Copprint

Conductive copper Pastes
Portfolio overview

Aug 2022

Transforming the foundation of conductive patterns

Copprint provides conductive copper inks,

enabling additive fabrication of conductive patterns.

Substituting incumbent technologies:

- Silver inks: 5-10x more expensive
- PCBs etching: hazardous, polluting, and more expensive

Backed by Top Strategics
with Significant World Market Share

Copprint

Henkel hp TATSUTA

Electronics is a growing multi-trillion $ market

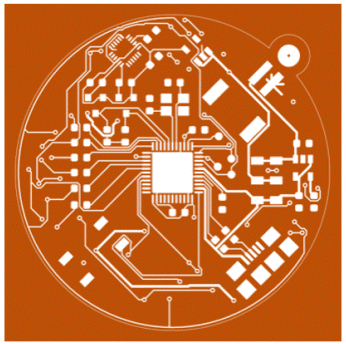
Consumer Electronics, Industrial Equipment, Communications, Automotive, Solar Power and more….

ALL electronics are powered by conductive patterns

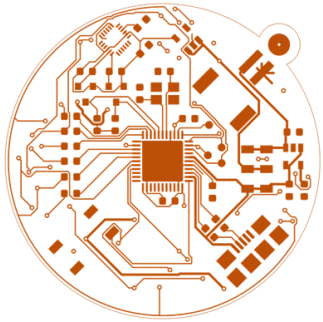
>$70B Market Inside

Copprint

Making conductive patterns:
1. Chemical etching
>$70B Mkt



Material Waste



Conductive Pattern

Chemical “cutting” of metal sheets (subtractive manufacturing)

- Material Waste
- Limited Substrates
- High Water Consumption
- Toxic/Polluting Chemicals
- Offshoring (90% APAC)
- Increasing Regulatory Costs

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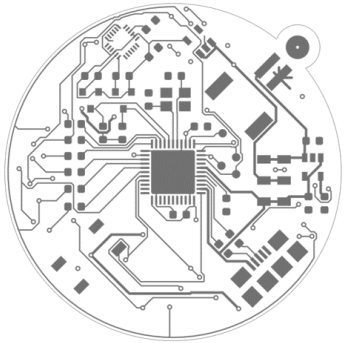
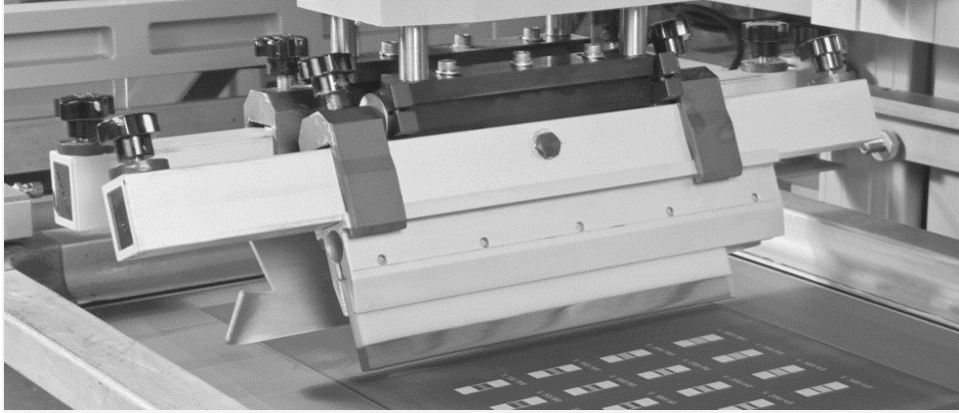
Making Conductive patterns:
2. Silver ink printing
> $3B Mkt



Screen printing of conductive silver inks (Additive Fabrication)



- ✗ Prohibitively Expensive
- ✗ Limited Adoption/Use
- ✗ Toxic

Copprint

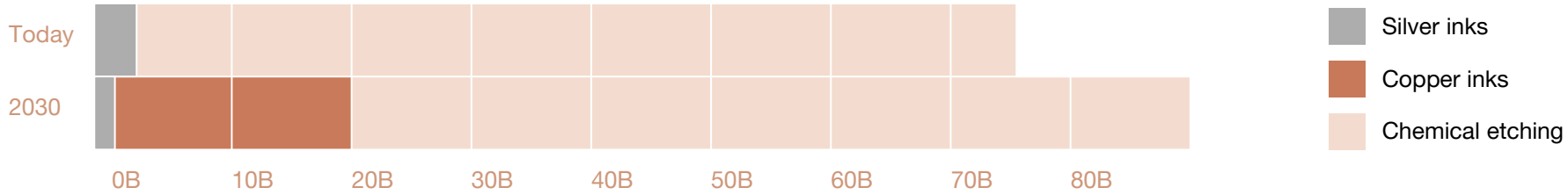
Introducing Copprint Conductive Nano Copper inks

Simply print conductive patterns, using copper

The future of printed electronics is...copper

Low cost, **sustainable**,**‘reshoring’** printed circuit fabrication alternative!

Unleashing a $70B market for additive fabrication of PCBs, antennas and photovoltaic cells...



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Silver vs. Copper

Conductive silver inks are used since 100 years ago for many applications:

E.g. Photovoltaics, Membrane switches, sensors, heaters and more

Silver is expensive and recently **surged ~50%** relative to its 5-years average.

