NANO DIMENSION

Changing the Way the World Manufactures

A brief introduction to **AME** ADDITIVELY MANUFACTURED ELECTRONICS

June 2022

NANODIMENSION
Electrifying Additive Manufacturing®

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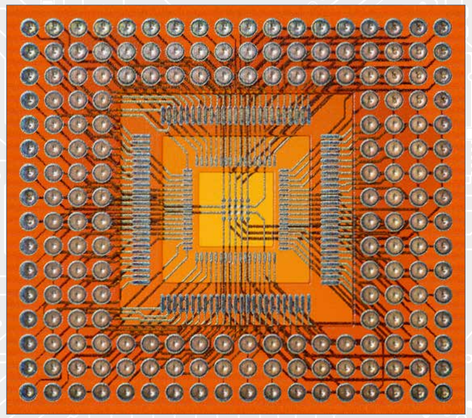
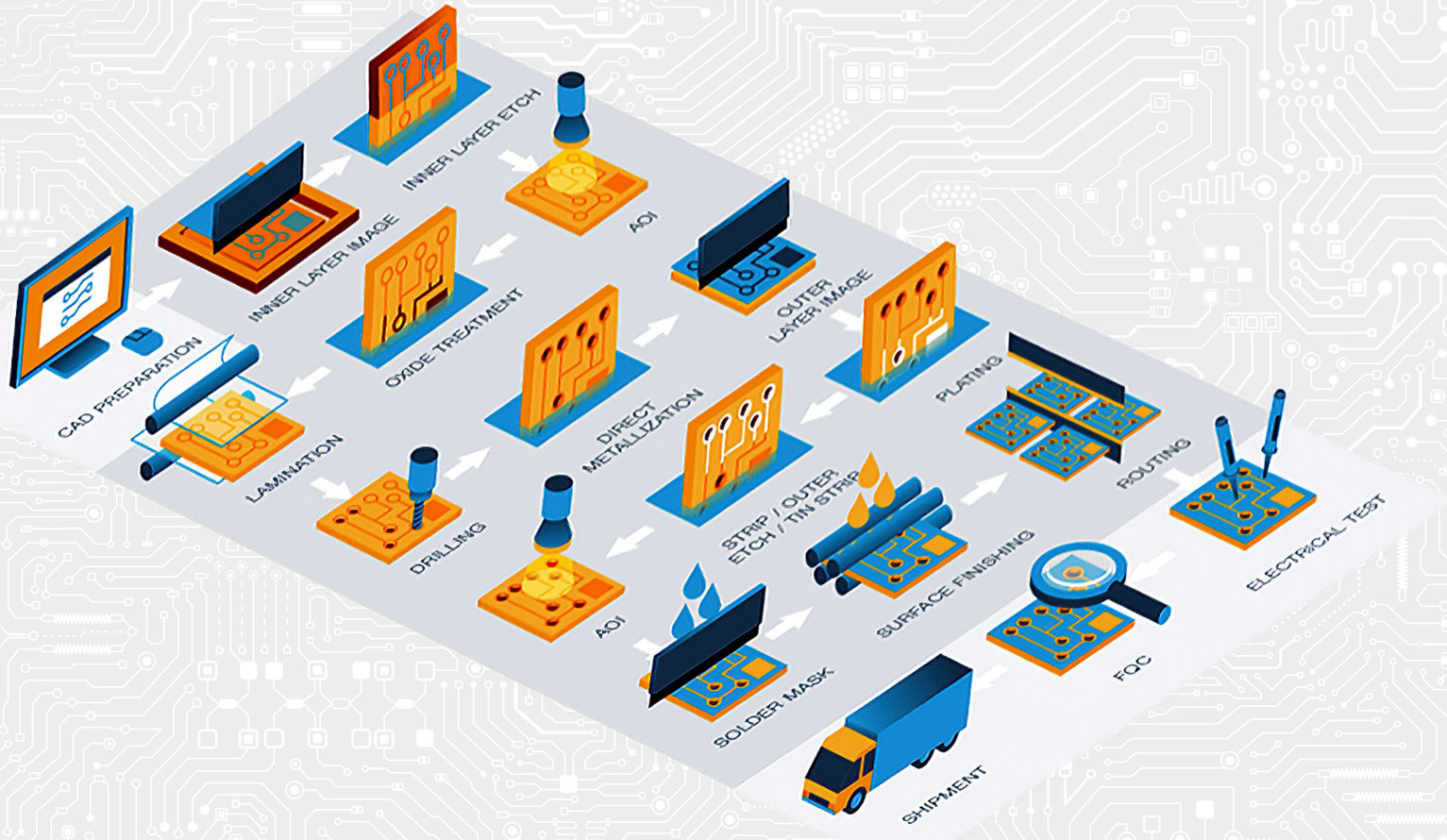
USE CASE STUDIES



THE CHALLENGES IN ELECTRONICS PRODUCTION

Printed Circuit Board (PCB) Production — More than 100 Manual and Semi-Manual Tasks

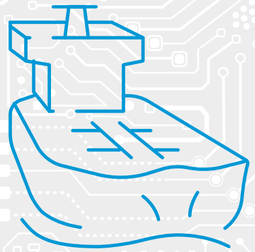


THE CHALLENGES IN ELECTRONICS PRODUCTION

The PCB Factory — an Old Model that Resists Innovation

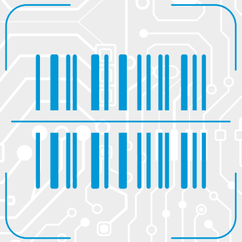
Poor energy, material, and water efficiency

