# Breakthrough in the packaging industry to unleash innovation

## *Heterogeneous integration & 3D packaging technology*

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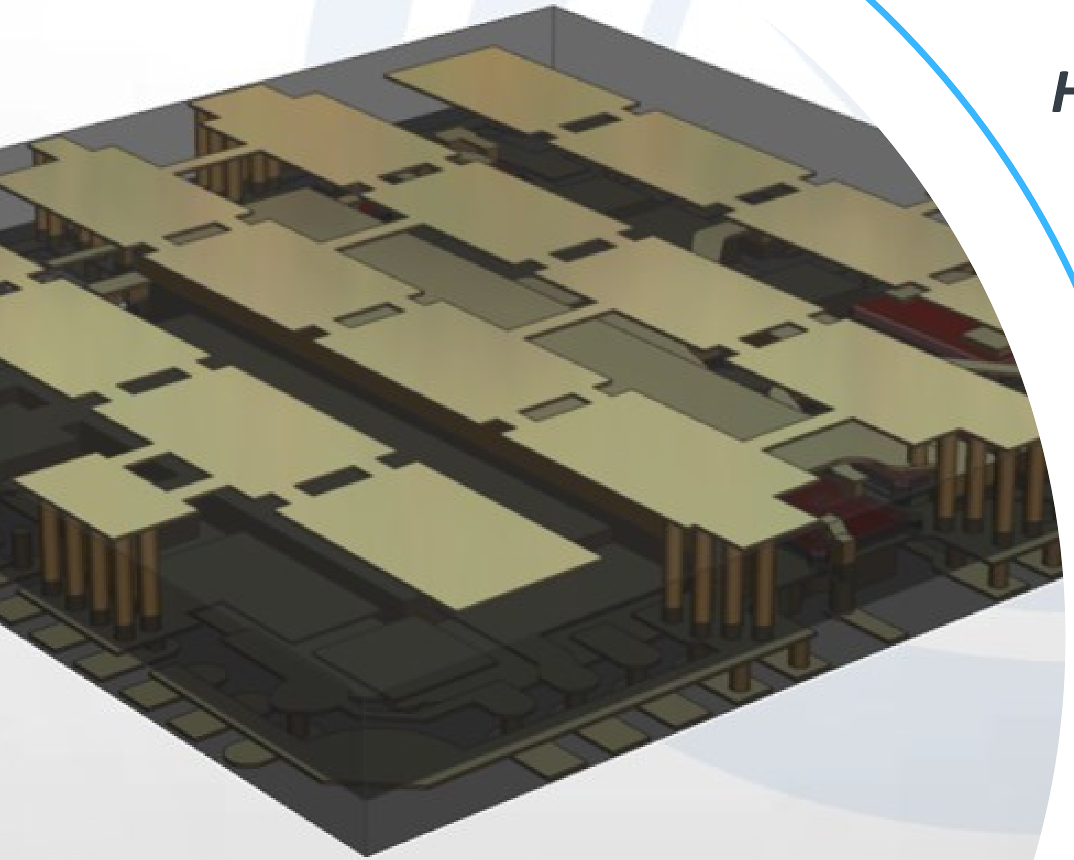
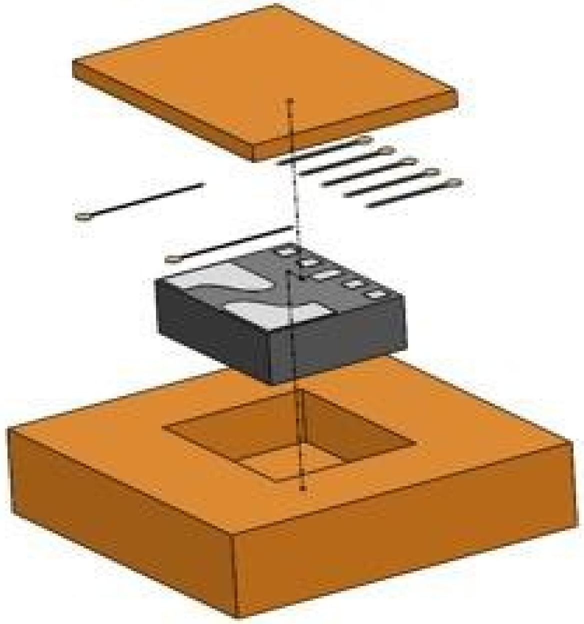
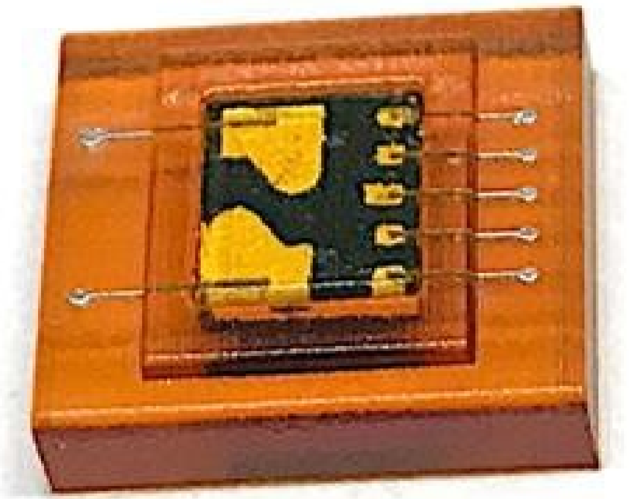
June 2023



# Agenda

- Nano Dimension introduction
- Why AME? Motivation
- AME Packaging History & Process Evolution
- AME Technology Basics and opportunities
- System in Package (SiP) Development Flow
- RF SiP Case Study
- Power Transistor AME Packaging Case Study
- Summary





Acronyms:

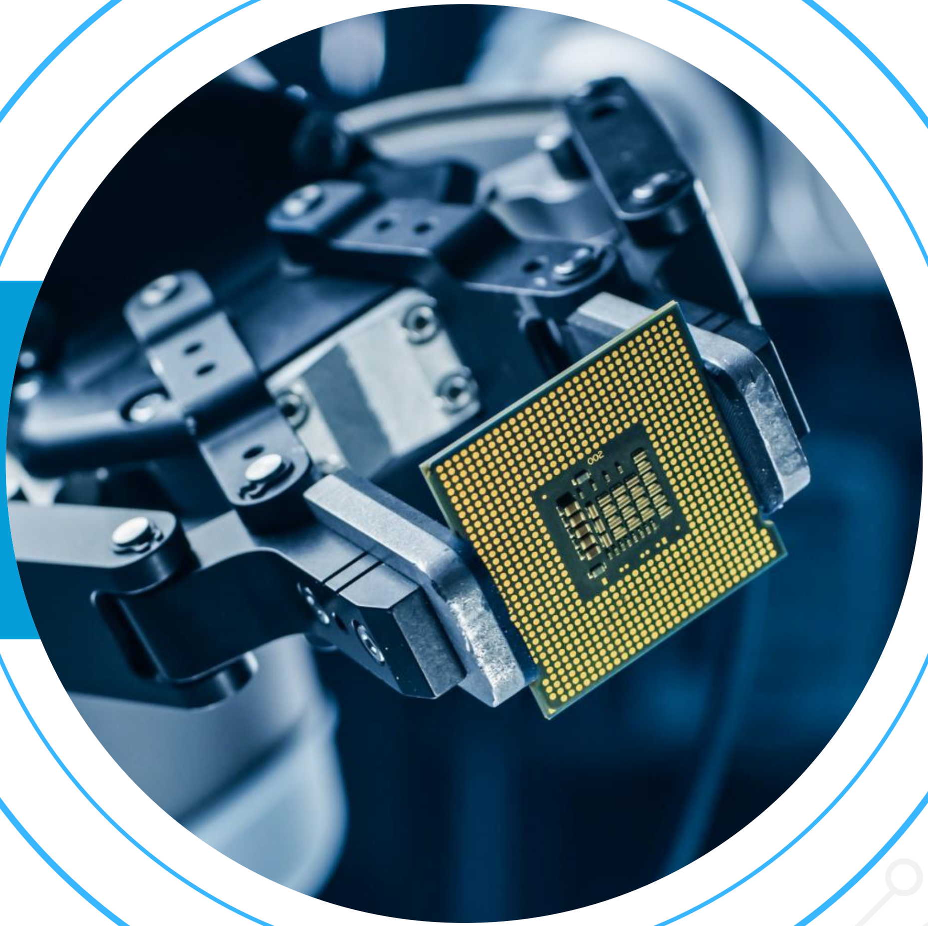
AM = Additive Manufacturing

AME = Additively Manufactured Electronics

SiP = System in Package

# Who is Nano Dimension?



# We make...

...all of these

**advanced deep learning-AI led manufacturing solutions**

that are used by

**industrial-level organizations**

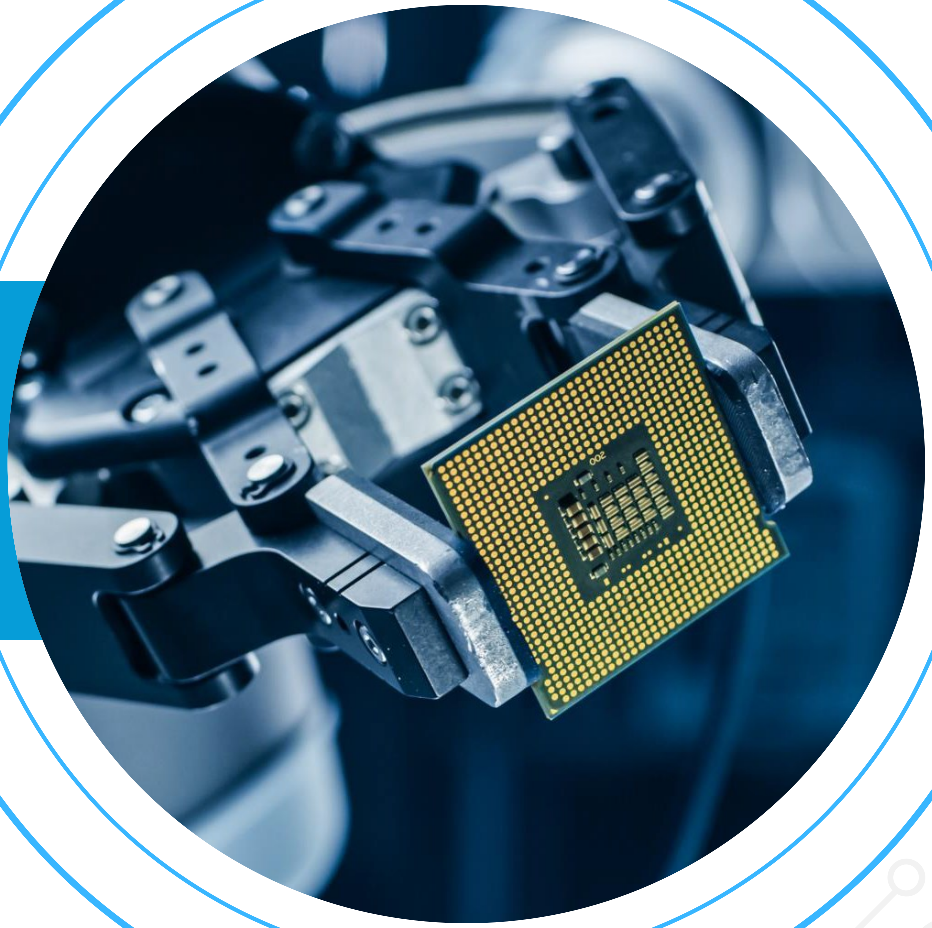
to 3D print and assemble

**High Performance Electrical & Mechanical Applications**



NANODIMENSION
Electrifying Additive Manufacturing®


# Why AME?



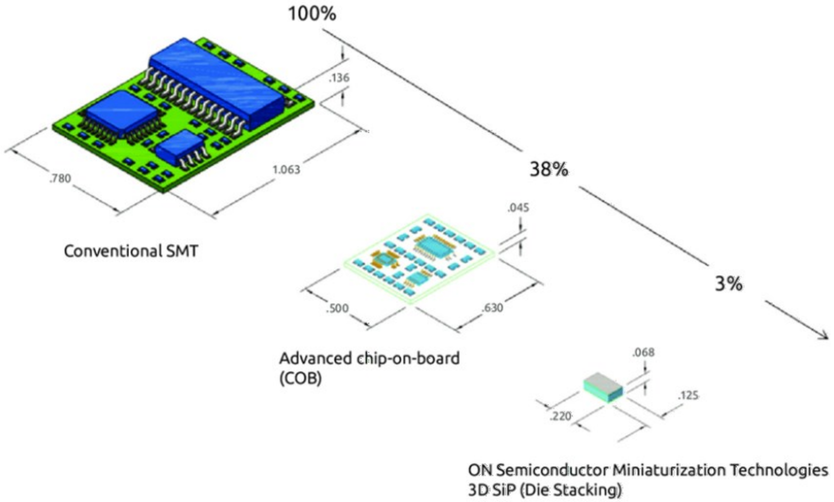
  

# Motivation

## CURRENT WORLD OF ELECTRONICS

### 1. Technical Limitations:

preventing improvement of performance and reduction of other factors such as weight and size




**Weight and size over 90% down**

### 2. Supply chains:

hurting most in the high variety small mix and when prototyping (long R&D cycles)

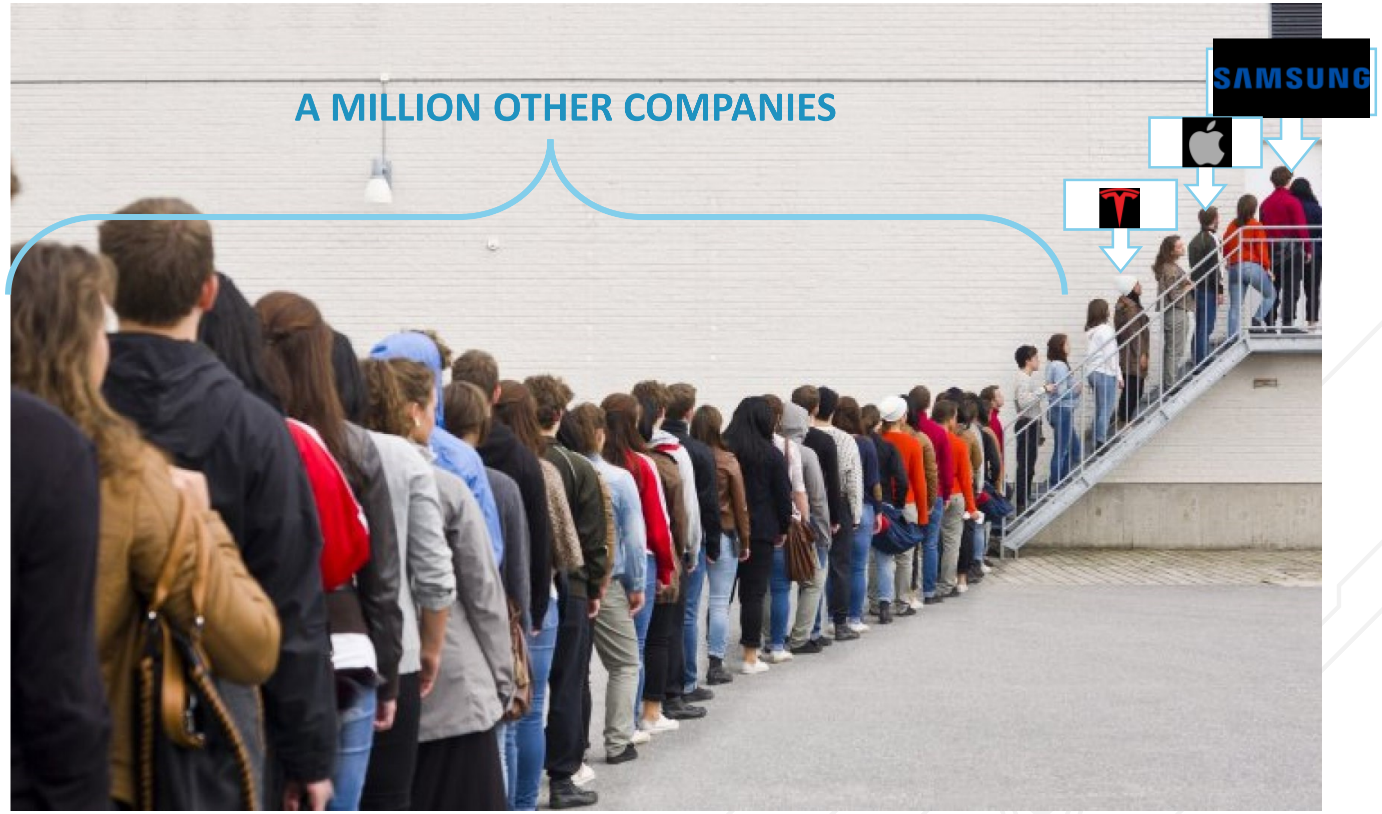
 

# Motivation (cont.)

## LONG LINES FOR PACKAGING AND PROTOTYPING

Very long lead time for small & medium-sized enterprises and very long R&D-cycles

- To produce a prototype, 4 R&D cycles are required
- each cycle has a 3-4 months lead time until supplied from the global packages & electronics manufacturer



# Motivation (cont.)

## TRADITIONAL MANUFACTURING VS. SUSTAINABLE AM SOLUTIONS

### 3. Sustainability

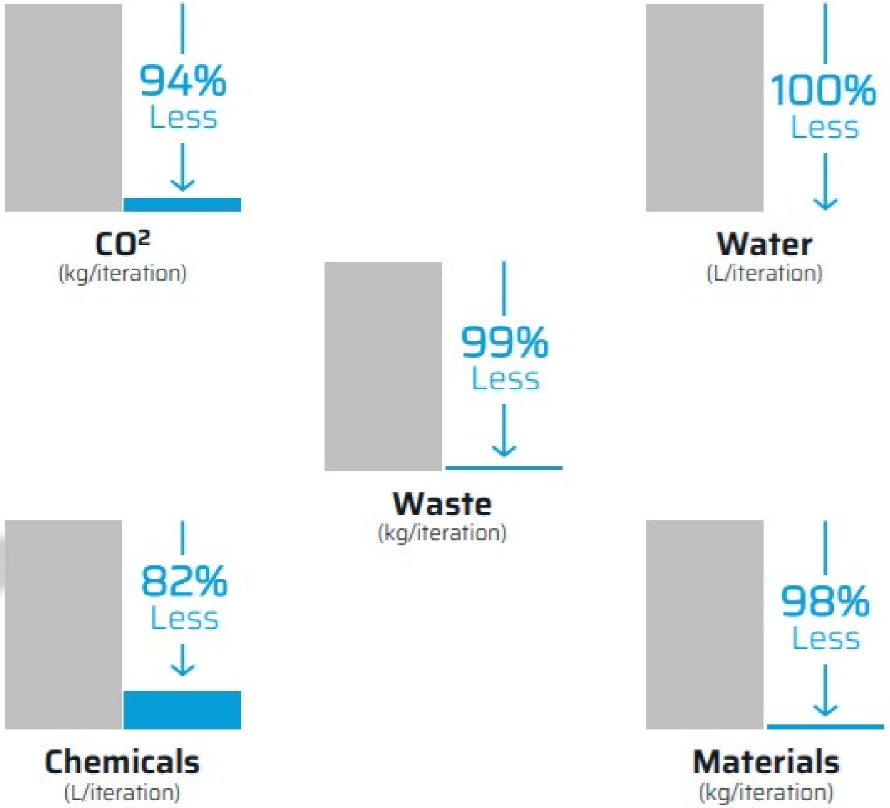
A holistic approach towards functional electronics with net zero carbon emissions

