ElectroJet™
Additive Printed Electronics

COMPLETE TURNKEY SYSTEMS FOR NEXT LEVEL ADDITIVE MANUFACTURING

# THE NEXT BIG WAVE

Multi-Layer
Multi-Material
Digital Printing
Solutions for
Tomorrow's Electronics

# Who We Are

- Research, development and manufacturing company of specialty materials for Additive Manufacturing (3D Printing)
- Technical and business professionals with over 25 years experience in the printing industry
- Focused on end-use applications for the material properties and the final product specifications

# Key Market Segments

- Advanced Manufacturing
- Aerospace
- Automotive
- Electronics
- Medical/Dental
- Military/Defense
- Optics
- Security

# Engineered for Performance
# ChemCubed Brand Solutions

NanoCubed™
3D Printing Material Solutions

## NANOCOMPOSITE PHOTOPOLYMERS FOR EXPONENTIAL PERFORMANCE

- RIGID AND FLEXIBLE MATERIALS
- OPTICAL MATERIALS

ElectroJet™
Additive Printed Electronics

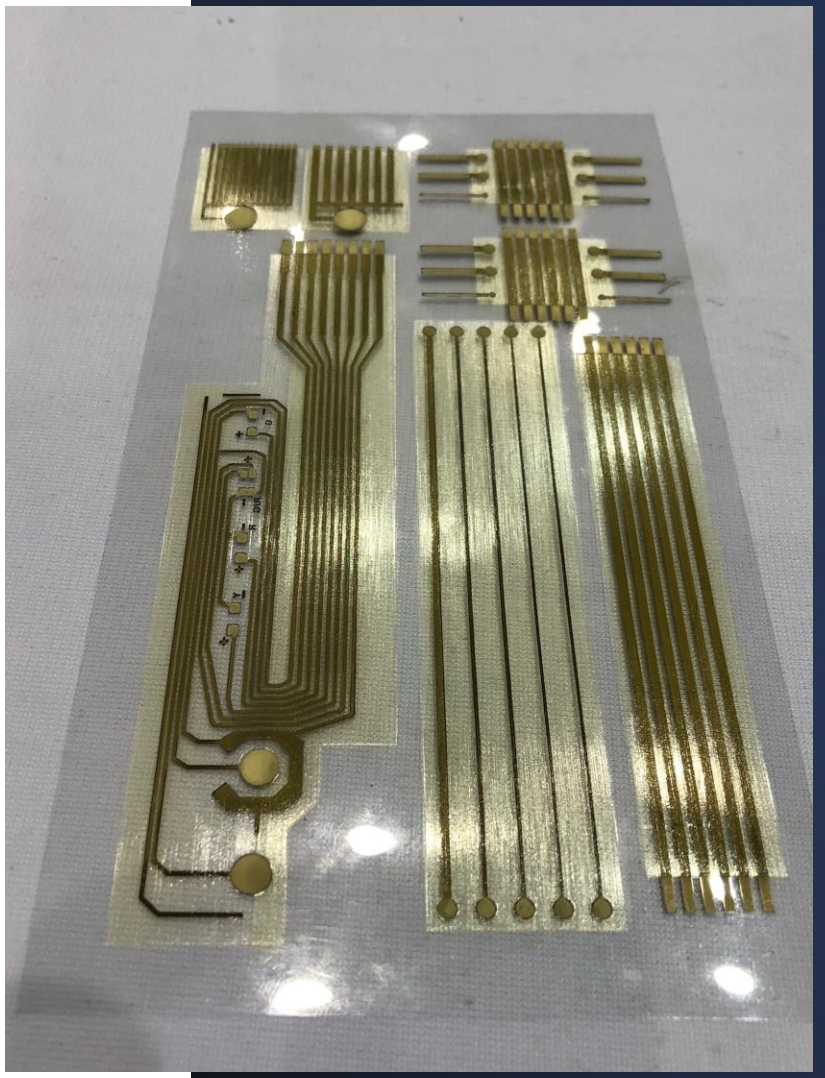
## MULTI-LAYER, MULTI MATERIAL DIGITAL PRINT SOLUTIONS FOR ELECTRONICS

- NANOPARTICLE-FREE SILVER CONDUCTIVE INKS AND DIELECTRICS
- UV 3DPRINTING TECHNOLOGY

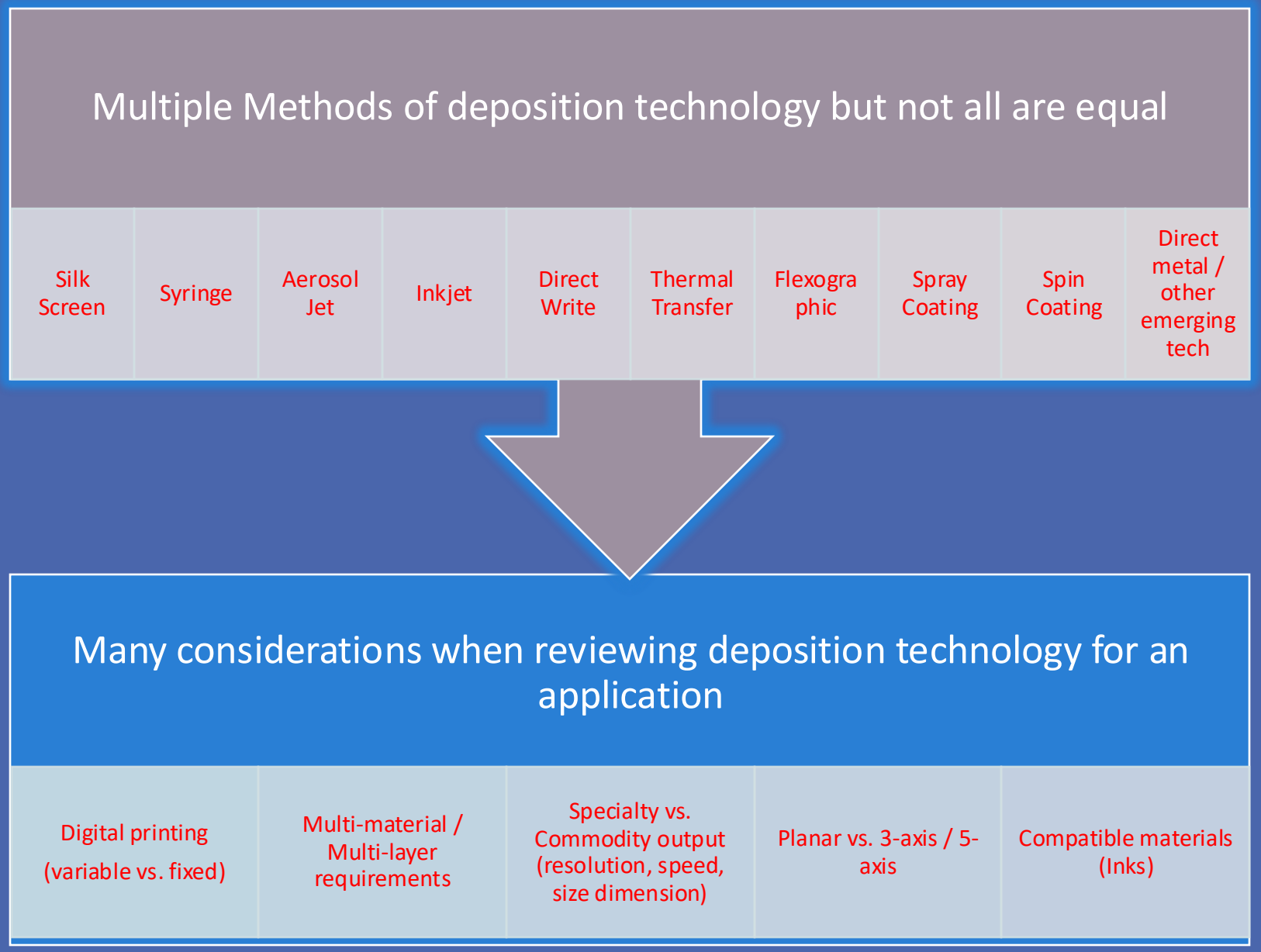
# Printed Electronics Defined

Printed electronics is an all-encompassing term for the printing method used to create electronic devices by printing on a variety of substrates

- Originally related to organic or plastic electronics that use inks made of carbon-based compounds
- Demand for wearable devices, thinner electronics, higher performing applications are driving material and printer developments
- Evolving over time toward print technologies capable of speed and cost efficiencies
- Printed materials are becoming thin, light and flexible enough to be integrated into existing production lines



# Printed Electronics Methods



# Benefits of printed electronics

**Sustainable Impact (additive vs. subtractive)**

Fewer input materials

Less energy

**Design, Development and Rapid Prototyping**

Hours vs. weeks / Immediate design testing feedback

Speed of modification / Speed to market

In-house vs. outsourcing potential (IP security)

**Custom fabrication / retrofits**

Mitigate fleet electronics obsolescence

Reduced technical constraints typically associated with mass producing electronics

**Component miniaturization / weight reduction**

**Functional optimization - multi-layering / embedding / protective encapsulation**

# Additive vs. Subtractive

**Traditional etch process**

- Mask resist to determine copper trace
- Etch away unmasked copper
- Fixed subtractive process
- Changes require new mask/etch