Hazardous waste from both processes and products



Extended time to market with high costs and minimums

Supply chain shortages and delays



Substantial risk of IP theft

Use of outsourced vendors may result in design piracy

A NEW MODEL FOR INDUSTRY 4.0

A Fully Digital Manufacturing Model is Necessary

INCLUDING

New Degrees of Freedom
for Designers

Re-shored Production — Sustainable Processes — Intelligent Automation

Customizable Small Runs
On Demand

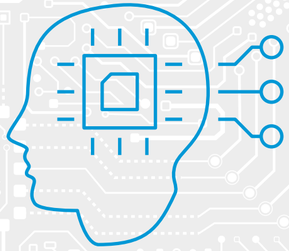
CAD PREPARATION → AME PROCESS → ELECTRICAL TEST → FQC → SHIPMENT

THE ADDITIVE APPROACH TO ELECTRONICS

Additively Manufactured Electronics (AME) — Solves Major Production Issues

Sustainable Processes

95% less material waste
92% less water waste



Self-Learning Systems

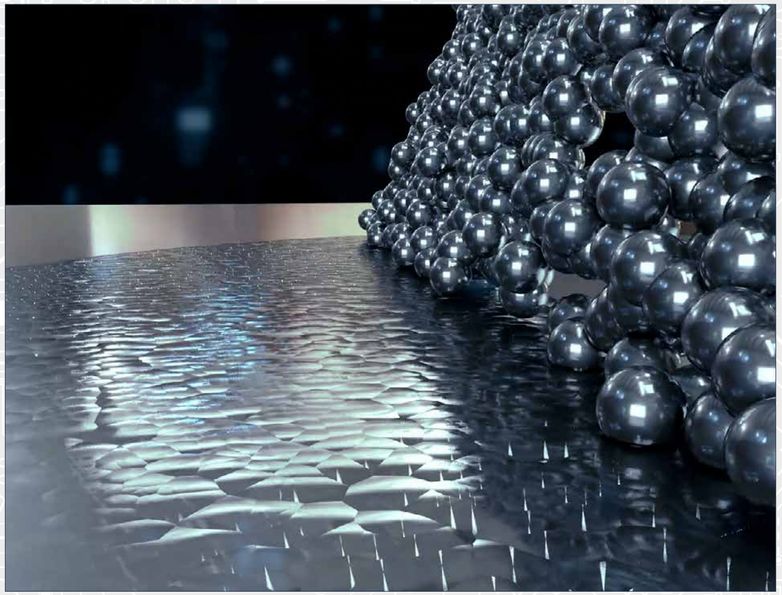
Integration with
CAD, AI and logistics

Locally Controlled IP

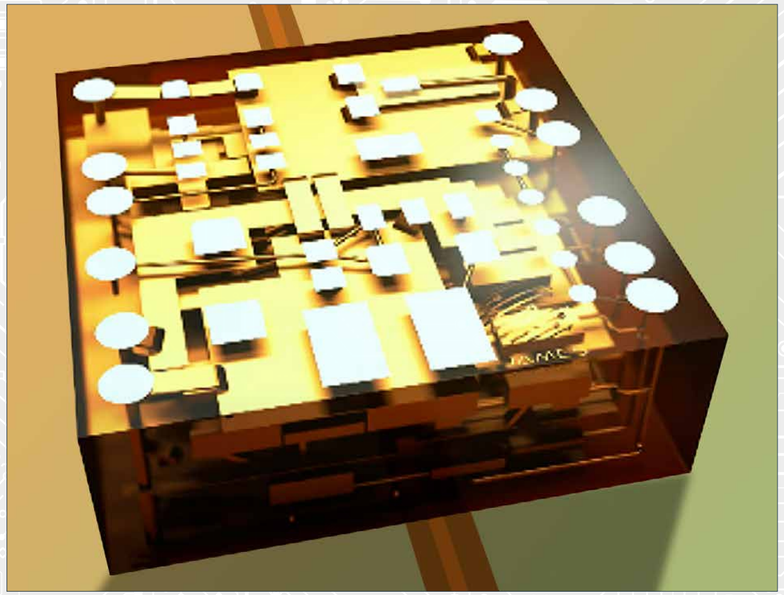
Compact machines
operating in-house

THE AME 3D PRINTING PROCESS

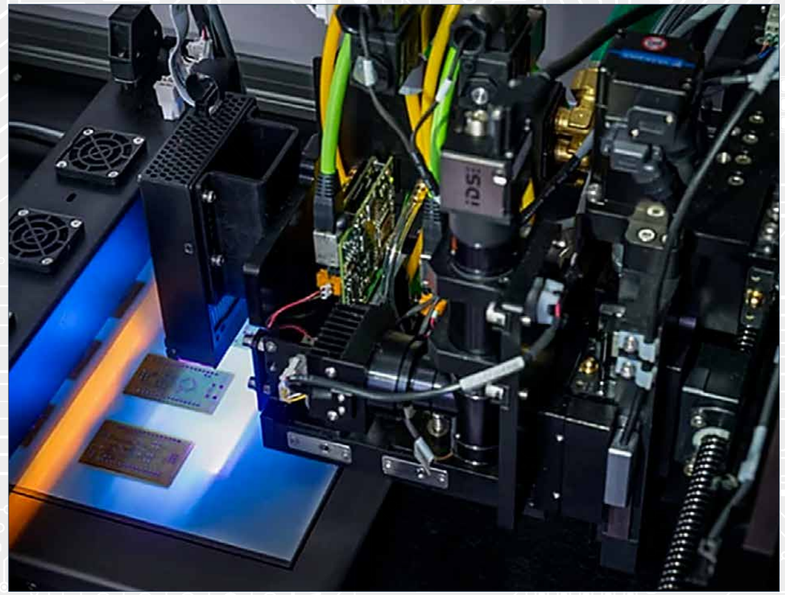
Multiple Materials Simultaneously — Accelerating the Production of Electronics



The AME process uses a conductive metal ink for connections and components.



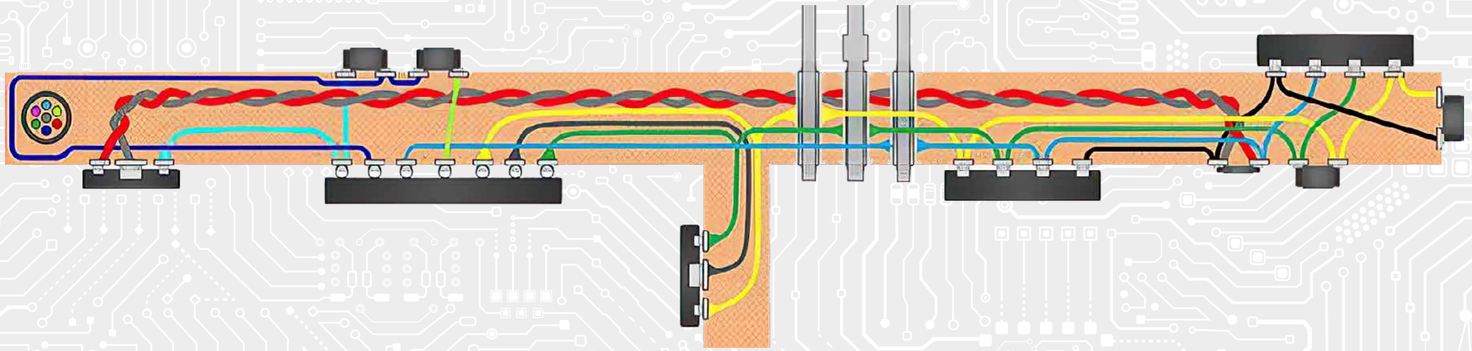
At the same time, the printer also deposits a dielectric material that provides insulation and structure.