# Motivation (cont.)

## TRADITIONAL MANUFACTURING VS. SUSTAINABLE AM SOLUTIONS

**Before**

**After**

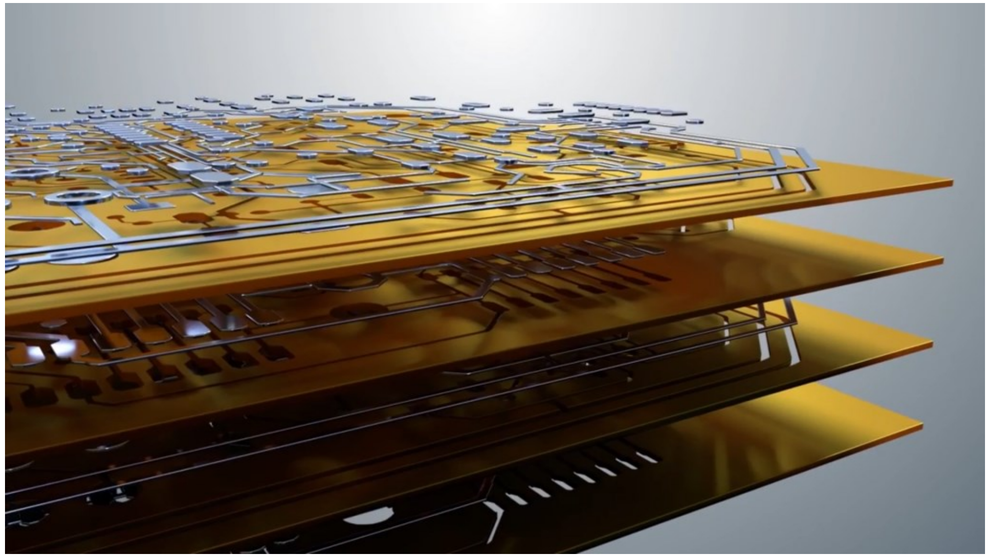

1 Based on a 2021 study by HSSMI, a UK based sustainability consultant

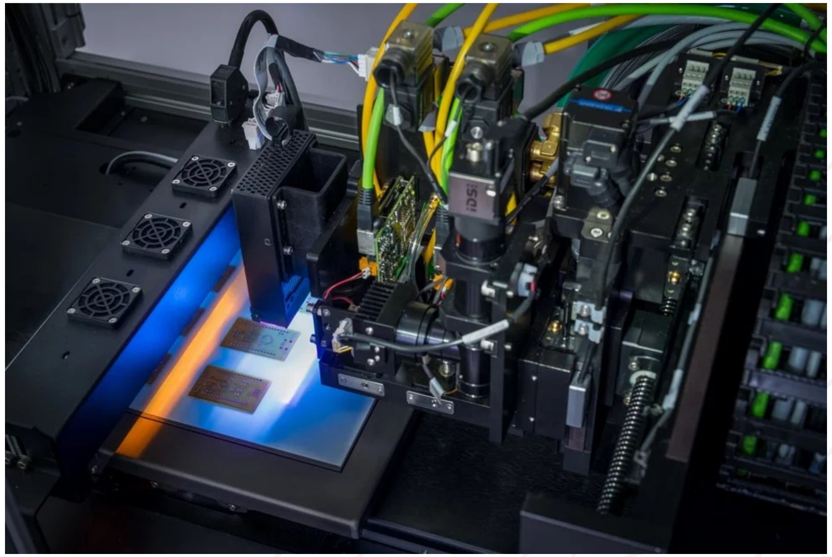
# But how it works?

## ADDITIVE MANUFACTURING ELECTRONICS (AME) - PROCESS DESCRIPTION

- Inkjet technology that combines UV-cured dielectric material (acrylic monomers) with silver nanoparticles (Ag NP) that undergo sintering upon IR radiation.

  Result in solid objects with highly conductive patterns in shapes unachievable through traditional processes





# Additive Manufacturing Electronics (AME) - DragonFly

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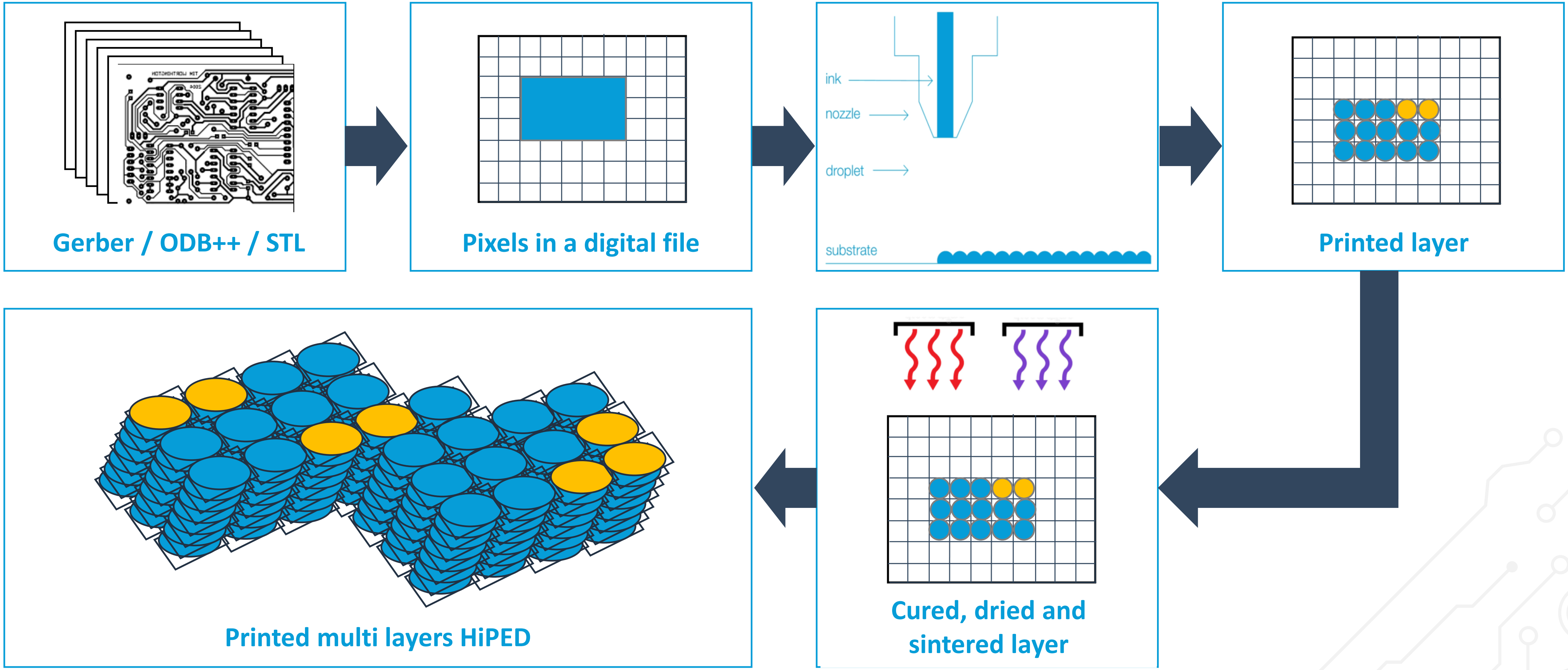
# From a Digital design file to a Printed Hi-PED

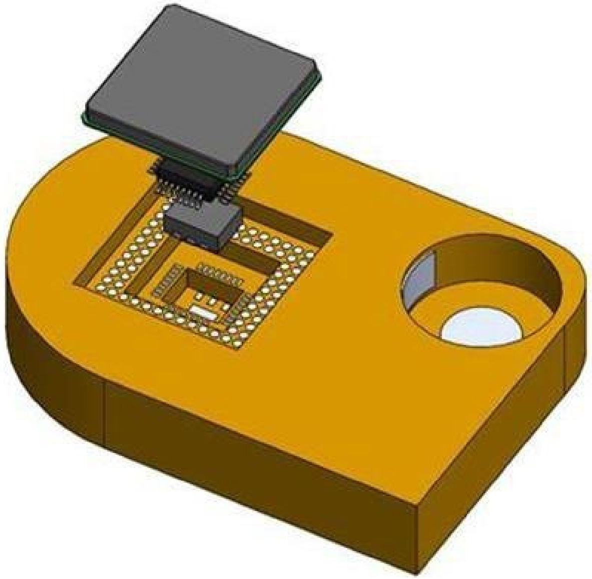


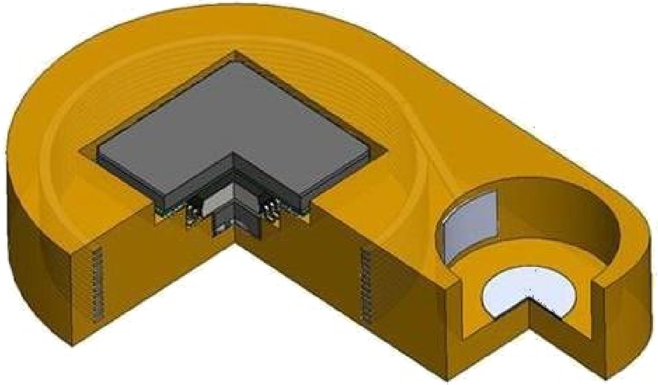

  

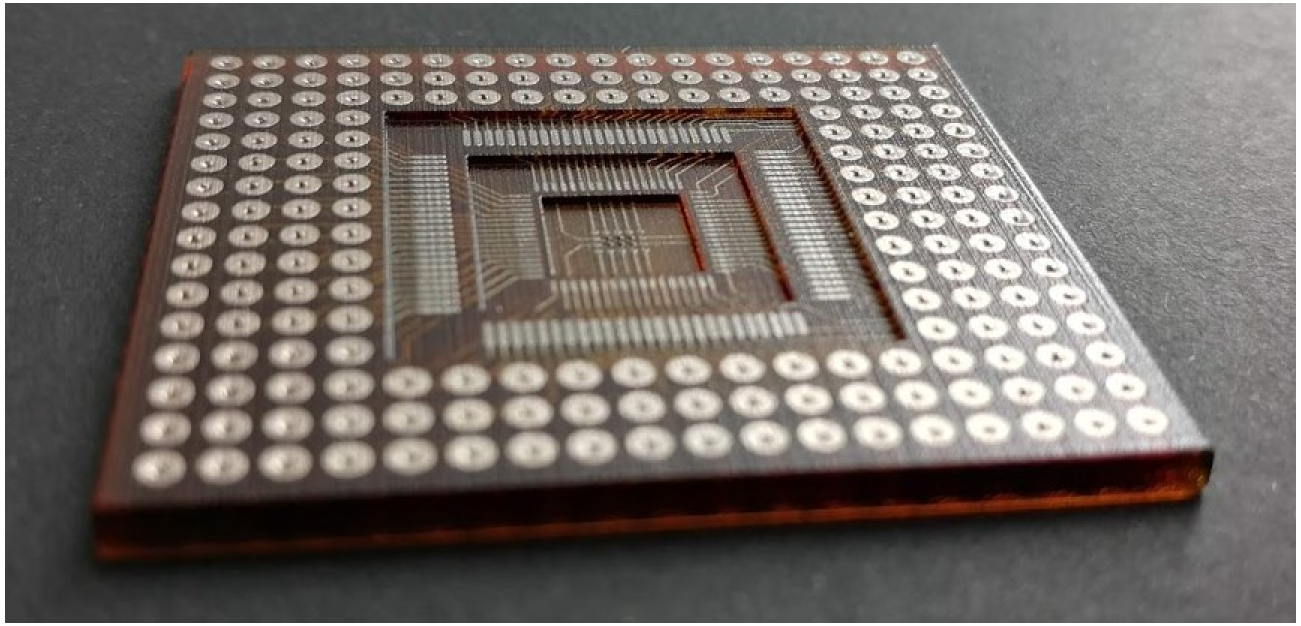
# History

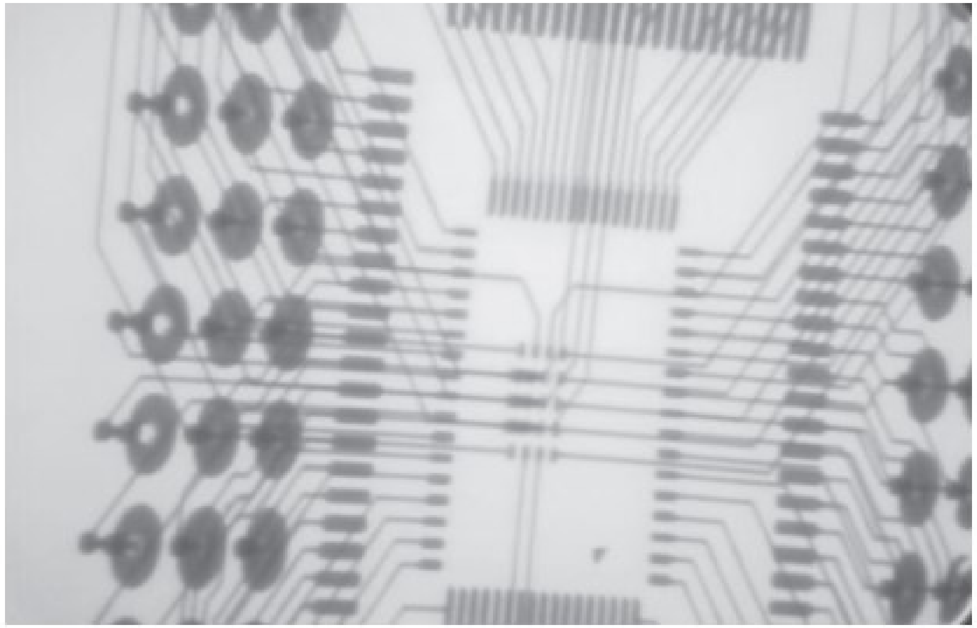
## AME SOCKETS & INTERPOSERS

- Very first encapsulation concept: Stacking of packaged ICs and interposers









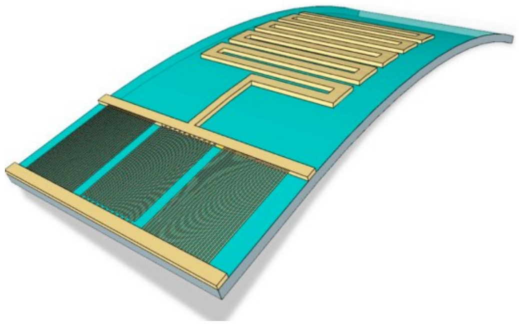
  

ISTITUTO ITALIANO DI TECNOLOGIA CENTER FOR BIOMOLECULAR NANOTECHNOLOGIES

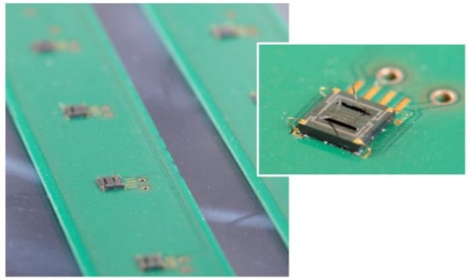
NANODIMENSION Electrifying Additive Manufacturing

# History (cont.)

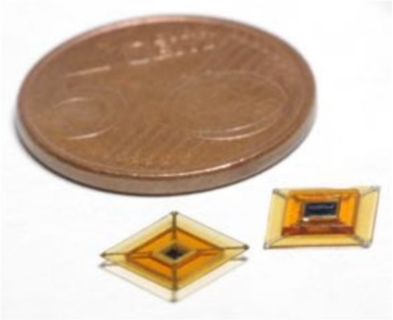
## AME SENSOR APPLICATIONS



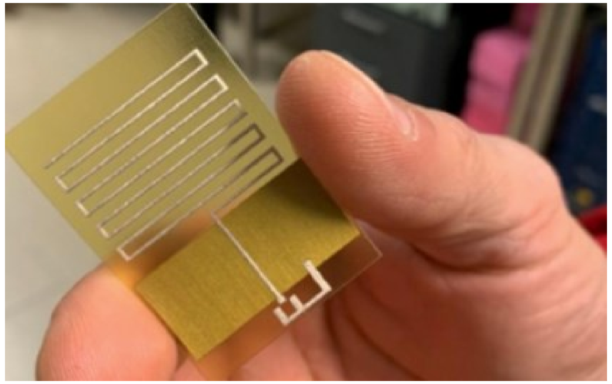
*Artificial Hair Cells for Flow Sensing*



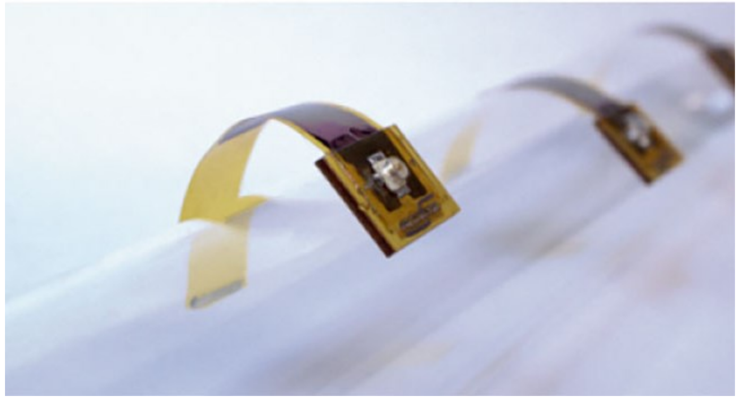
EMBEDDING FLOW SENSORS IN SEALED PACKAGE



Sensor direct print packaging (3D printed wirebonding)



Compact and flexible meander antenna for Surface Acoustic Wave sensors



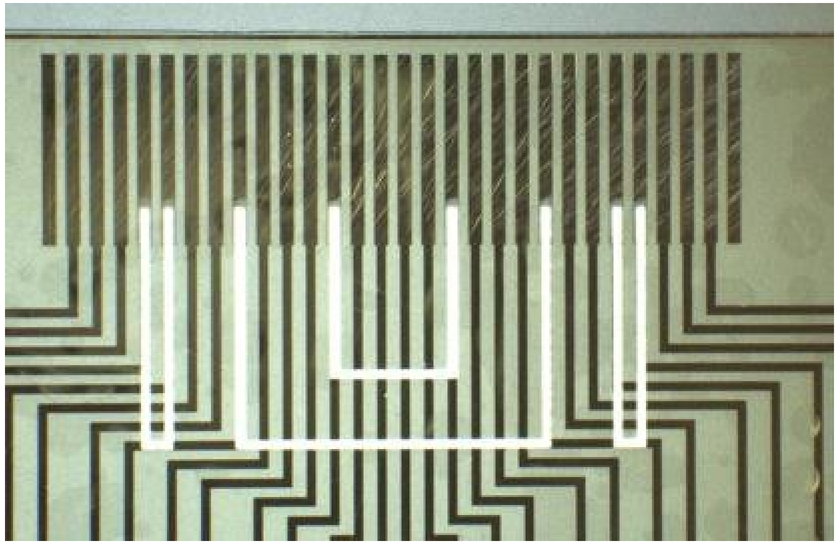
3D embedded sensor in electrical packaging

Optoelectronic Neural Surface

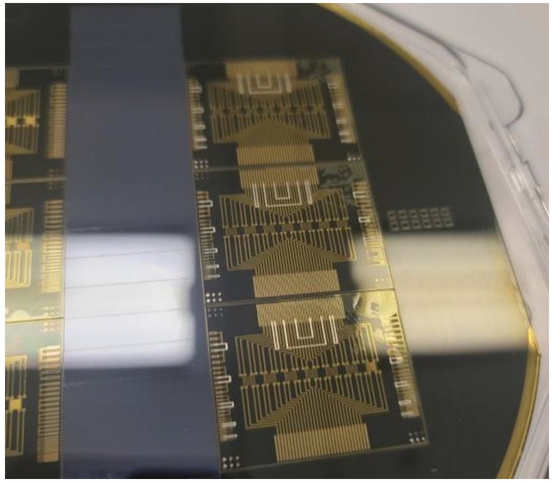
# History (cont.)