Copper is a great alternative

Raw material comparison:	Silver	Copper	Copper vs Silver
Price per Kg	$850	$8	100X cheaper
Conductivity	1.59×10^{-8} Ωm	1.68×10^{-8} Ωm	5% less conductive
Carbon footprint	155 kgCO2/kg	3.97 kgCO2/kg	40X better
Max level in drinking water (EPA)	0.1mg/litter	1mg/litter	10X less toxic
Abundance in Earth's crust	0.08 ppm	68 ppm	~1000X more abundant

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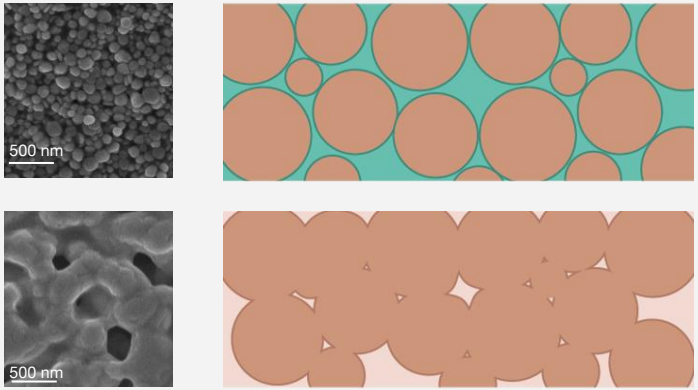
Copper Oxidation, Impeding Conductivity



Copprint Chemical Rapid Sintering

Motivation: raw copper is 100x cheaper than silver
Problem: **Copper oxidation** prevented conductivity

The Innovation

Copprint overcome the copper oxidation using a patented chemical sintering agent:

- Rapid low temperature Sintering which Prevents Oxidation
- Highly Conductive results
- Low Cost, Efficient (No Material Waste)
- Substrate Freedom
- Standard “Air” Printing Process & Equipment

Copprint

Copper inks that outperform Silver

Anything you can print with conductive silver inks,

Copprint can do better. Faster. At a fraction of the cost.

Copprint screen-printing pastes for a range of substrates:

LF-300 – paper substrate

LF-350 – PET substrate

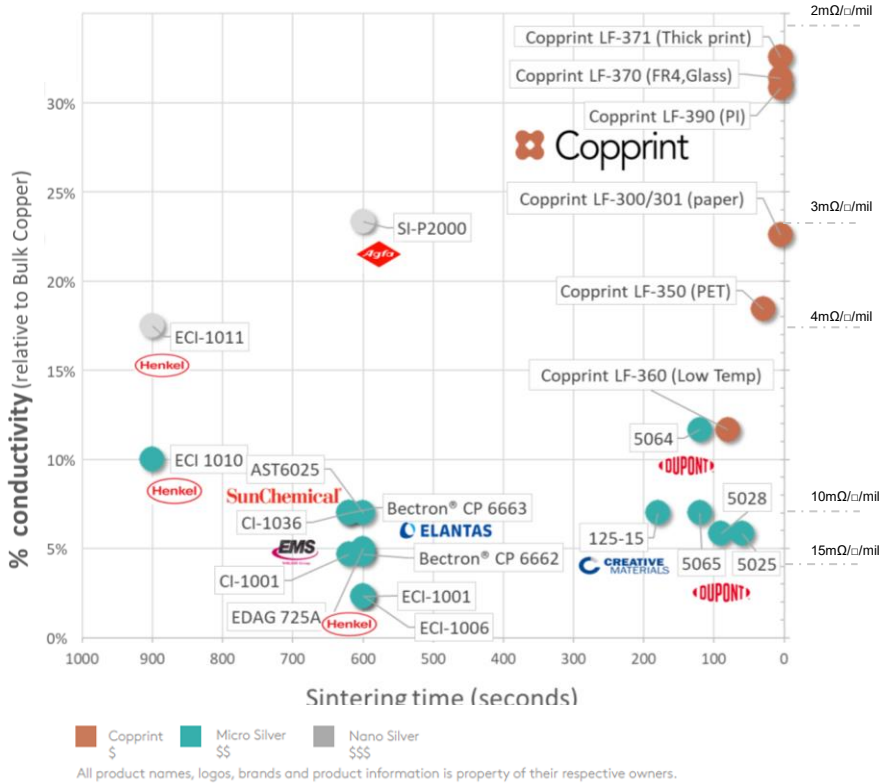
LF-360 – Low temp for PET/PC

LF-370 – FR4 substrate

LF-371 – Thick printing (FR4, PV, Glass, PI)

LF-390 – PI substrate

Additional substrates: Glass, Alumina, Aluminum, PC, PEN, CFRP, Tesline



Copprint

Copprint's pastes for various substrates

Paste	Substrate	Viscosity (cPs)	Sintering Temp °C	Processing	Sheet resistance mΩ/□/25μm	Solid content
LF300	Paper	7,000	280-300	R2R	<3	83%
LF301	Paper	2,000	240-260	R2R	<3-6	81%
LF350	PET	6,000	200	S2S	<4	81%
LF360	Low-temp PET, PC	15,000	160 140	S2S + R2R	<6 <9	88%
LF370	FR4/Alumina/Glass/Aluminum..	9,000	240-300	S2S + R2R	<2.3	88%
LF371	FR4/Alumina/Glass/Aluminum..	30,000	240-300	S2S + R2R	<2.3	90%
LF380	HJT PV	500,000	240-300	S2S	<2.3	90%
LF390	PI	15,000	240-300	S2S + R2R	<2.3	88%

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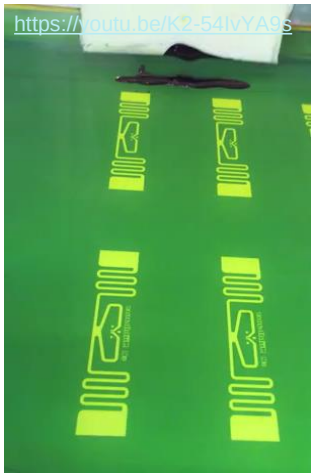
Really Simple Fabrication (Prototyping, Short Runs)