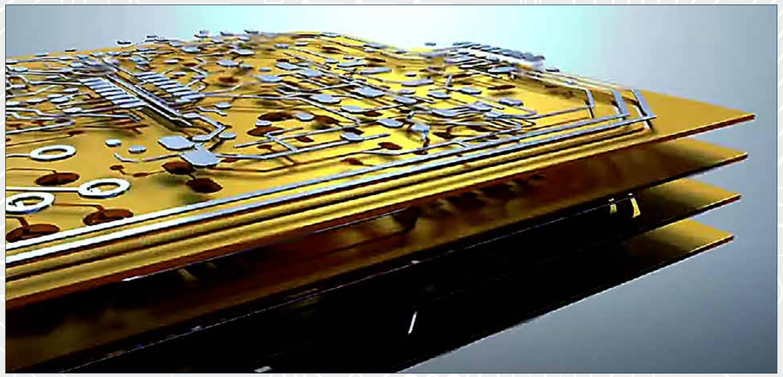


Inside the printer, both materials are dried, cured, and sintered by specialized systems.

THE AME 3D PRINTING PROCESS

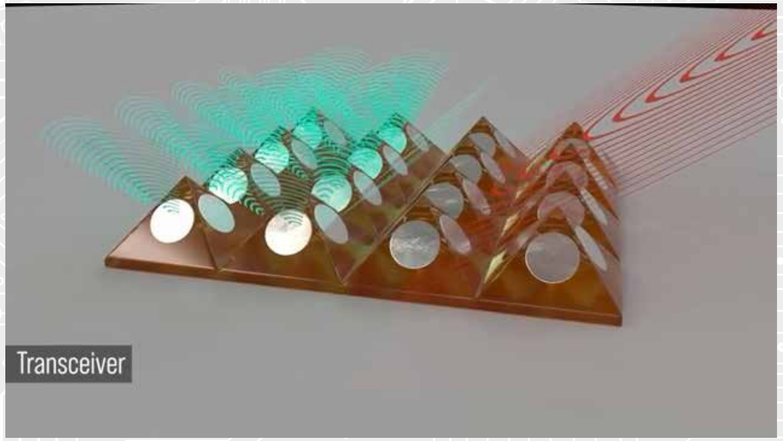
Multiple Layers — Completely New Configurations





COMPARED TO TRADITIONAL TECHNIQUES

- Designs can employ as many layers as needed
- Connections can be made in any 3D direction
- Cables and passive components can be printed as part of the structure
- IC chips can be mounted anywhere on the surface



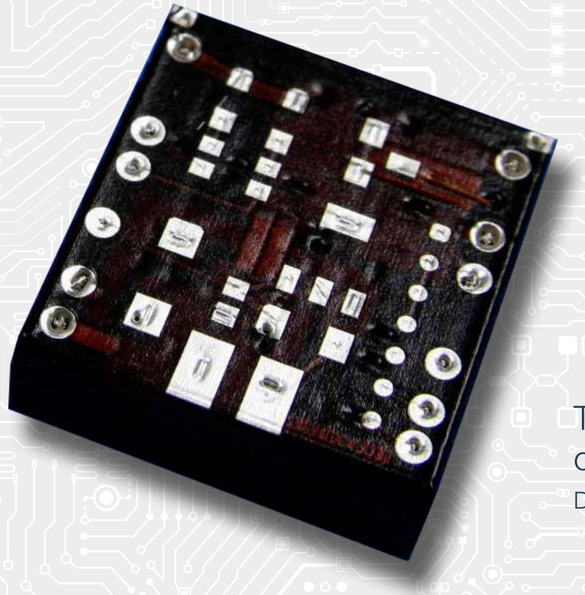
Complex metal-and-polymer structures like these sphere-phased antennas can also be crafted through multiple additive layers.

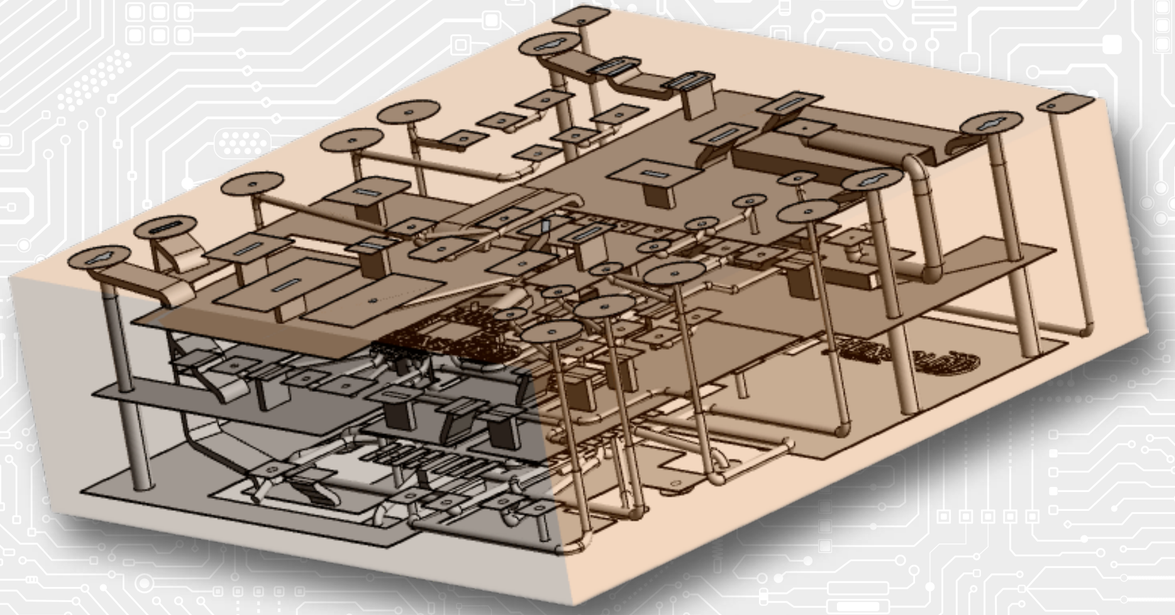
THE AME 3D PRINTING PROCESS

ECAD + MCAD — Preparing Layouts for a New Medium

Because of AME's unique stackable configurations, electronic CAD (ECAD) circuit designs are converted to a specialized modeling platform that contains elements of 3D mechanical CAD (MCAD) plus the ability to designate multiple materials.

Once the design file is properly composed according to machine guidelines, the data is sent directly to the 3D printer.





This compact radio frequency (RF) synthesizer takes advantage of AME's multilayer capabilities.