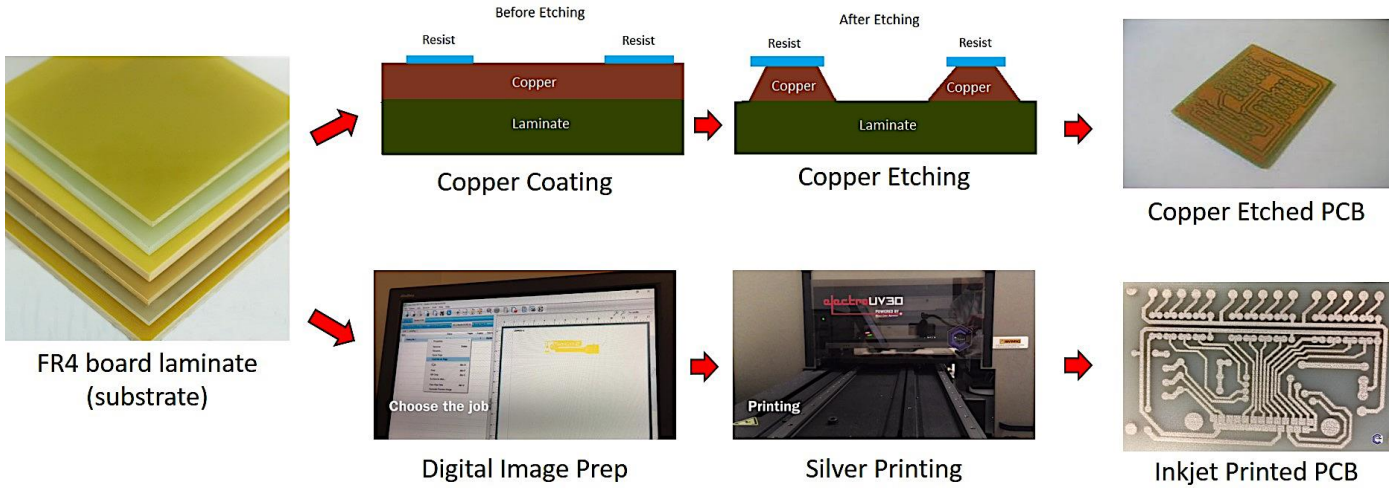
**Digital print process**

- Computerized image for copper trace
- Print directly on substrate
- Variable additive process
- Changes by file and reprint

**Multi-layer process**

- Traditional by repeat etch, lamination, drilling
- Inkjet by sequence of file print / materials

## Digitally printed circuits vs. traditional copper etching (additive vs. subtractive mfg)

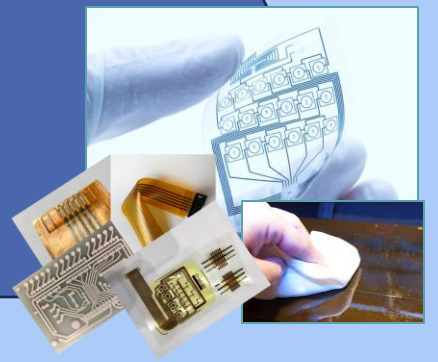


# The ElectroJet™ Additive Printed Electronics System

## THE ELECTROJET™ BRAND IS A CULMINATION OF HIGH-PERFORMANCE MATERIALS, INKJET PRINTING TECHNOLOGY, AND PROCESS CAPABILITIES

- **Materials** are commercially available for a wide variety of applications
- Our eight-channel **printers** provide multi-layer, multi-material electronics with unparalleled performance
- Our **process** support gets your team trained within hours; our dielectric templating supports printing accuracy < 10 microns.


The trio provide a full synergistic solution for our end-user

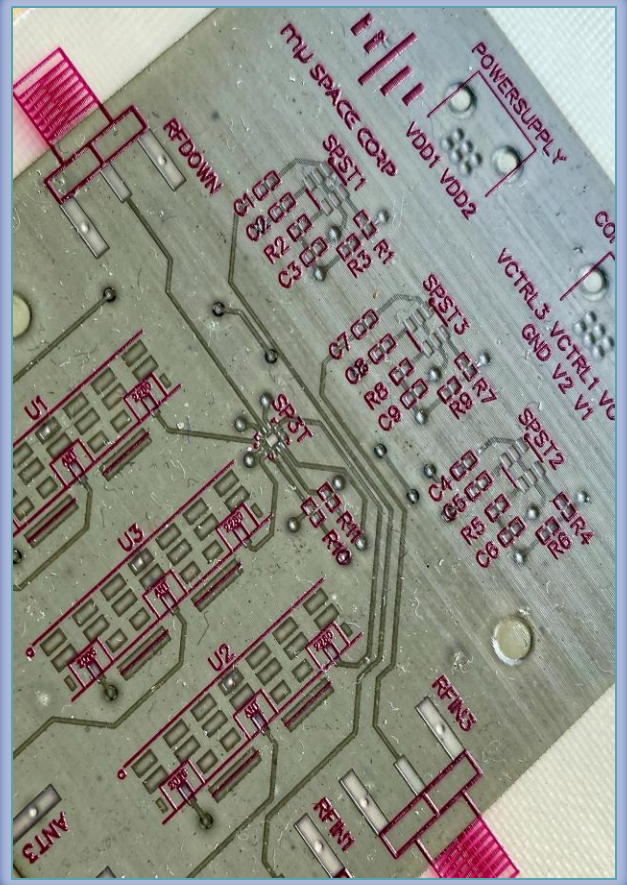


## Nanoparticle-free Silver <u>CONDUCTIVE</u> Ink

- Best-in-Class Conductive Performance
  - near bulk conductivity of silver
  - bulk resistivity in the range of $10^{-8}$ ohm-m
- Unmatched Sintering Efficiency
  - as low 80°C in 5 minutes
  - as fast as seconds >100 °C
- Superior printability and reliability with repeatability to within 1%
- Excellent Adhesion to multiple substrates

C3-Ag-1037-2: Standard for electroUV3D printer

C3-Ag-1037-2h: Viscosity tuned for brand inkjet heads




## UV Curable <u>DIELECTRIC</u> Insulating Ink

- Superior Insulating performance between conductive layers
- Adhesion promoter to high surface energy substrates
- Encapsulation to protect from moisture, chemicals and physical abrasion of the external environment
- Multiple formulations optimized to end-use applications

