

# Metallization in the Electronics Industry

- Metallization is the cornerstone for manufacturing and operation of nearly all electronic devices, from solar panels to TFTs
- Advances in core technology such as display, sensors, and advanced semiconductor node/packaging is dependent on thin-film metallization
- Metallization is complex, and requires cooperative approach with materials chemistry (or rheology), surface science, and equipment expertise
- Conventional Metallization approaches include Sputter (PVD), CVD/ALD, Plating, LDS
  - Technology Limitations: Temperature, LOS/non-orthogonal parts, highly toxic, will require patterning/etching
  - TCO Limitations: Lower HVM, high tooling/utility costs, limits on implementation
- **Competing approach is using metal inks**

# Features of NPs and MODs

Metric	NPs	MODs
<b>Film Purity</b>	Limited: 95 – 97% Ag	Excellent: semiconductor grade at >99.99% Ag
<b>Solid Loading</b>	Excellent: Up to 98% wt Ag	Limited: 12 – 50% wt Ag
<b>Film Reliability</b>	OK: 10 – 40% ΔR for 85/85 1000 hours	Excellent: 0% ΔR for 85/85 1000 hours
<b>Curing Temperature</b>	OK: Typically >150C for > 30 minutes	Excellent: 100 – 180C for 1 – 20 minutes
<b>HVM – Low Viscosity</b>	Limited: Nozzle clogging, low print times (hours)	Excellent: Print time of >20 days
<b>HVM – High Viscosity</b>	Excellent: Well-suited for screen/stencil printing	Limited: Typically impossible; EI has succeeded at 30,000 cPs
<b>Fine Patterning</b>	Limited: Limited to ~20 microns, and low Etchability (binders)	Excellent: Only limited by equipment, easily etchable
<b>Stability, Shelf Life</b>	Limited: typically settles, and needs freezer	Excellent: >6 months of shelf life
<b>Layer Build-up</b>	Excellent: 3 – 20 um in “one pass”	Limited: 50nm – 2um in “one pass”, but can build up with heated platen (no intermediate cure)

# El's Brand: Particle-Free Metal Inks

## 1. Particle-free

- Molecular metal solution (Ag, **Pd, Pt, Au, Ni, and alloys**)
- Does not rely on nanoparticle “sintering” mechanism
- Highly conductive (30 – 90% bulk silver) films in ambient environment at relatively low cure profile (thermal, NIR, UV)

## 2. No traditional binders/surfactants

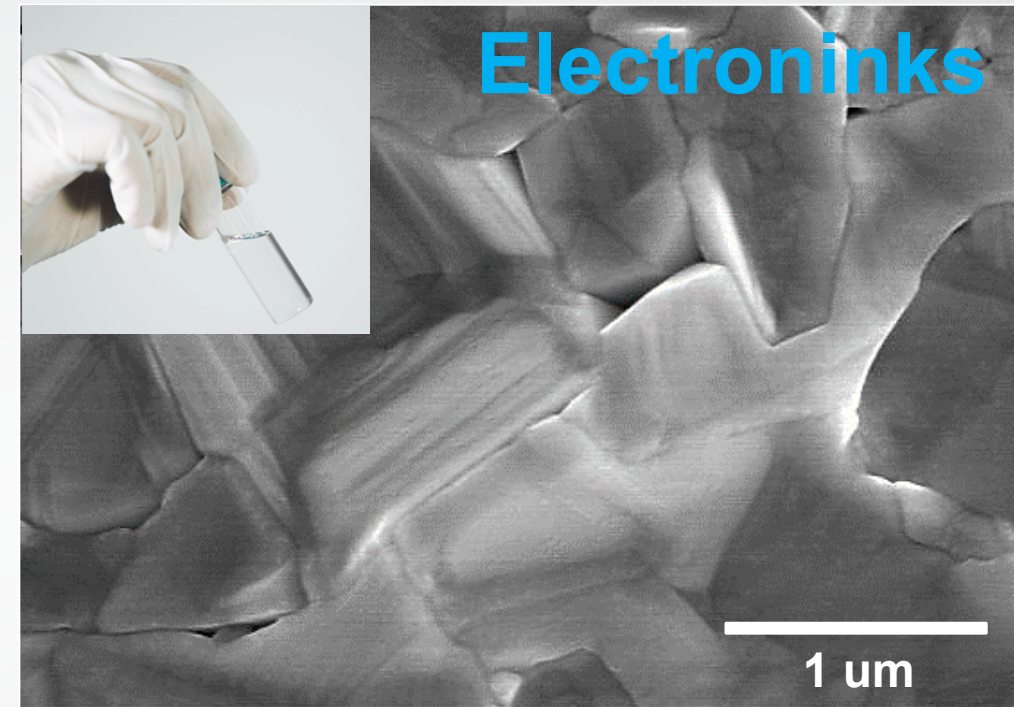
- Superior environmental stability and reliability
- No impurities in final film – approaching 99.99% metal
- More predictable long-term behavior and REL testing