Design and images courtesy of J.A.M.E.S. https://j-ames.com/

AME PROTOTYPING

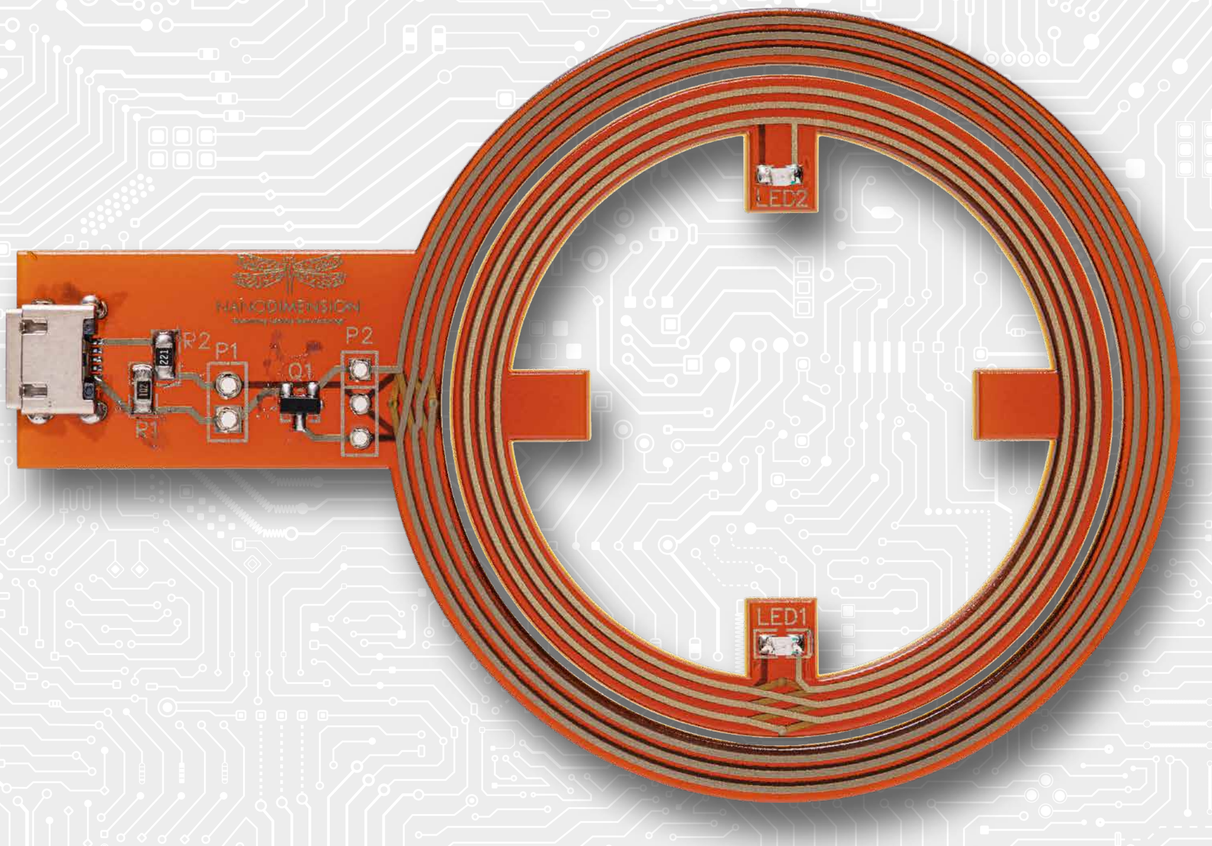
Prototypes in Less Than a Day — Quick Iteration of New Electronic Products

The largest immediate effect of additively generated electronics has been in the R&D lab.

Prior to AME, a working prototype to test the viability of a circuit or to compare alternative designs required outside fabrication at a distant factory with long setup times and high costs.

Where rapid prototyping has been around for decades for plastic and metal structural parts, electronic engineers had no similar digital method for proof-of-concept boards.

For academic labs, AME now gives immediate one-offs for the design of experiments. For commercial manufacturers, AME means shorter development timelines to bring quality products to market faster than the competition.



The printed induction coil above functions as a wireless mobile phone charger.

AME PROTOTYPING

IoT and Wi-Fi Access Port — In-house Prototyping Example

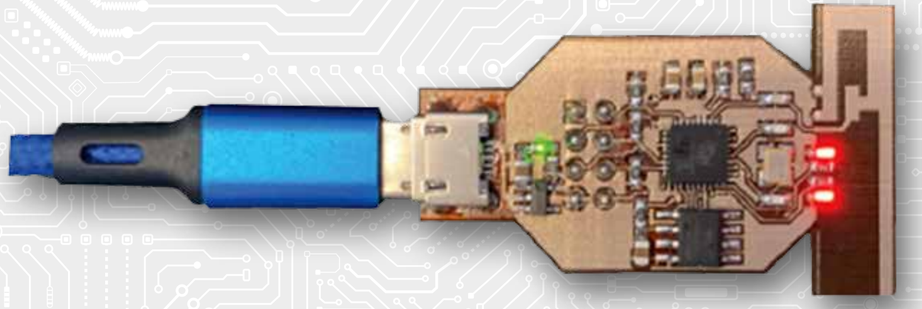
5G — and eventually 6G — communications will allow Internet of Things (IoT) sensors to amass huge amounts of data about our work and our lives onto the cloud. We will use artificial intelligence (AI) to make sense of the data and to make informed decisions locally. AME will be essential to developing these customized networks.

The prototypes of this IoT/Wi-Fi access point circuit through AME resulted in a fully functional device with a tested data transmission and reception accuracy of over 99%.

The high accuracy of the 2.4GHZ data transmission is due to the dielectric properties and the antenna's tight dimension control, made possible by the additive manufacturing technique.

FEATURES

- 2.4Ghz signal generation with printed antenna
- Full system using MPU (esp8266)
- Wi-Fi host I/O
- Wi-Fi connections to smartphones or computers
- ON/OFF of two LEDs controlled via web page



Four prototypes required just 20 hours of printing, using 2.5 ml of conductive ink, and 5.8 mil of dielectric material.

AME SUPPORTING TECHNOLOGIES

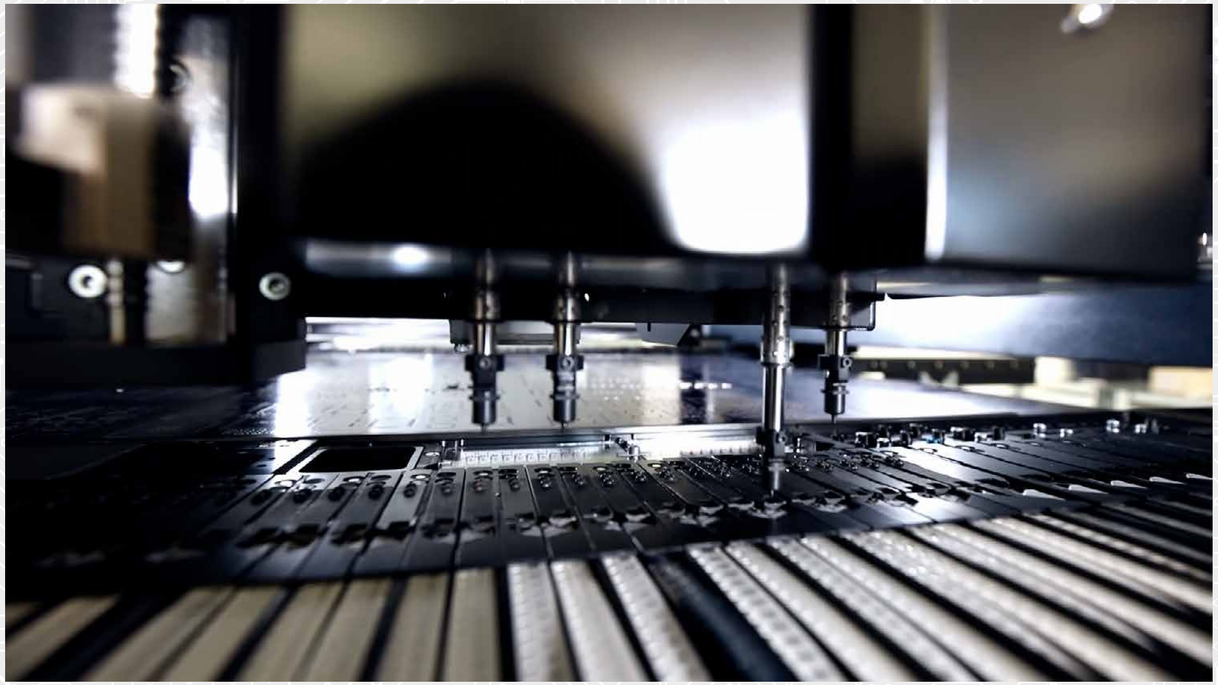
Automated 3D Assembly — Completing the All-Digital Process for Electronics Products

