

# Coppriint

Copper inks:  
From printing PCBs to  
PCBA (PCB Assembly) -  
cutting more than 100  
Megaton CO<sub>2</sub> per annum

Dr. Ofer Shochet, CEO & Co-founder

Improving CO<sub>2</sub> emissions  
Cutting costs  
Reducing pollution  
Manufacture anywhere

# Copprint: Transforming the foundation of conductive patterns

## Lower-cost, Sustainable



# RFID antennas

## Today

>40 Billion tags/year

Chemical etching aluminum on plastic

- Cost sensitive
- Eco-enemy – non-recyclable, non-degradable plastic & aluminum
- Polluting manufacturing (APAC)



 Copprint

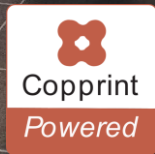
## Copprinting™

Printed conductive copper ink on paper

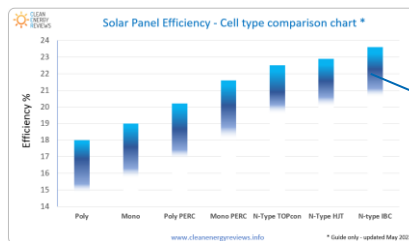
- Green eco-friendly **Compostable RFID tags**
- Onshore manufacturing
- Lower cost
- First 1M tags made by an EU customer shipped for commercial usage –2024



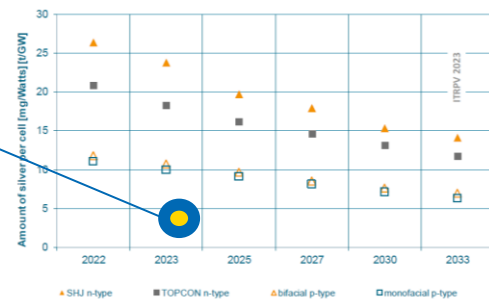
# IBC Cu-Zebra Solar Modules



- ✓ Highest efficiency, lowest Silver
- ✓ Passed all durability tests: incl 3500h 85/85 test
- ✓ 10 years ahead of the market!
- ✓ First 1GW line is planned in ~12 month
- ✓ Cost saving per 1GW line relative to silver: \$11M/year



Trend for remaining silver for metallization per cell (front + rear side)  
(Values for M6, M10, and G12 cell size, average)



Electronics is a growing multi-trillion \$ market



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

ALL electronics are powered by conductive patterns  
“circuit board” aka PCB



>\$80B Market

# PCBs: Highly polluting industry

~0.5% of total world CO<sub>2</sub>e



# Equivalent to CO<sub>2</sub>e of Argentina



Why do we call it a PCB?

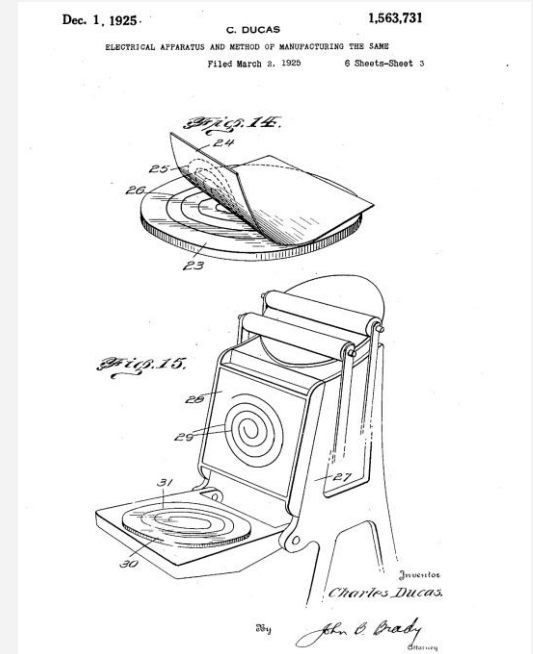
## Printed Circuit board



But it is not printed !?  
It is made using chemical  
etching.