1) Print



Screen printing in few seconds

2) Dry

Drying oven/conveyor/UV

Oven/Conveyor: 30-120 sec at 70-150°C
NIR/UV lamps – 1-5 seconds

3) Sinter

https://youtu.be/Hd5vRxiqODs

Standard hot-press/contactless Laminator
140-300°C
Laminator – 3-12 sec dwell time
Hot-press – 30-240 sec

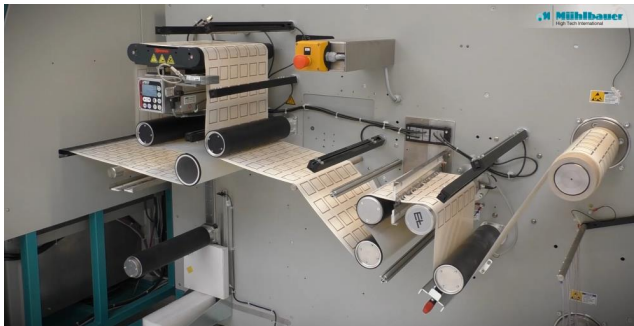
Copprint

Muhlbauer APS tailored to Copprint ink

Industrial Scale Antenna Printing Solution

1) Print 2) Dry 3) Sinter

https://youtu.be/lRwgXEcGViA



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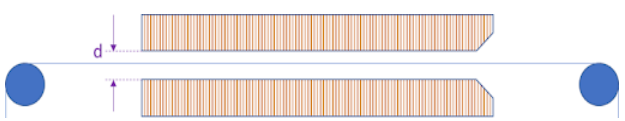
Snap heating is required for sintering

Contactless laminator:

Simple and robust system for S2S and R2R implementation.

Temperature 170^{o}-320^{o}C

Typical dwell time – 3-12 seconds.



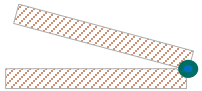
<$200 @Amazon.com

Simple hot-press (Manual or pneumatic):

Simple and robust system for S2S - Temperature 140^{o}-300^{o}C

No significant pressure is required – just efficient heat transfer.

Sintering of >30 sheets in parallel in a single press was tested



<$200 @Amazon.com

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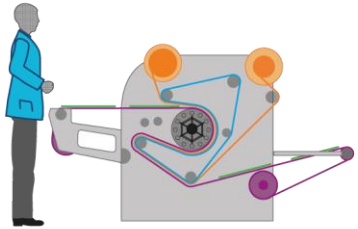
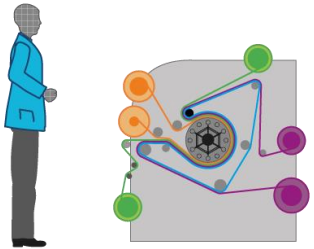
Hot roller sintering

Sheet to Sheet



Roll to Roll



Sheet to Sheet sintering on PET @2meter/min

https://youtu.be/kYLSc9YqFQY

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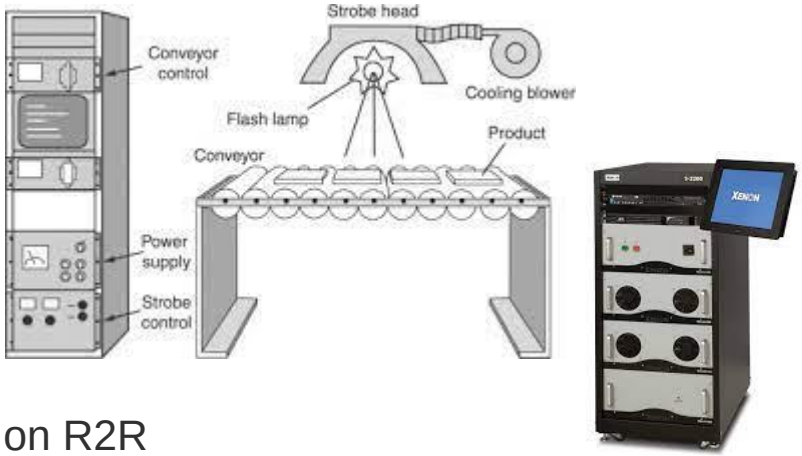
R2R sintering (cont)



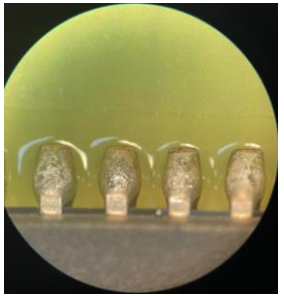
Photonic sintering – Reported to be working well on R2R

NIR sintering – In beta for R2R sintering

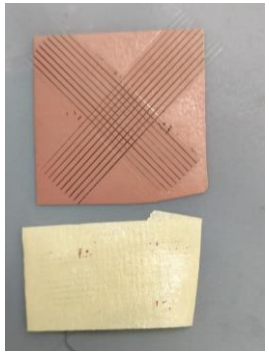
Copprint

Durable printed patterns on multiple substrates

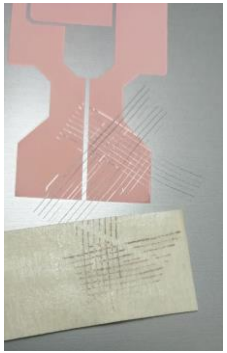
- ✓ Paper, PET, PI, Teslin, Aluminum, Alumina, FR4, Glass, PV cells
- ✓ Accelerated durability tests (90°/60%, 85°/85% tests)
- ✓ Excellent adhesion
- ✓ Crosshatch test – 4-5b
- ✓ Bending tests (25x rolls over 5mm radius rod, <10% change).
- ✓ Solderability



