



NANODIMENSION

Electrifying Additive Manufacturing®

# The Future is Already Here

## The Machine that Would Print the Cell Phone



# Digital AME board vs. Analog PCB processing

Process of using Additive Manufacturing Technology (AME) for manufacturing of Functional Electronic Circuits, by direct printing of both Dielectric and Metal Elements – **A Digital Process**



Printed Circuit Board (PCB) and the other devices, like interposers, packages, IC manufactured by solid state technology processes – An Analog Process

# AME machine- real 3D printing tool



DRAGONFLY AME MACHINE

## SYSTEM IN PACKAGE

- Multilayer thick print – thousands of layers, up to 12 mm
- Embedded electronic and optical components

## RAPID PROTOTYPING IN HOUSE

- Months > days > hours

## INNOVATIVE RAPID PACKAGING

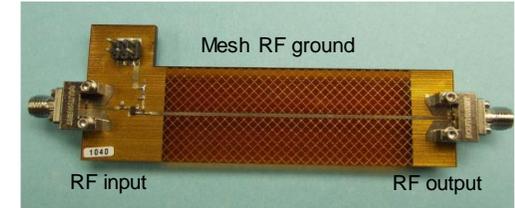
- Compact, lightweight and robust package

## PRINTED ELECTRONICS COMPONENTS

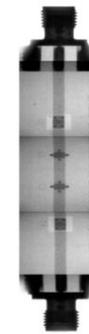
- High Accuracy Capacitors, Inductors and transformers  
Integrated in the board

## DEFENSE, AEROSPACE, MEDICAL AND AUTOMOTIVE

- Light weight
- Integrated design
- No outgassing



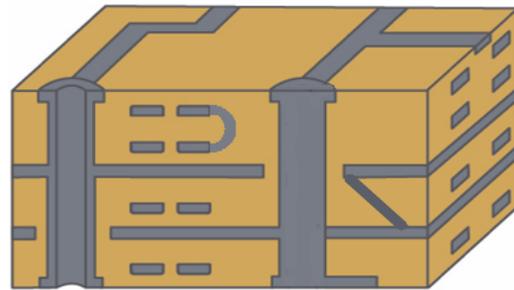
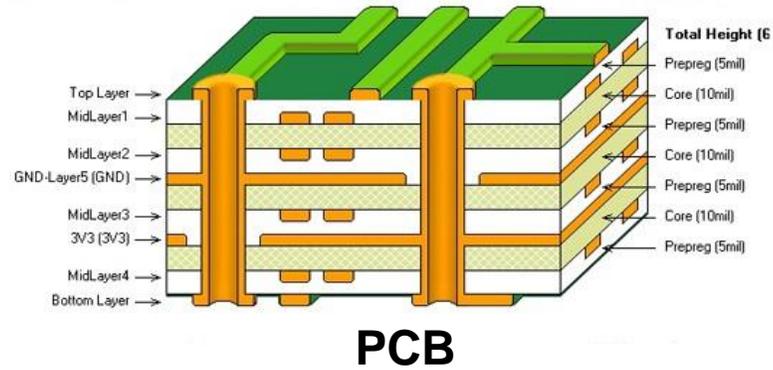
Printed LP



