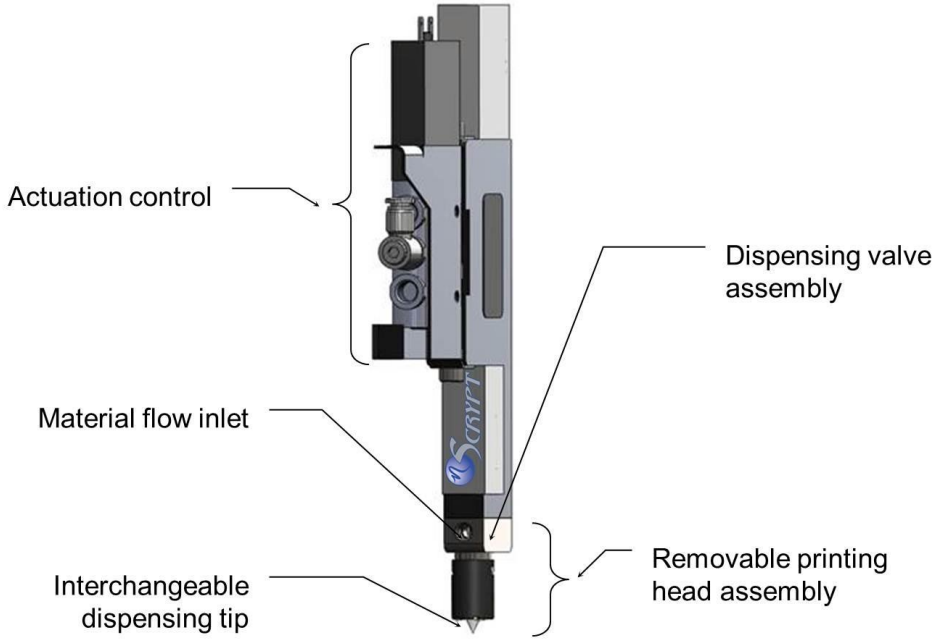
Performance of these printed cells demonstrate consistently a higher efficiency in performance (0.5% overall improvement). It also demonstrates a reduction in silver use (20%). So what would keep this from dominating front metallization?
Speed!!!!!

Parallel Printing and Scale-up

To meet the manufacturing industry throughput requirement, parallel printing by scaling up the number of nozzles is critical.

A new pump that has significant size reduction for this application has been designed

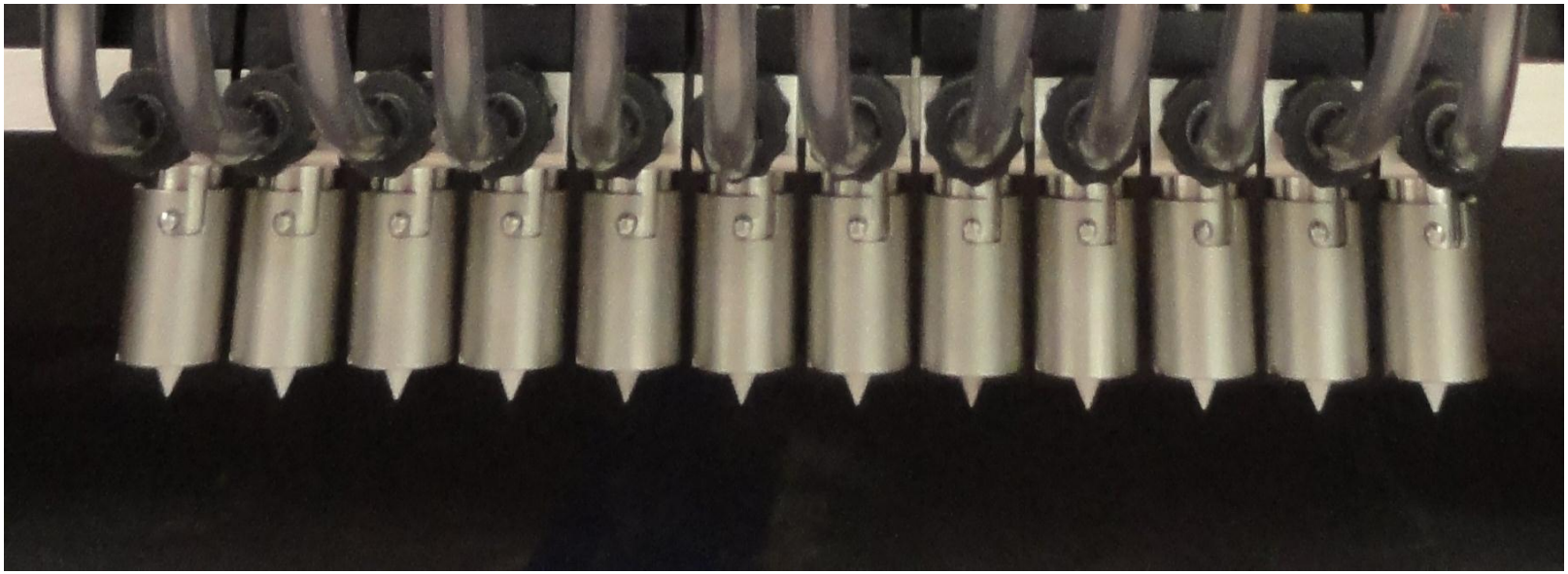




Parallel Printing and Scale-up

A working multi-nozzle prototype printing head has been assembled and tested.