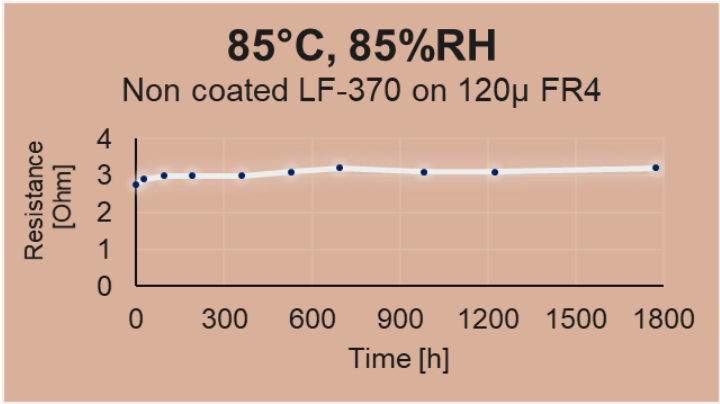
https://youtu.be/JedfsK63tXs



LF-350 on PET



LF-370 on anodized aluminum



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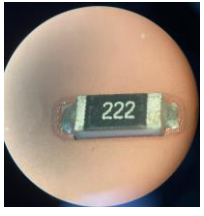
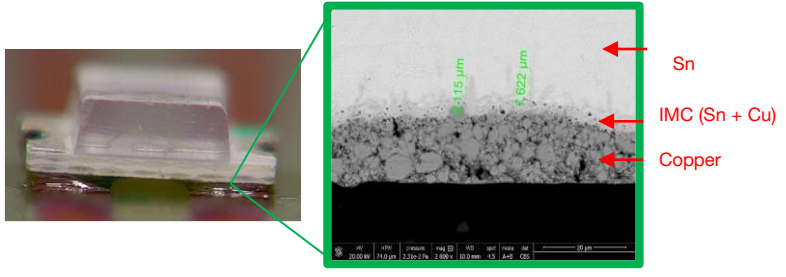
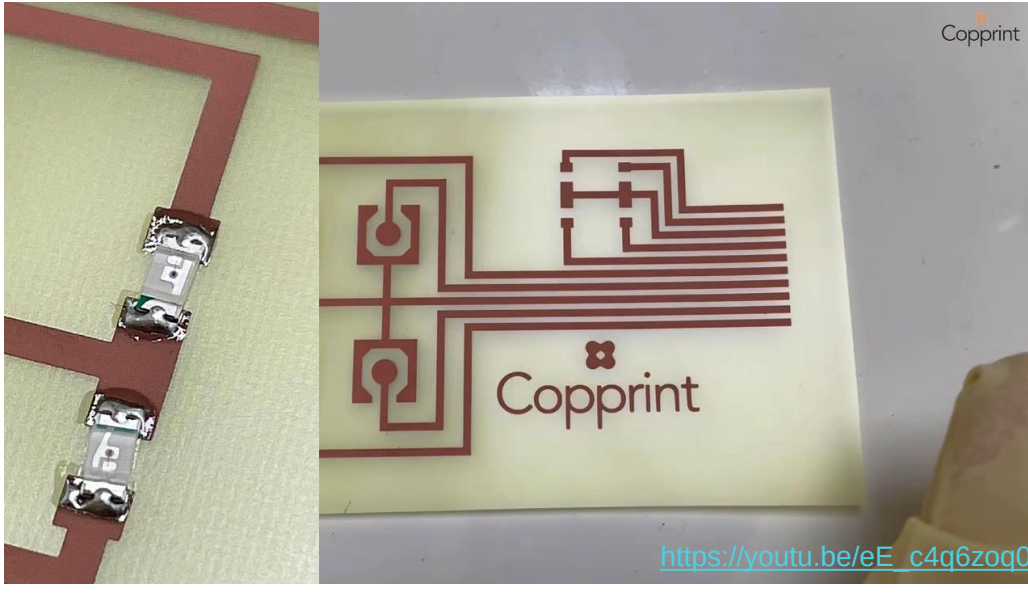
Soldering in a reflow oven (printed copper traces on FR4 & PET):

- Excellent adhesion and high-quality IMC (Intermetallic compound)





- On PET - Finally, an alternative to ECAs (electrically conductive adhesive). These ECAs are silver based and much expensive relative to soldering.



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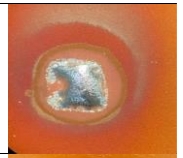
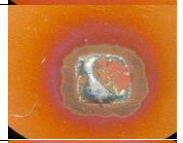
Testing soldering using die-shear

Copprint

Soldering on FR4: Wetting vs. Shear force

Composition	Brand	Name	Minimal force [Kgf]	Wetting	
SAC305	Loctite	318	>3.1	OK (best)	
SAC305	AIM	M8, 88.5-T4	>4	Some dewetting	
63-37	AIM	M8 89.5-T4	>3.2	Poor (balling)	
SAC305	Shenmao	PF606-P(20-38um)	>3.7	Some dewetting	

Wetting test does not predict the shear force performance

Copprint

LF-300/LF-301

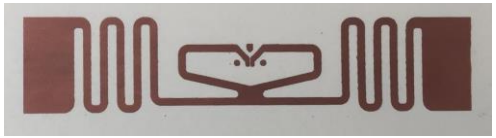
Conductive copper paste for screen-printing on Paper substrate