1925 - first PCB was  
patented and fabricated:  
**Printing** conductive paste  
(silver based) on a board

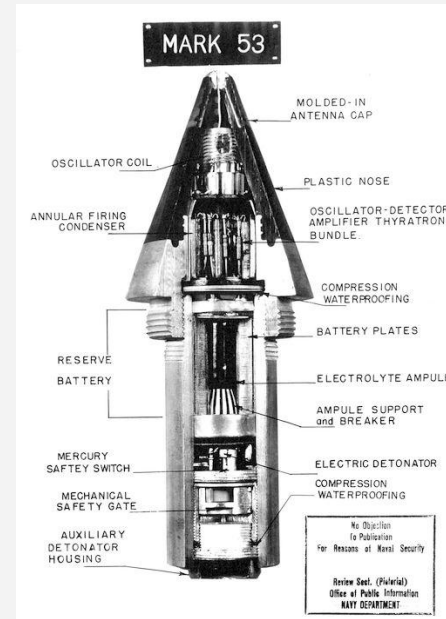


# WWII: MARK 53 Proximity fuse

Large-scale production of multi-layer silver-printed PCB in 1943

Requirements:

- withstand being fired from a gun
- could be produced in quantity
  
- Silver circuit screen printed on a ceramic puck - subminiature vacuum tubes soldered in place.
- Price per fuse went from \$732 to \$18
- 1945 over **22 million fuses** were built.



# New Advances in Printed Circuits

Brunetti, Cleo (22 November 1948). [\*New Advances in Printed Circuits\*](#). Washington DC: National Bureau of Standards.

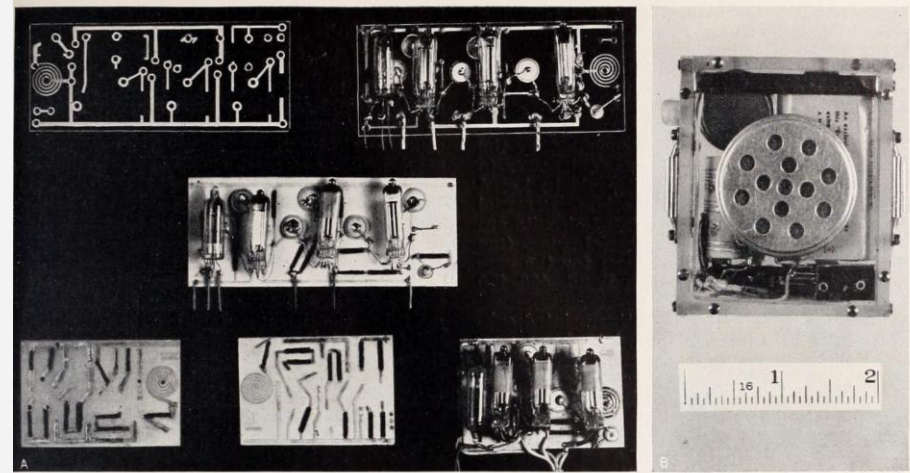
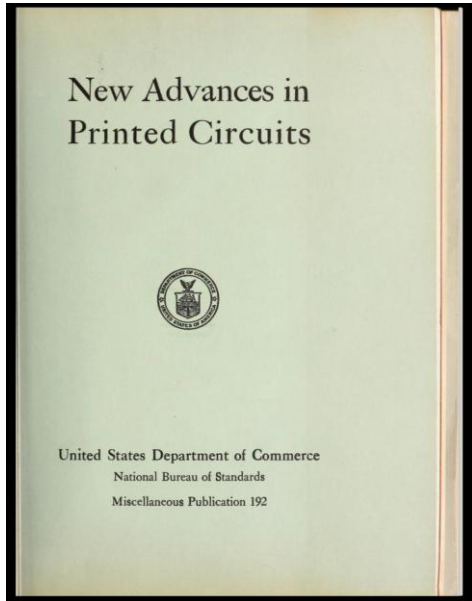
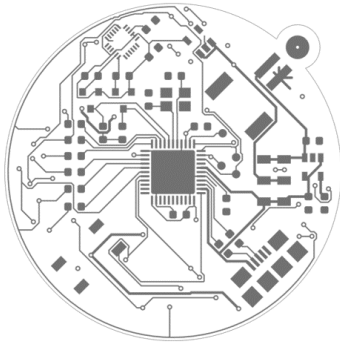