## TESTPATCH AGCITE® BONDING



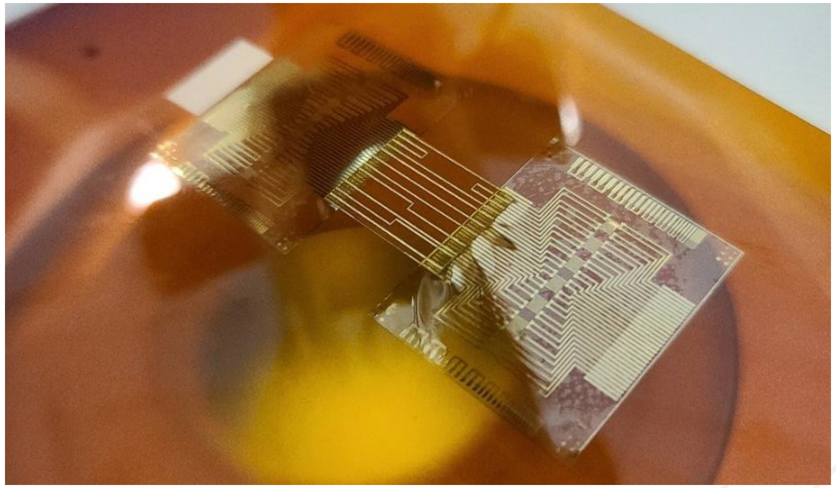
Print on foil

success



Print on wafer

success



Connect two foil on flex substrate

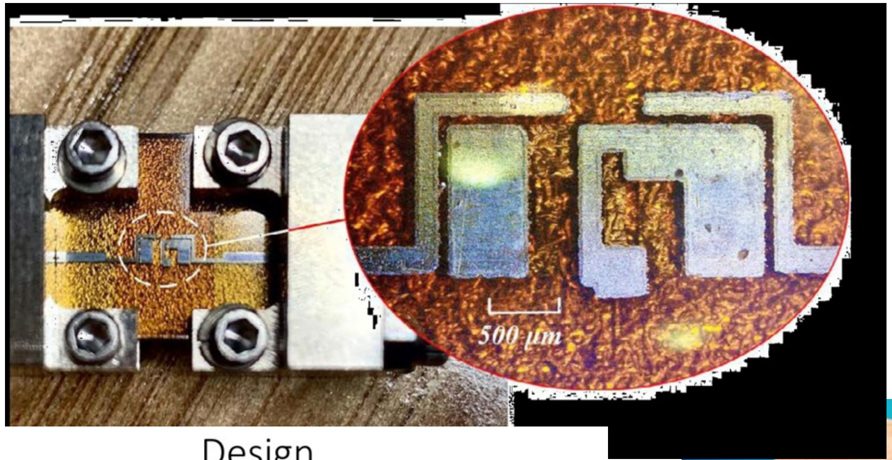
success

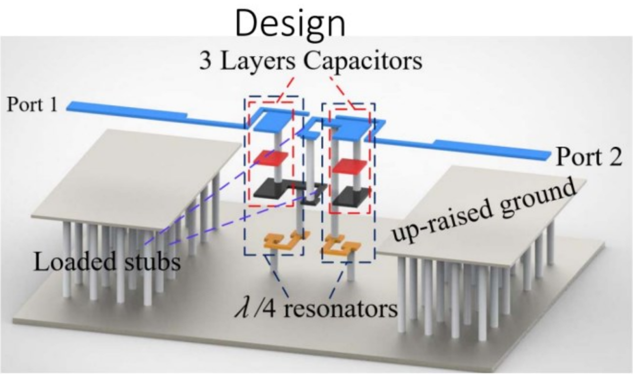
  

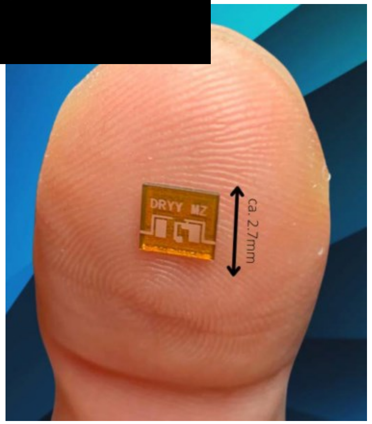
# RF Examples

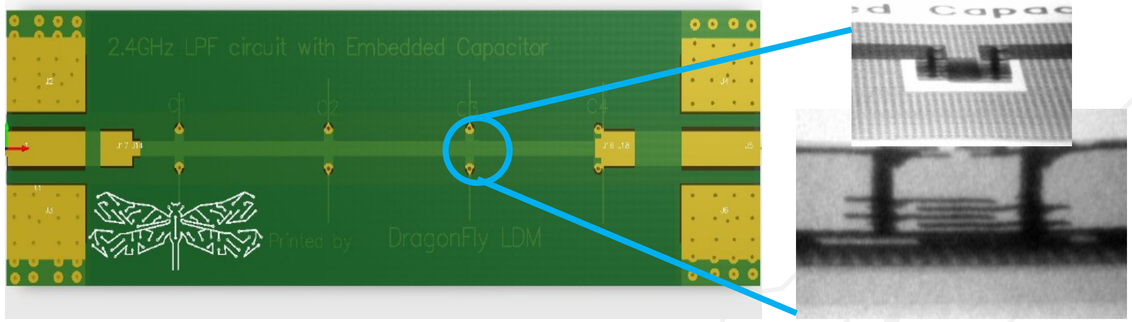
## HIGH FREQUENCY FILTERS

- Complex tuning iterations and extra laser trimming process is replaced by an overnight print



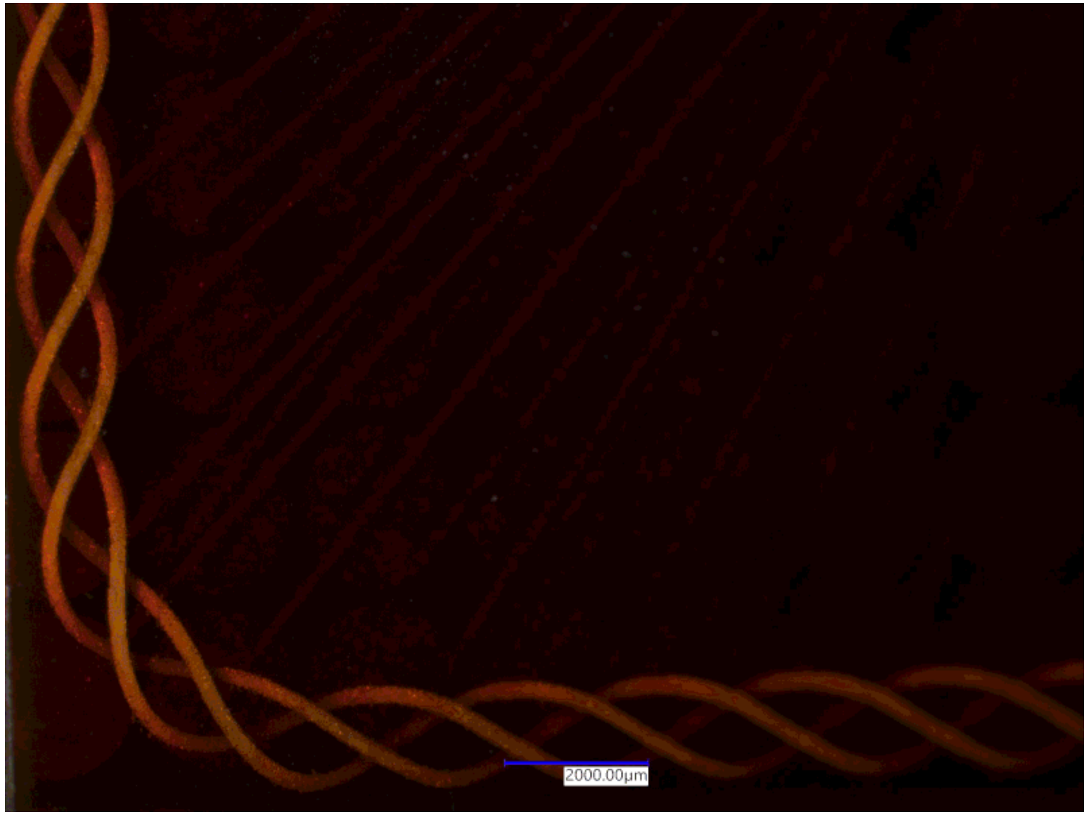



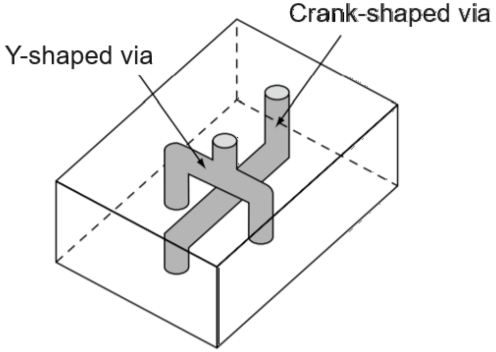
# New Design Thinking

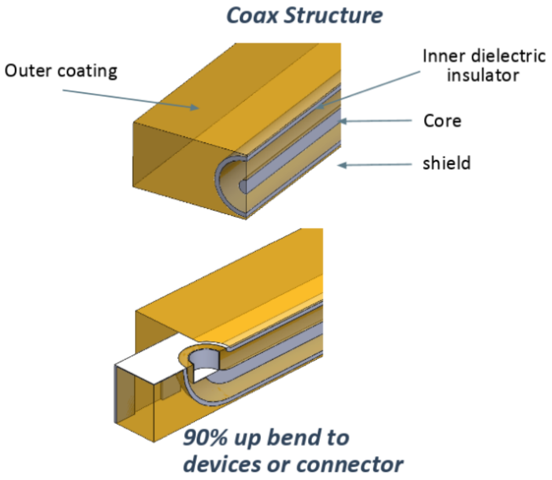
## NON PLANAR TRANSMISSION LINES

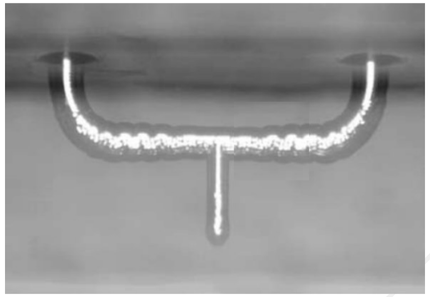
- Coaxials, twisted pairs, waveguides. Freedom of via intercon

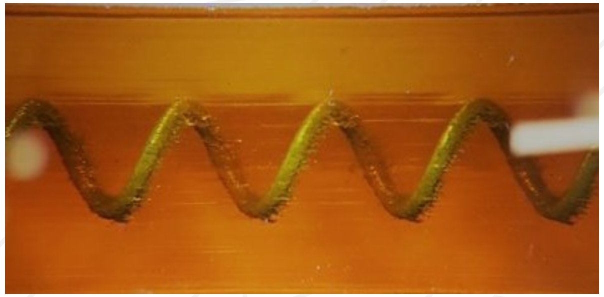



Source: J.A.M.E.S





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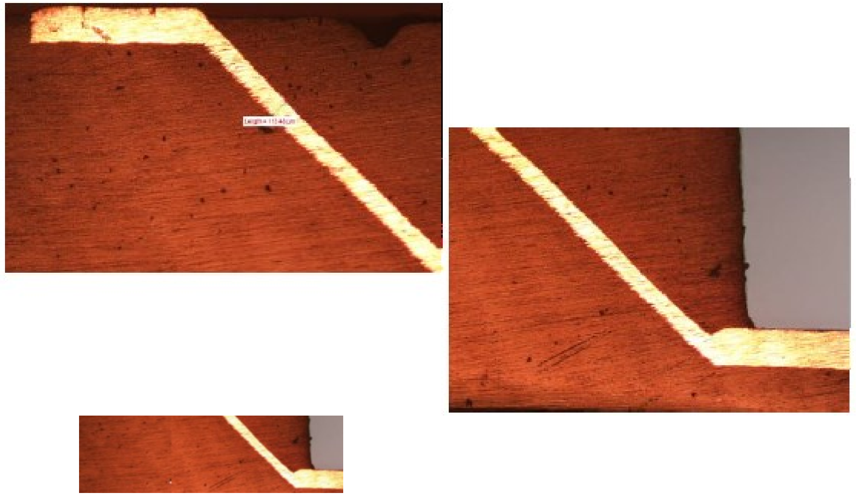
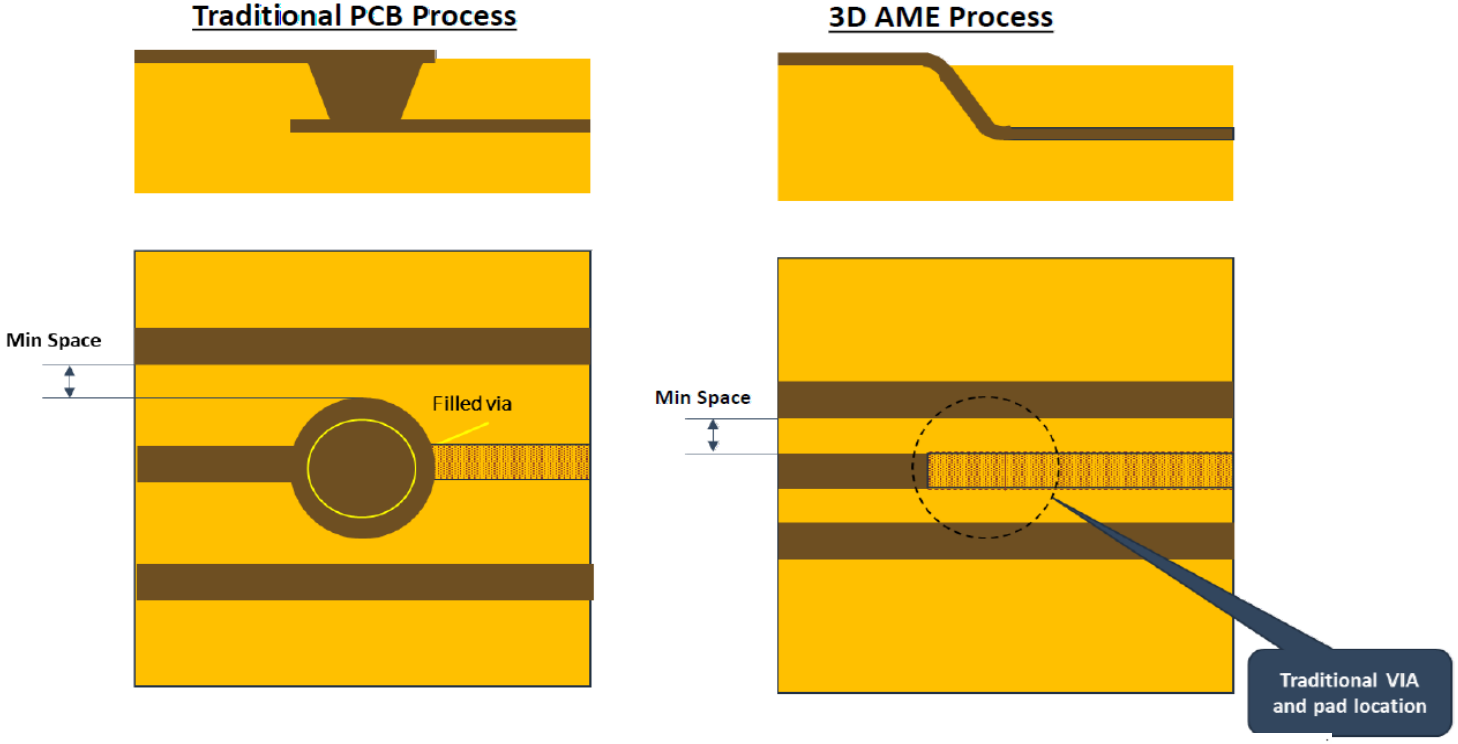
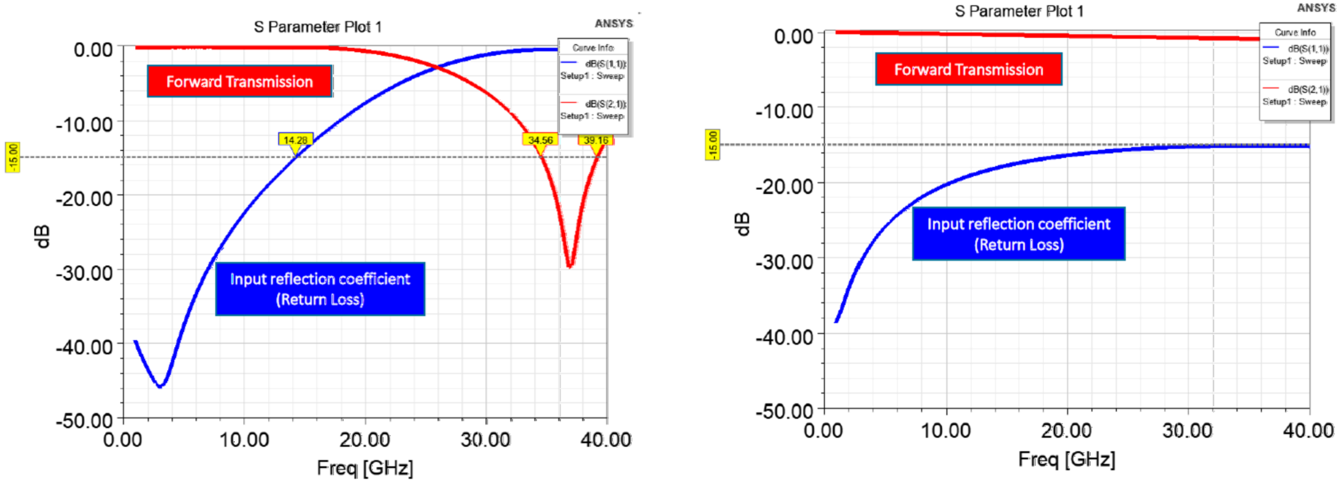
# New Design Thinking

## HIGHER DENSITY ROUTING

- Homogeneous Z-axis structures allow to 45 degrees vias with increased performance and space reduction





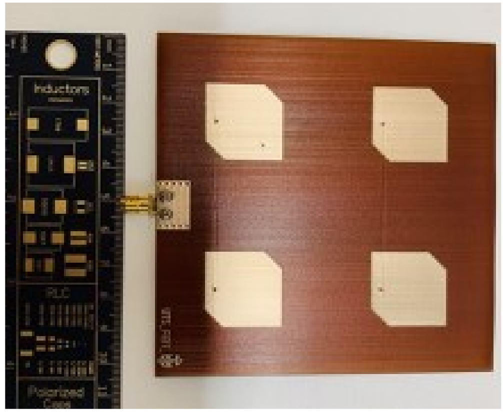



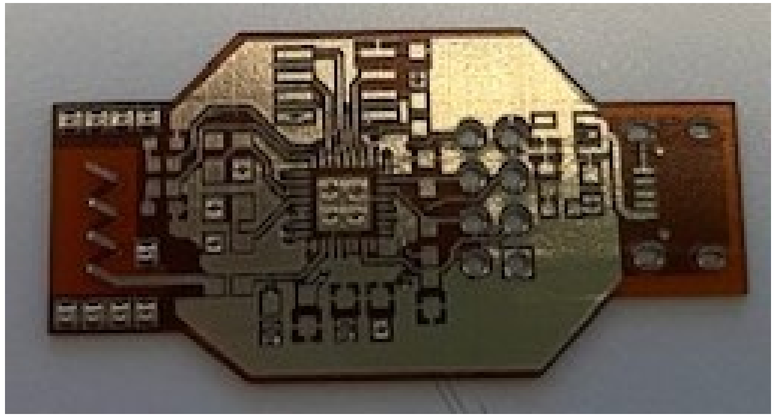
# New Design Thinking

## 3D-PRINTED ANTENNAS AND RESONATORS

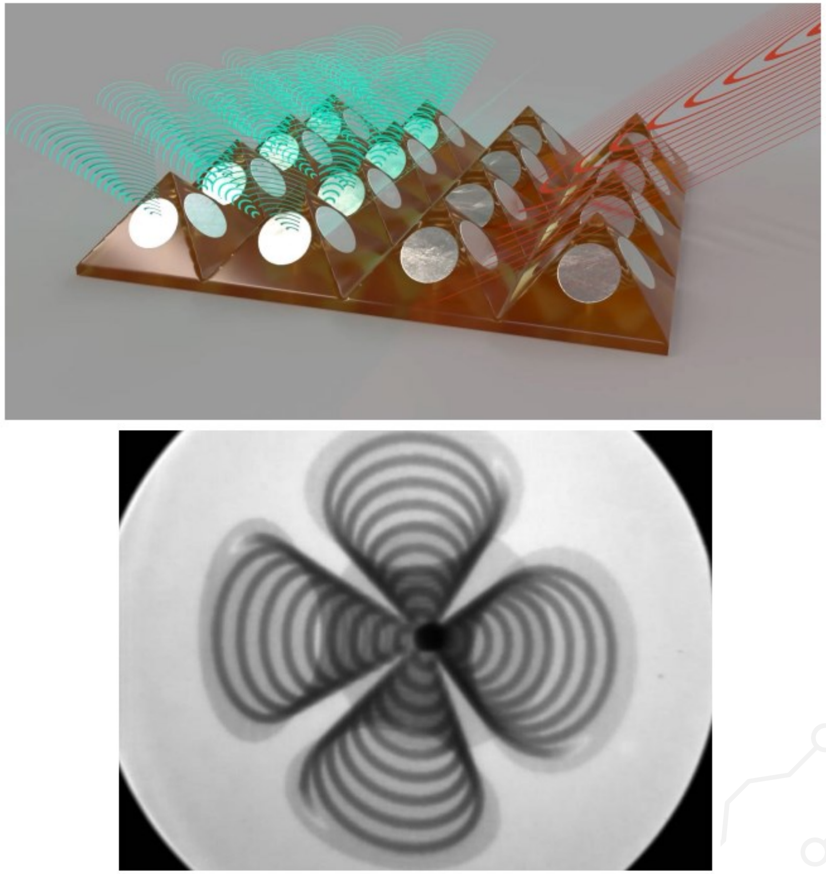
- AME technology is an enabler for new designs of antennas
- Design freedom in the 3D space enables unique antennas such as: Omni directional antennas, coils antennas, special shaped phased-array antennas, etc.