## 3. Low Cost and Cost of Ownership

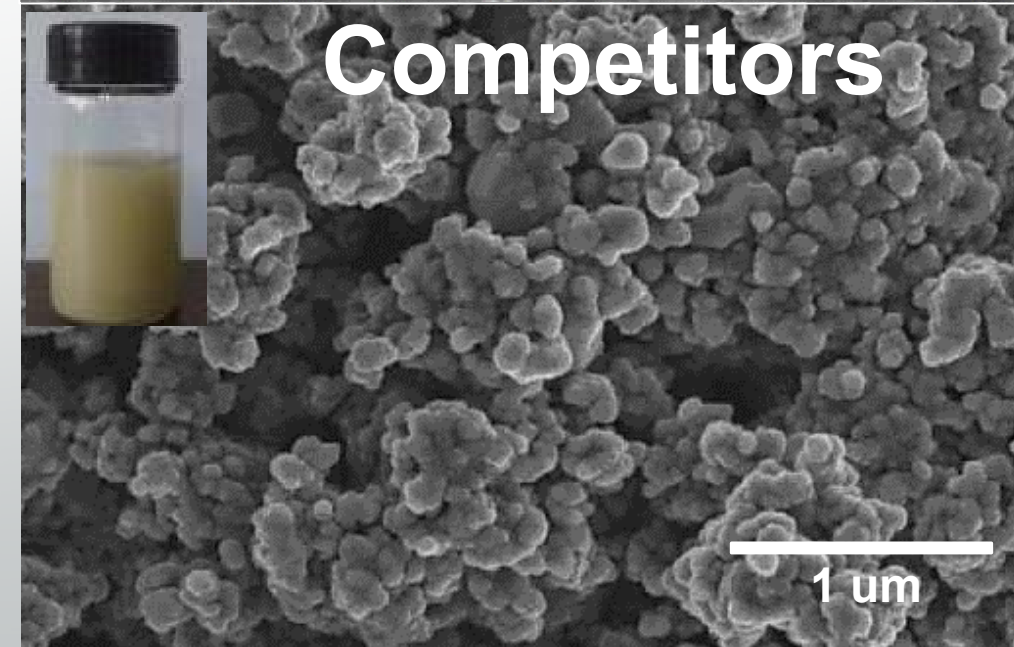
- Patented formulations without metal particle as starting material
- Customers use far less material for same or better performance
- Fine-line features and high conductivity enable streamlined manufacturing