Part of the appeal of 3D-printed electronics is that many passive components, like resistors, capacitors, inductors, antennas, and coils can be printed inside the device.

The parts AME cannot print include integrated circuits (IC) and microprocessors. The printer, however, can leave precise connectors and pinpoint-precise cavities for mounting these chips with no need for drilling.

Fortunately, today's advanced mechatronics can achieve surface mounting, adhering, and soldering ICs within seconds.

Together, AME and surface mount technology (SMT) can create finished, functional electronic hardware.



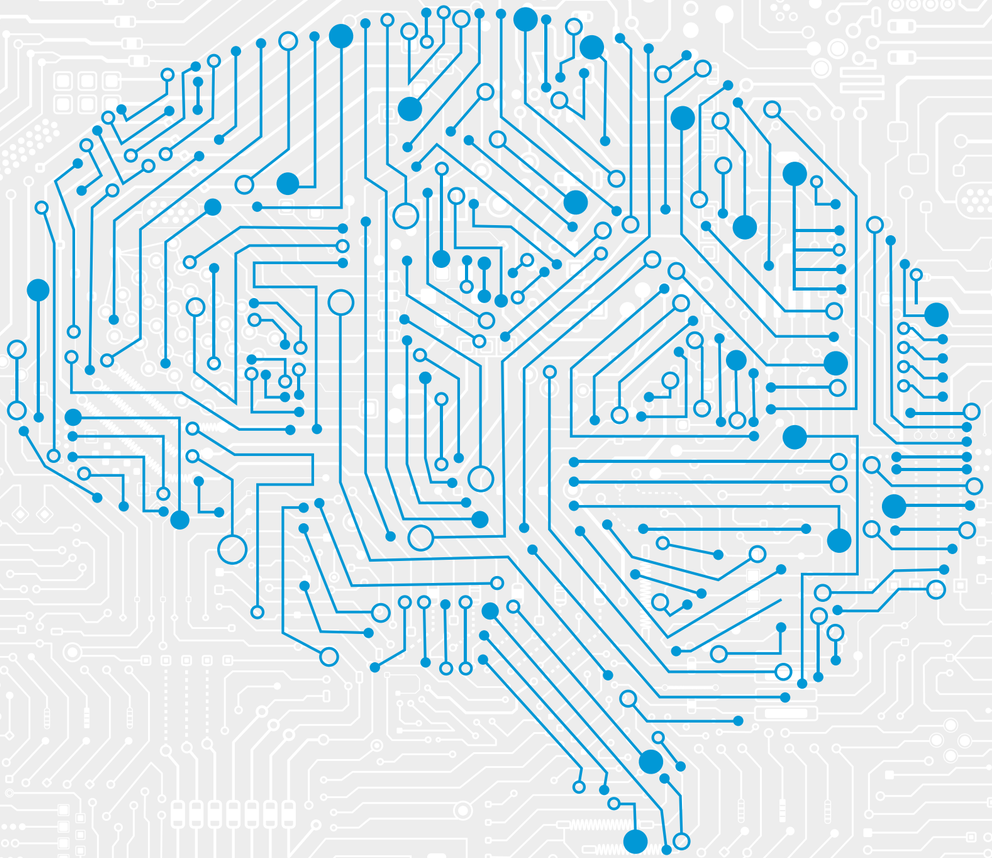
AME SUPPORTING TECHNOLOGIES

Deep Learning — Micro Improvements in Quality Correlate to Macro Improvements in Yield

A subdomain of machine learning called Deep Learning (DL) has recently made breakthroughs in the realms of image, voice, and text recognition, bringing accurate inference rates up above 95%.

Applying this same artificial intelligence to AME is a strategy to recognize fabrication errors during a print and recalibrate inkjetting in real time to prevent flaws from developing further.

The more a machine prints, the better the quality. The effect of DL on the new electronics assembly line process is expected to be 25-30% greater yield, helping to make AME a viable option for large-scale production applications in the future.



APPLICATIONS OF AME

Electronics are Everywhere — AME has Unlimited Applications

Since the industries and disciplines that rely on electronic hardware are numerous and wide-ranging, so too are the applications for AME.

Here are some major categories where the technology is finding practical benefits:

- Aerospace
- Defense
- Automotive
- Consumer electronics
- Medical research and devices
- Scientific and academic research
- Industrial manufacturing
- Radio Frequency (RF) communications (5G / 6G / IoT)
- Micro Electronic Mechanical Systems (MEMS)

L3 HARRIS TECHNOLOGIES

AME Use Case 3D-printed RF Amplifiers

L3 Harris Technologies explored the potential of 3D printing technology for the development of radio frequency (RF) systems with an interest in reducing the time and cost of development while also fabricating complex systems that might not be easily produced with conventional means.

Specifically, L3 Harris wanted circuits integrated with both rigid and flexible packaging that can be achieved in a single print without cables and connectors.

Using a dual-material 3D printer, L3 Harris was able to fabricate functional RF amplifiers. A 101mm x 38mm x 3mm thick circuit was 3D printed in 10 hours.

This amplifier was launched in 2021 to the International Space Station for testing in harsh environments.

L3 HARRIS TECHNOLOGIES

AME Use Case 3D-printed RF Amplifiers (continued)

Test Results

The resulting data showed similar RF performance between the 3D printed and the baseline amplifiers, demonstrating the viability of 3D printing technology:

- There was no noticeable difference in the input or output return loss response over the frequency range from 10 MHz to 6 GHz.
- No noticeable difference was detected in the gain of the 3D printed circuit and the conventionally manufactured amplifier. The gain difference between the 3D-printed circuit and the conventionally manufactured circuit was less than 1 dB up to 4.7 GHz and less than 1.3 dB up to 6 GHz.