**Multilayer Array of Stacked Patches**



**Metamaterial Antenna**



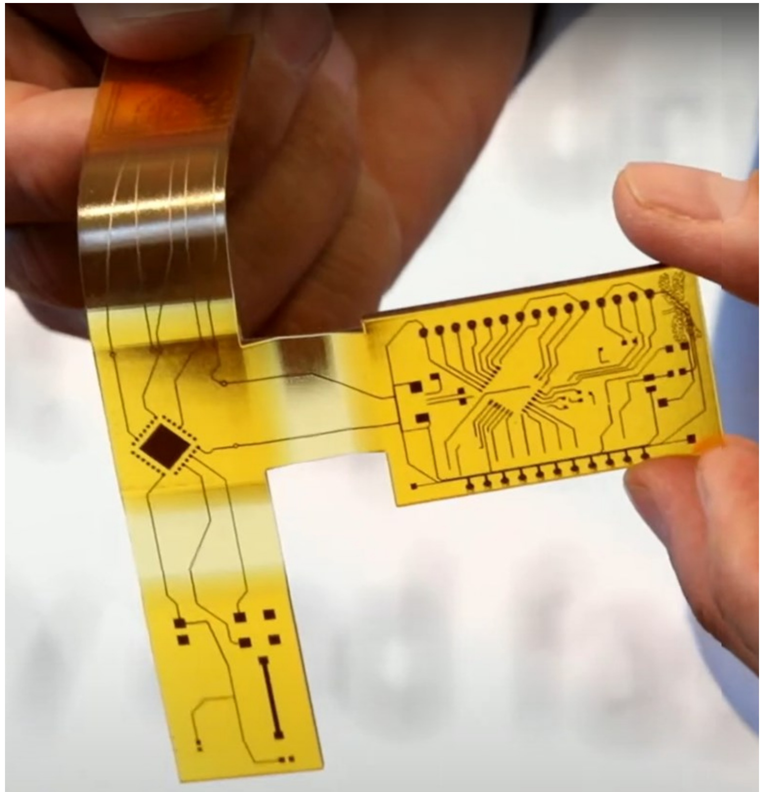
**Phased array Antenna**

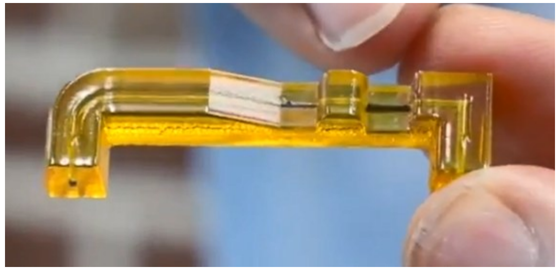
 

# New Design Thinking

## FLEXIBLE AND FLEX-RIGID STRUCTURES

- Flexible structures
- Flex-rigid assemblies
- MID (Molded Interconnect Devices)

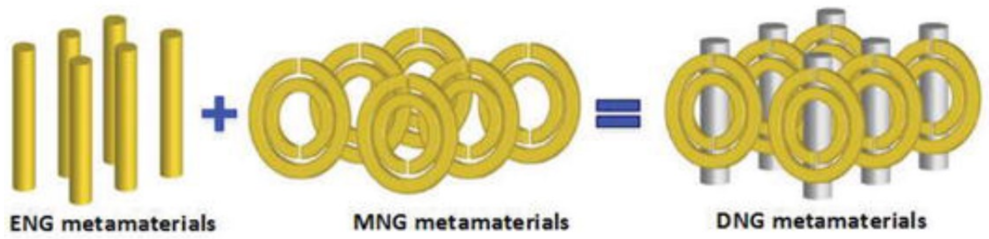


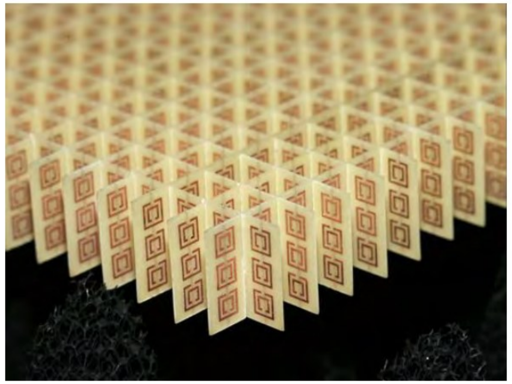


# New Design Thinking

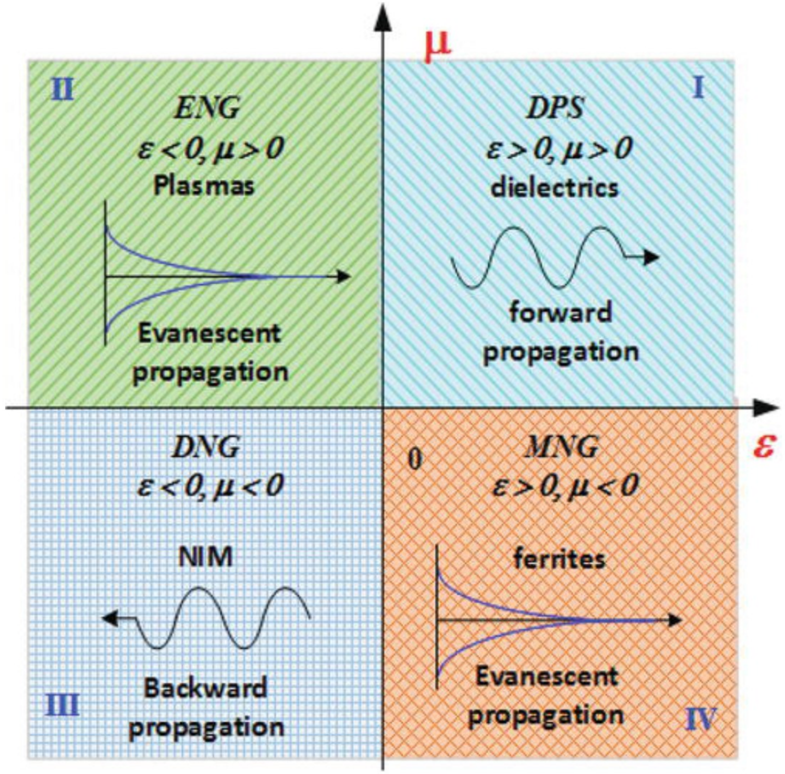
## 3D-PRINTED METAMATERIALS

- Conventional technologies rely on time consuming precise assembly
- AME is an enabling technology for agile design of 3D metamaterials with isotropic or quasi-isotropic behavior



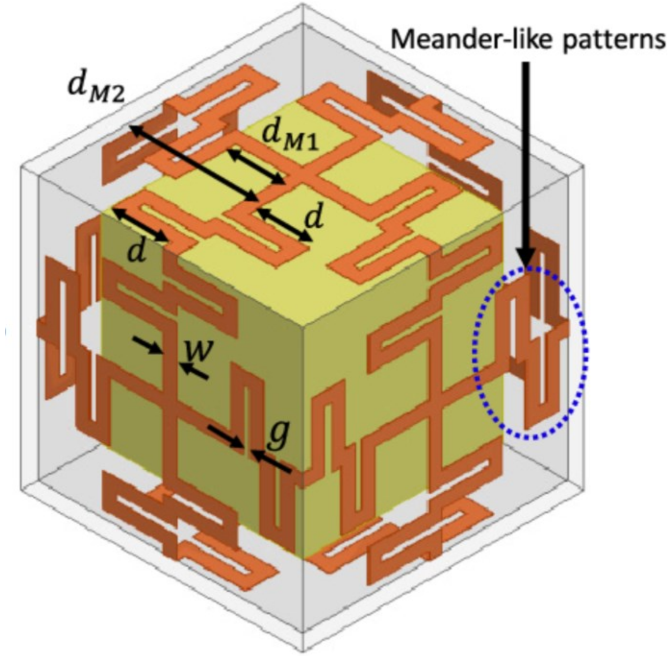
Conventional technologies

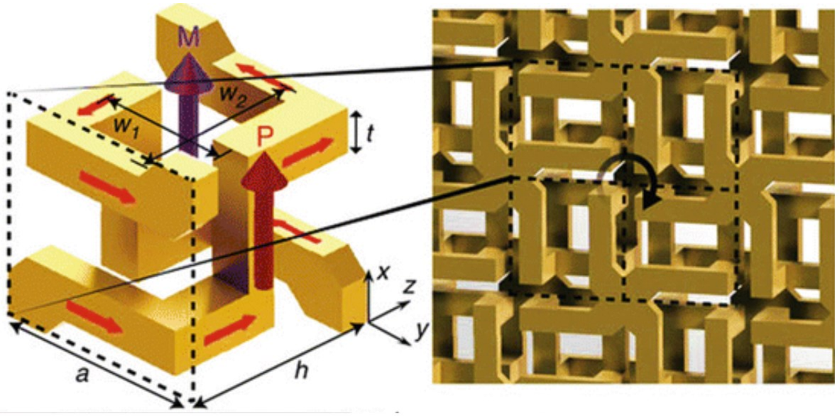


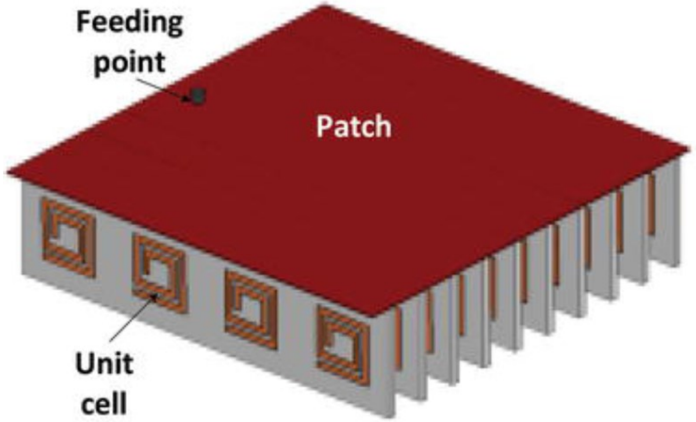
# New Design Thinking

## 3D-PRINTED METAMATERIALS

- 3D Metamaterial cells and structures possible with AME:

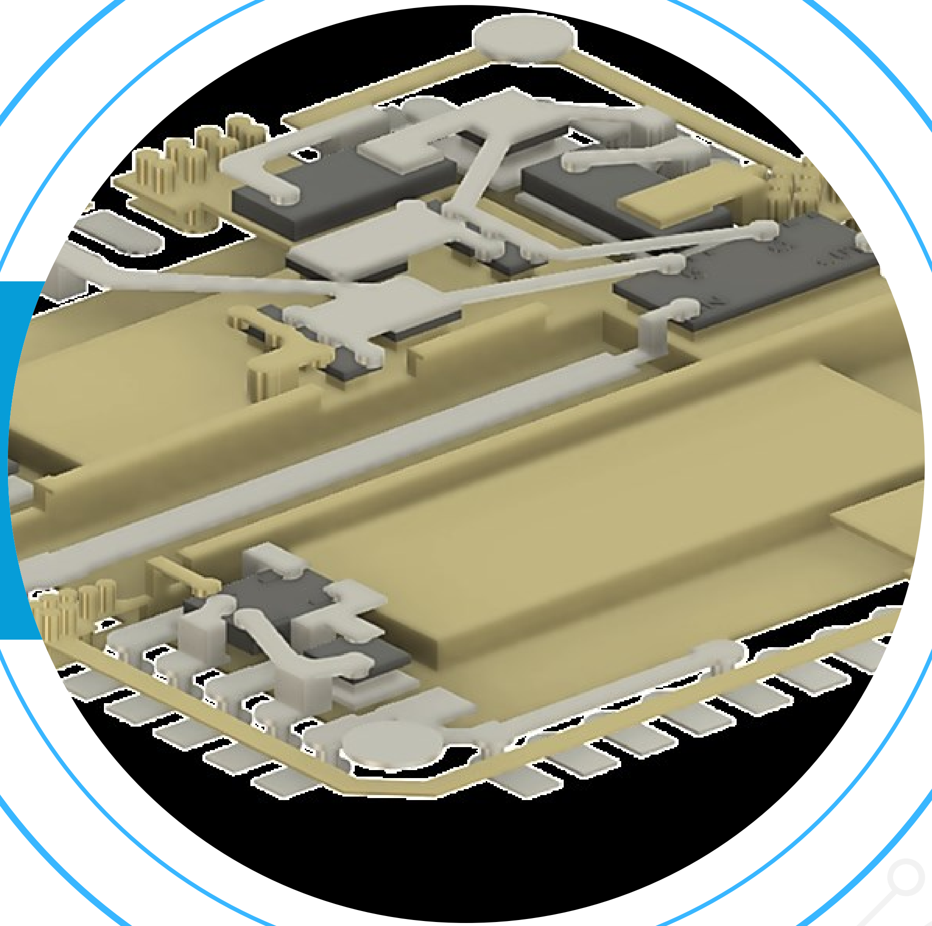


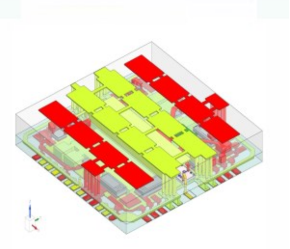
# SiP development flow



# Process Evolution

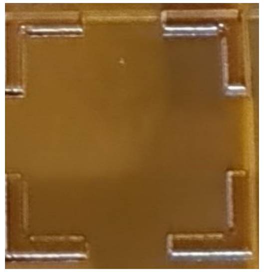
## PROCESS PLANNING, SYSTEM DESIGN AND DIE IMPLEMENTATION

**Desing optimization**

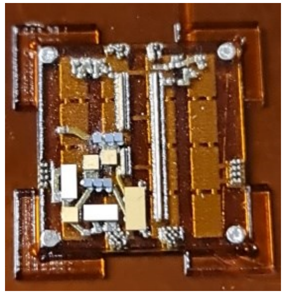


**Die embedded PoC**

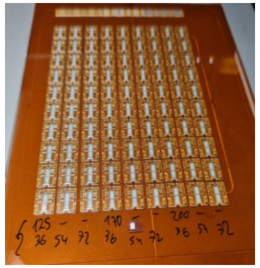
**IC Substrate Alignment**



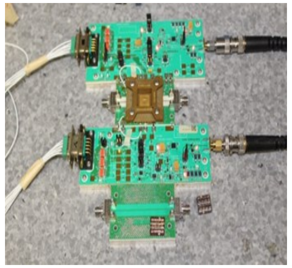
**Wire bonding less**



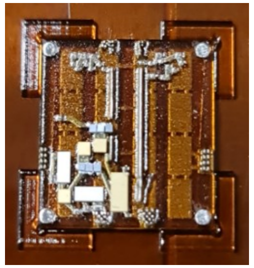
**Wire bonding less Repeatability**



**Passive SiP electrical measurement**



**Face up vs Face down**



**Functional SiP (3.5W)**

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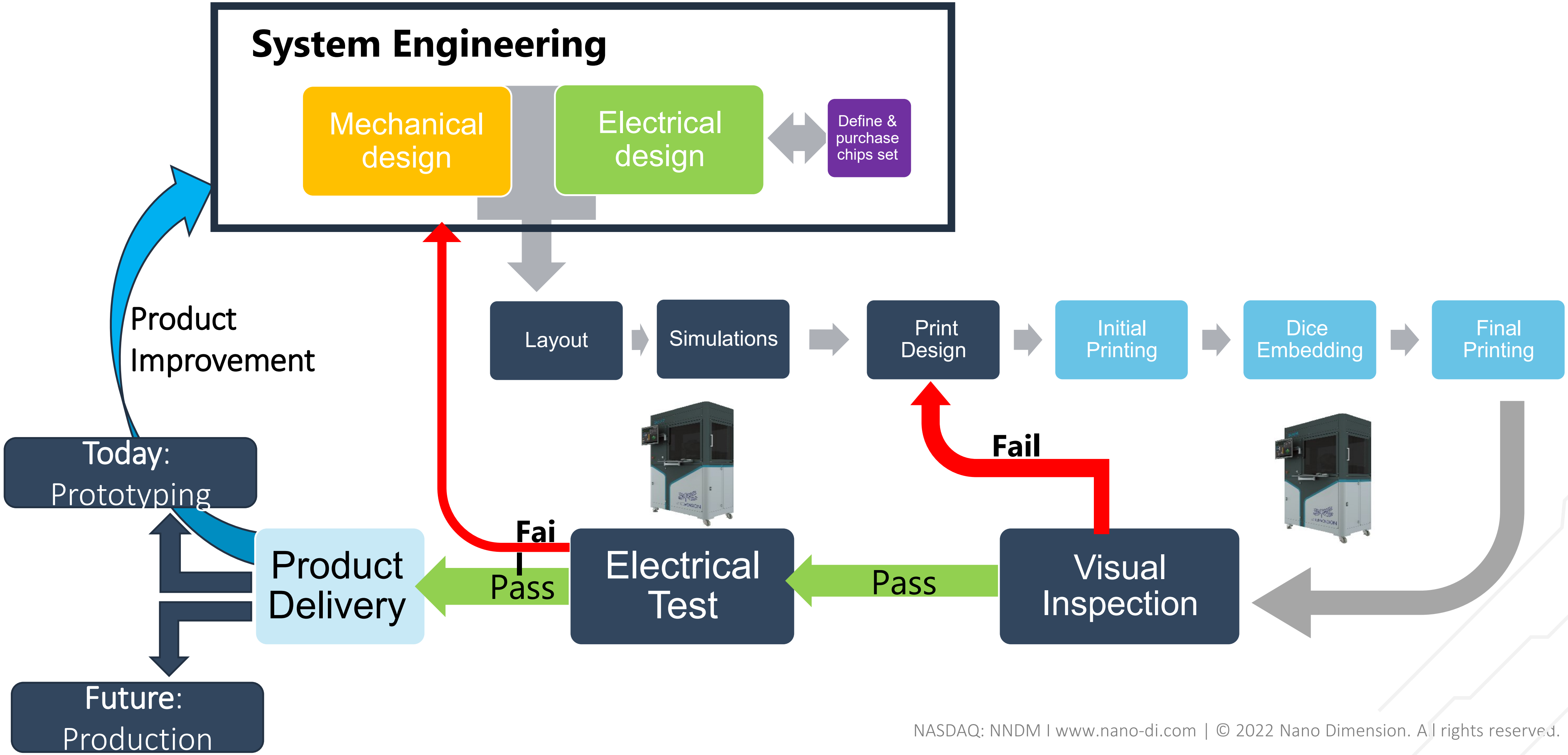
# System in Package (SiP) development flow