**Electroninks**



**Competitors**



# EI's Digital Printing Products

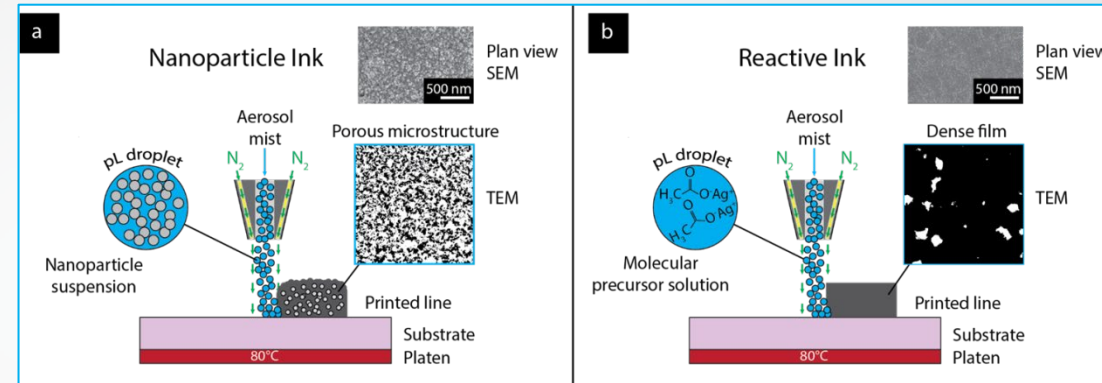
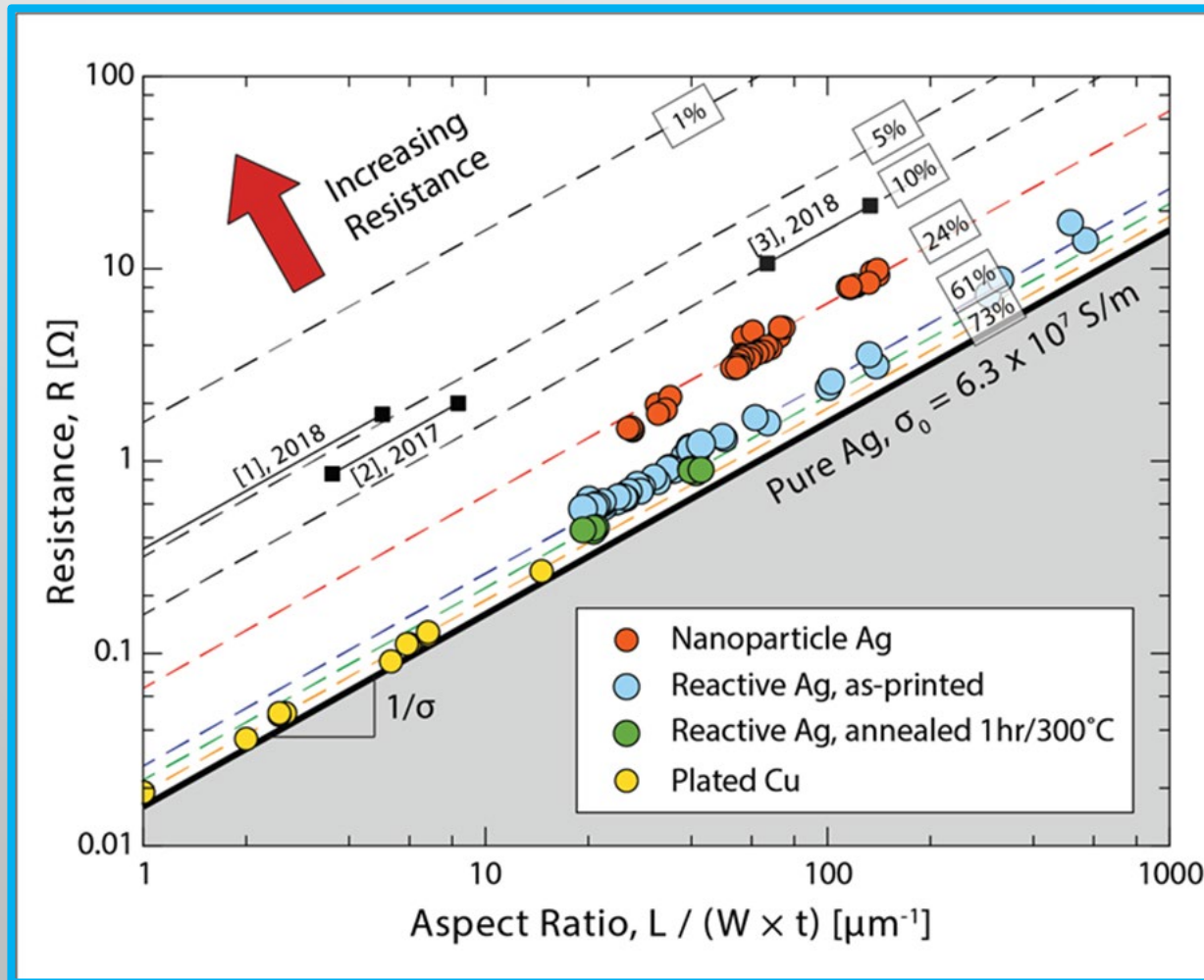
- Digital Printing is an overwhelming majority of current and future products
  - Ag, and beyond including Au, Pt, Pd, Ni
- Engineered with tunable viscosity and curing methods (thermal, photonic)