View the full case study

"The ability to manufacture RF systems in house offers an exciting new means for rapid and affordable prototyping and low-volume manufacturing."

— **Dr. Arthur Paolella**, Senior Scientist
Space and Intelligence Systems
L3 Harris Corporation

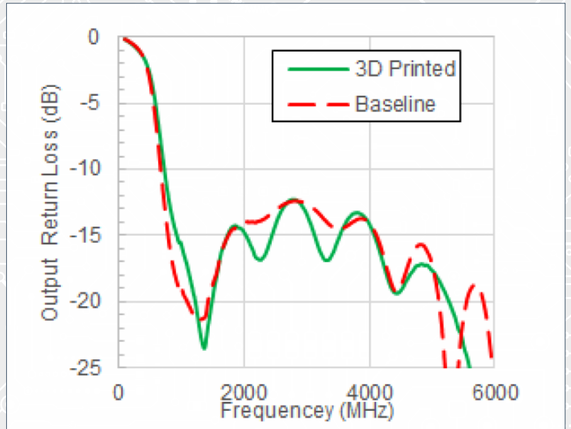


Figure 4. Amplifier return loss (output) comparison: 3-D printed and conventionally manufactured amplifiers.

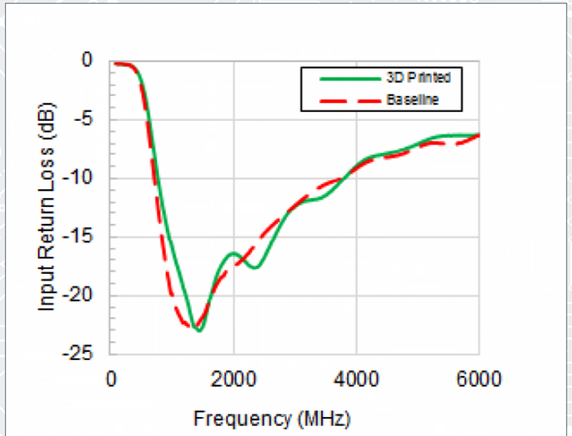


Figure 3. Amplifier return loss (input): comparison of 3-D printed and the conventionally manufactured amplifiers.

CENTER FOR BIO-MOLECULAR NANOTECHNOLOGY

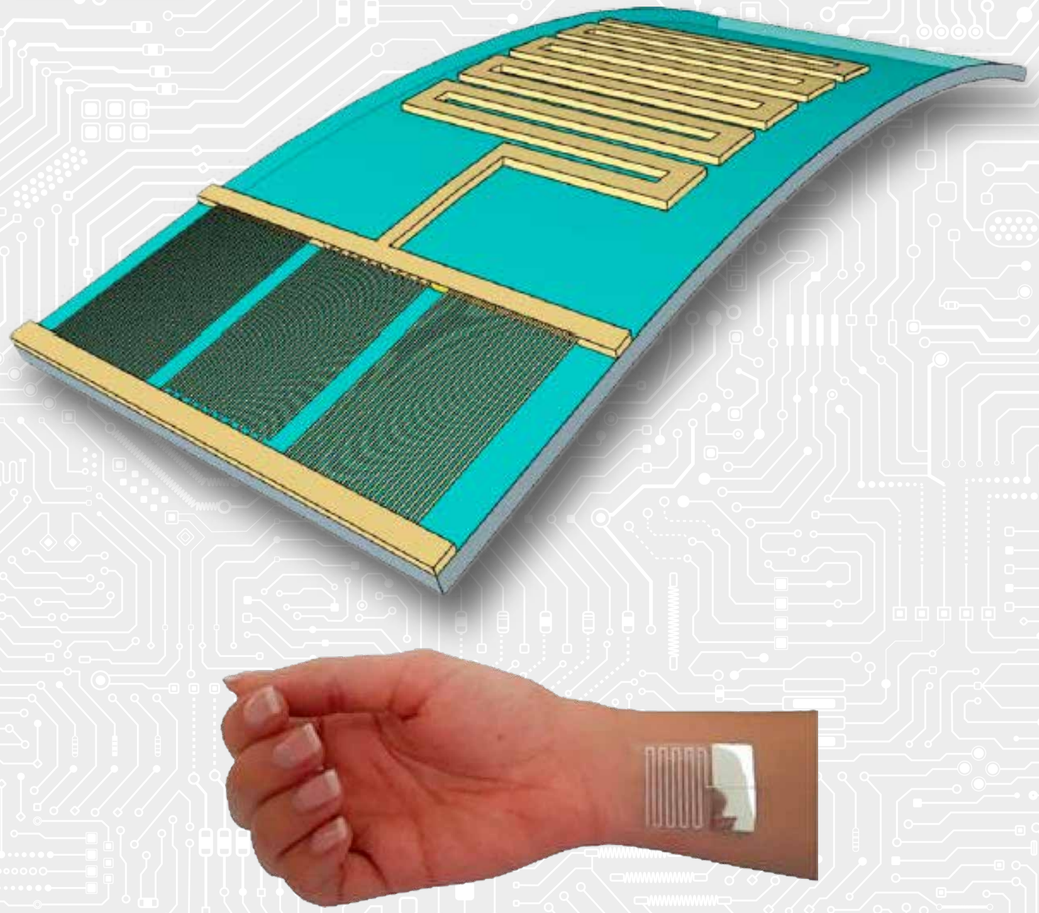
AME Use Case SAW Sensors + Integrated Antennas

A medical R&D team at Istituto Italiano di Tecnologia (CBN-IIT) saw the potential for advancing research into wearable, self-powered sensing mechanisms.

Surface Acoustic Wave (SAW) devices represent one of the most important class of MEMS due to their low cost, low power needs, and rapid manufacture.

By integrating piezoelectric thin film with multi-material metal-and-dielectric 3D printing, the sensors could be flexible and suitable for testing opto-electro-mechanical performance and biochemical sensing.

The team decided on a meander antenna design built at a thickness of 40 µm to achieve optimal electrical conductibility of the silver nanoparticle-based ink.