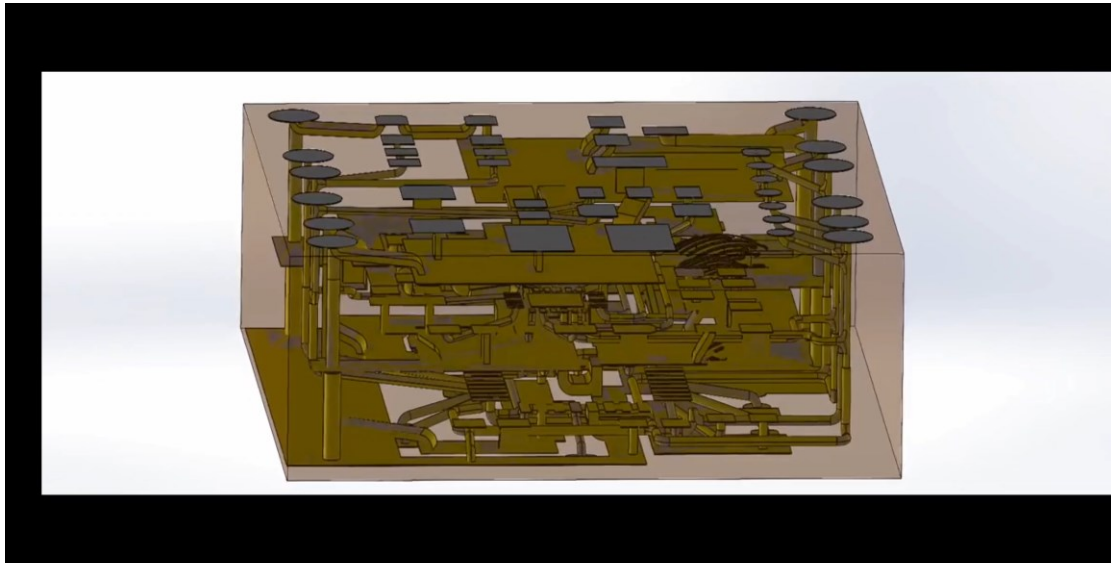
## PROCESS PLANNING, SYSTEM DESIGN AND DIE IMPLEMENTATION

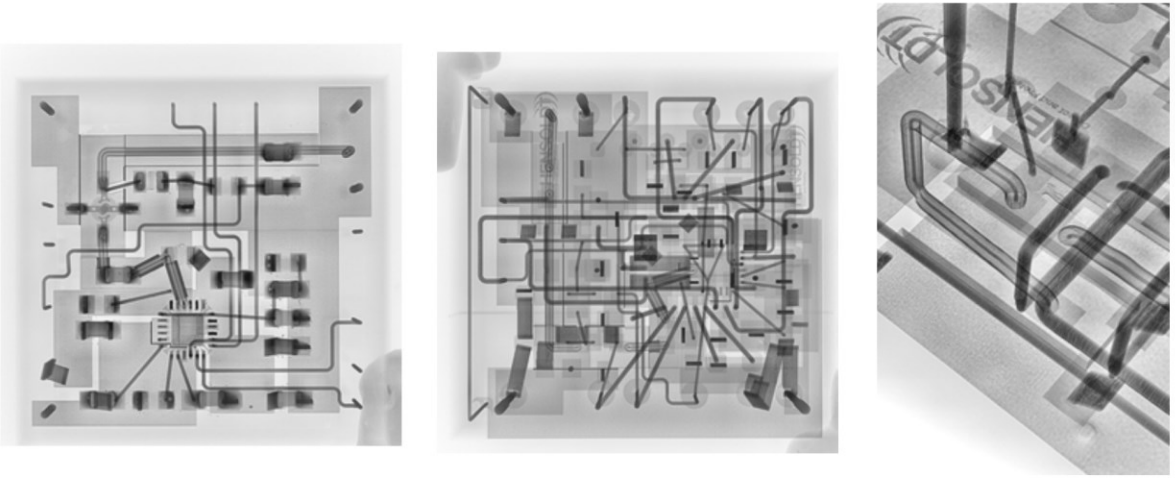


# New Design Thinking

## RF SYNTHESIZER

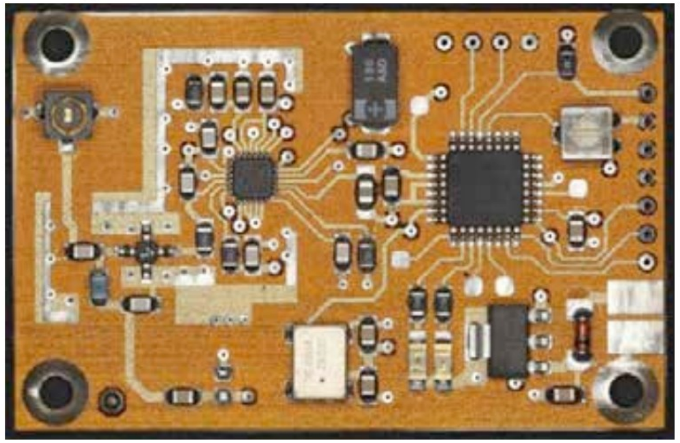
- 3D Heterogeneous Integration
- Includes DC, digital signals and also RF
- Shielded coaxial lines to keep signal integrity/Impedance controlled interface
- Printed passive components (coils, capacitors)
- Miniaturization

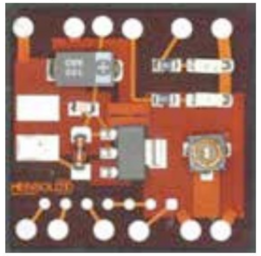




High Resolution X-ray Views

Original PLL board



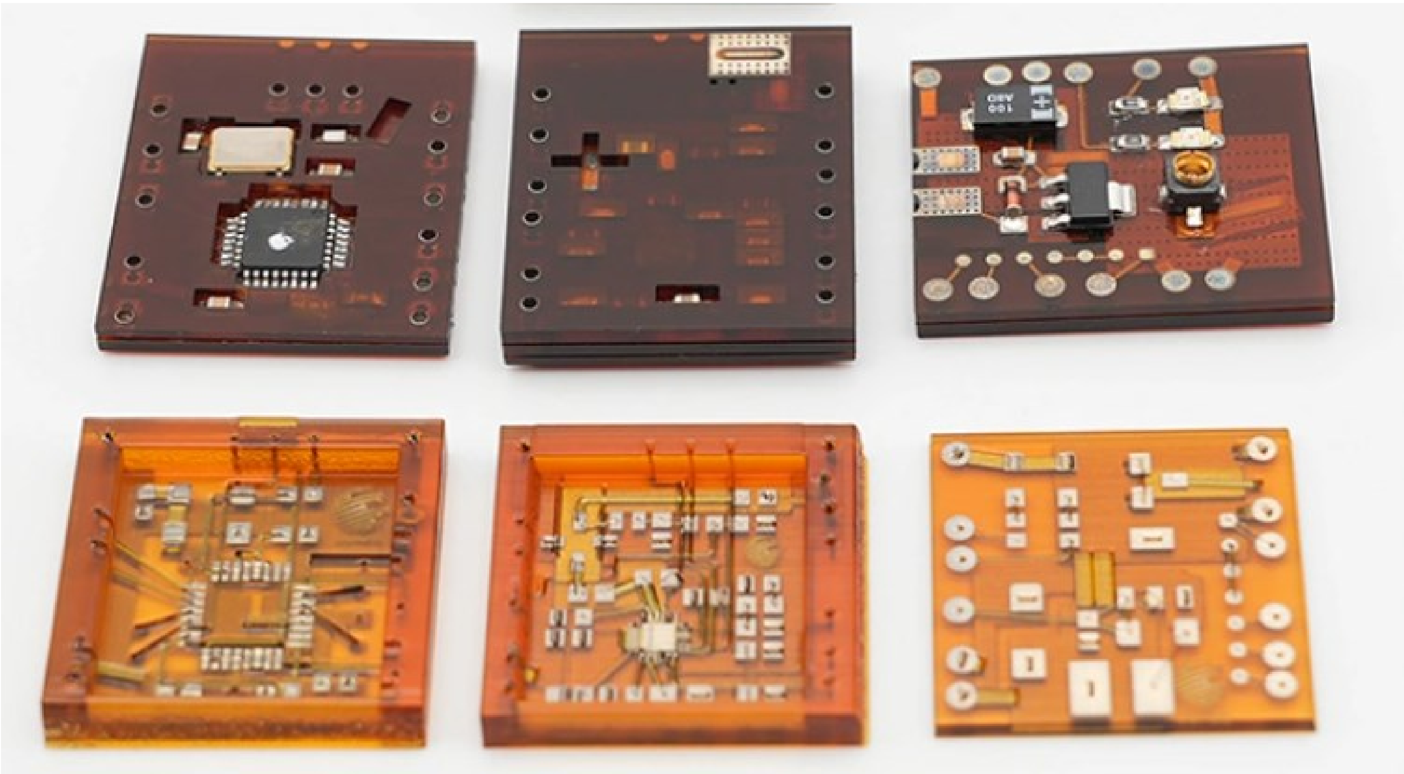


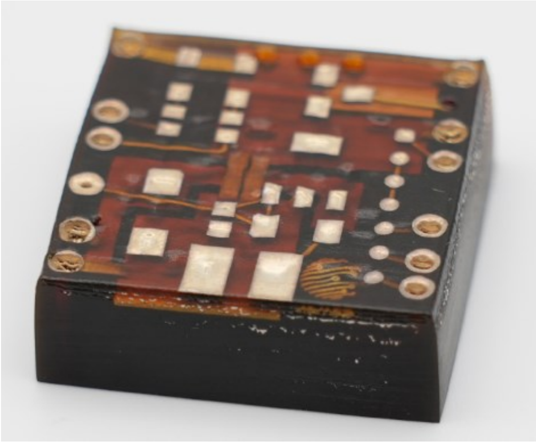
 

# New Design Thinking

## RF SYNTHESIZER –CONT'

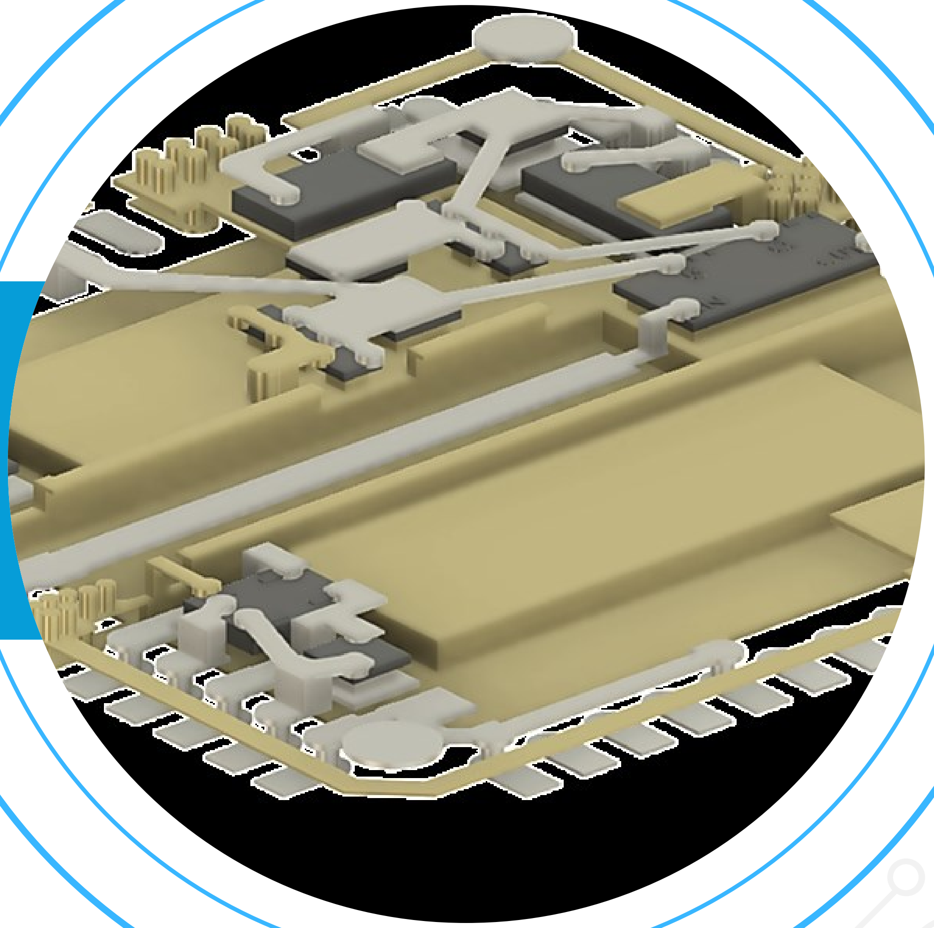
- 3 steps process





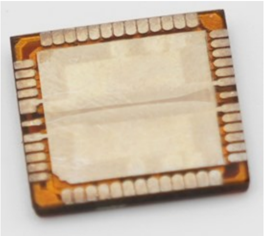
# RF SiP



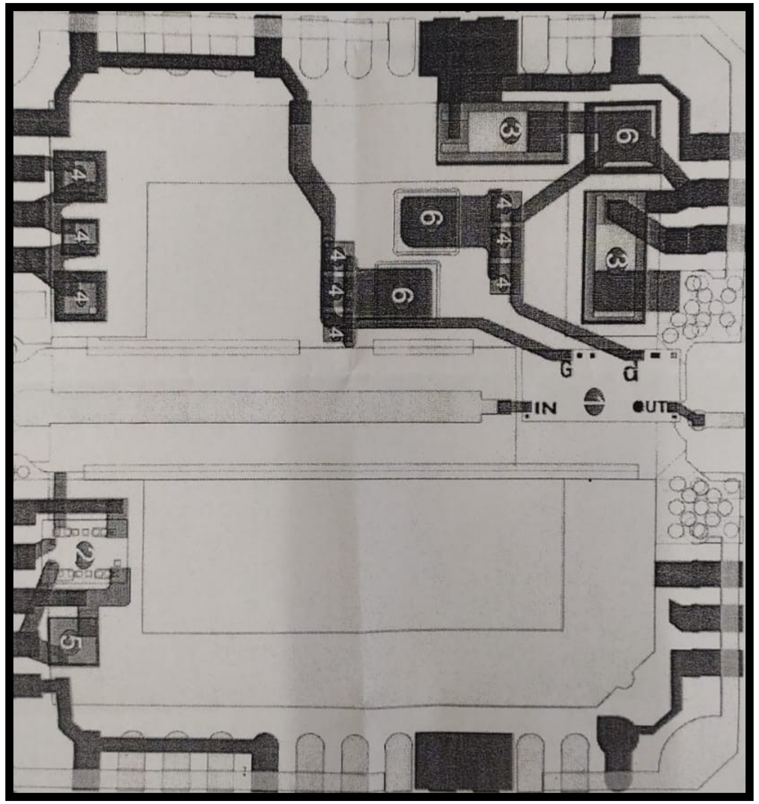
 

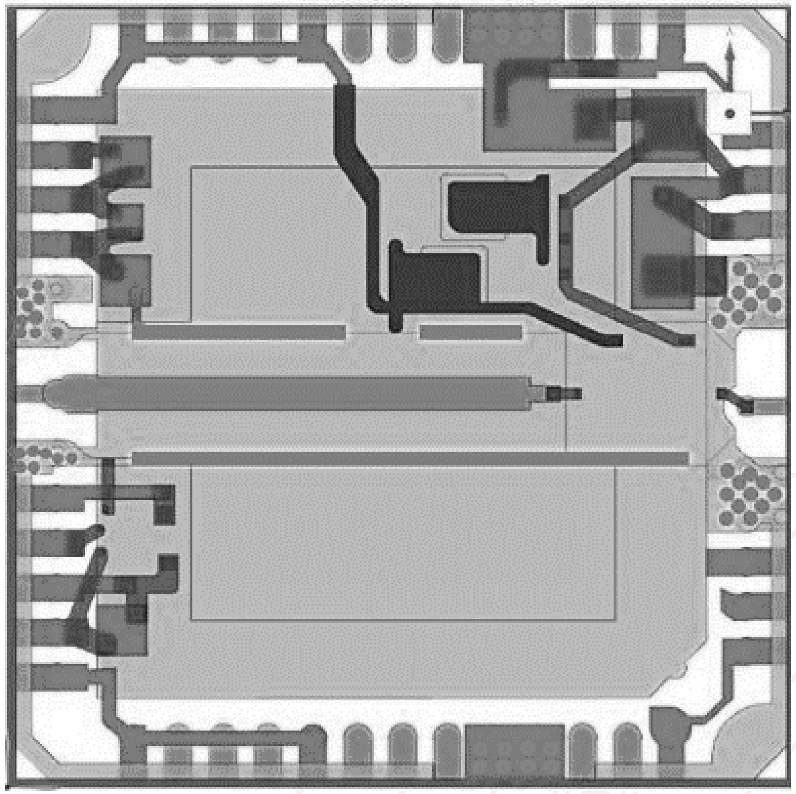
# Schematic

- Main component:
  - MMIC 4W X-band die (QPA1022D)
- Other: Resistors (6), capacitors (3) and MOSFET dies.