This can be a single material feed or a multi-material feed.

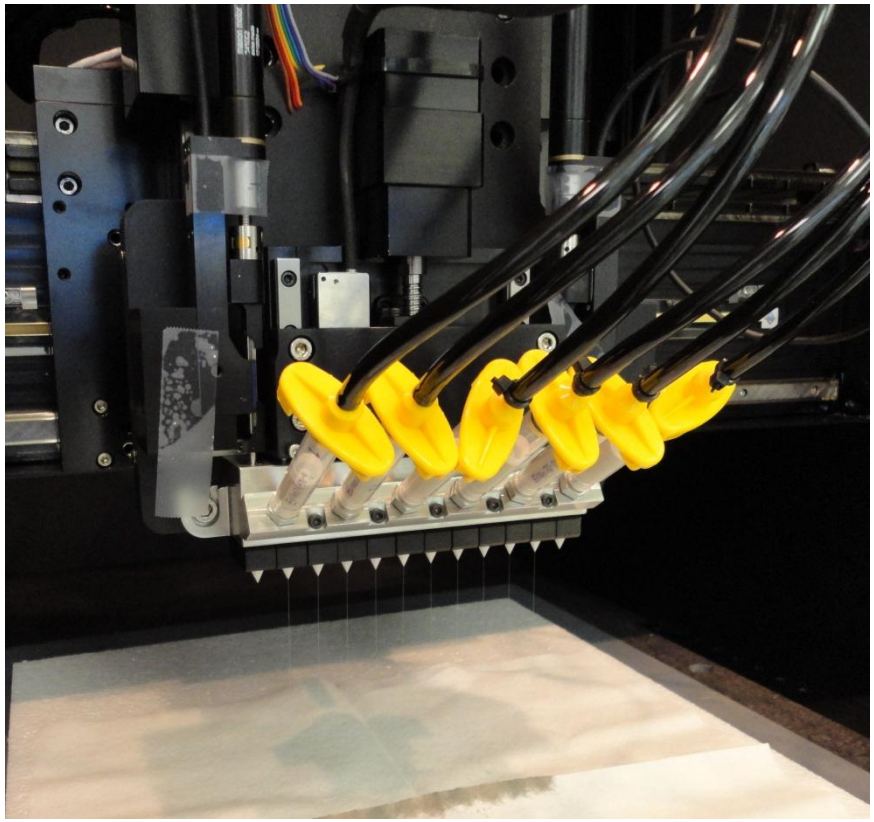


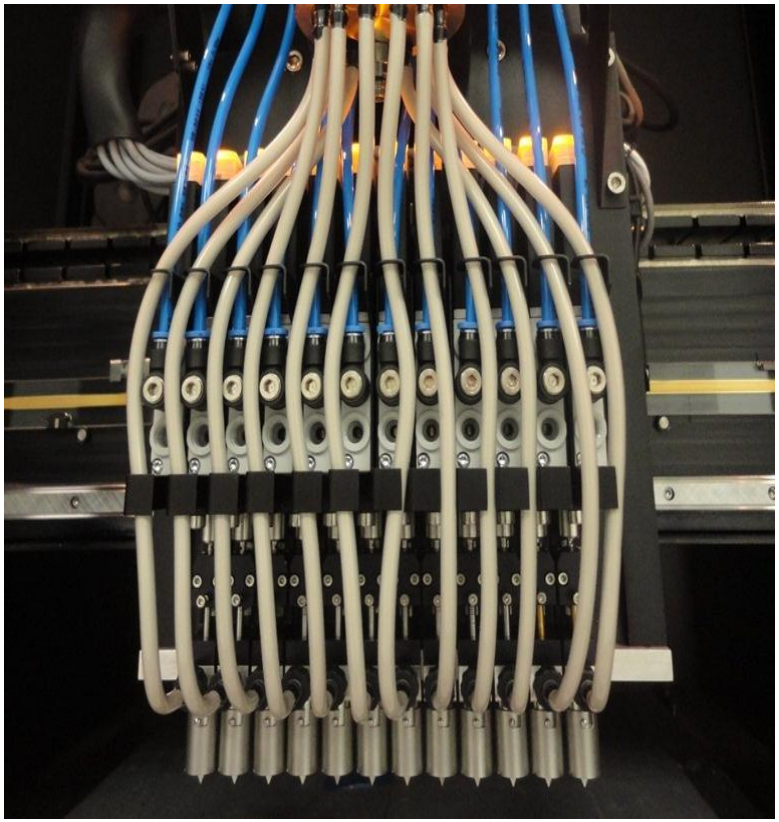
multi-nozzle printing head prototype (12 nozzles)