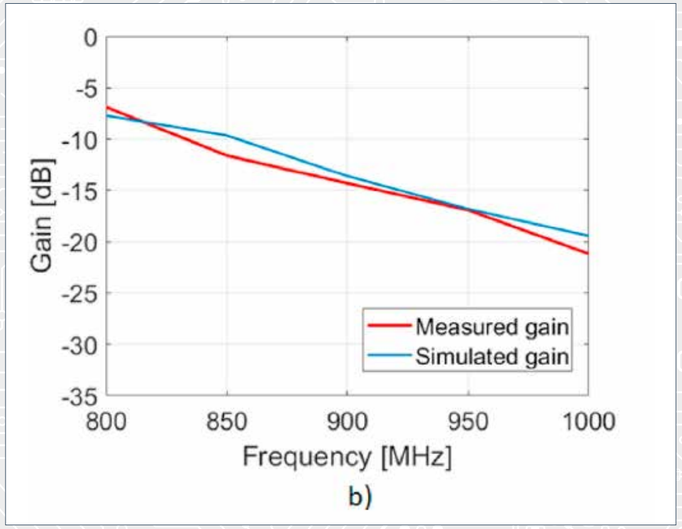
CENTER FOR BIO-MOLECULAR NANOTECHNOLOGY

AME Use Case SAW Sensors + Integrated Antennas (continued)

Test Results

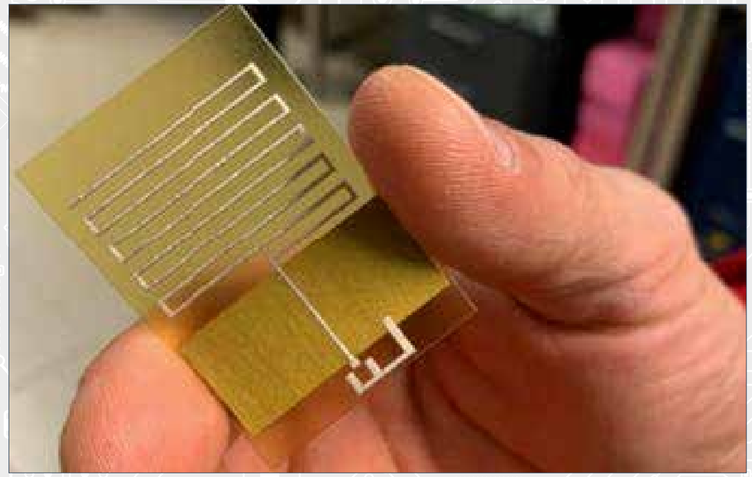
The results show the potential advantages of 3D printing on PEN substrate.

The technique paves the way for the integration between flexible body-friendly antennas and a flexible SAW for wearable sensing for the Internet of Healthcare Things (IoHT).



"The ability to rapidly and affordably manufacture functional prototypes makes it ideal for our team."

— **Prof. Massimo De Vittorio**
CBN-IIT

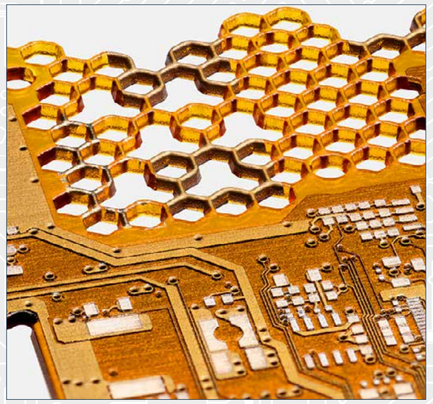


View Journal Article

MANUFACTURING ELECTRONICS WITH DRAGONFLY

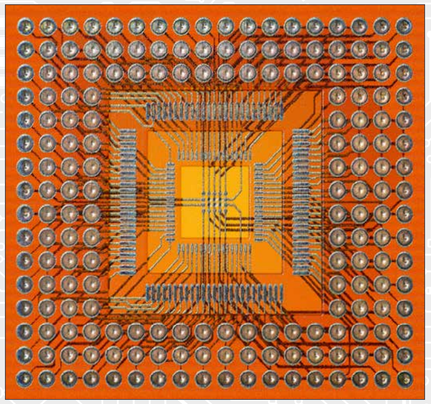
Build, Test, and Iterate Electronics in a Single Day

DragonFly IV is a multi-material, multi-layer 3D printer that generates entire circuits in one step — including substrate, conductive traces, and passive components

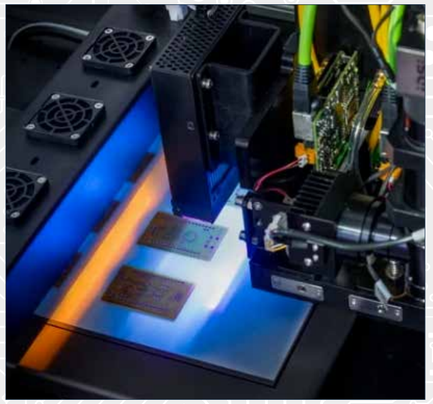


Design Flexibility Beyond Traditional Boundaries

Transformational Processes



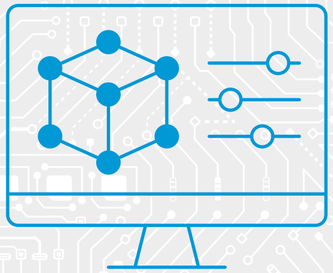
Generate Devices in House



Guided by Deep Learning

NANO DIMENSION OFFERINGS

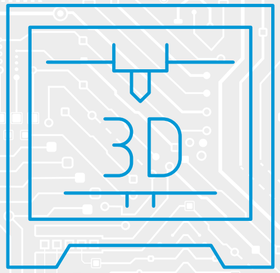
Process Integration — AME Assembly Line Incorporates Advanced Technologies