EI Product	BKR	Material	Market	Print Application	Print Viscosity (cps)	Processability	
900 Series	904	Silver	All screen print applications	Screen print	>30,000	Thermal, NIR, UV	
	909		All screen print applications	Screen print	>40,000	Thermal, NIR, UV	
	918		Via-fill	Dispensing	1,000 – 2,000	Thermal, NIR, UV	
	906		Biomedical/wearable	Screen print – silver/silver chloride	>30,000	Thermal, NIR, UV	
1200 Series	1207		EMI	Spray – adhesion promotion	10 – 30	Thermal, NIR, UV	
	1208		EMI	Spray	10 – 30	Thermal, NIR, UV	
1100 Series	1104, 1121		Jetting – glass/PI	IJP or spray – high temp	10 – 40	Thermal, NIR, UV	
	1112		Jetting – glass/PI	EHD – Drop on demand	10 – 40	Thermal, NIR, UV	
	1125		Jetting – glass/PI	EHD – Electrospin	>10,000	Thermal, NIR, UV	
700 Series	710		Jetting – PET	IJP – low temp	6 – 12	Thermal, NIR, UV	
	711		Jetting – PET	IJP – Adhesion promotion	6 – 12	Thermal, NIR, UV	
EI 600 Series	604		Pre-cursor to downstream EI products	AJP, wire-draw, flexographic	200 – 1000	Thermal, NIR, UV	
EI 1600 Series	1604		Gold	Medical Device/High Temp/Hypersonics	AJP, IJP	10 – 30	Thermal, NIR, UV
EI 1500 Series	1505		Platinum	Gas Sensors	AJP, IJP	10 – 30	Thermal, NIR, UV



# Performance Validated by Customers

<https://pubs.acs.org/doi/abs/10.1021/acsami.0c06959>



- 60 – 70% bulk Ag “as printed”
- 70 – 80% bulk Ag with additional curing
- Electrical properties are similar to plated Cu
- Fundamentally different regime compared to NP inks (~5 – 25% bulk Ag)