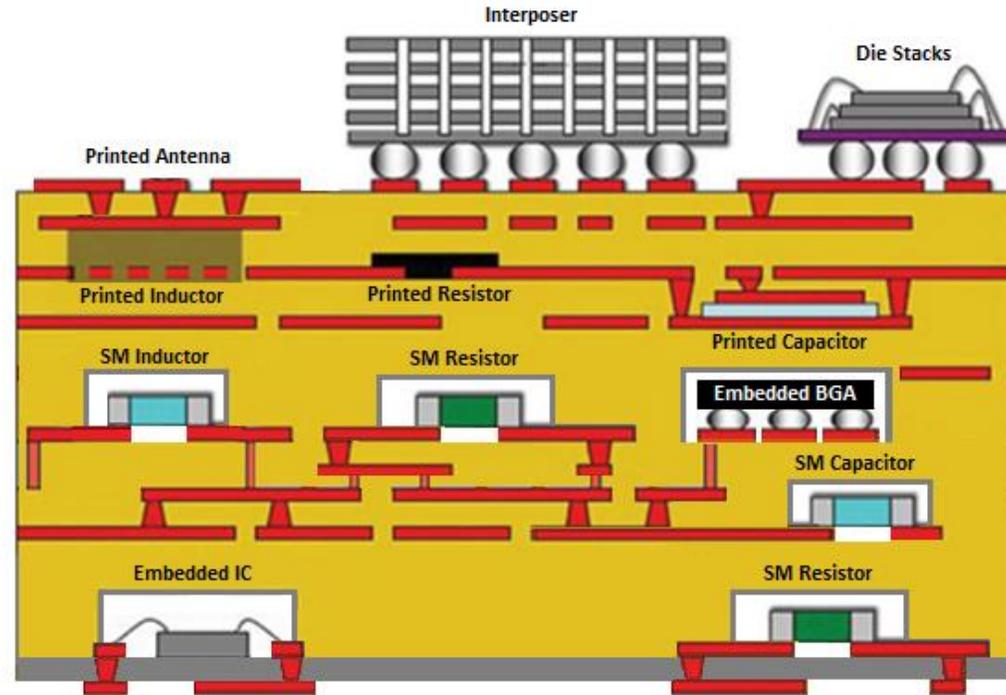
X-ray of Printed LP



# PCB vs. AME and SiP boards



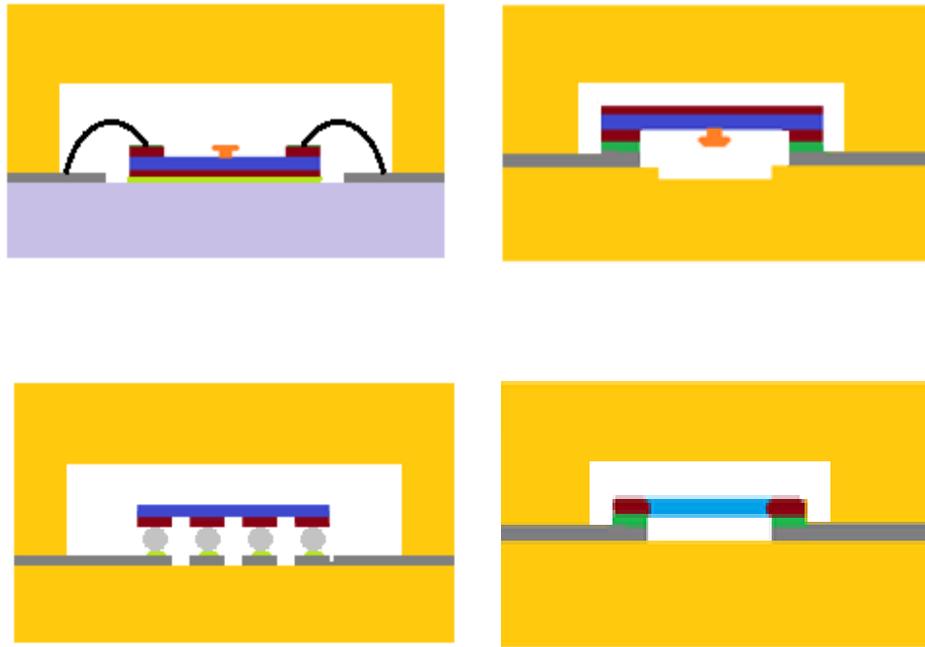
**3D Printed Board**



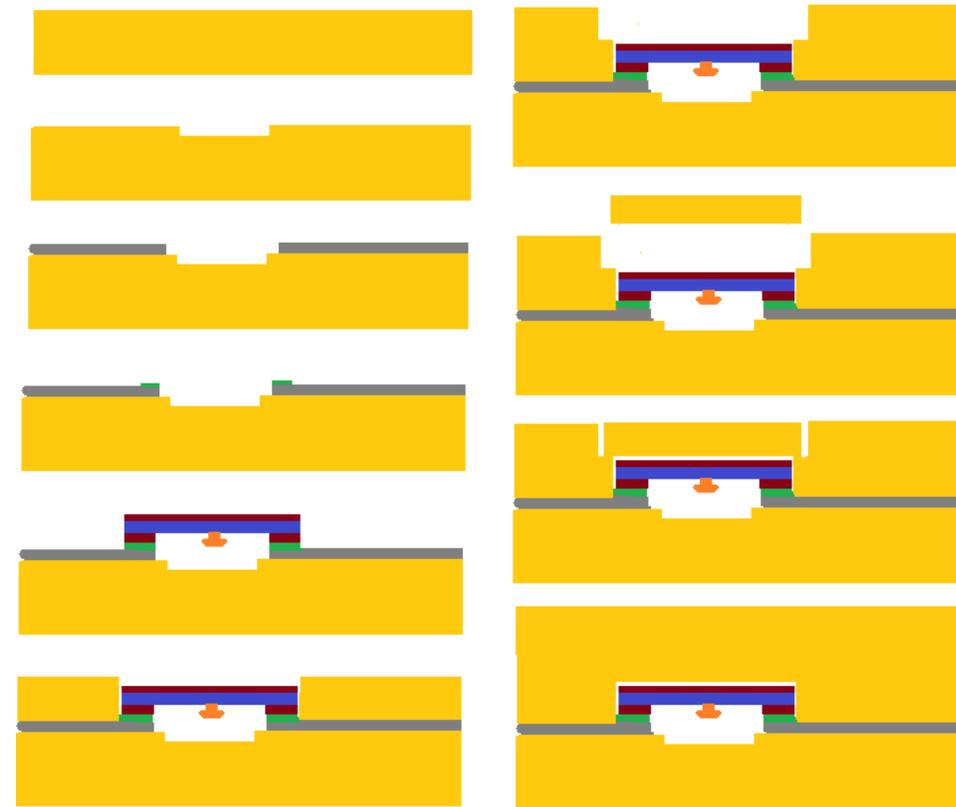
**System in Package (SiP)**



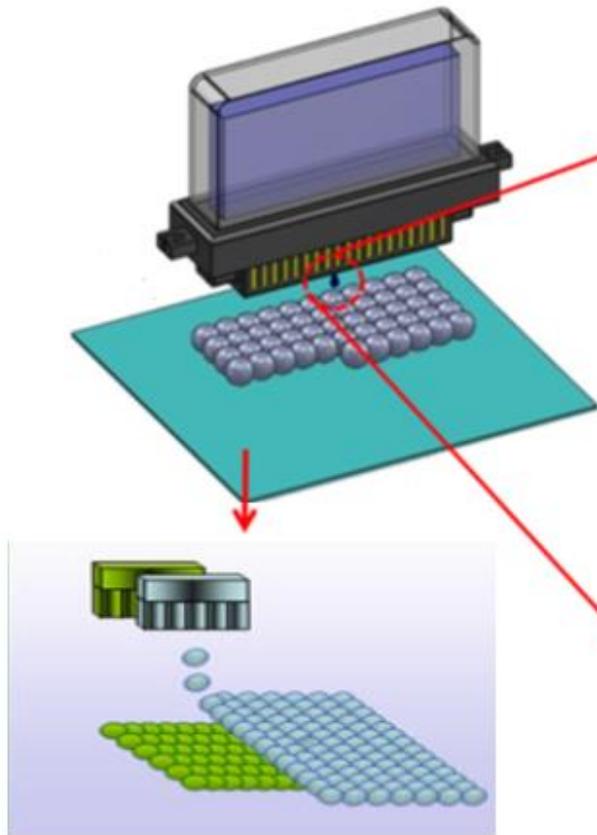
# RF/Electronics components assembling



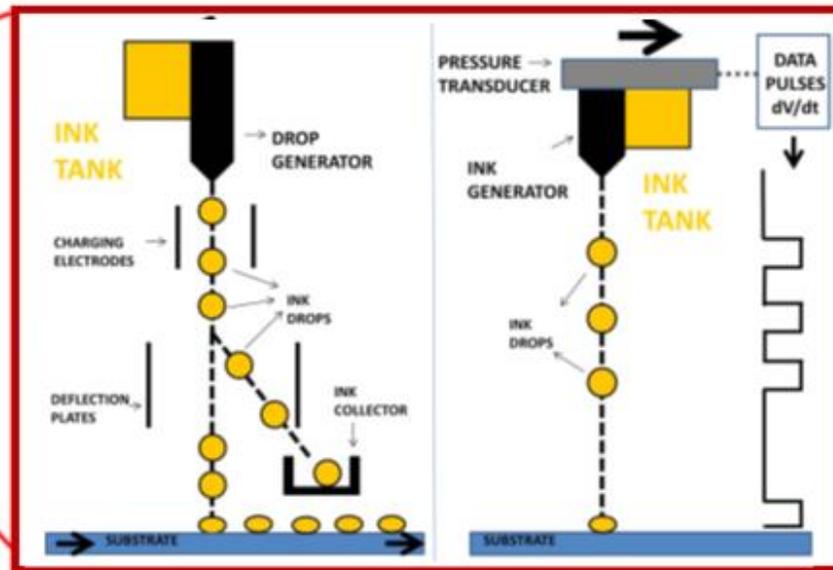
**RF components**



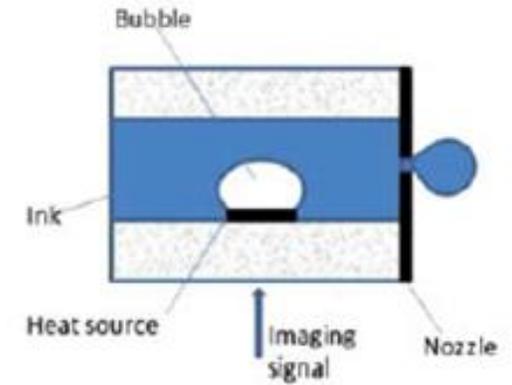
**SiP process flow**



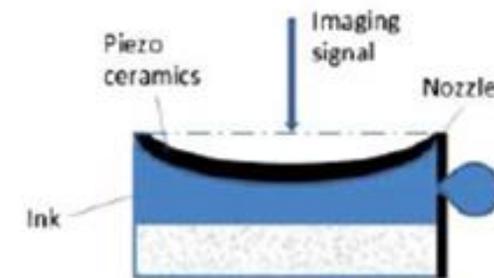
Drop Continuously      Drop on Demand



### Thermal Ink Jet (Bubble Jet)



### Piezo Ink Jet



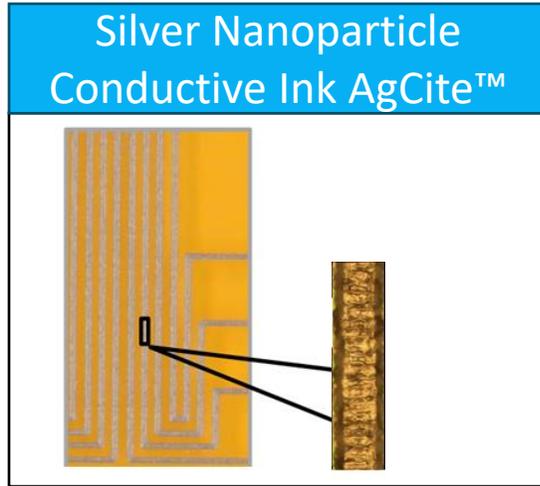