C3-DI-7: Standard workhorse formula

C3-OPT-7: Optically clear high-pot insulating

C3-DI-8: Optically clear flexible layers

# ElectroJet™ Materials

## It is more about the ink than you think

# ElectroJet™ Materials
## The difference is clear

### Nano-particle Silver Inks


- Opaque in color
- 15 - 40% silver particle loading
- Contains other fillers/resins
- Particles settle and require recirculation prior/during use

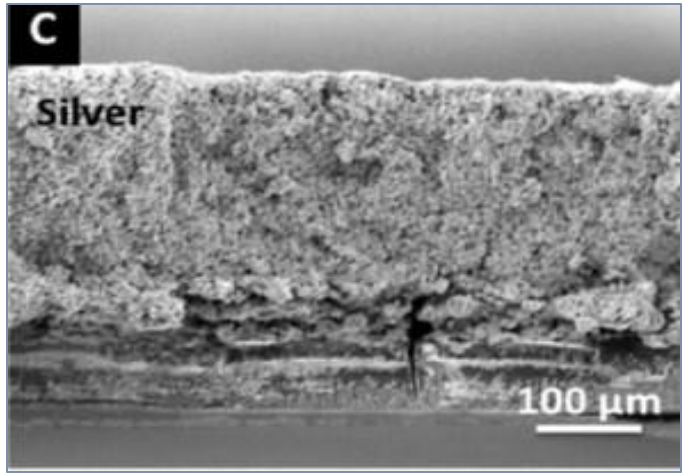
### ElectroJet™ Particle-Free Silver Ink


- Transparent in color
- Particle-free
- Contains NO fillers or resins
- Simply filter prior to use and ink remains stable without recirculation

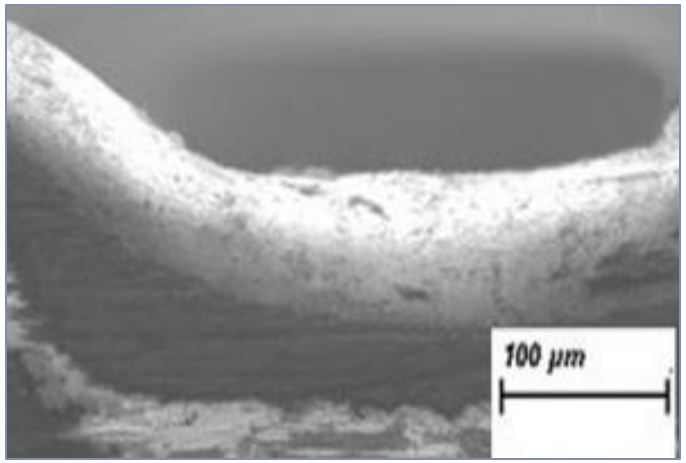
ElectroJet™
Additive Printed Electronics

# Materials

Clearly, there is a difference




- Particles can clog inkjet heads
- Sintering temp 130c / 30 min
- Sintered silver and fillers (40 – 60%)
- Filler and/or voids are non-conductive



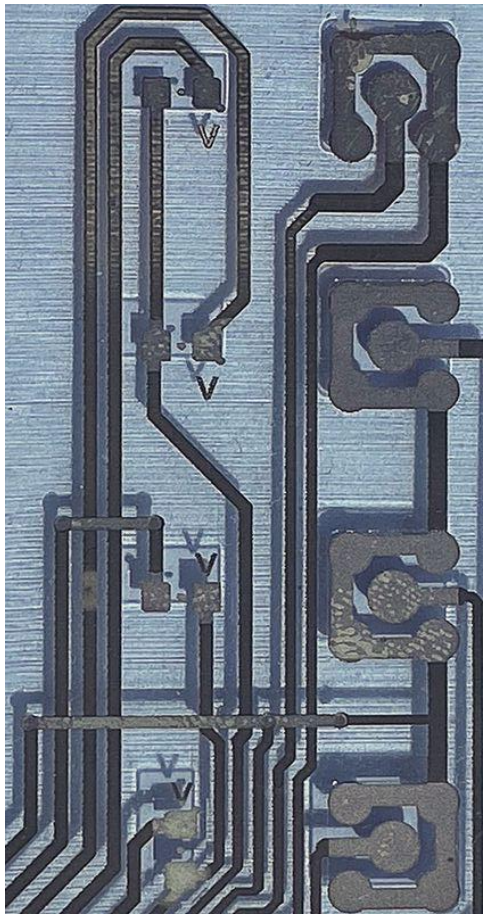

- Jettable reliability
- Sintering temp 80c / 5 min
- Sintered silver only (99%)
- Void-free silver is fully conductive

# High Performance Dielectric – our newest ink

Our most recent formulation is a revolutionary nanocomposite dielectric material that:

- insulates layers between the circuits,
- masks material for soldering, and
- supports at connection points; thereby allowing it to replace F board for two-sided boards

| | DI-7 | HPD-3D |
|---|---|---|
| Coefficient of Thermal Expansion ($10^{-6}$/K) | 177 | 25 |
| $T_g$ (°C) | 70 | 133 |
| Young's Modulus (MPa) | 400 | 1150 |
| Tensile Strength (MPa) | 21.1 | 66 |
| Elongation (%) | 25 | 15 |