Copprint

LF 300/LF 301 – Copper paste for screen printing on a Paper substrate

- Key usage: RFID antennas – **compostable RFIDs**
- High conductivity
- Low cost and compostable UHF/HF/NFC RFID antennas
- Typical printing thickness for RFID antennas 3-8 micron thickness.
- Multiple durable paper approved (Verso, Mitsubishi and more).
- Accelerated durability tests (90°/60%, 85°/85% tests)
- Bending tests (25x rolls over 5mm radius rod, <10% change).
- Die-shear tests

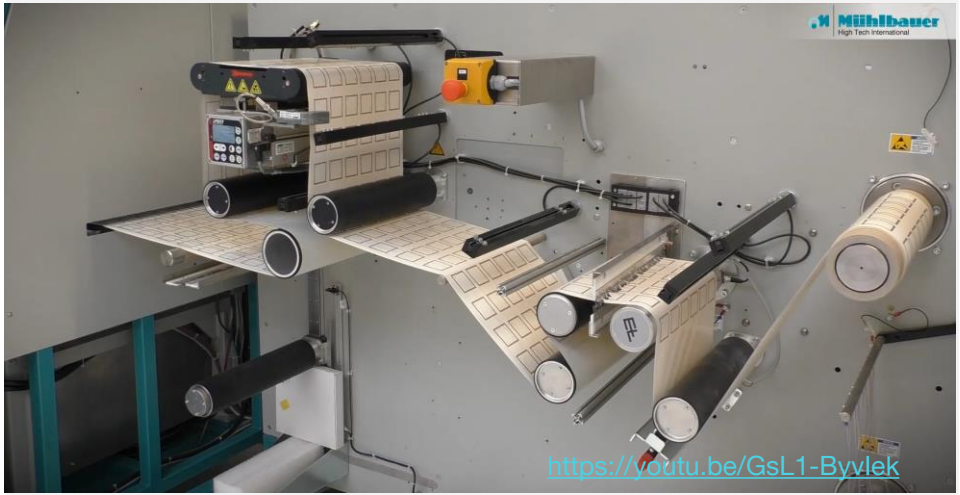
Copprint



https://youtu.be/JedfsK63tX

Partnership: Muhlbauer

- >90% of RFID manufactured using MB machines
- Custom built printer for Copprint inks - APS – available



Copprint

Printed RFID antennas – on every merchandise

Printed antennas are cheaper and eco-friendly

RFID	Etched Aluminum on Plastics (PET) (>90% of the market)	Copprint Printed Nano Copper on Paper
Manufacturing	Highly polluting (China and Malaysia)	Simple printing
Turnaround	6 weeks	1 week
Tag disposal	NON recyclable: Plastics, Aluminum High volume, small pieces	Compostable, Green RFID Paper, Minimal copper traces
UHF antenna cost	0.2-0.6¢	Up to 30% cheaper (depending on geometry/volume)
NFC antenna cost	1¢	<0.4¢

20B units 2019 to 1T units by 2025

Cheaper than Etching!

Copprint

LF 300/LF301 - Additional resources

- Video – How to Copprint LF-300 : https://youtu.be/8pDF_dUSxL0
- TDS LF300 - http://copprint.com/wp-content/uploads/2020/11/TDS-LF-300.pdf
- TDS LF301 - https://www.copprint.com/wp-content/uploads/2021/12/TDS-LF-301-Beta-22-08-21.pdf
- MSDS - http://copprint.com/wp-content/uploads/2020/11/MSDS-rev10-LF-products.pdf
- Application notes - http://copprint.com/wp-content/uploads/2020/11/Application-notes-Copprint-LF-300.pdf

- Video – Who cares about the Tag? Compostable RFID antennas https://youtu.be/5S8alzlz4b0
- Video - Compostable NFC antennas https://youtu.be/obncn1XtWLU

Copprint

LF-370/LF-371

Conductive copper paste for screen-printing on FR4, Glass, Alumina, Aluminum…

Copprint

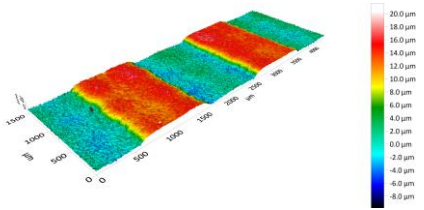
LF-370 / LF-371 - High-end Printed electronics inks

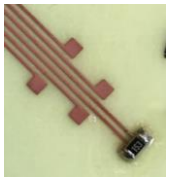
- ✓ ~2.2mΩ/□/mil
- ✓ ~5.3 μΩcm
- ✓ 85-90% solids
- ✓ Excellent 85/85 performance
- ✓ Excellent adhesion
- ✓ Crosshatch test – 5b
- ✓ Solderability
- ✓ Simple S2S and R2R implementations via contactless sintering

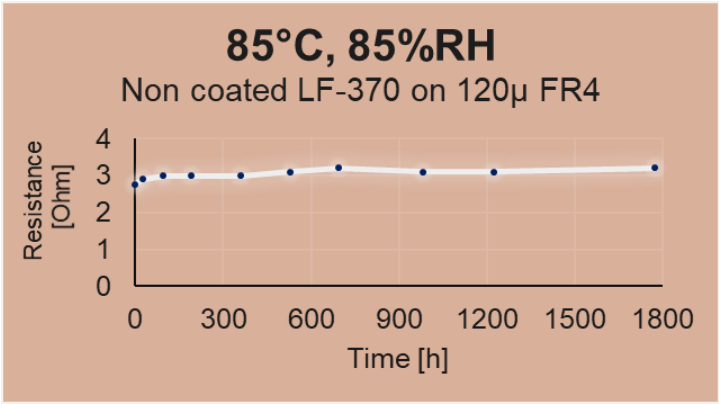
- ✓ FR4, Glass, Alumina, Aluminum

- ✓ LF-370 Viscosity – 7,000cPs.
- ✓ LF-371 Viscosity – 30,000cPs (Thick printing)