Specifications(example):  
Drop frequency: ~10-20 KHz  
Drop diameter: ~30µm

# How does it work?

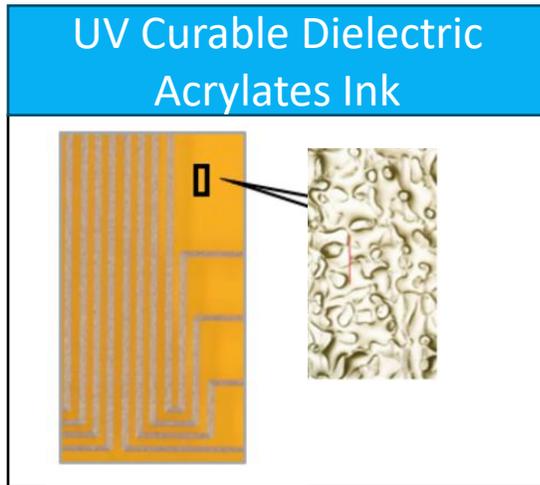


- The objects are built up, layer by layer, through full stack thickness
- Inject printheads prints the dielectric and conductive layers
- Conductive layers and dielectric layers are printed simultaneously
- Lines, pads, filled vias, hole vias, inductors, capacitors, cavities,
- Just one manufacturing step: No need for PR coating, photolithography, etching, pressing, electroplating!