FIGURE 1.2

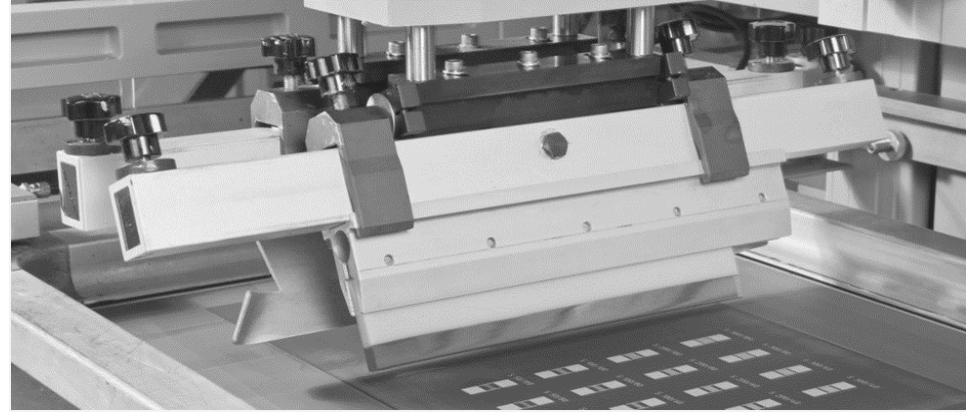
A. Top row, four-tube radio receiver printed on a  $3/32$  in. lucite plate, 2 in. wide and 5 in. long. The silver circuit wiring (applied through a stencil) is shown on the plate at the left, with the completed receiver at the right. Battery and speaker are omitted. Center row, four-tube radio receiver unit printed on thin steatite plate. All receivers have four stages, consisting of an input stage of square law detection followed by two stages of pentode amplification, and a triode output stage feeding a permanent-magnet type speaker. Bottom row, two developmental stages of a four-tube radio receiver printed on a thin steatite plate, 2 in. wide and 3 in. long. The plate at the left shows a complete circuit wiring (less tubes and capacitors) applied free hand with a camels-hair brush except for the spiral inductors. Wiring on the center plate was applied with a squeegee through silk screen stencils. The leads from the complete receiver at the right are for a battery and speaker.

B. Two-tube wrist transmitter for personal use, complete with batteries.

# 1. Silver ink printing > \$5B Mkt



Screen printing of conductive silver inks (Additive Fabrication)

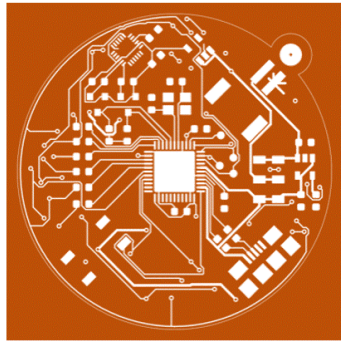


## First silver PCBs: 1920s

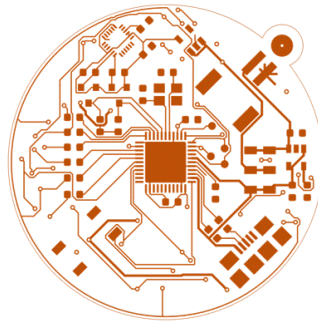
Today – mainly for photovoltaics.  
For Consumer Electronics – mainly keyboards,  
membrane switches and sensors.

- × Prohibitively Expensive
- × Limited Adoption/Use
- × Toxic
- × >40x CO<sub>2</sub>e than Copper

## 2. Chemical etching



Material Waste



Conductive Pattern

Chemical “cutting” of metal sheets  
(subtractive manufacturing)