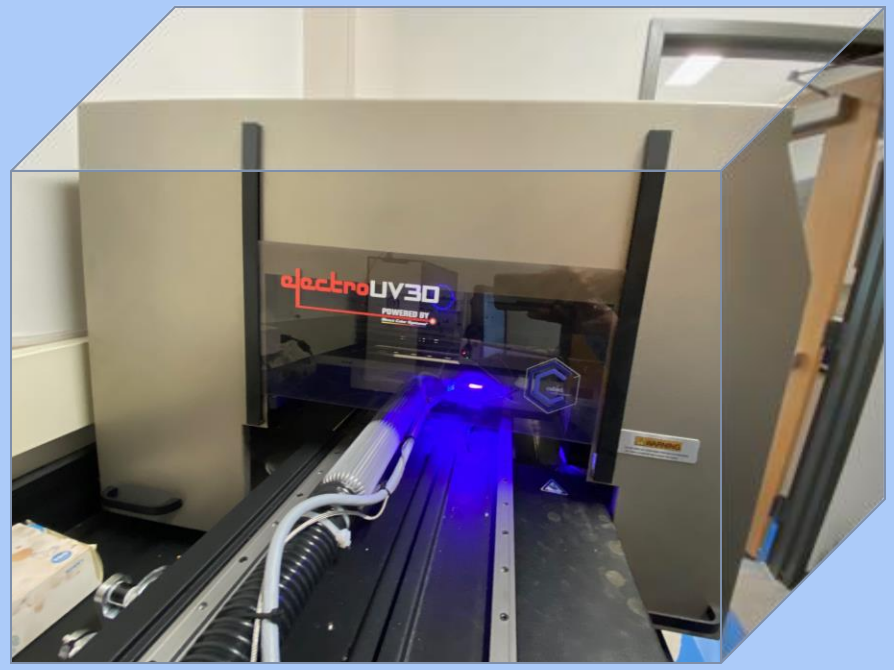


# Printing Technology

**There is not only a need for higher performing materials,
but also, the combined solution of a ready-to-use and fully capable printing technology**

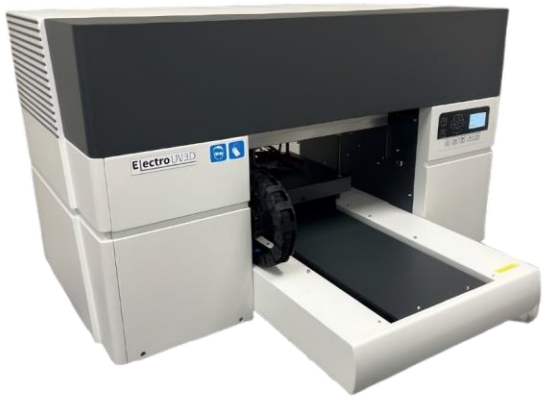
**Needs of a Commercial Printing Tool Solution:**

- Inkjet process to replace multiple steps and hands-on techniques
- Unprecedented low cost and efficient production
- Flexibility to design/develop/prototype ***and finally PRODUCE*** for the majority of digitally printed electronic applications
- Multi-material layering of functional coatings and laminations