Next Generation Ink-Jet Printer will be a

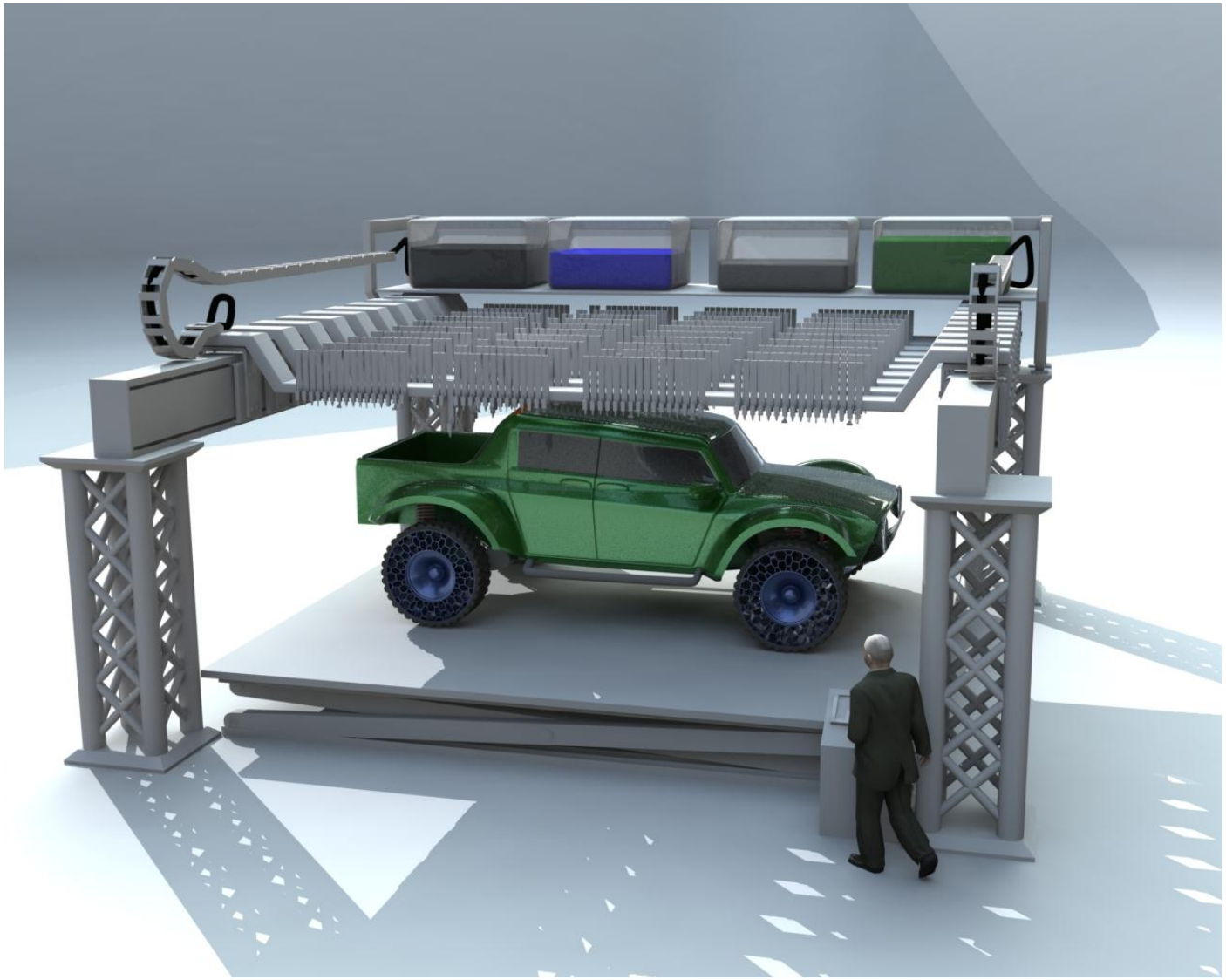
Paste Place Printer

Gen I => 12 nozzles: either on or off
Gen 2 => 12 nozzles: independent control
Gen 3 => 24 nozzles: independent, now
Gen 4 => 400+ nozzles: Future





The Future of Direct Printing



Conclusion

- Printed Electronics will meld with 3D Printing
- A new 3D printing technique has potential to enhance AM (DPAM)
- RF 3D has great potential….large obstacle is performance
- DPAM potential will have obstacles….large obstacle is software
- To move from Rapid Prototyping to true Rapid Manufacturing…..SPEED

Passive Wireless Sensor Technology Workshop

June 6-7, 2012

Hyatt Regency, La Jolla, CA

Passive Direct Print Sensors

Mike Newton
mnewton@nscrypt.com

nScrypt Inc.
Orlando, Florida

University of Texas at El Paso

University of South Florida