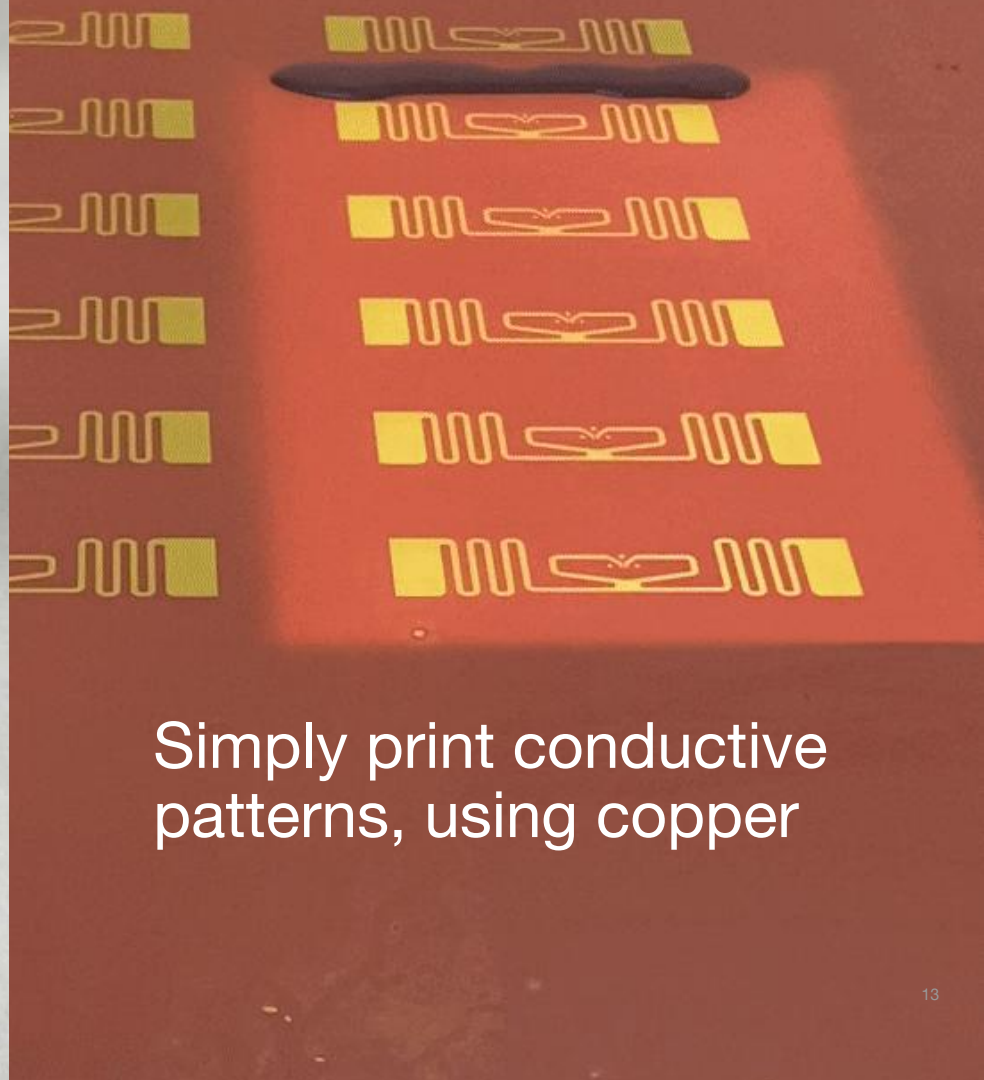


Since 1950s, PCBs are etched!

- × Toxic Materials & Waste 
- × Limited Substrates
- × High Water Consumption
- × ~90% manufacturing @APAC
- × ~0.5% of total world CO<sub>2</sub> emission!
- × Increasing Regulatory Costs