# CIRCUITWRAP™

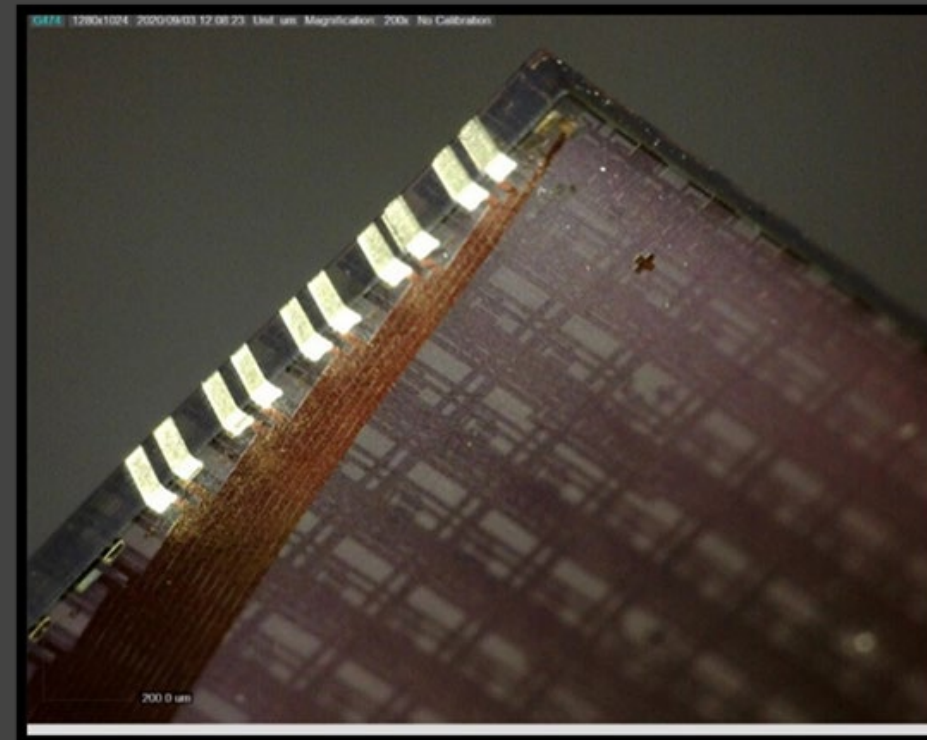
Display – LCD, MiniLED and MicroLED

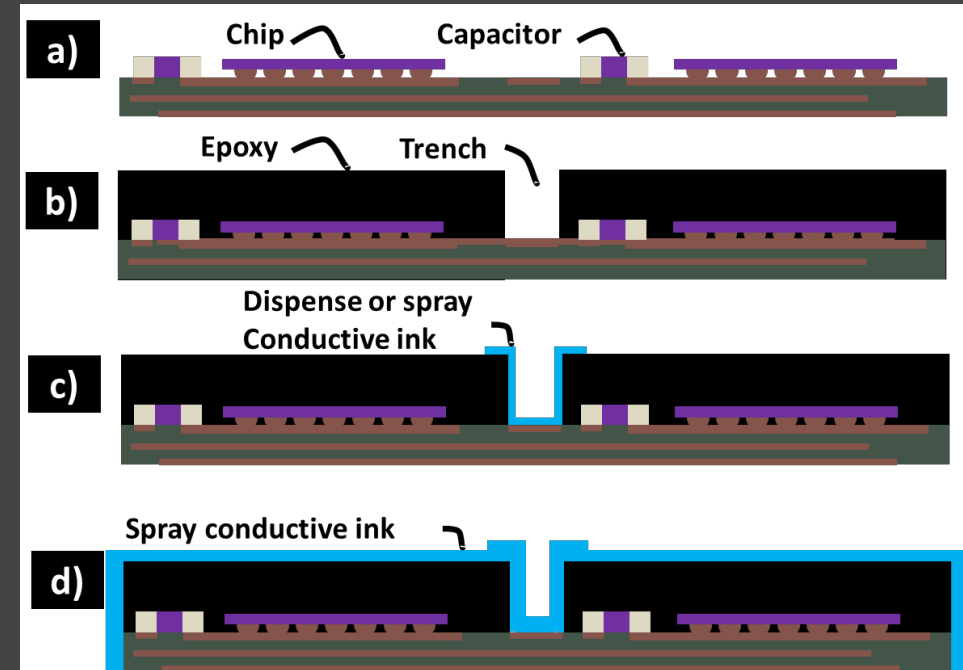
TSP/DA Electrode

Edge-Electrode

Via

Repair





# CIRCUITSHIELD™

## EMI Shielding Work

Package/Chip/Board Conformal

Laminate

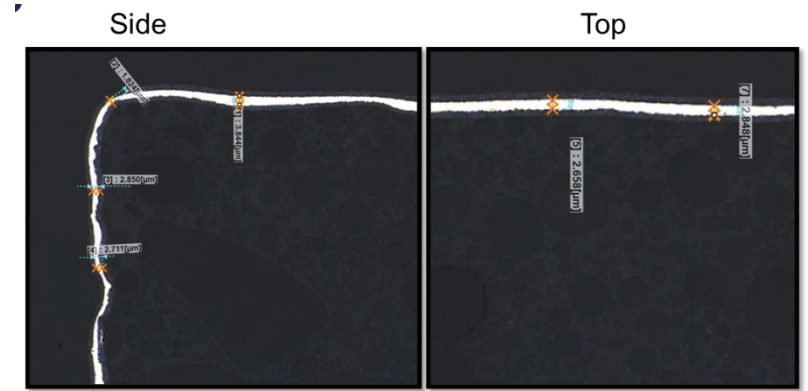
Cable

Fabric

# Process - Metallization of SiP

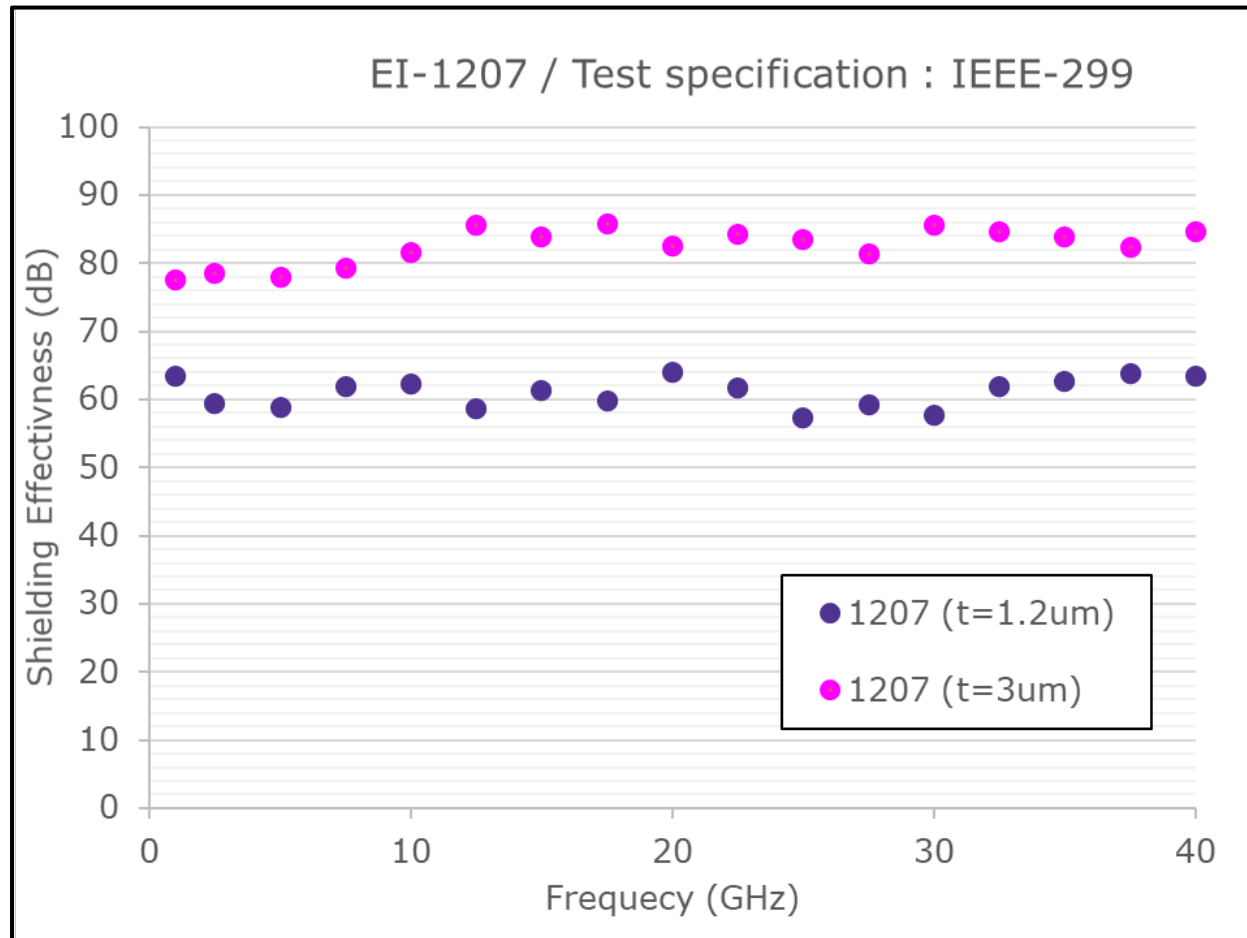


- Film Thickness and Coverage on EMC chips