ECAD + MCAD

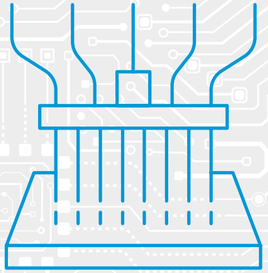
NANODIMENSION FLIGHT

PLAN - CHECK - CONTROL



3D Printing

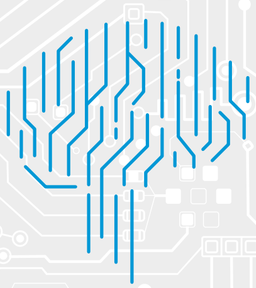
DragonFly IV®



Inkjet Drive Electronics

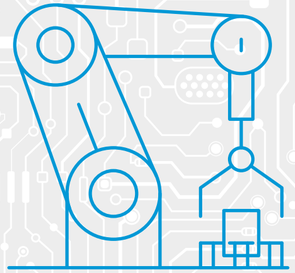
GIS | GLOBAL INKJET SYSTEMS

A NANODIMENSION DIVISION



Deep Learning

DEEPCUBE



Surface Mount

essemtec

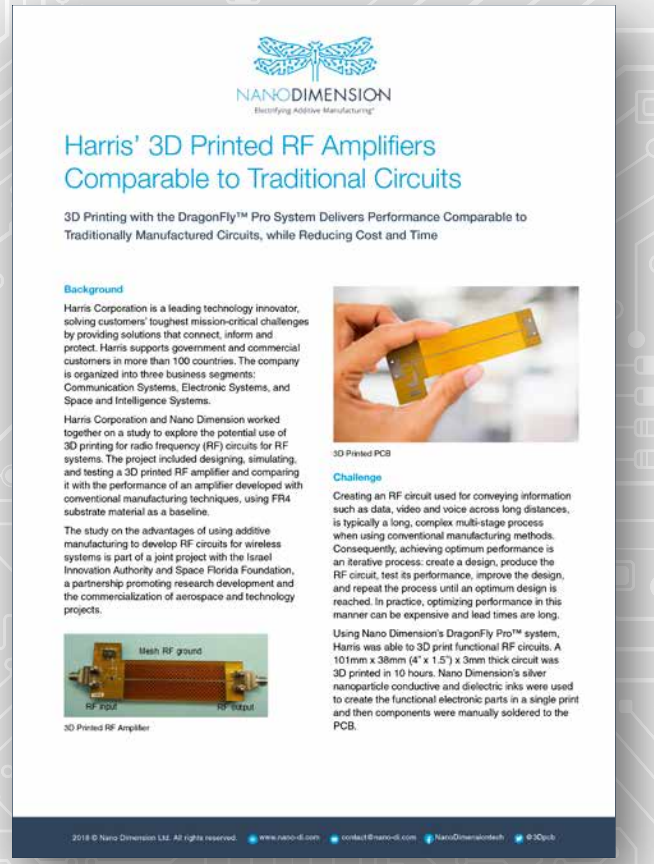
A NANODIMENSION DIVISION

VENTURE FURTHER INTO AME

Explore Additively Manufactured Electronics Resources from Nano Dimension

DragonFly
AME

Essemtec
SMT


NANODIMENSION
Electrifying Additive Manufacturing

Harris' 3D Printed RF Amplifiers Comparable to Traditional Circuits

3D Printing with the DragonFly™ Pro System Delivers Performance Comparable to Traditionally Manufactured Circuits, while Reducing Cost and Time

Background

Harris Corporation is a leading technology innovator, solving customers' toughest mission-critical challenges by providing solutions that connect, inform and protect. Harris supports government and commercial customers in more than 100 countries. The company is organized into three business segments: Communication Systems, Electronic Systems, and Space and Intelligence Systems.

Harris Corporation and Nano Dimension worked together on a study to explore the potential use of 3D printing for radio frequency (RF) circuits for RF systems. The project included designing, simulating, and testing a 3D printed RF amplifier and comparing it with the performance of an amplifier developed with conventional manufacturing techniques, using FR4 substrate material as a baseline.

The study on the advantages of using additive manufacturing to develop RF circuits for wireless systems is part of a joint project with the Israel Innovation Authority and Space Florida Foundation, a partnership promoting research development and the commercialization of aerospace and technology projects.

Mesh RF ground
RF input
RF output

3D Printed RF Amplifier

3D Printed PCB

Challenge

Creating an RF circuit used for conveying information such as data, video and voice across long distances, is typically a long, complex multi-stage process when using conventional manufacturing methods. Consequently, achieving optimum performance is an iterative process: create a design, produce the RF circuit, test its performance, improve the design, and repeat the process until an optimum design is reached. In practice, optimizing performance in this manner can be expensive and lead times are long.

Using Nano Dimension's DragonFly Pro™ system, Harris was able to 3D print functional RF circuits. A 101mm x 38mm (4" x 1.5") x 3mm thick circuit was 3D printed in 10 hours. Nano Dimension's silver nanoparticle conductive and dielectric inks were used to create the functional electronic parts in a single print and then components were manually soldered to the PCB.

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Case Study
L3 Harris Technologies

Other AME
Case Studies


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Research paper

Compact and flexible meander antenna for Surface Acoustic Wave sensors

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ARTICLE INFO

Keywords:
Surface Acoustic Wave
Piezoelectric materials
Passive wireless sensors
Antennas
Wearable electronics
Multi-material 3D printer

ABSTRACT

This paper presents an innovative, flexible and biocompatible Ultra High Frequency meander antenna, operating at about 800 MHz, realized by means of sputtering on a Polyethylene Naphthalate substrate, and by means of a multi-material 3D printer. The fabricated antennas were characterized in terms of scattering parameters, showing a good impedance matching and a bandwidth in the order of tens of megahertz, gain and 3D radiation patterns. A numerical model was also introduced to investigate the limits of the proposed technologies in terms of metal thicknesses. The fabricated antenna could be efficiently integrated with Surface Acoustic Wave resonators to realize compact, wireless, wearable and battery-less sensing platforms.

1. Introduction

Flexible wearable devices, directly worn on the skin, have gained considerable attention owing to their ease of collecting primary vital signs in real time, both continuously and non-invasively [1]. Power consumption and, in prospect, the creation of self-powered devices is a fundamental issue to be studied [1]: such devices would not require external power to run the sensing activity or generate a read-out signal. In particular, Surface Acoustic Waves (SAW)-based sensors integrated with an antenna, by converting an electrical signal into surface acoustic mechanical vibrations to be coupled with proper sensing mechanisms, generate new totally passive sensing platform for self-powered devices [2].

SAW devices represent one of the most important class of Micro Electro Mechanical Systems (MEMS) thanks to their low cost, low power needs and quick manufacturing. This class of device is usually fabricated on silicon substrate, using crystals of LiNbO3 or LiTaO3 as piezoelectric material, and shows good performances despite the high stiffness of these materials and their bulky dimensions [3–5]. The development of better techniques of deposition of thin film piezoelectric materials brought to a new type of SAW devices based on thin piezoelectric films of aluminium nitride (AlN) or zinc oxide (ZnO) on silicon substrate [6]. Nevertheless, wearable devices require flexible mechanical behaviour, paving the way to the exploitation of flexible material as substrate. Piezoelectric thin film sensors are affirming themselves as the main technology for the development of self-powered wearable technologies, operating across multiple domains as opto- electro-mechanical and biochemical sensing on the human body. The piezoelectric thin film enables the integration of multiple functions onto different substrates such as polymers [1]. Polymers are particularly important for development of flexible and wearable sensing devices, tactile transducers and energy harvesting devices based on piezoelectric thin films [1]. The fundamental challenge is represented by obtaining a thin piezoelectric layer on a flexible substrate with a high effective piezoelectric coefficient (d33) [1]. Flexible polymeric materials and piezoelectric thin films have very different thermal expansion coefficients; this difference can cause the formation of creeps in the thin piezoelectric layer during the high temperature growth. Recently, an aluminium-nitride-(AlN)-based SAW device on a thermoplastic polyethylene naphthalate (PEN) substrate has been fabricated by the low-temperature sputtering deposition of a multilayered AlN-based stack [5]. A large transmission signal amplitude, up to 20 dB, for the Lamb resonance mode below 1 GHz and an electromechanical coupling of the Lamb mode (2.27%–2.91%) were achieved [5]. These are essential characteristics for combining an AlN-based transparent and flexible SAW device with a wireless antenna for wearable electronic communications, paving the way for a new class of battery-less piezoelectric flexible SAW devices for vital parameter (physiological or biochemical) monitoring by mobile communications.

The aim of this work is to realize an antenna to be integrated with a

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