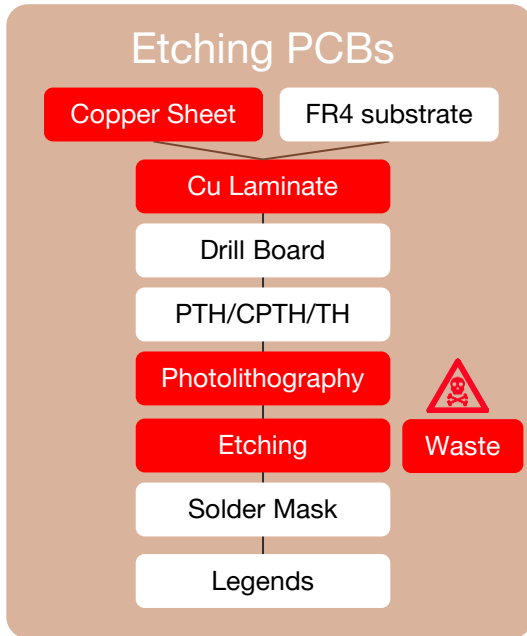


Introducing Copprint  
Conductive Nano Copper  
inks

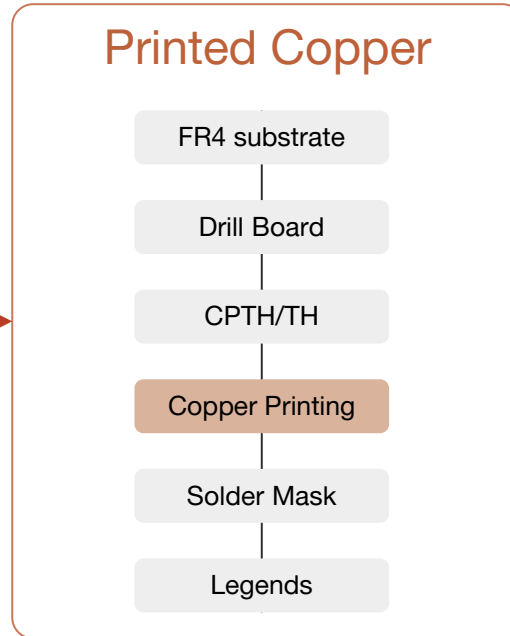


Simply print conductive  
patterns, using copper  
inks

# Shifting from etching to printing: circuit boards' Holy Grail!



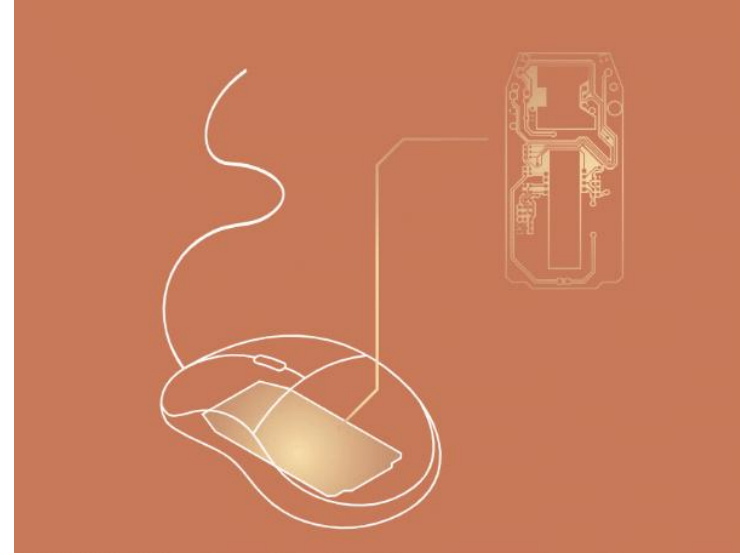
\*Represents 40-55% of PCB costs



- ✓ Reduced waste
- ✓ Reduced water consumption
- ✓ Reduced toxic chemicals
- ✓ Reduced energy
- ✓ Reduced costs
- ✓ Additional substrates e.g. paper
- ✓ Manufacture everywhere – no limitations on factory location
- ✓ ~50% CO<sub>2</sub>e per PCB

# CO<sub>2</sub>e implications

- Moving from subtractive chemical etching reduced the CO<sub>2</sub>e by more than 50%.
- Relative to 0.5% of the PCB industry this translates to more than 100 Megaton CO<sub>2</sub>e per year.
- Additional benefits:
  - Saving waste
  - Potential cost-cutting
  - Reducing energy, water, and toxic chemicals
  - Enabling additional sustainable substrates