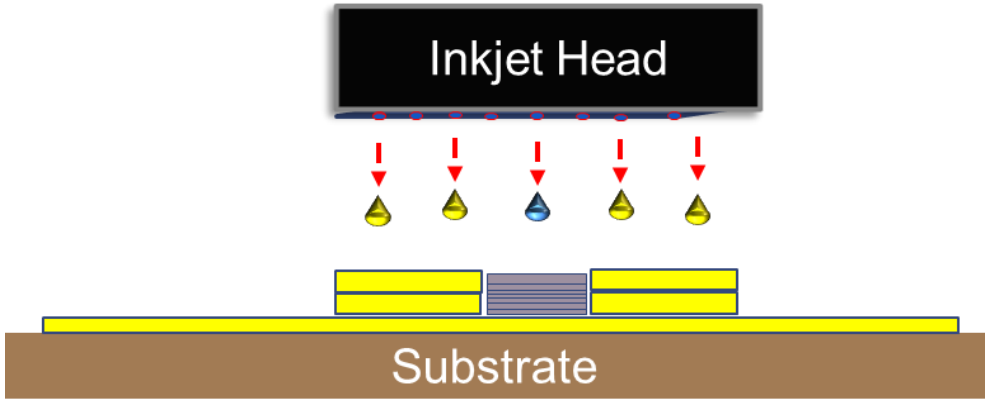


*The Original ElectroUV3D Printer*

*ElectroUV3D-1216*



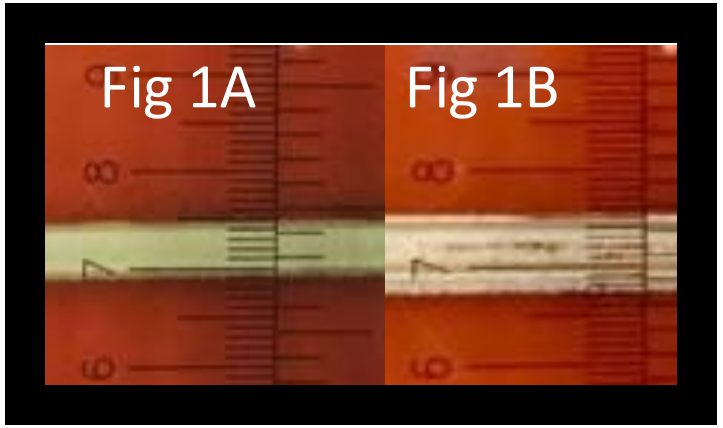
*ElectroUV3D-3200*




# Dielectric Templating

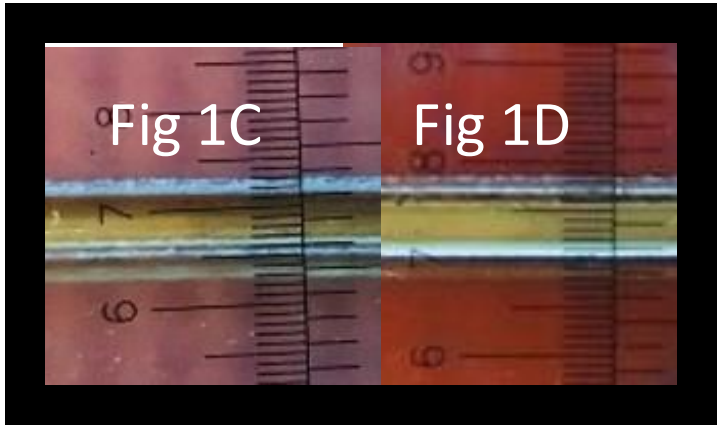
- Controlled Trace Widths
- Increased Trace Heights
- Optimized Conductivity

# Silver trace layering effect



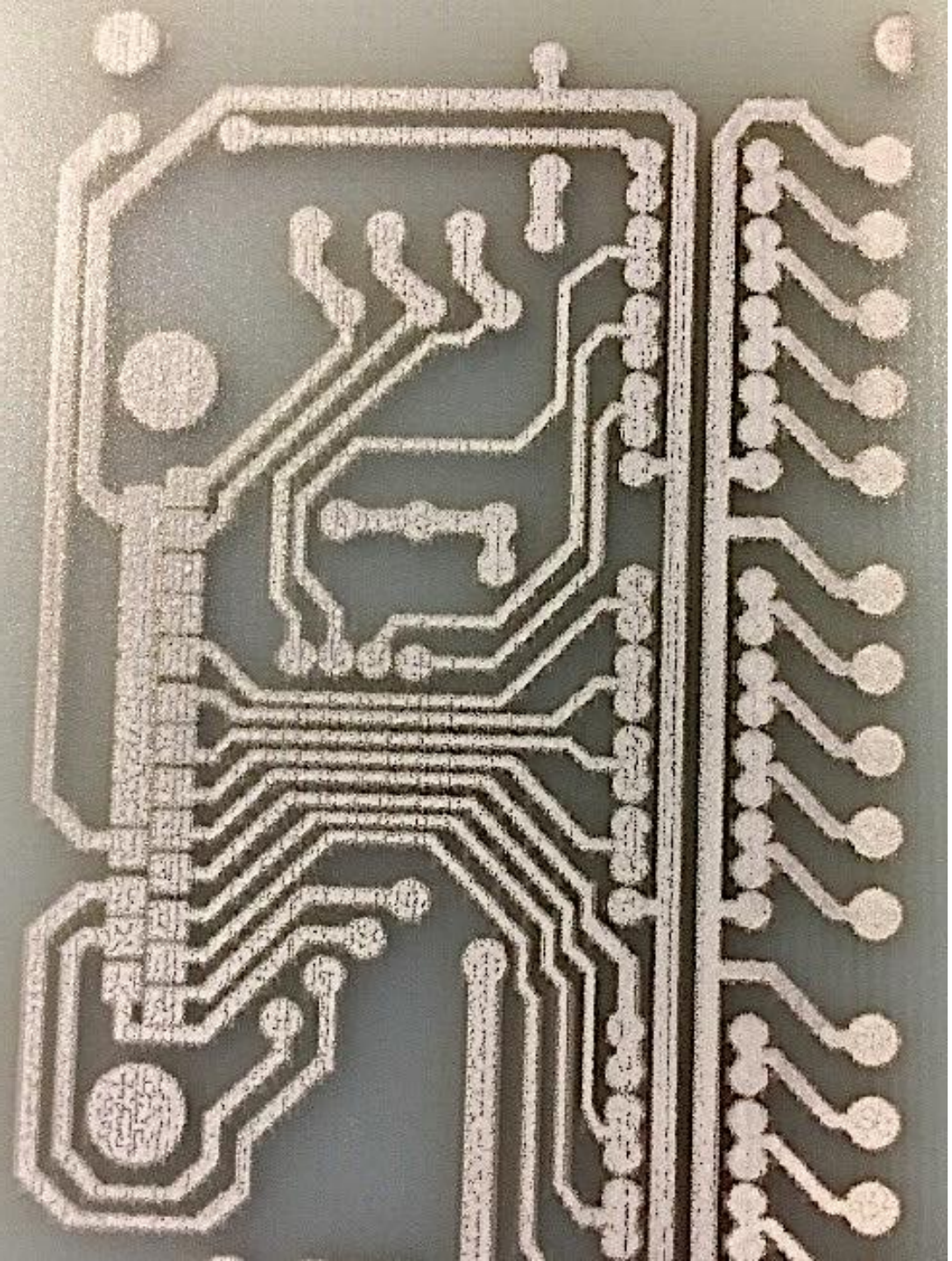

**<u>Without</u> dielectric templating:**

- Fig1A – 3 passes of silver ink
- Fig1B – 18 passes of silver ink
- Trace height fails to build in z-direction effectively (~max 5 um)
- Trace width continues to spread (0.55mm to 0.80mm)