13.2x13.2x1.5mm

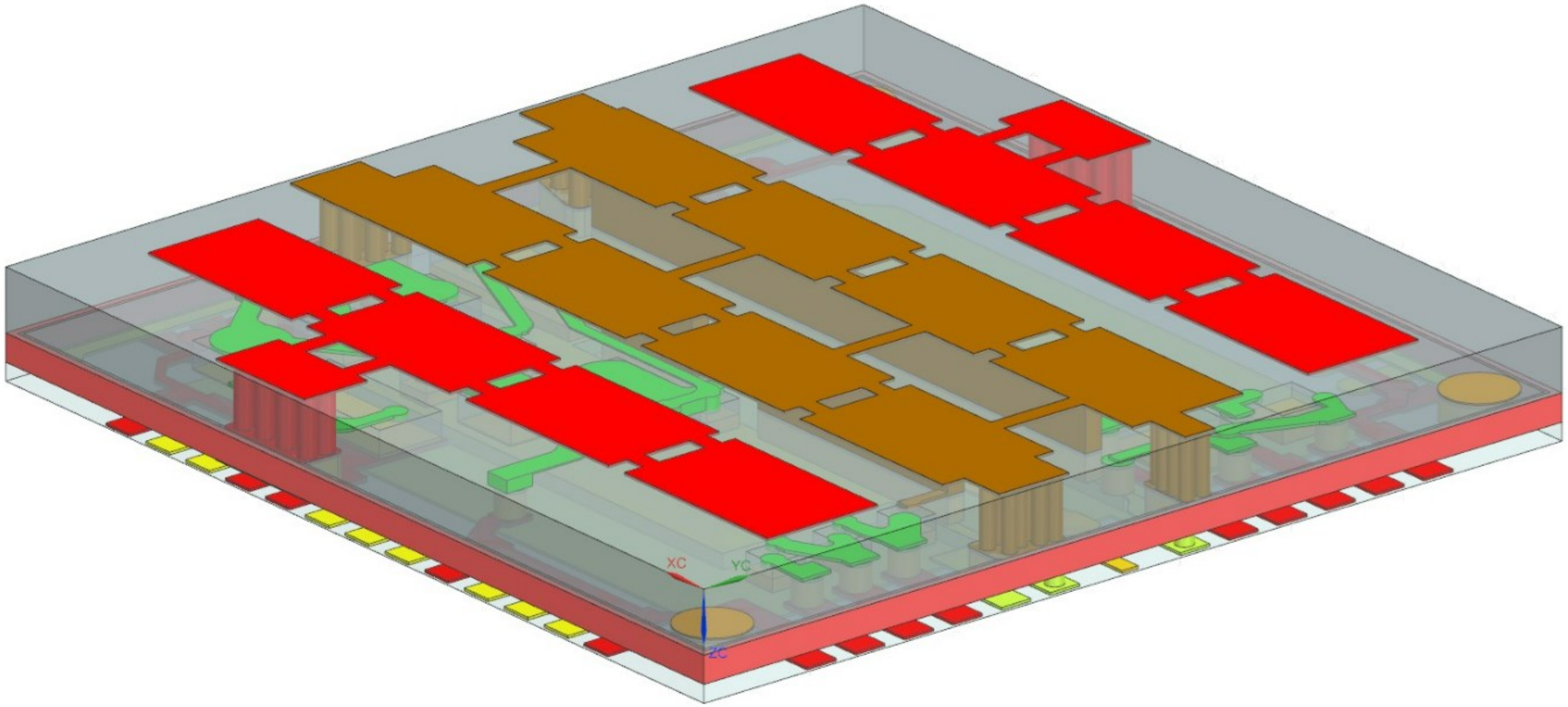




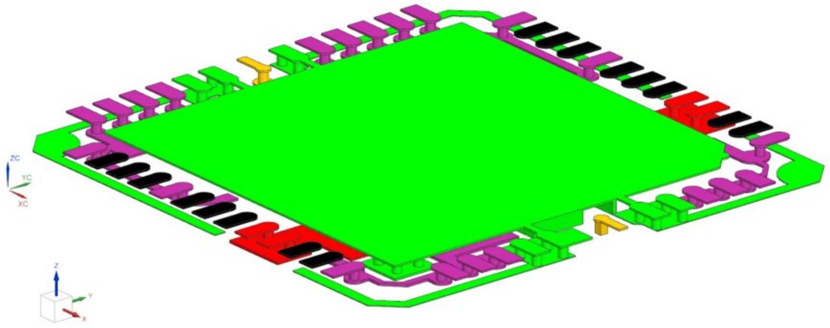
# Layout and BOM

- Main component:
  - MMIC 4W X-band die (QPA1022D)
- Other: Resistors (6), capacitors (3) and MOSFET dies.
- Overall physical dimensions
  - 13.2x13.2x1.5mm
- Minimum pad size on die 80um.

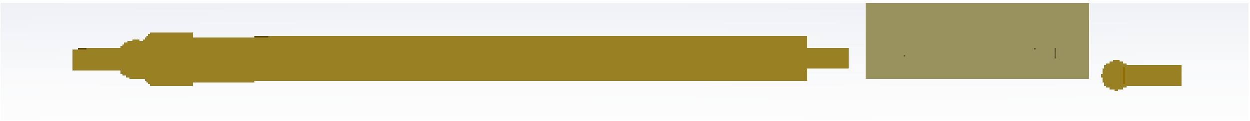


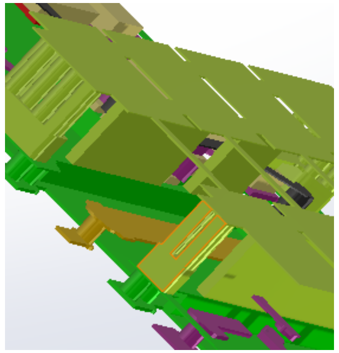
# Layout and BOM –cont’



- QFN on bottom side.



- Main 50-Ohm line

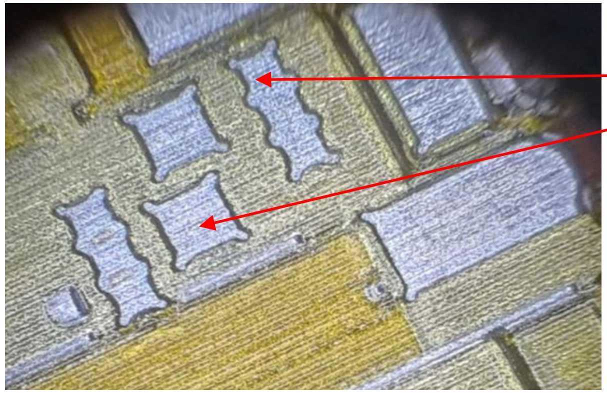


- Shielding for the RF line (walls)

# Layout and BOM –cont'

- CAVITIES

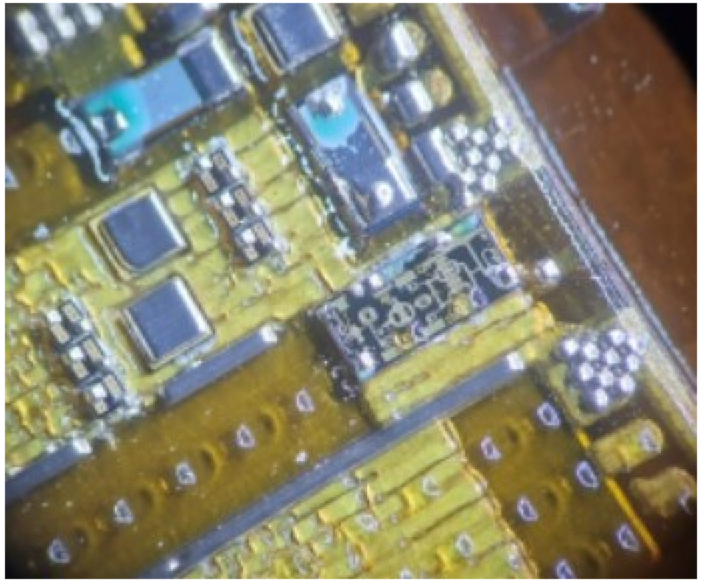


Cavities

- Before components placement

# Layout and BOM –cont’

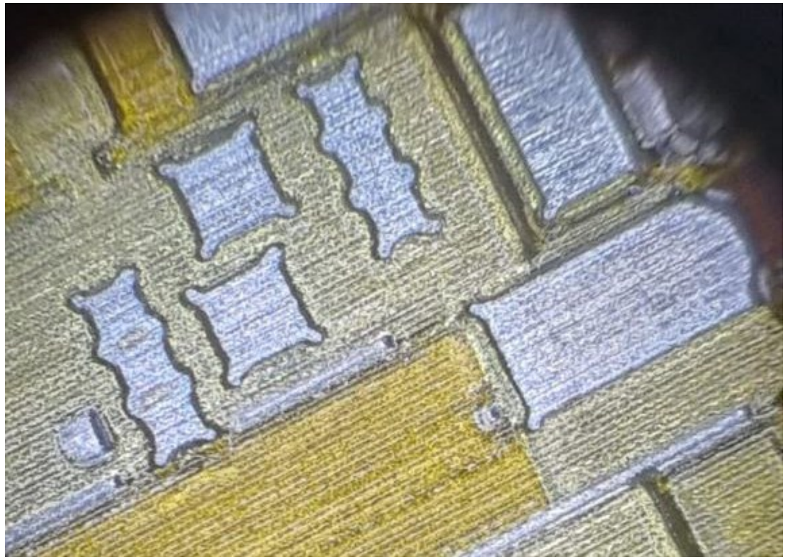
- COMPONENTS PLACEMENT



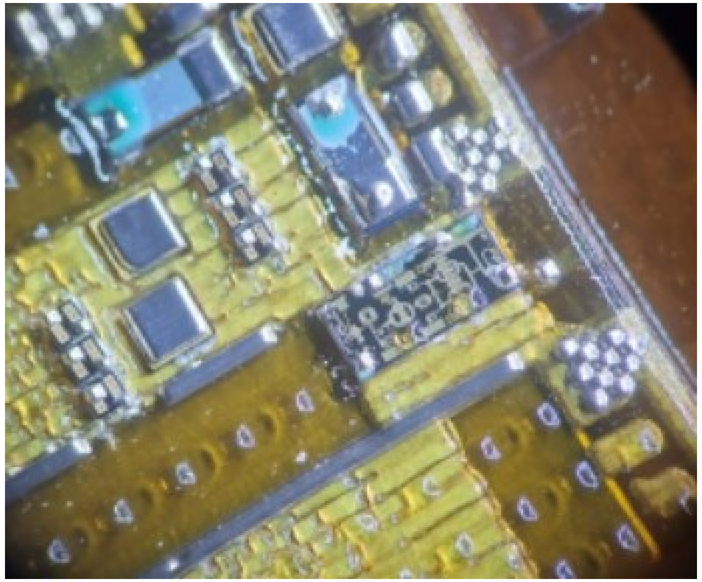
- After components placement

# Layout and BOM –cont’



- Before components placement

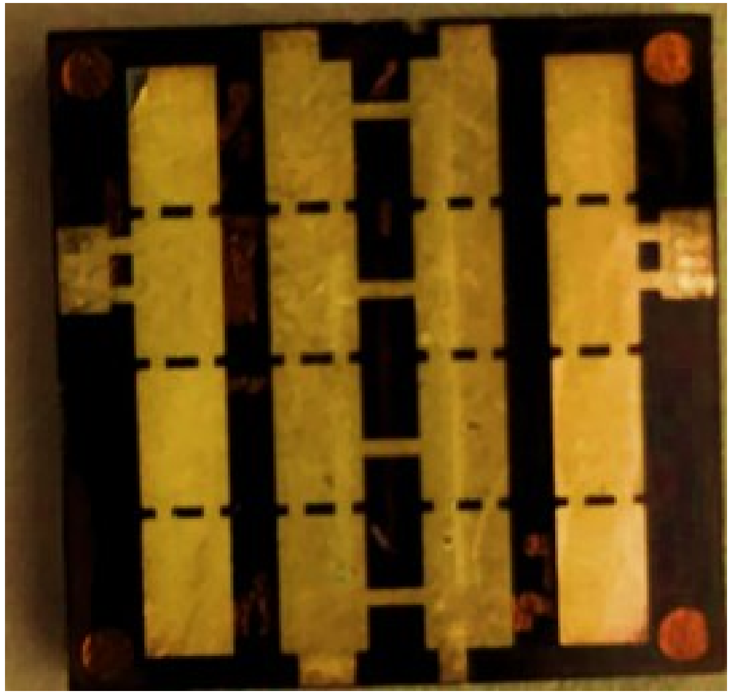


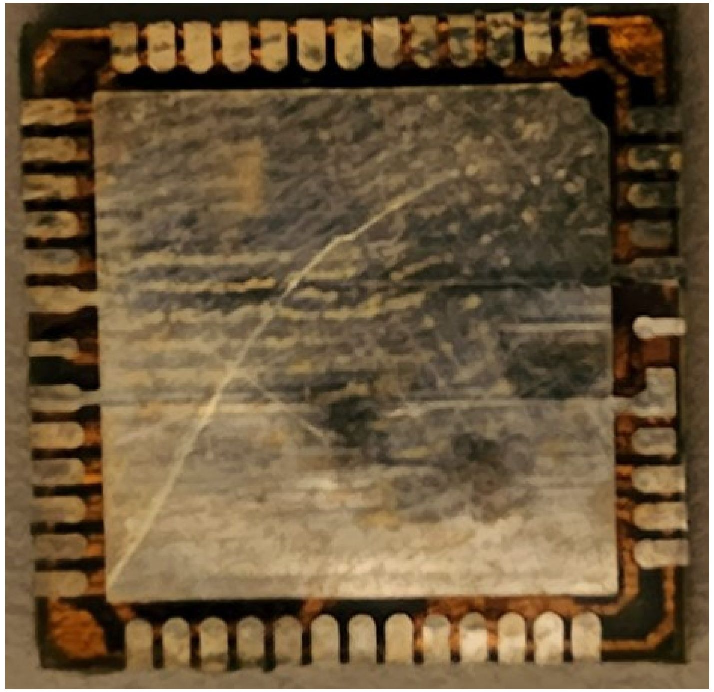
- After components placement.