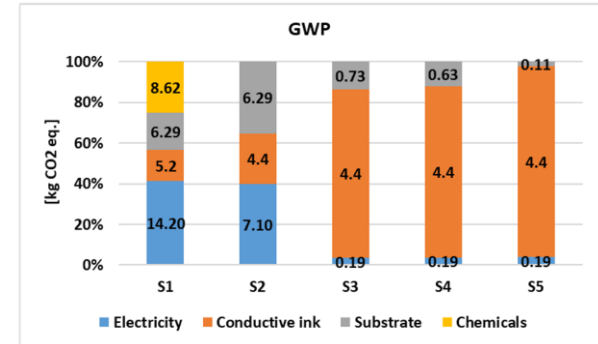


# 50% CO<sub>2</sub>e reduction: from PCB etching to printing Ag

- ~50% CO<sub>2</sub>e reduction due to transition from Etching to silver ink

	Etched PCB (s1)	Printed PCB (Silver ink s2)
Chemicals	8.6	
FR4 substrate	6.3	6.3
Conductive material	5.2	4.4
Electricity	14.2	7.1
Total Kg CO <sub>2</sub> e per 1m <sup>2</sup> of PCB	34.3	17.8

Other literature sources estimated 20-[288](#) Kg CO<sub>2</sub>e per 1m<sup>2</sup> of etched PCB



Nassajfar, M.N.; Deviatkin, I.; Leminen, V.; Horttanainen, M. Alternative Materials for Printed Circuit Board Production: An Environmental Perspective. **Sustainability** 2021, 13, 12126. <https://doi.org/10.3390/su132112126>

# Additional 10% CO<sub>2</sub>e reduction from Ag printing to Cu

- 8-40x CO<sub>2</sub>e reduction due to transition from silver to copper
- -> CO<sub>2</sub>e savings ~60% from etched PCB to printed Cu PCB

## LIFE CYCLE ASSESSMENT OF MINERALS & METALS FOR PV: CASE STUDY WITH HJT

Alexis Barrou<sup>1</sup>, Selin Kandyoti Eskenzazi<sup>1</sup>, Laurie-Lou Senaud<sup>1</sup>, Bertrand Paviet-Salomon<sup>1</sup>, Agata Lachowicz<sup>2</sup>, Jun Zhao<sup>1</sup>, Nicolas Badel<sup>1</sup>, Jonathan Champlaud<sup>1</sup>, Jérôme Payet<sup>2</sup>, Christophe Ballif<sup>2</sup>

<sup>1</sup> CSEM / <sup>2</sup> EPFL

**MW** Mineral & Metallurgy  
WORKSHOP

Neuchâtel, May 8<sup>th</sup> 2023

- Silver = **36** x Copper impact on RUM
- Silver = **76** x Copper impact on CC

<https://miworkshop.info/wp-content/uploads/2023/06/7-Life-Cycle-Assessment-A-Barrou...pdf>

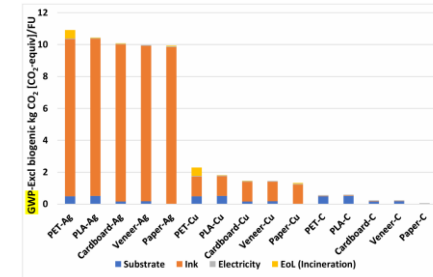
### PAPER

The effect of conductive ink alternation on the sustainability and functioning of printed electronics

Mohammad Naji Nassajfar, Marja Välimäki, Liisa Hakola, Kim Eiroma, Kirsi Immonen, Mariam Abdulkareem and Mika Horttanainen  
Published 30 May 2023 • © 2023 IOP Publishing Ltd

[Flexible and Printed Electronics Volume 8, Number 2](#)

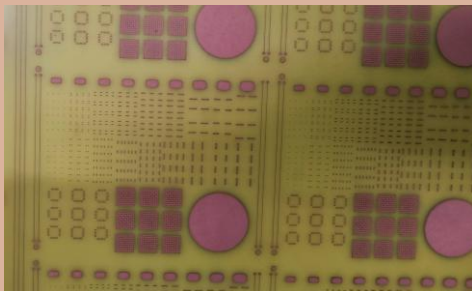
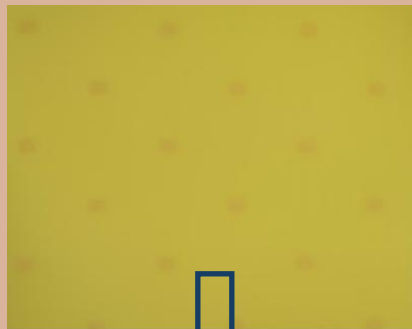
Citation Mohammad Naji Nassajfar et al 2023 *Flex. Print. Electron.* 8 025015  
DOI 10.1088/2058-8585/acd650