**<u>With</u> dielectric templating:**

- Fig1C – 3 passes of silver ink
- Fig1D – 18 passes of silver ink
- Trace height builds effectively in z-direction (~24 um)
- Trace width is maintained (0.40mm)



# Post Print Process

- Solder Mask Procedure

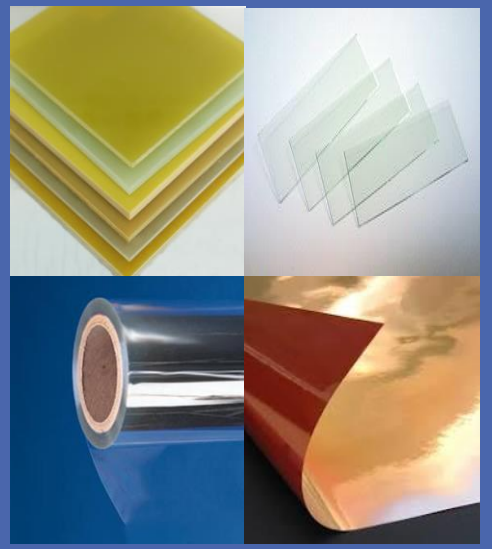
  - Protects a printed circuit against oxidations/prevents solder bridges between solder pads
  - Widely used in reflow soldering
  - Printed by ElectroUV3D printer, same process as dielectric ink

# Substrates

## Rigid, Flexible and Rigid/Flex* planar materials

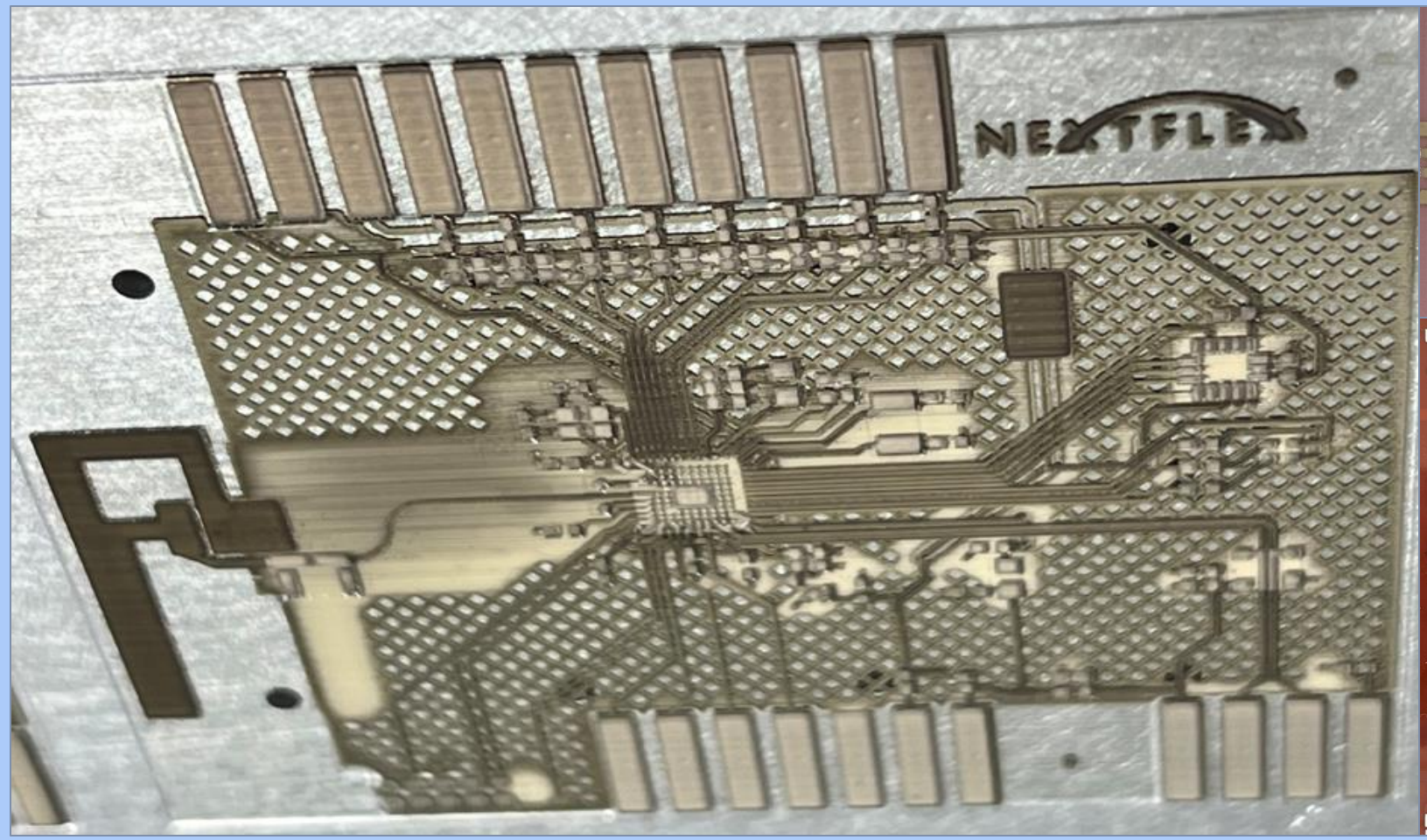
- FR4 board
- Liquid Crystal Polymer (LCP)
- Polyester (PET)
- Polycarbonate
- Polyimide Film (Kapton)