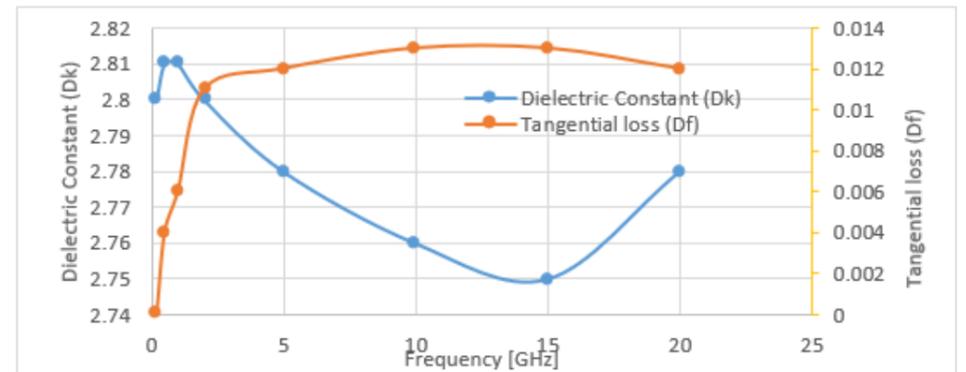
# Inks: Dielectric (DI) and Conductive Ink (CI)



Conductivity (Silver nano particles) (S/m) at 20 °C] *up to 60% bulk Silver	15x10 <sup>6</sup> – 30 x10 <sup>6</sup>
Tg (DMA, 10 Hz, tan delta)	162
Decomposition temp. (Td 5%) (TGA)	351
Flexural strength (crosswise) N/mm <sup>2</sup>	106.4
Dielectric breakdown (thickness 0.6mm) KV	40.3

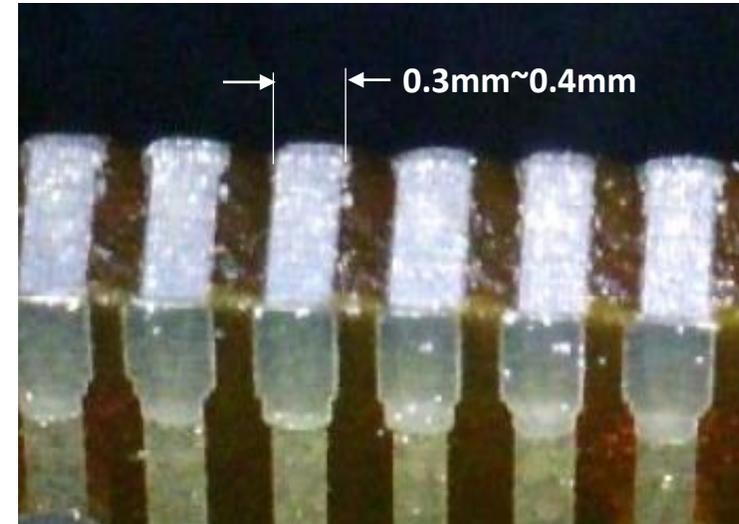


	Dielectric Constant (Dk)	Tangential loss (Df)
200MHz	2.80	0.000
500MHz	2.81	0.004
1GHz	2.81	0.006
2GHz	2.80	0.011
5GHz	2.78	0.012
10GHz	2.76	0.013
15GHz	2.75	0.013
20GHz	2.78	0.012



# Design Rules – Basic Data

- Minimum dielectric thickness: 35um +3um step
- Minimum metal plate thickness: 17um+0.3um step
- Width trace: 108um
- Release between traces: 108um
- Maximum number of dielectric layers: 55
- Minimum Via diameter: 200um
- Minimum Through-Hole Via: 400um
- Max Board dimension: 160x160x3mm<sup>^3</sup>
- Min BGA pitch: 0.5mm