# Layout and BOM –cont'

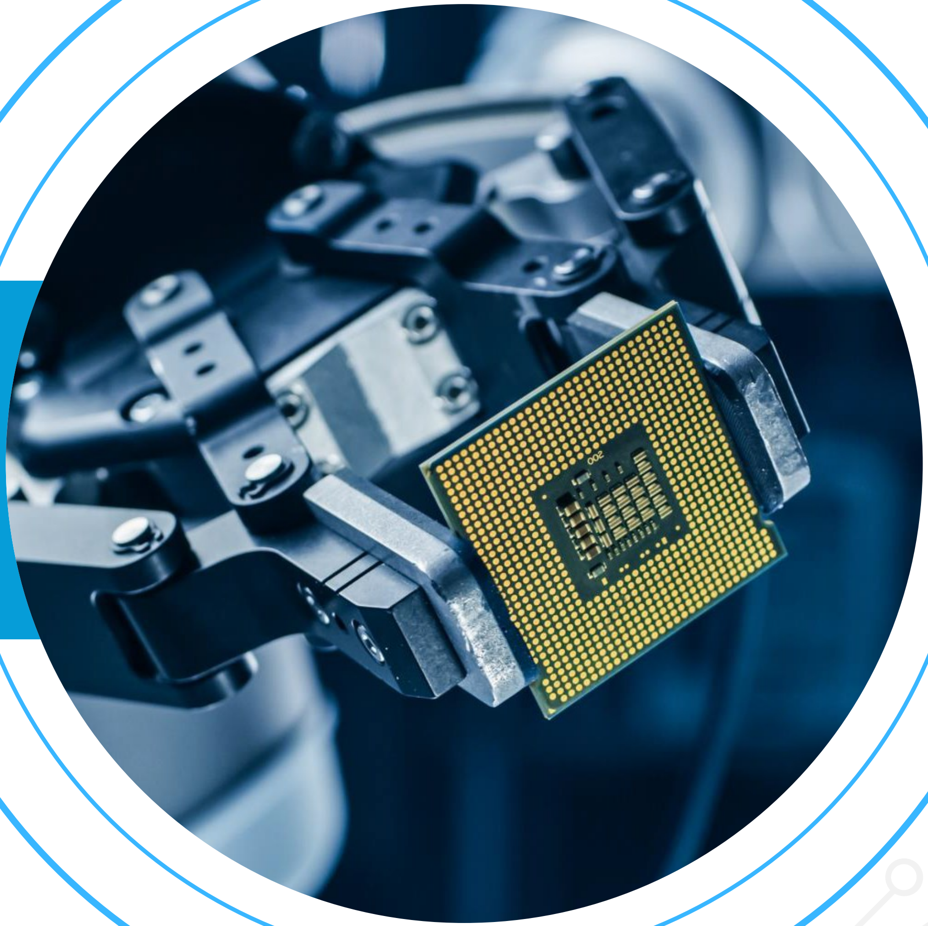
- FINAL TOP & BOTTOM VIEW





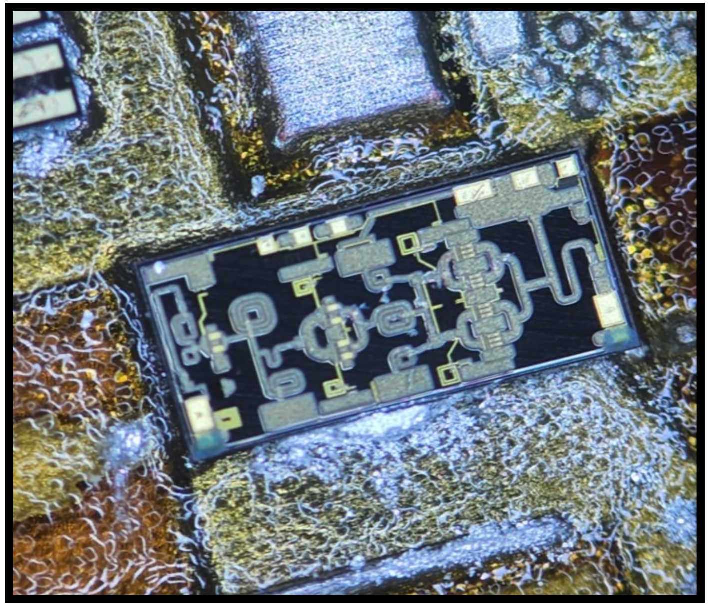
# AME Packaging Processes



# Top level processes available

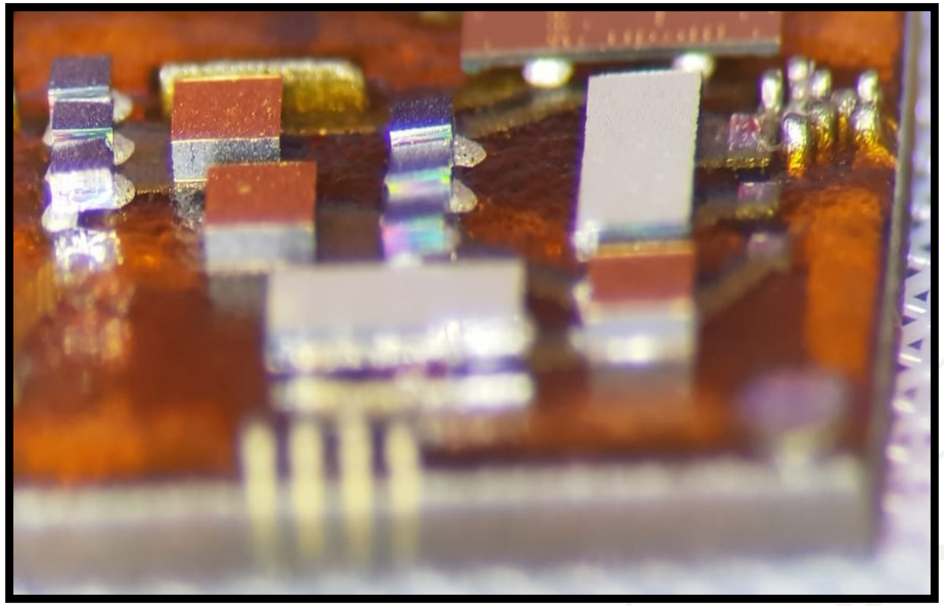
## AME PACKAGING PROCESSES

Split Assembly



Manual placement of Die is possible

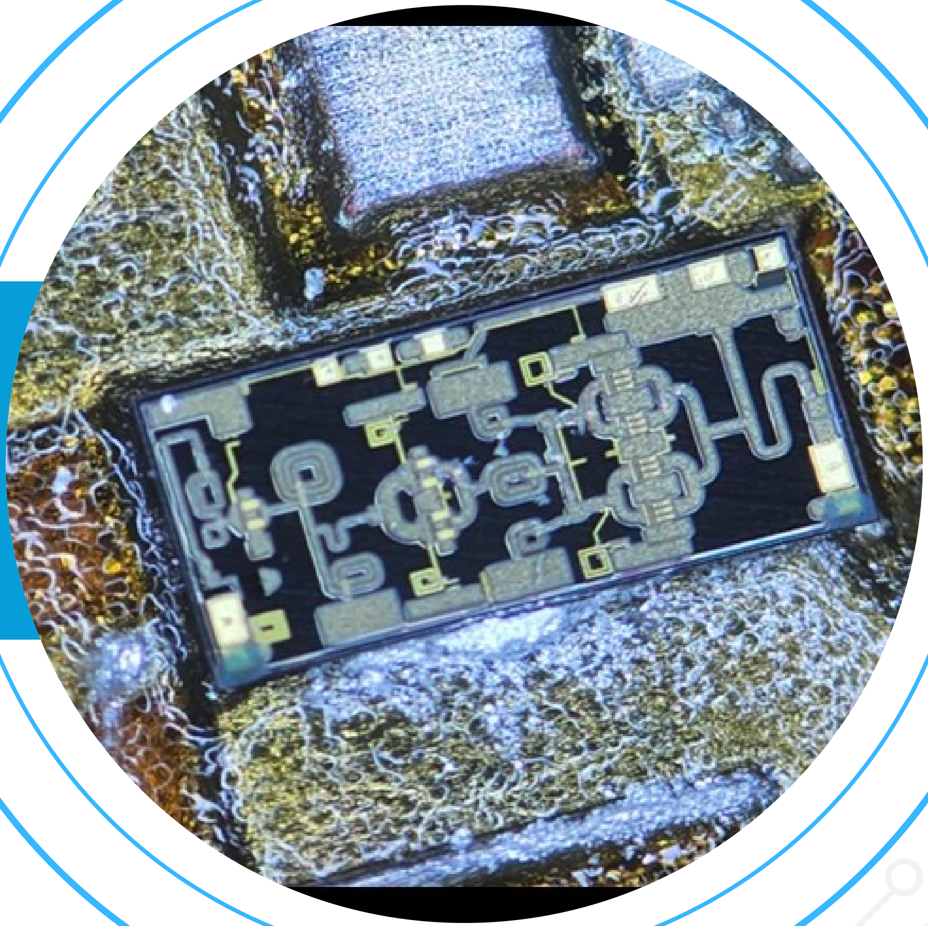
Flip Chip



High Accuracy Automatic placement is required

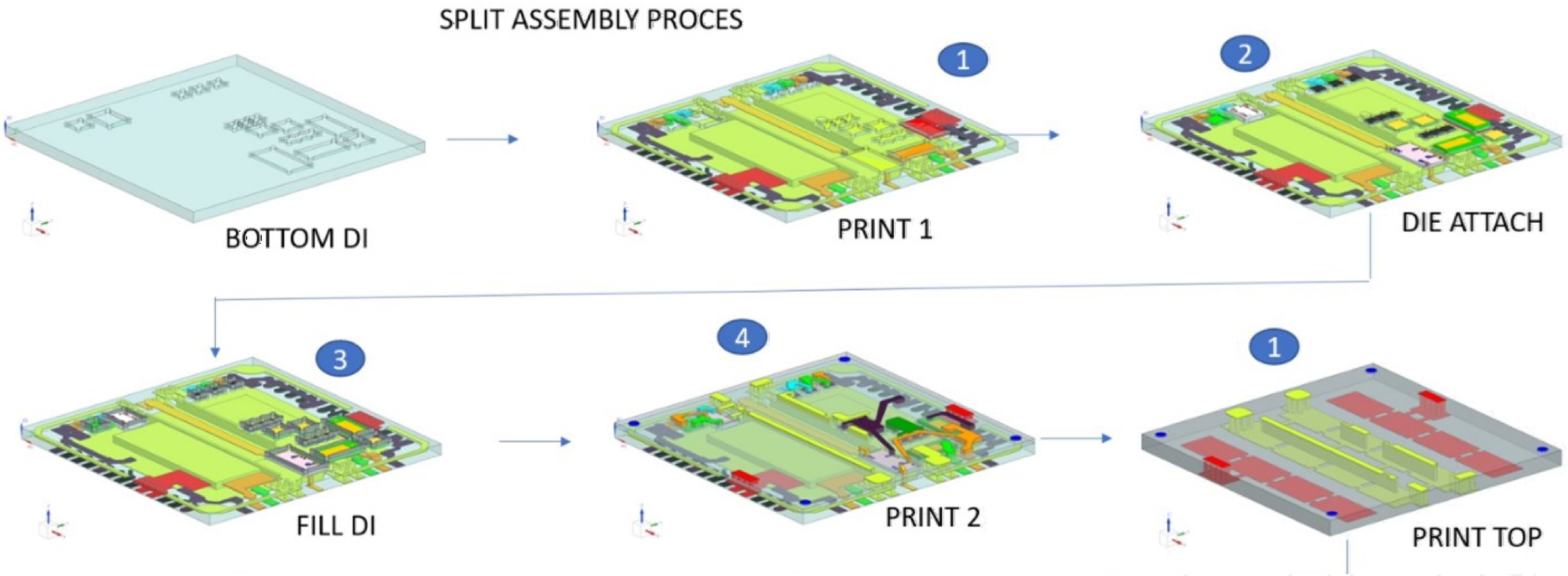
 

# Split Assembly



# Split assembly process

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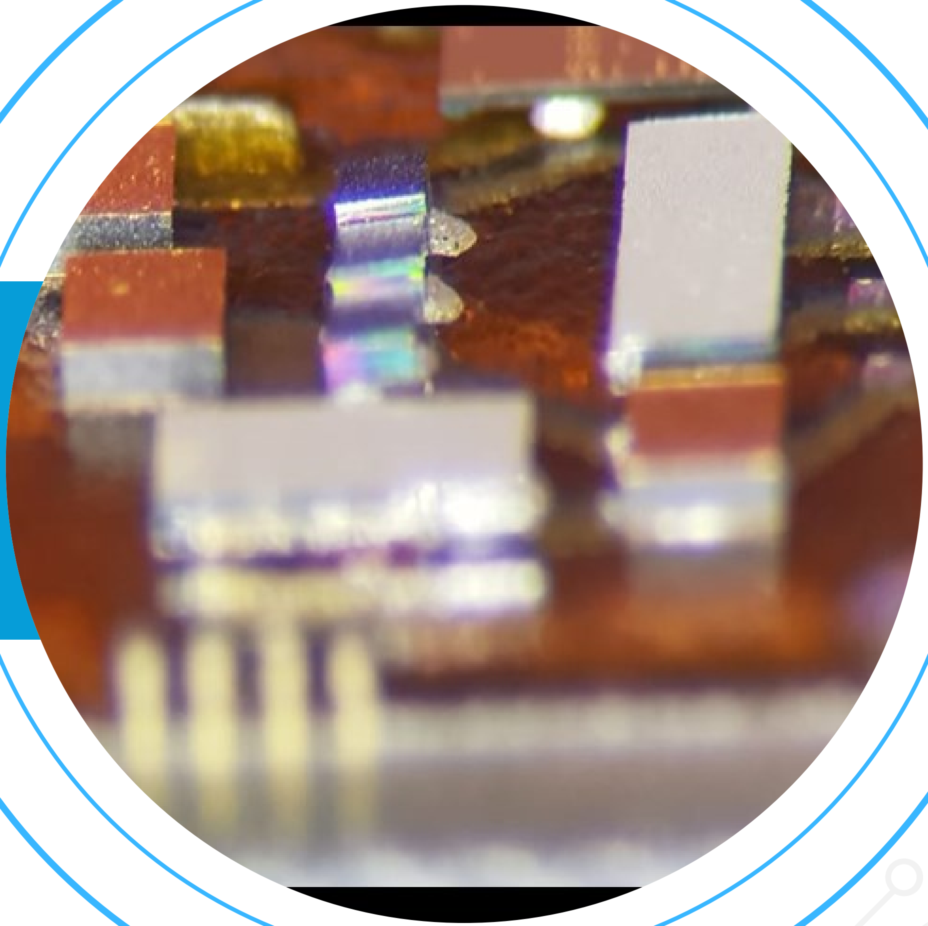
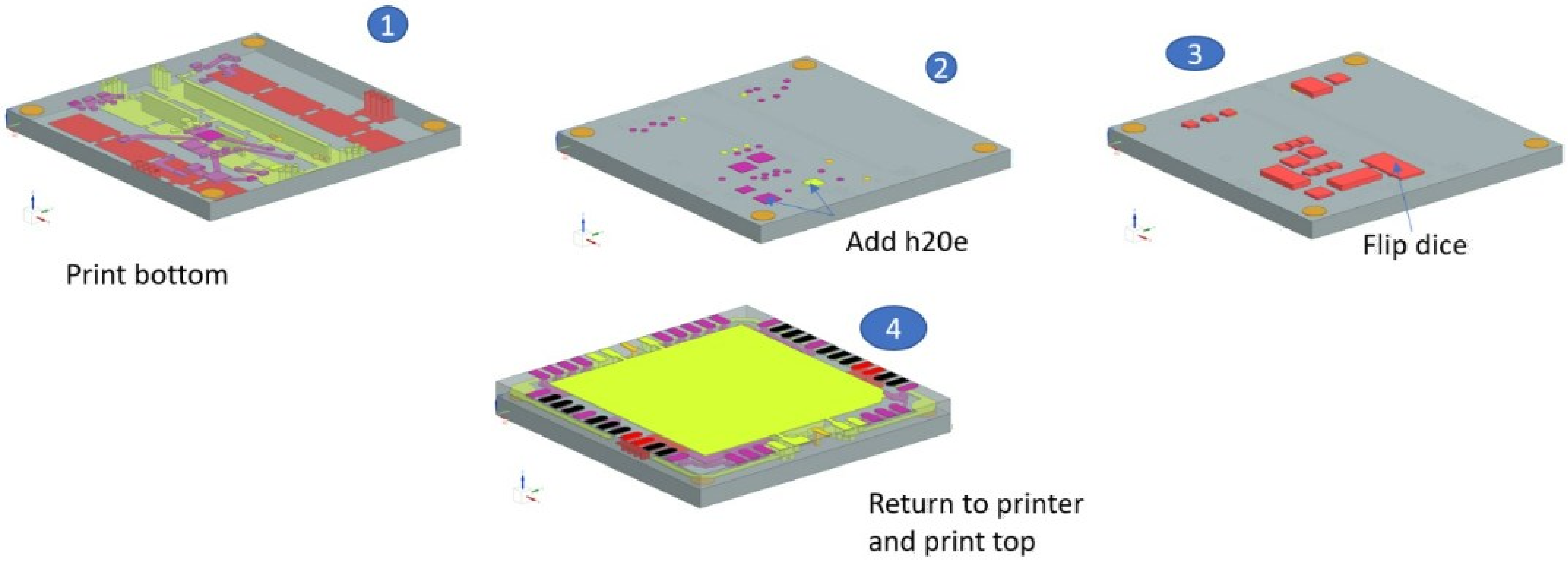
# Flip-Chip



# Flip chip assembly process

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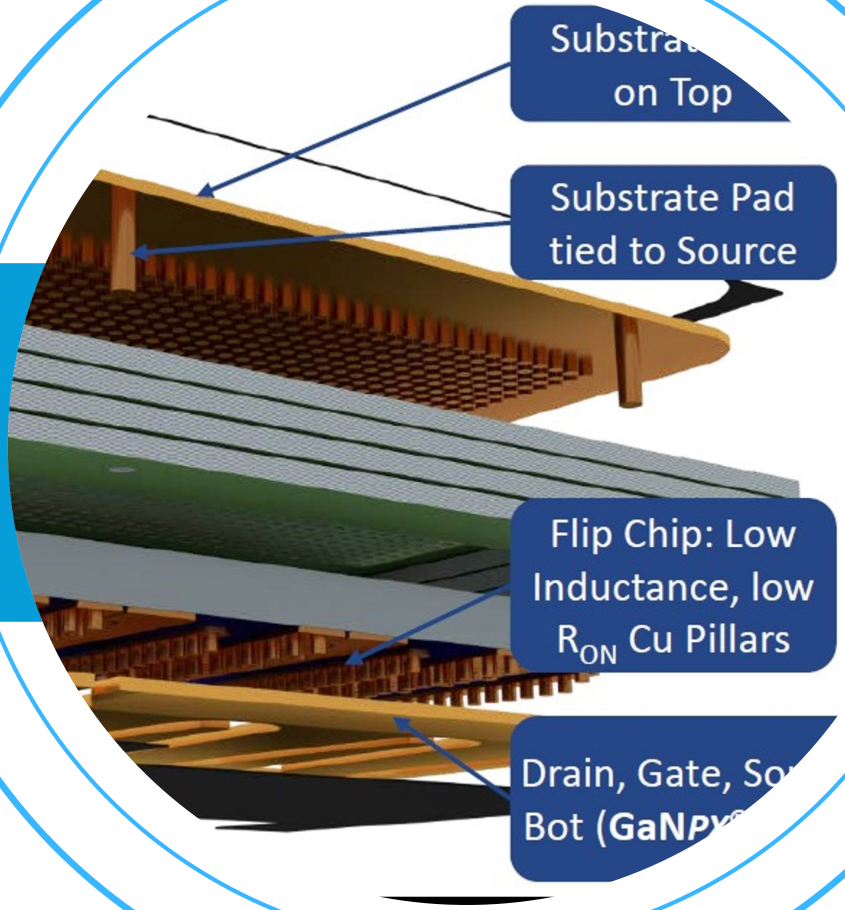
# Power Transistor AME Packaging



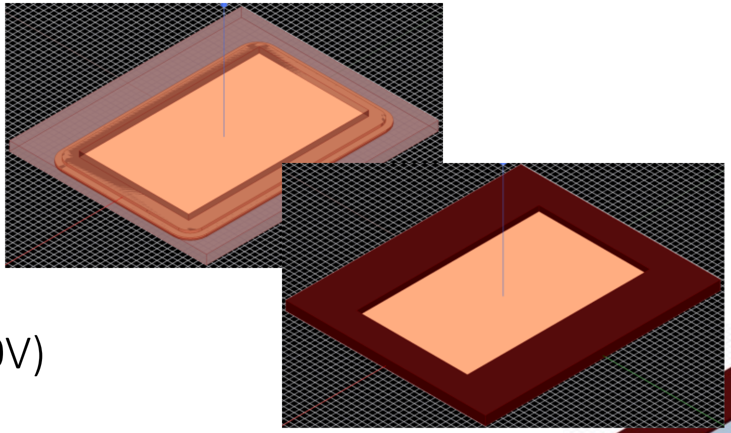

2

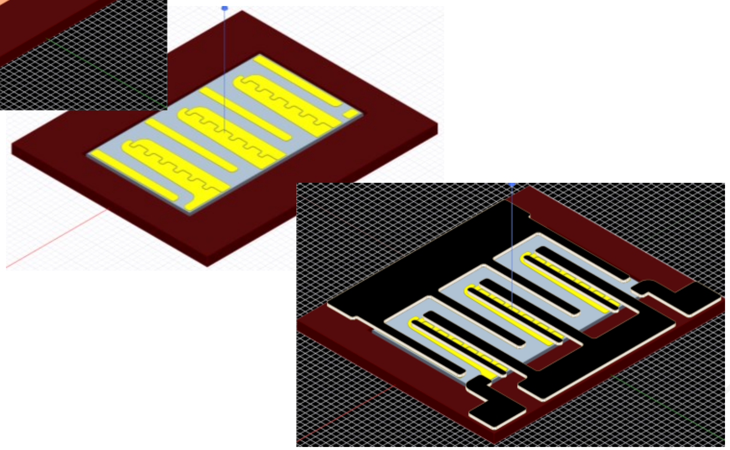
 

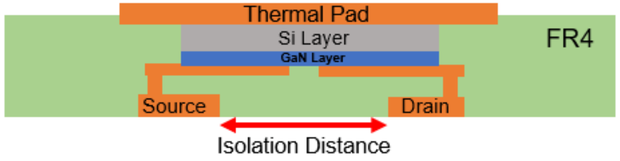
# Power Transistor SiP

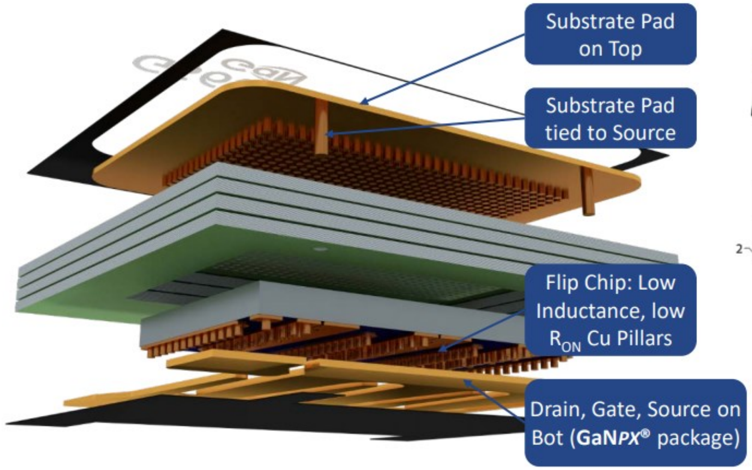
## GAN-ON-SILICON

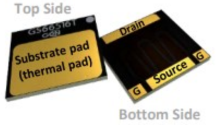
- Enhancement mode GaN-on-silicon power transistor (650V)
- Top-side cooled configuration
- High current $\mathrm{Ids}(max) = 60A$
- $\mathrm{Rds}(on) = 25m\Omega$
- Very high switching frequency (> 100MHz)
- Small 9 X 7.6 mm PCB footprint

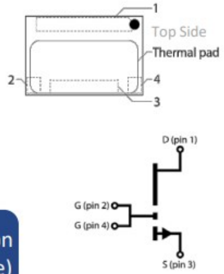


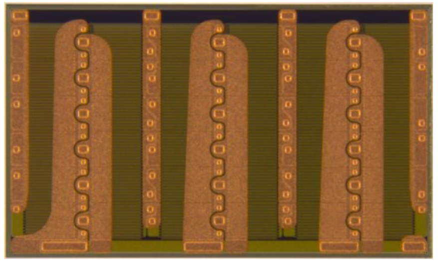


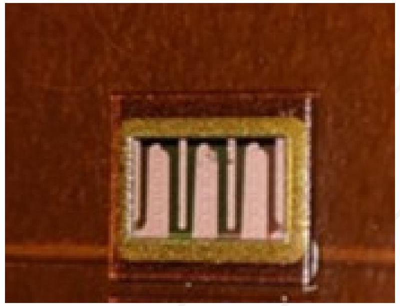


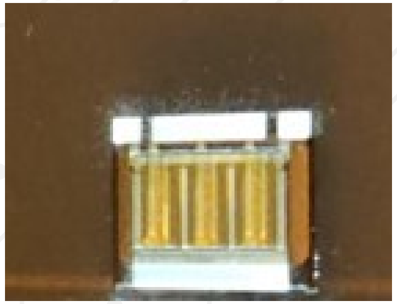







Commercial package: complicated manufacturing process: lamination, drilling, electro-plating, etc.