- ✓ Applications:
- ✓ One-sided / Two-sided PCBs
- ✓ LED mounts on FR4, Aluminum
- ✓ Glass printing for displays
- ✓ PV metalization



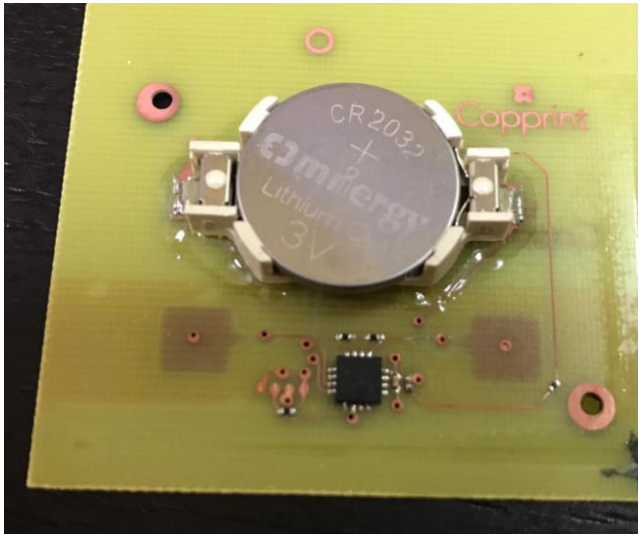


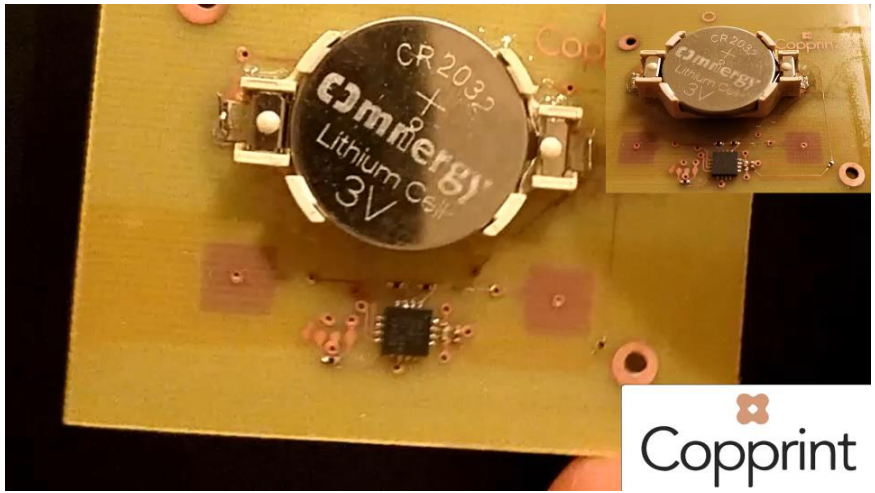


LF-370 / LF-371 – Simpler production of 1-sided and 2-sided PCBs

- ✓ Sintering via contactless sintering
- ✓ Sintering of both sides (and the via paste) together

https://youtu.be/mnsLaIBA5iA





Coppint

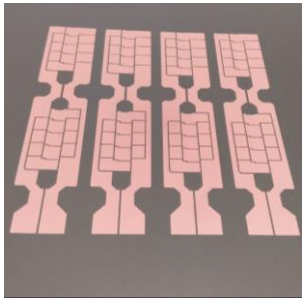
Glass printing for LED display boards

- Printing on Glass for transparent glass LED display

Copprint

Printed copper traces on LED aluminum baseboard

Pre-cut anodized aluminum

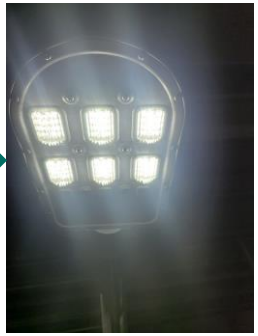


Copper printing

SR Printing

LED SMT

Assembly



Testing

ipss.co.kr

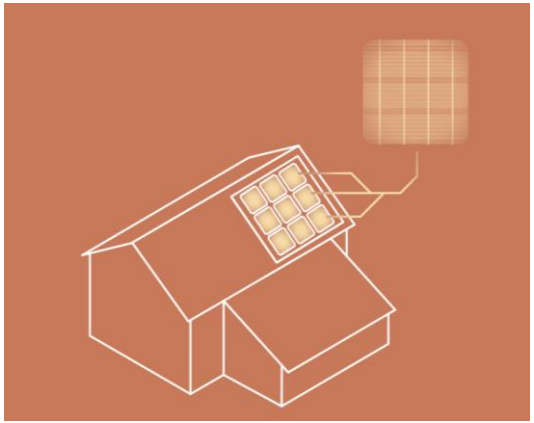
Copprint

Printed copper traces on PV wafers

Silver inks used in PVs are made comprise 20-30% of the PV module cost

Copprint already demonstrated high-efficiency working HJT and IBC PV cells with >10% $/watt cost saving per module!

Passing DH2000 (85°/85%, 2000 hours) , TC400 (-40°:+85° x 400 cycles)

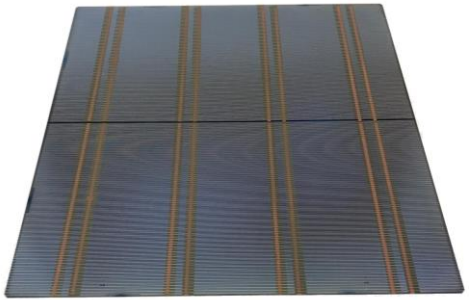


Dramatically reducing cost / Accelerating green energy sources.