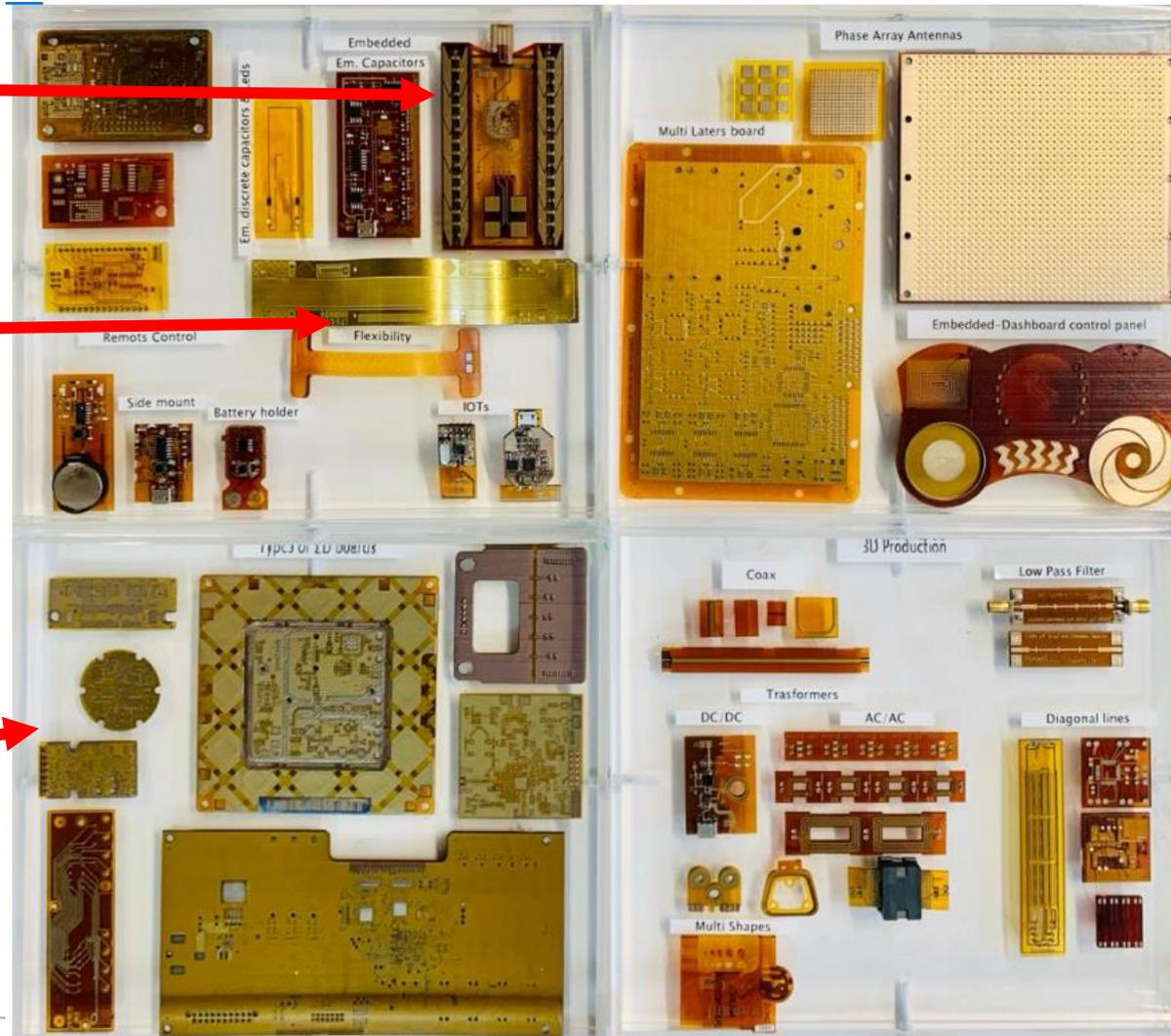


# Applications

3D Shapes:  
Embedded solution  
(System on package)

Side mount,  
Flexibility boards

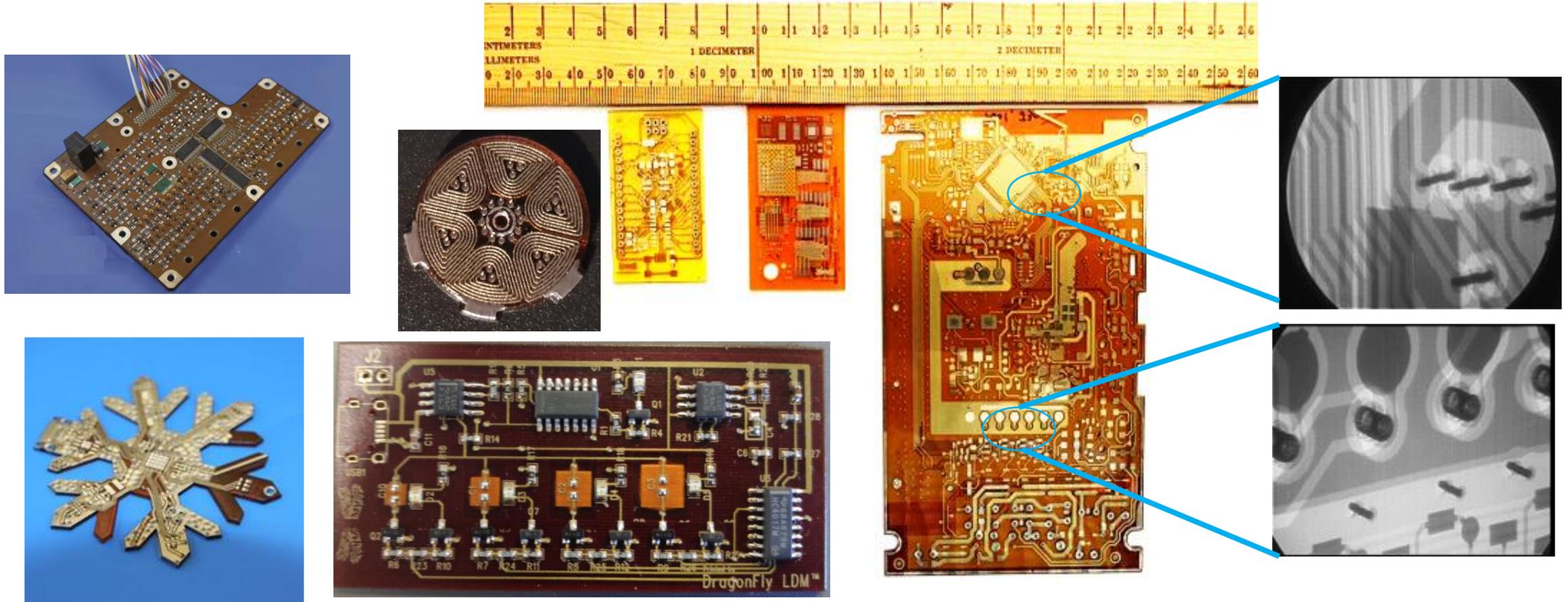
Multi layers,  
Standard Board



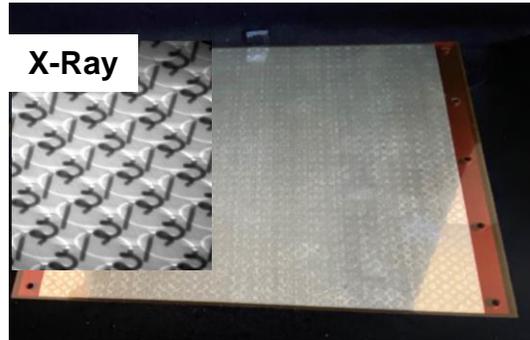
Antennas:  
Microwaves – High frequencies  
From 5- 35Ghz.  
Phase array antenna, flat antenna