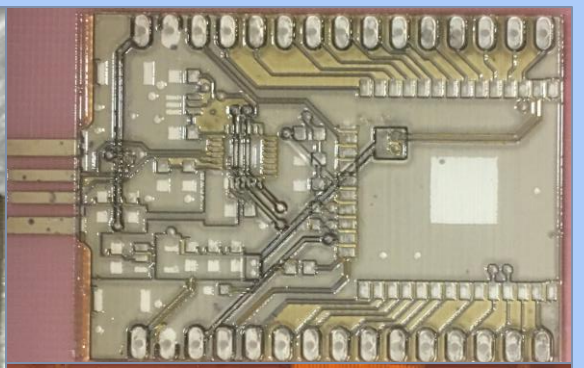
- Glass
- ITO coated glass
- Ceramic
- Foil / Metal
- Paper / Coated Paper
- Label stock

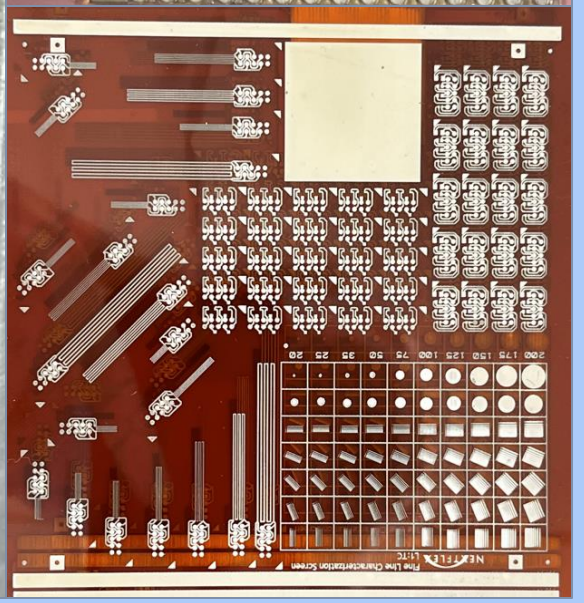


*Rigid material may be printed on flexible substrates

# Multi-layer Processes

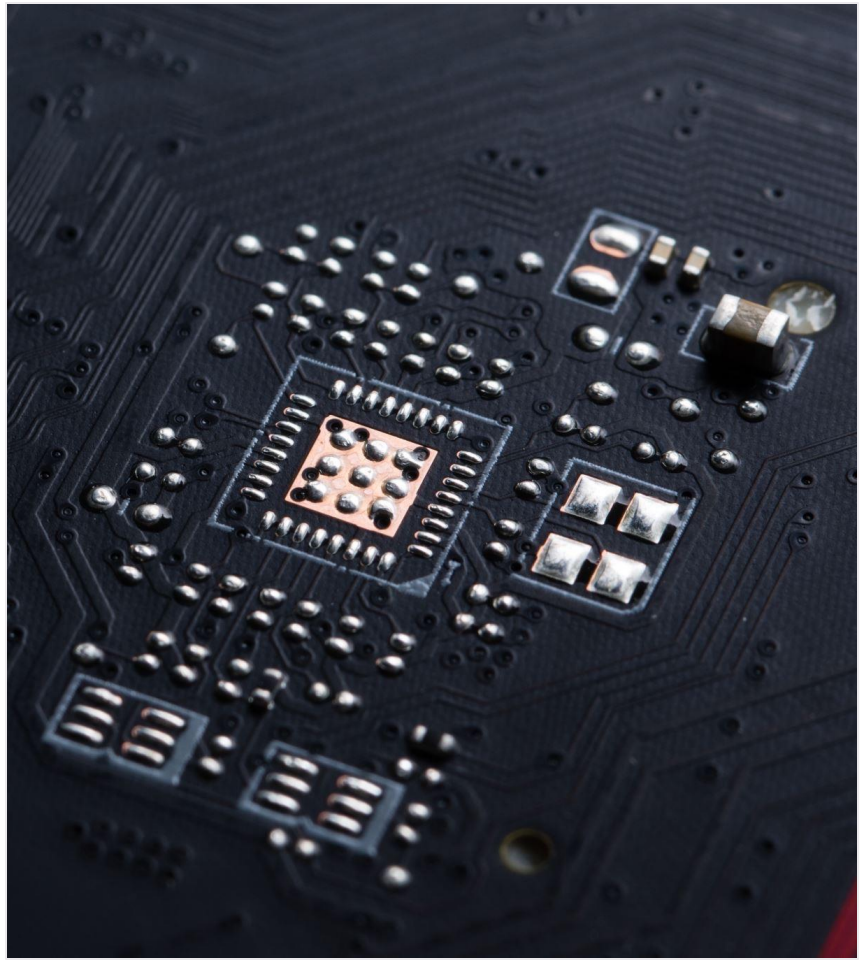




# Applications

- Printed circuitry/circuit boards/electronics packaging
- Displays
- Flexible hybrid electronics, writing harnesses
- Passive components (resistors, capacitors, inductors)
- RFID, sensors, shielding and antennae applications
- Semiconductor manufacturing
- Photovoltaics
- Wearables



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