  - 3 um for top
  - 2.8um for side





# Performance - Shielding Effectiveness of EI Particle Free Ink (IEEE-299)



# CIRCUITEX™

## E-Textiles

Fiber → Yarn → Fabric

Mobility, Healthcare

Antiviral

Electronics for pressure sensing, electrodes

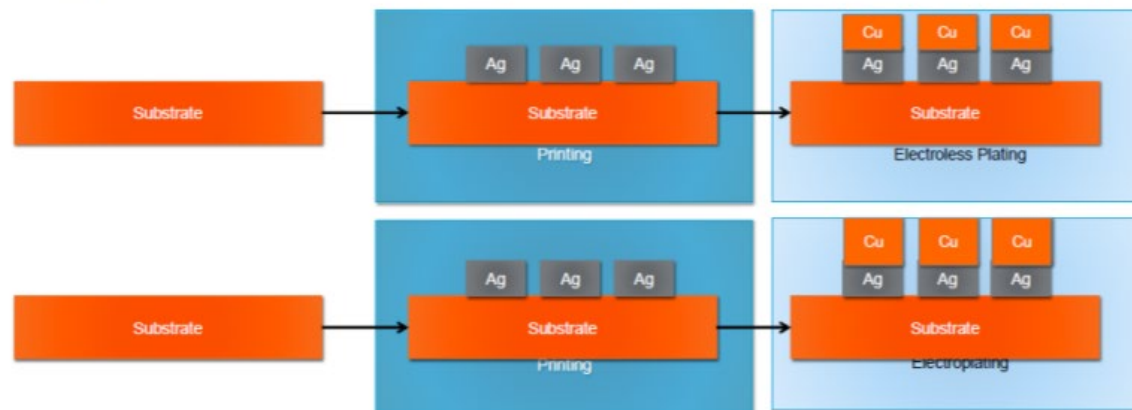
Circuitry for interior LED lighting



IME (in-mold electronics)

E-textiles for embedding electronics into fabric, leather