3D Shapes:  
Internal & External  
Capacitors, Coils, Filters, Flat  
Motors

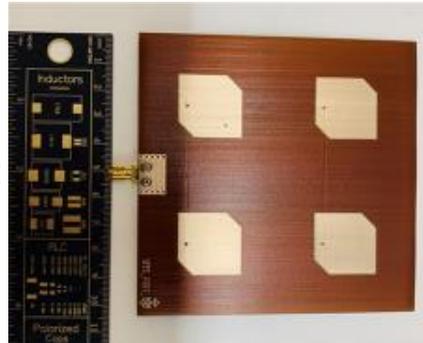
# EXAMPLES: Boards



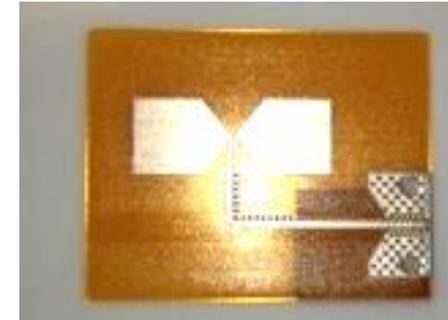
# EXAMPLE: RF antennas and components



**Phase Array Antenna**



**Tunable Antenna**



**Printed LPF**



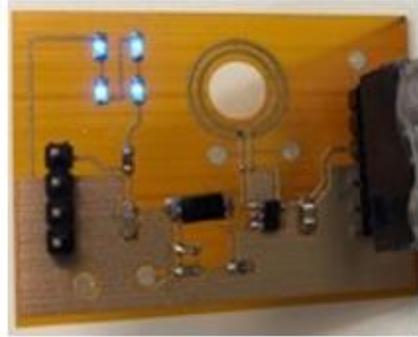
**Co-planar line**



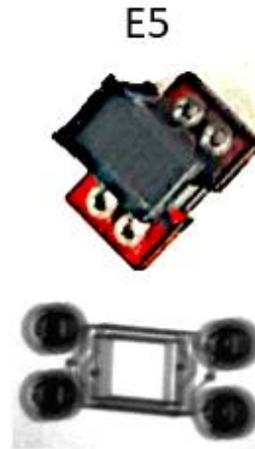
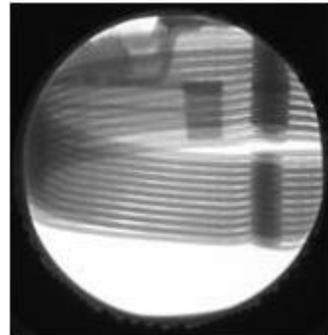
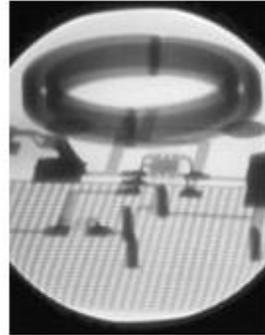
**Strip line**



# EXAMPLE: Transformers



In Board Power  
DC-DC Up  
Voltage  
Converter  
Example 5V to  
20V



E5

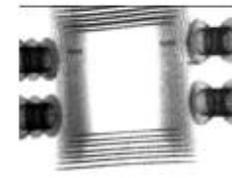


No-Core  
Weight - <0.5g  
Inductance - 0.2uH-4uH

E5 Ferrite Core (N27 Ferrite)  
Weight - <1g  
Inductance - 0.27uH-1000uH  
Interwinding Capacitance -  
5pF

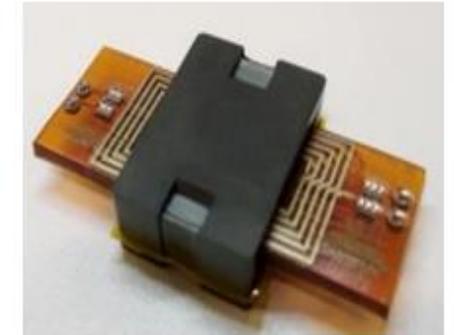


E14.5



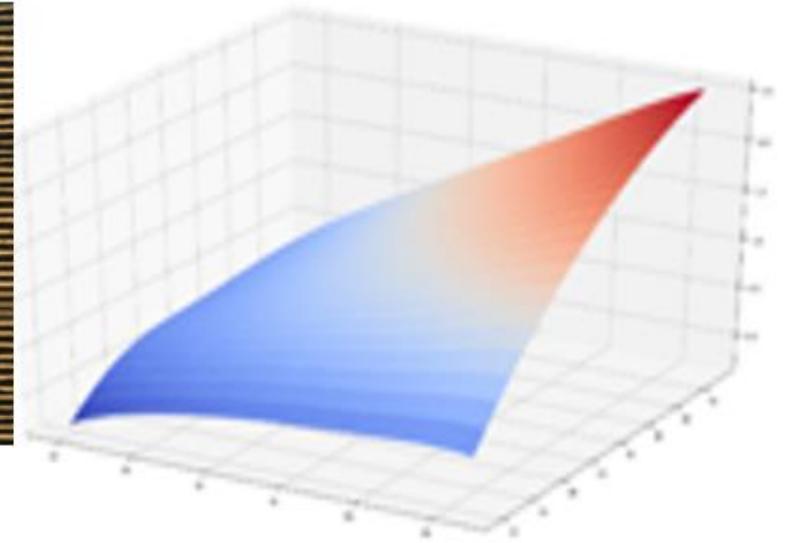
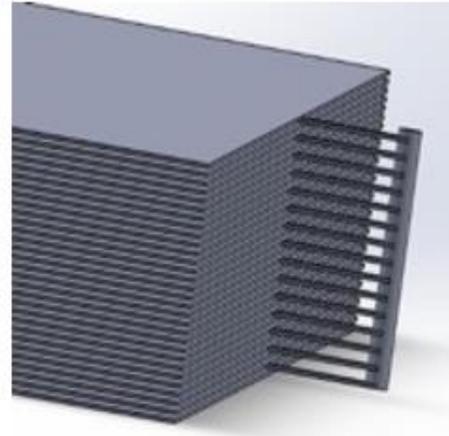
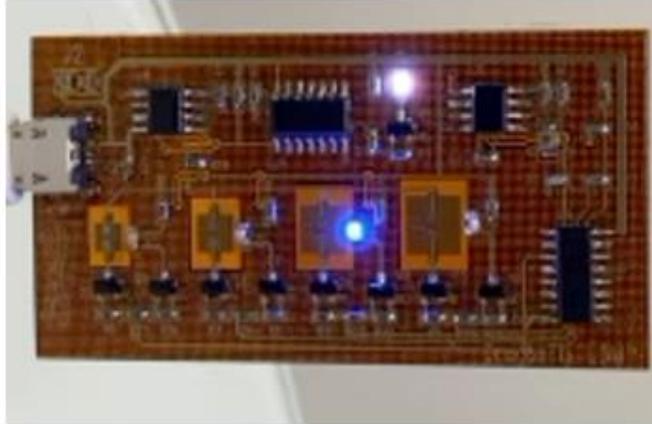
No-Core  
Weight - <0.5g  
Inductance - 2.5uH-50uH