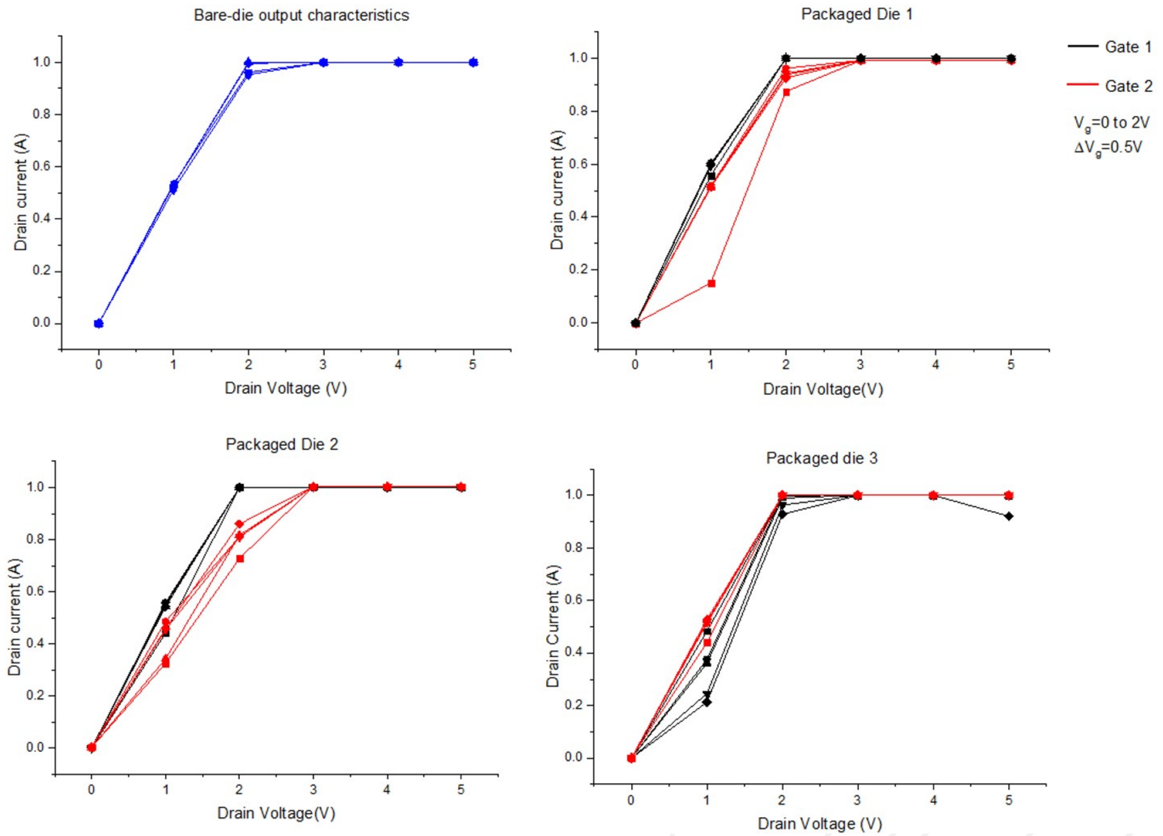
# Power Transistor SiP

## GAN SYSTEMS (GS66516T)

Commercial Package



Printed Package

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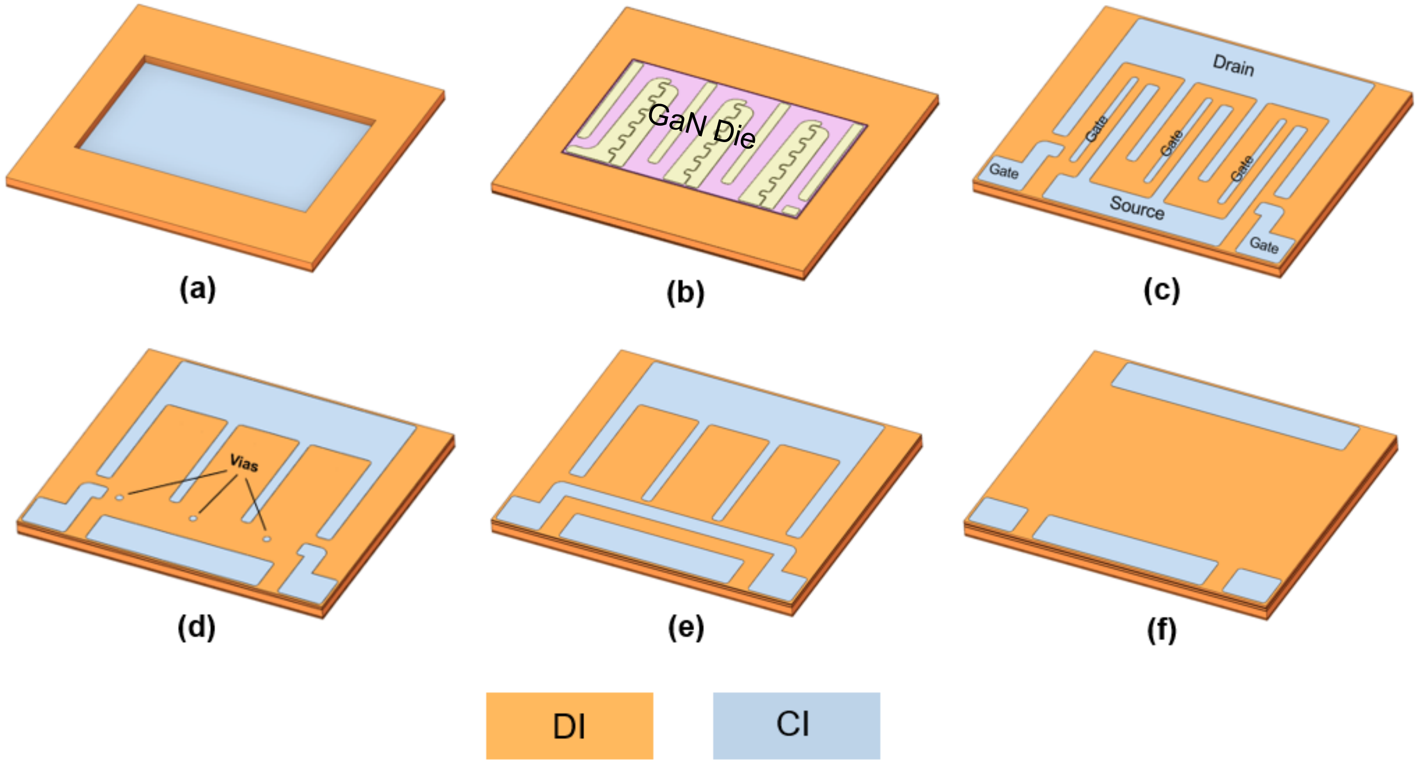
# Power Transistor SiP

GAN-ON-SILICON

Process:

a) Printing dielectric cavities & pause the print (keeping chuck at 100°C)
b) Placing the silicon dies and adding Epotek conductive glue on the bare pads
c) Print DI “soldermask alike” and fill gaps
d) Print CI pads connection
e) Print interconnecting tracks
f) Print cover layer



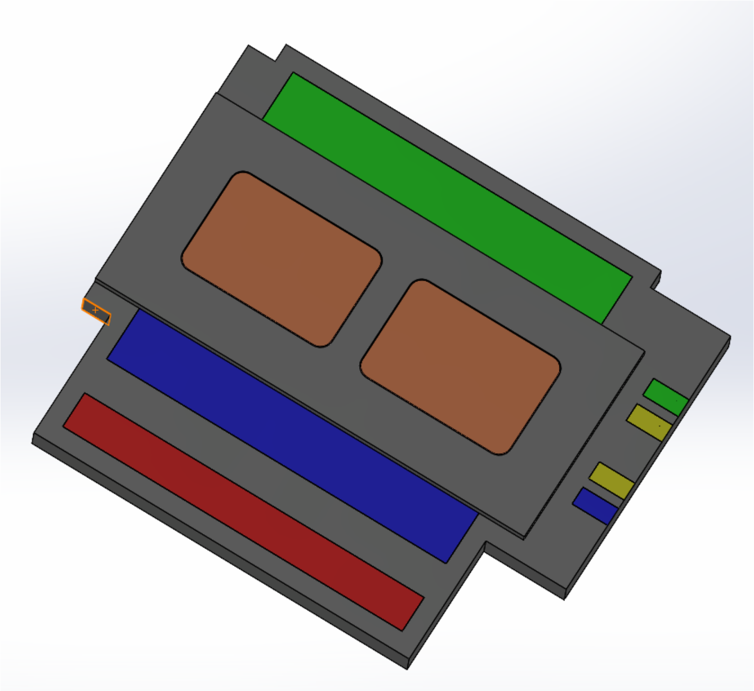
# Power Transistor SiP

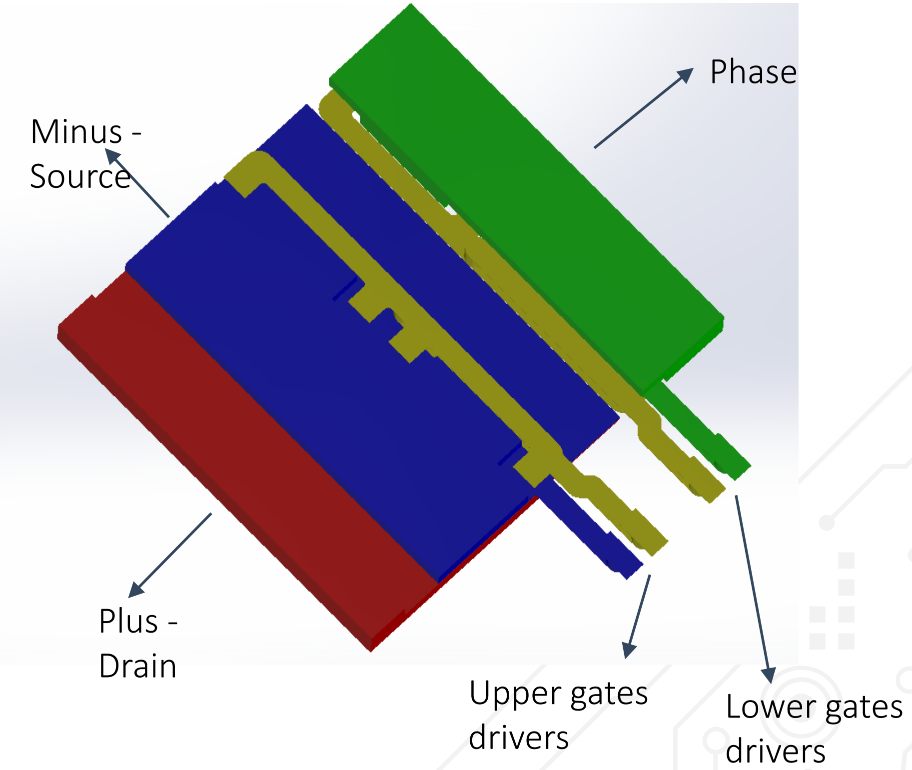
## RI.SE DESIGN FOR AME

- A very compact module with four GaN discretes was designed.

Challenges:

- Meeting the application targets – High voltage, high current
- Effective heat dissipation – High current

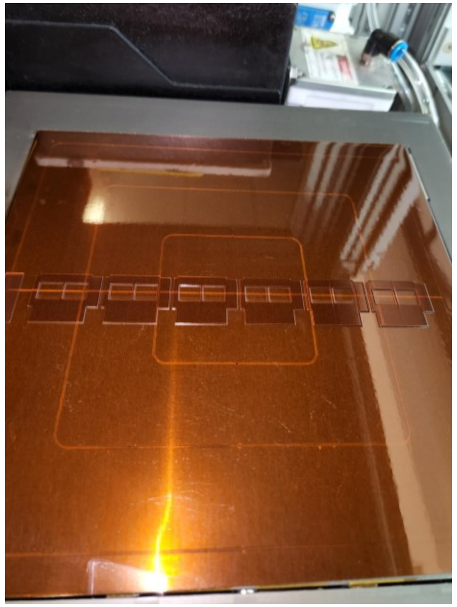


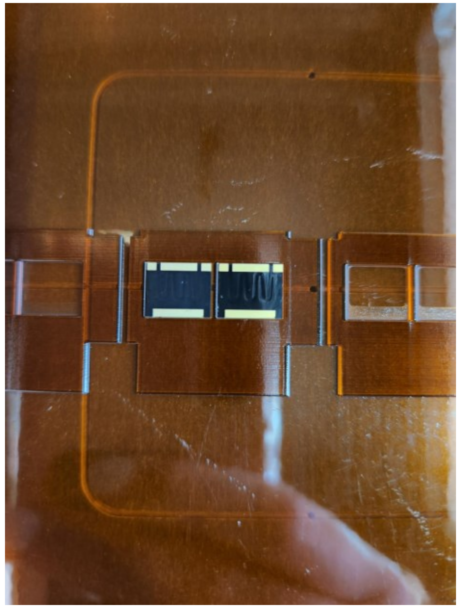


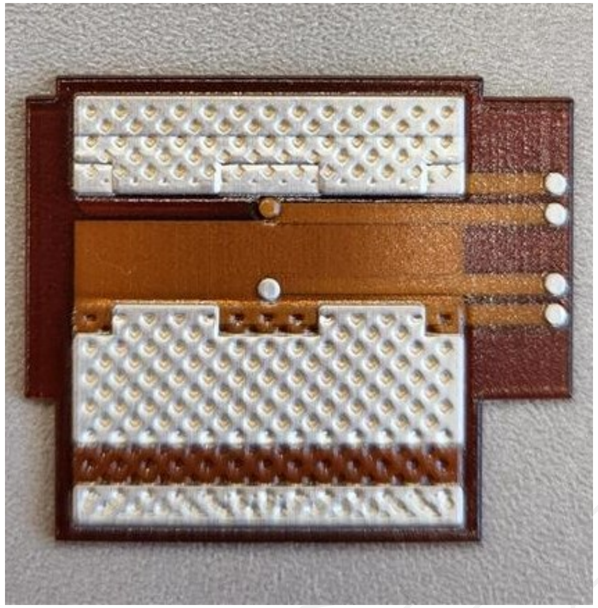

  

# Power Transistor SiP

## GAN-ON-SILICON





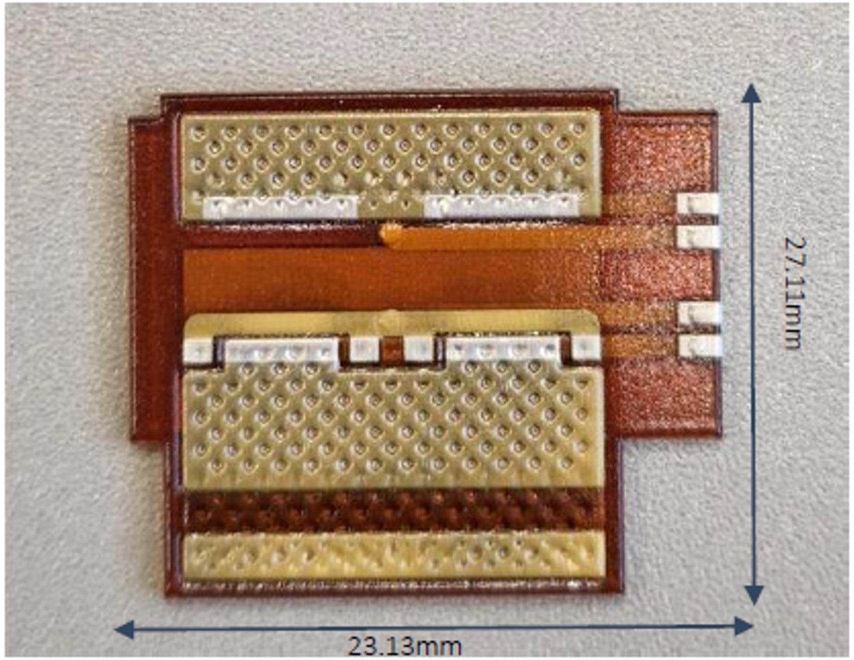


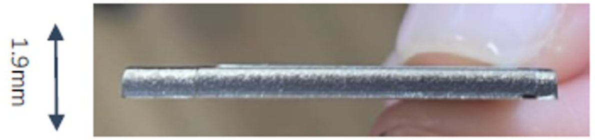
  

# Power Transistor SiP

## GAN-ON-SILICON

Module with four GaN HEMTS ($V_{DS}$ = 650 V, $I_{DS}$ = 60 A, $R_{DS(ON)}$ = 25 mΩ)




- The AME method have proven to be very time efficient!
  - 2-3 complete packaging iterations within 2-3 months – this normally takes years

**The Smallest High Power Module of its Kind**

Printed with AME technology

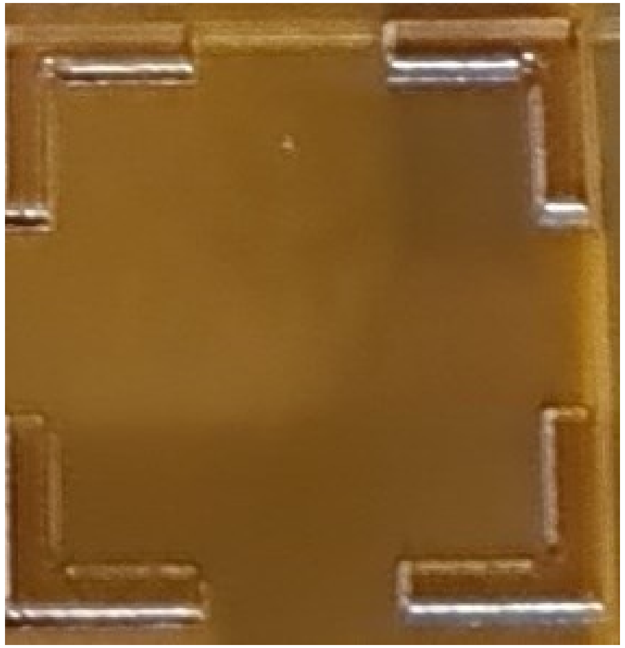
" The device's mechanical characteristics are approximately 64% smaller than the smallest similar functional devices existing in the market and will create the highest power density for this kind of device.

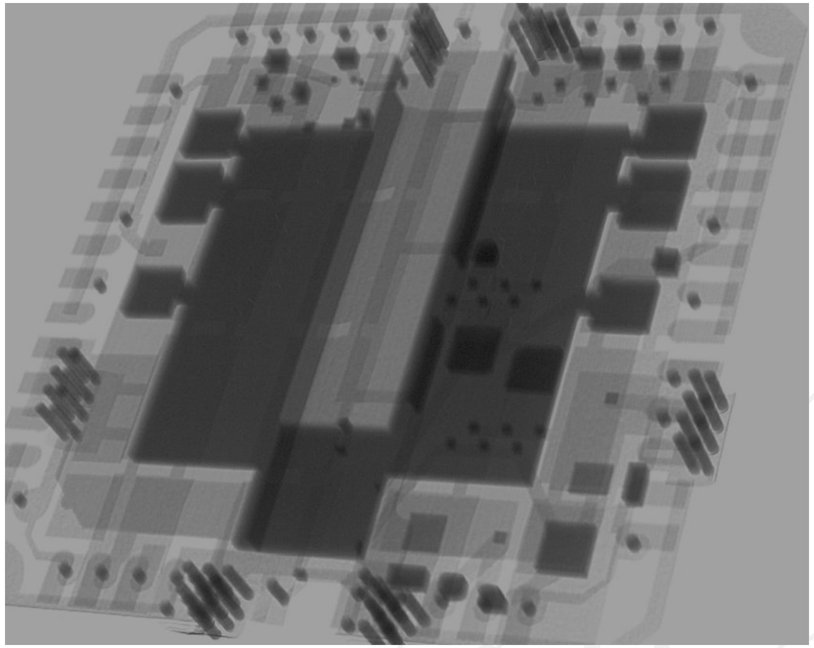
Furthermore, this is the first attempt to use 3D AME technology to reduce size, reduce manufacturing time and improve power density in this kind of circuit."

# Main Process Challenges

- CHALLANGES AND SOLUTIONS

  - Registration:
    - Dies placement.
    - Building up the VIAS on top of the dies
    - Removing print for P&P.
  - Pushing the current boundaries of design rules and process.





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# THANK YOU!


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