- Our films are pure metal
  - Catalytically active – electroless plating is feasible (1-10 microns of copper or nickel)
  - Highly conductive – can be directly electroplated (>10 microns of any metal)



# CIRCUITSEED™

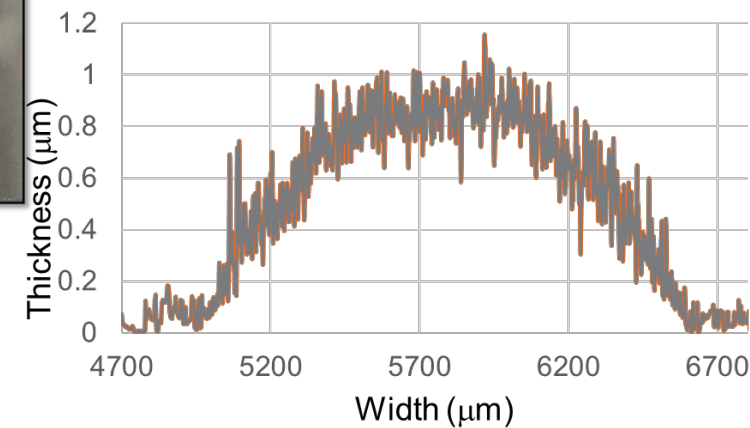
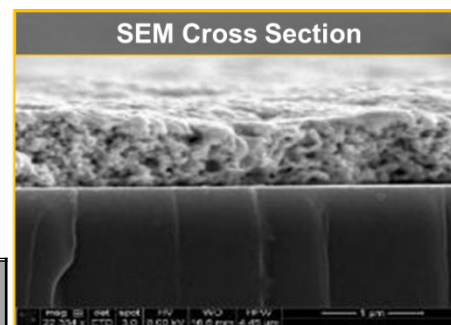
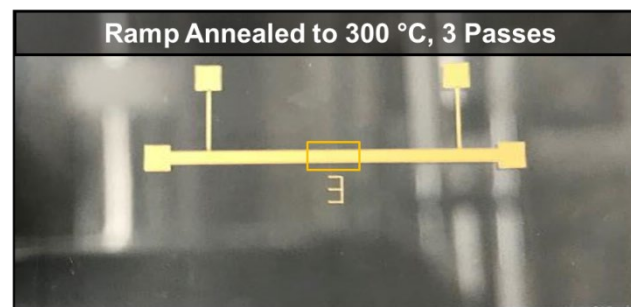
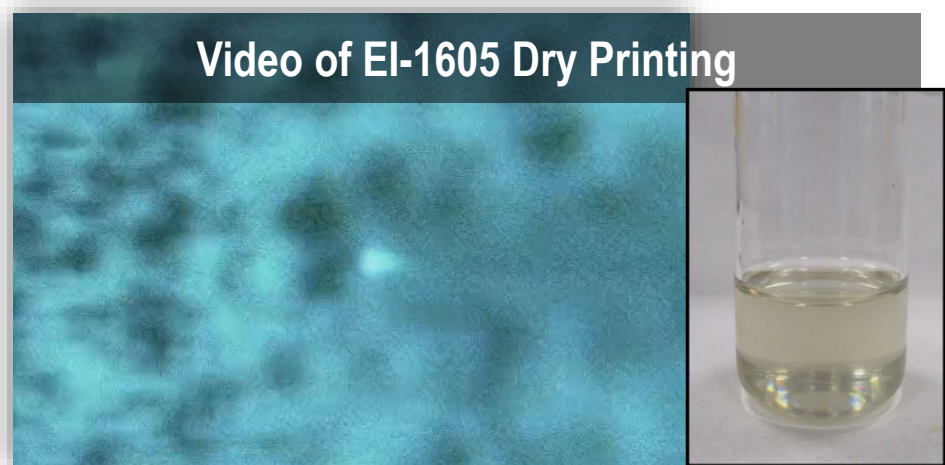
## Directed Seed and Plate