E5 Ferrite Core (N27 Ferrite)  
Weight - <3g  
Inductance - 1.05uH-34mH  
Interwinding Capacitance - 18pF



AC- AC Transformer with ferrite core

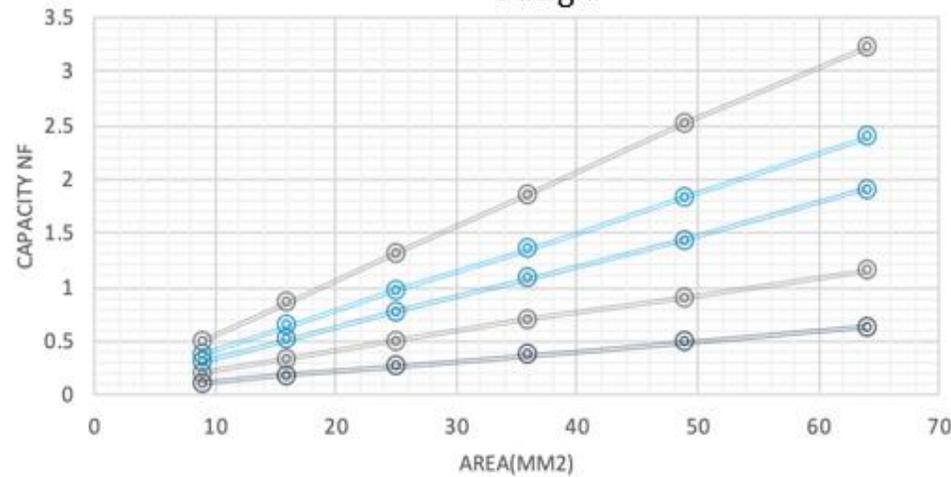
# EXAMPLE: Capacitors



Design

Actual

In AME  
Capacitors



● 10 Layers ● 20 Layers ● 30 Layers ● 40 Layers ● 50 Layers

<b>Studied Capacitance Range, other values are possible</b>	<b>0.1nF to 3.2 nF (at 25°C)</b>
<b>Capacitance Tolerances</b>	1%
<b>leakage current</b>	<5e-24 A
<b>breakdown voltage</b>	>1 kV
<b>temperature stability factor</b>	25°C-95°C 0.2 [%/°C], 95°C-125°C 0.4 [%/°C]