IBC cells in collaboration with:

ISC International Solar Energy Research Center Konstanz

Copprint



LF 370/371 - Additional resources

- Video – How to Copprint LF-370 : https://youtu.be/CdjpUZjjPg0
- TDS - http://copprint.com/wp-content/uploads/2020/11/TDS-LF-370.pdf http://copprint.com/wp-content/uploads/2020/11/TDS-LF-371.pdf
- MSDS - http://copprint.com/wp-content/uploads/2020/11/MSDS-rev10-LF-products.pdf
- Application notes - http://copprint.com/wp-content/uploads/2020/11/Application-notes-Copprint-LF370-371.pdf
- Laminator modification guide - https://www.copprint.com/wp-content/uploads/2022/03/TLC-laminator-modifications-Nov21.pdf

Copprint

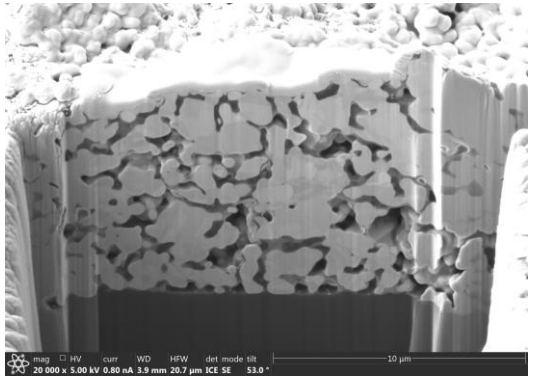
LF-390

Conductive copper paste for screen-printing on PI

Copprint

LF-390 – Conductive copper ink for PI (Polyimide)

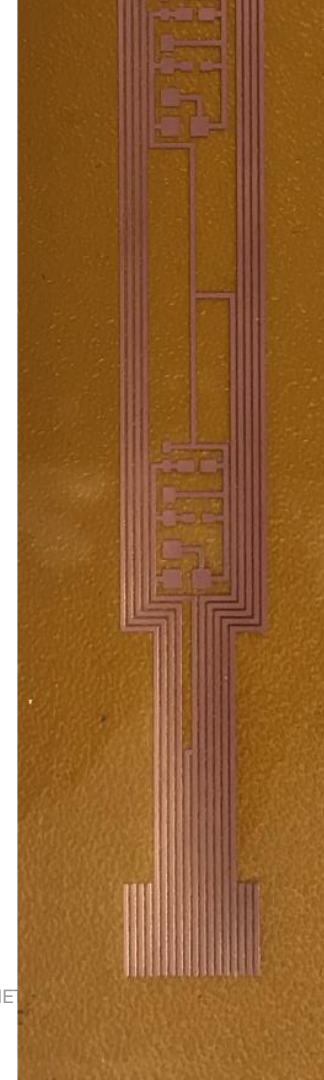
- ✓ ~2.2mΩ/□/mil
- ✓ ~5.3 μΩcm
- ✓ LF-390 Viscosity – 15000cPs
- ✓ 85-90% solids
- ✓ Excellent 85°/85% performance
- ✓ Excellent adhesion and flexibility
- ✓ Simple S2S and R2R implementations via contactless sintering



Cross-section after sintering

Applications:

- ✓ Sensors
- ✓ Flexible PCBs
- ✓ Connectors



Copprint

LF 390 - Additional resources

- Video – How to Copprint LF-390 – same video as LF-370 : https://youtu.be/CdjpUZjjPg0
- TDS - http://copprint.com/wp-content/uploads/2020/11/TDS-LF-390.pdf
- MSDS - http://copprint.com/wp-content/uploads/2020/11/MSDS-rev10-LF-products.pdf
- Application notes - http://copprint.com/wp-content/uploads/2021/02/Application-notes-Copprint-LF390.pdf

LF-350

Conductive copper paste for screen-printing on PET

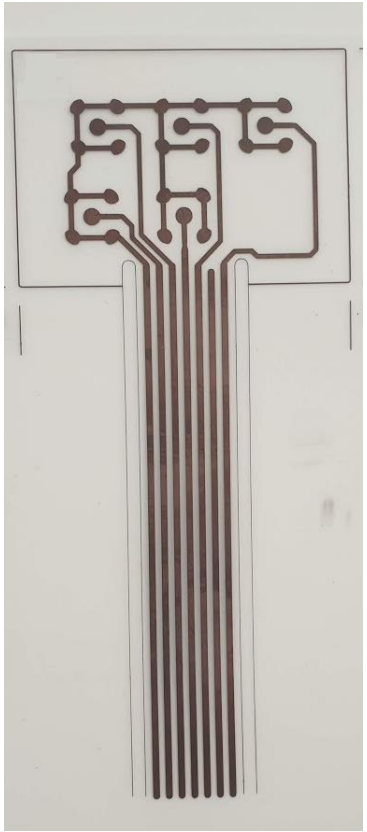
Copprint

LF-350 – Conductive copper ink for PET

- ✓ ~4mΩ/□/mil
- ✓ LF-350 Viscosity – 5000cPs
- ✓ Excellent adhesion and flexibility
- ✓ Solderability
- ✓ Simple, high throughput S2S process
- ✓ R2R via photonic sintering (tested), hot-roller and NIR (beta)

Applications:

- ✓ Heaters
- ✓ Membrane-switches
- ✓ Sensors
- ✓ Antennas



Copprint

Automotive Silver heaters vs Copper heaters

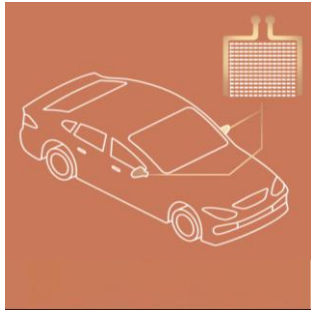
- Seat heater
- Interior panel heater
- Battery Heater
- Technical heater

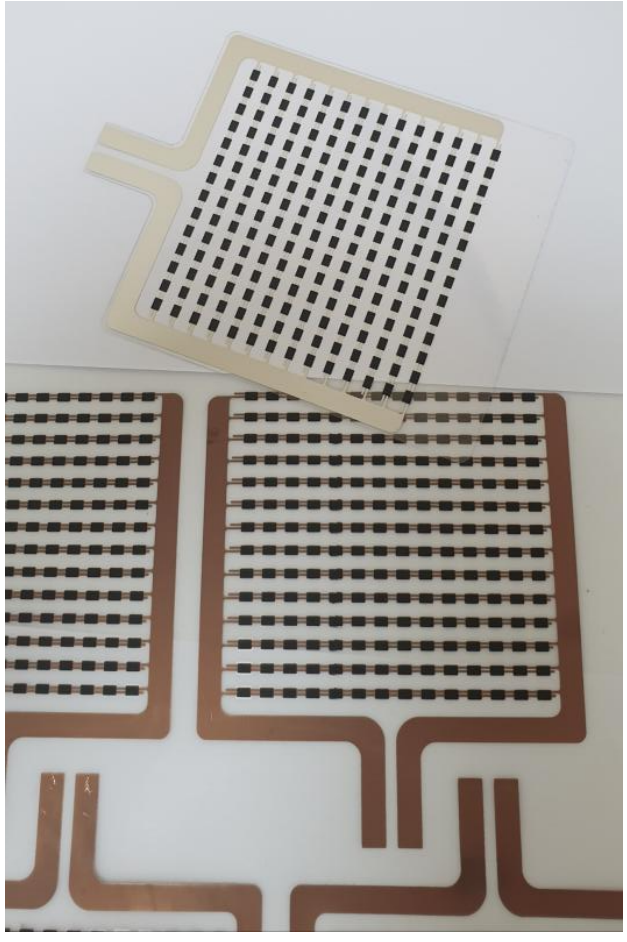
Same design

Same electrical properties

Same performance

5-10x cheaper





Copprint

LF 350 - Additional resources

- Video – How to Copprint LF-350 - https://youtu.be/0chiF8vVGFY
- TDS - http://copprint.com/wp-content/uploads/2020/11/TDS-LF-350.pdf
- MSDS - http://copprint.com/wp-content/uploads/2020/11/MSDS-rev10-LF-products.pdf
- Application notes – http://copprint.com/wp-content/uploads/2021/01/Application-notes-Copprint-LF350.pdf

LF-360

Conductive copper paste for low temp sintering on PET/PC

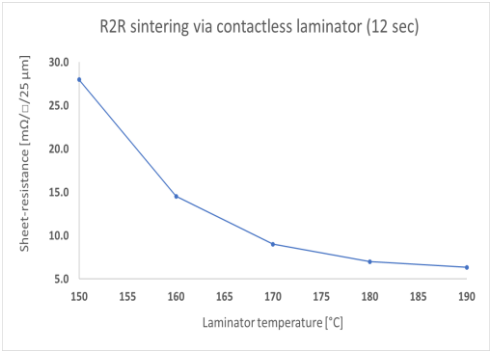
Copprint

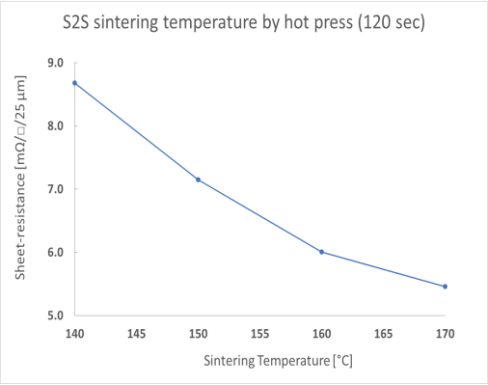
LF-360 – low-temp sintering

- ✓ ~6mΩ/□/mil
- ✓ PET and PC
- ✓ LF-360 Viscosity – 15,000cPs
- ✓ Excellent adhesion and flexibility
- ✓ Solderability
- ✓ Simple, high throughput S2S process 60-120 seconds using a heat-press 140°C-160°C

- ✓ R2R:
  - Contact-less laminator (between two hot plates) – 12 seconds @170°C -> ~9mΩ/□/mil
  - photonic sintering
  - NIR

Applications:
- ✓ Heaters
- ✓ R&R underfloor heaters
- ✓ Membrane-switches
- ✓ Sensors
- ✓ Antennas





Copprint

LF 360 - Additional resources

- Video – How to Copprint LF-360 – https://youtu.be/9OIQMHJWf50
- TDS - http://copprint.com/wp-content/uploads/2021/03/TDS-LF-360-draft-3-3-21.pdf
- MSDS - http://copprint.com/wp-content/uploads/2021/03/MSDS-rev11-LF-products.pdf
- Application notes: http://copprint.com/wp-content/uploads/2021/03/Application-notes-Copprint-LF360-draft.pdf
- Video – sintering using a hot-roller: https://youtu.be/kYLSc9YqFQY

Thank you.

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