Advanced Packaging

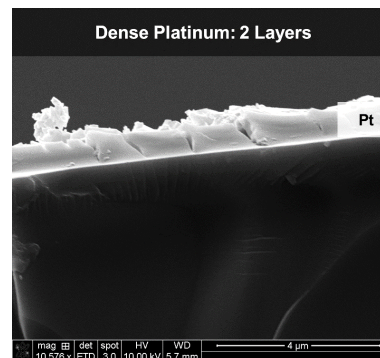
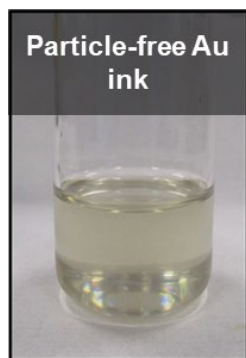
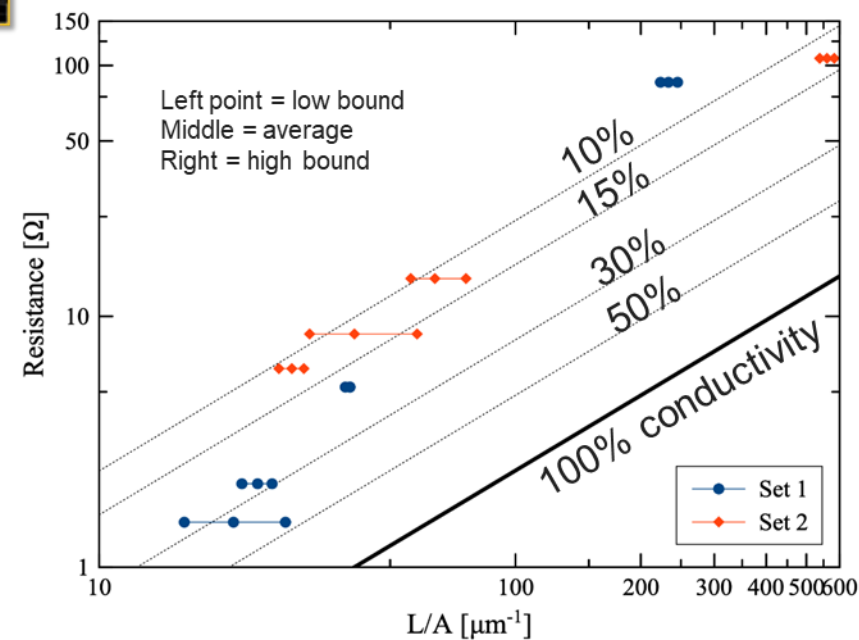
3D TSV and TGV

Gold, Platinum, Nickel Metal Complex Inks

# Beyond Ag: Au, Pt, Nickel inks



Ink ID	Anneal	Avg. Thickness (µm)	Bulk Au Conductivity (%)
EI-1605 (Au)	250C	0.362	30 – 40
EI-1605 (Au)	250C	0.575	45 – 55





# CIRCUITJET™

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All-in-One Closed Ecosystem Rapid PCB Printer

FR4 or PI boards

EI Proprietary Substrates

EI Proprietary Cartridges and Inks

Autodesk Eagle Software via Autodesk<>EI Residency

# CircuitJet

- CircuitJet uses inkjet technology to additive manufacture PCBs at the users desktop. Can literally just print from their desktop and test same-day
- Also partnering with Royal Circuits to roll out CircuitJet as a service
- Logistics Costs are drastically decreased as the boards are created on demand for the user
- Print dialog and menus integrated into Autodesk Eagle allows the user to access traditional professional PCB design tools

## AUTODESK® EAGLE

- Materials are non-toxic and cartridges can be recycled via traditional desktop cartridge recycling centers