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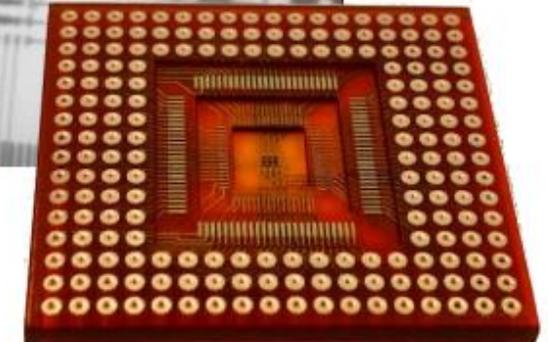
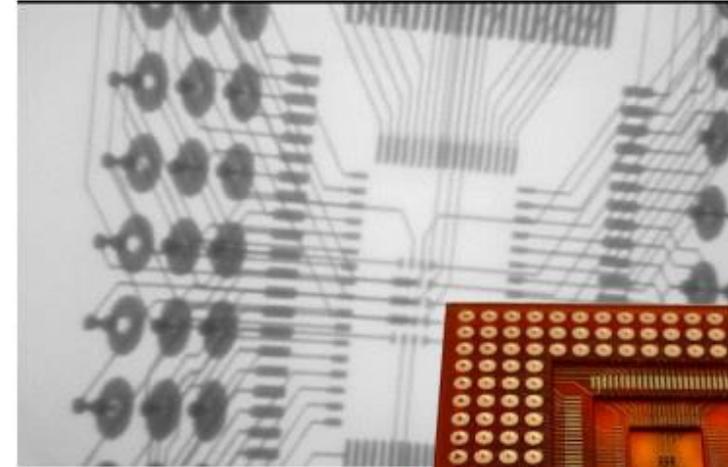
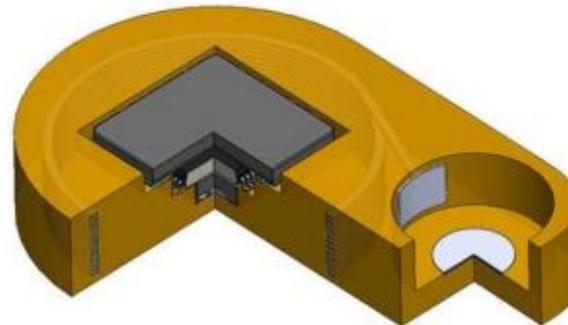
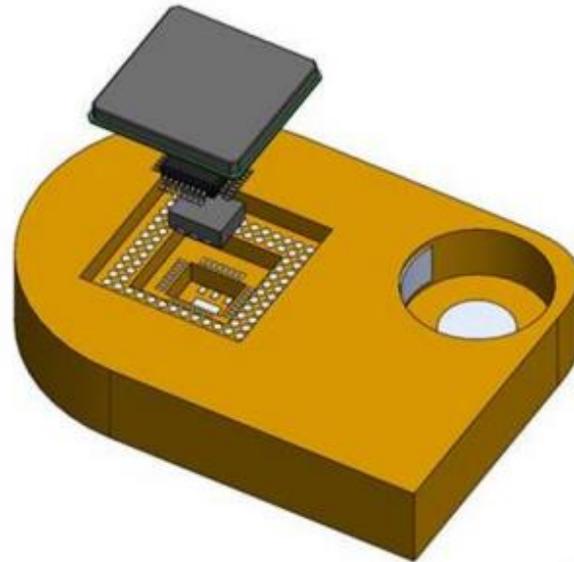
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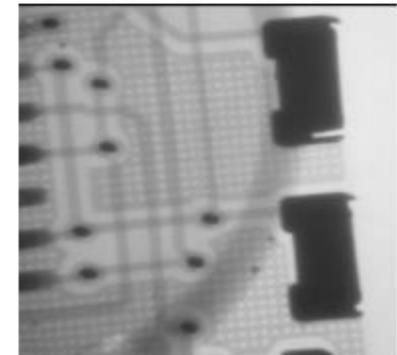
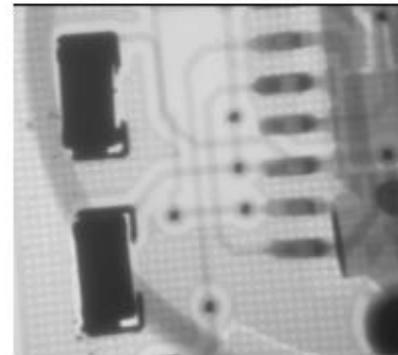
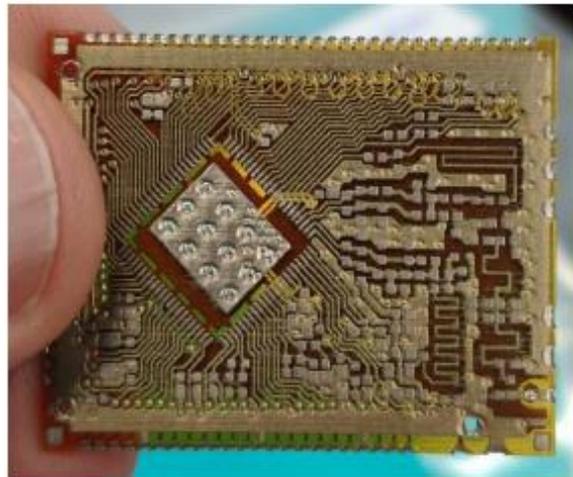
# EXAMPLE. Vertically Stacked ICs

Stacked ICs have a higher circuitry density than traditional PCBs by allowing ICs to be mounted and interconnected on top of each other.



# EXAMPLE: Side mount/contact

- Enables the use of an area not common for PCB components
- Enables the creation of customized small PCBs that can be inserted into a socket

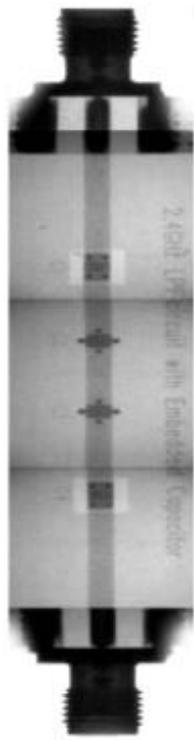


a) b)  
Figure 1 X-ray view of a) inserted, and b) side mounted components soldered to vertical contacts manufactured as part of the PCB additive manufacturing technology in the DragonFly LDM™

# EXAMPLE: Low pass filter



Printed LP

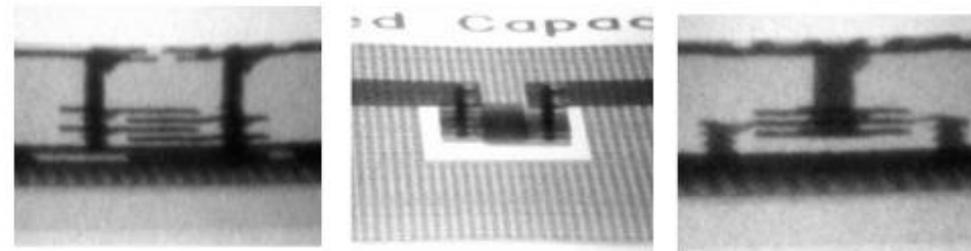


X-ray of  
Printed LP

LPF uses AME capacitors fabricated simultaneously inside the AME board together with strip lines.

The AME capacitor and the strip line can be placed on any layer or on different layers in the AME board

X-ray of LPF capacitors and transmission strip lines



S21 - AME transmission and capacitors vs AME transmission with SMT commercial capacitors



LPF with AME Capacitors filters the signal at least up to 20GHz. (less than -30db)

LPF with Commercial Capacitors stops filtering at 6GHz



# THANK YOU

Dr. Joseph Kaplun

CTO of applications, processes and materials

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