[naji\\_nassajfar\\_et\\_al\\_the\\_effect\\_aam.pdf](#)

# Additive PCB manufacturing

## 1. Printing



Printed pattern on FR4 with Through and Via Holes

### Technical Data Sheet

#### PRODUCT DESCRIPTION

Copprint LF-360 provides the following product characteristics:

Technology	Screen printing
Appearance	Copperish paste
Filler Type	Copper
Product Benefits	<ul style="list-style-type: none"> <li>• High conductivity</li> <li>• Excellent adhesion</li> <li>• Excellent printability with screen printing</li> <li>• High metal loading</li> <li>• High flexibility</li> <li>• Low temperature sintering</li> </ul>
Drying	Hot air
Sintering	Hot roller or Hot press
Application	Conductive Ink
Key Substrates	PET, PC
Typical Assembly Applications	Printed electronics

Copprint LF-360 screen printable paste is formulated to provide high electrical conductivity.

#### TYPICAL PROPERTIES OF UNCURED MATERIAL

Average particle Size, $\mu\text{m}$	D50 < 1.0, D90 < 7.0
Solids Content, after 10 minutes @ 150°C, %	91.5±1.5
Density, g/ml	4±0.2
Viscosity @ 25°C, DVEHA Brookfield spindle 14, 100rpm, mPa·s (cps)	13,000-17,000
Theoretical coverage @ 15 $\mu\text{m}$ dry film thickness	11.4 m <sup>2</sup> /kg
Shelf Life @ -10°C, days	180
Pot life @ 25°C, Hours	72
Flash Point - See SDS	

#### RECOMMENDED CURING

Drying cycle  
120sec @ 80°C (Hot air, Reflow oven)

Sintering cycle  
20 sec @ 180°C-210°C (Hot roller)  
120 sec @ 160°C-200°C (Hot press)

Relaxation cycle  
PET: 120 sec @ 140°C (Hot air, Reflow oven)  
PC: 120 sec @ 110°C (Hot air, Reflow oven)

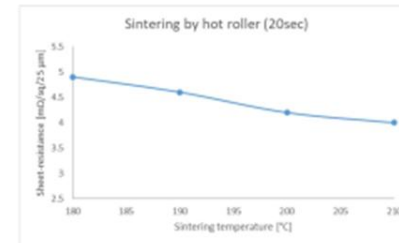
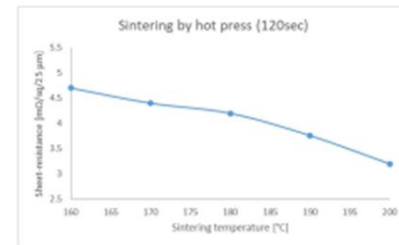
Copprint LF-360 can be dried using hot air, (near) infrared or ceramic lamps

Conditions (time and temperature) may vary based on customers experience and their application requirements, as well as customer drying equipment, oven loading and actual oven temperatures.

#### TYPICAL PROPERTIES OF CURED MATERIAL

Physical Properties  
Adhesion, (tape test 3M Scotch 234) pass  
Cross cut test ISO 2409-2007 3-4 b

Electrical Properties - Sheet resistivity  
Hot roller @ 190°C, 20sec ohm/sq/25  $\mu\text{m}$  <0.005  
Hot press @ 160°C, 120sec ohm/sq/25  $\mu\text{m}$  <0.006



# Additive PCB manufacturing

1. Printing
2. Drying and sintering



Hot-Press  
Small to medium  
production scale

Drying: 3 min @ 145°C  
Sintering: 2 min @ 250°C



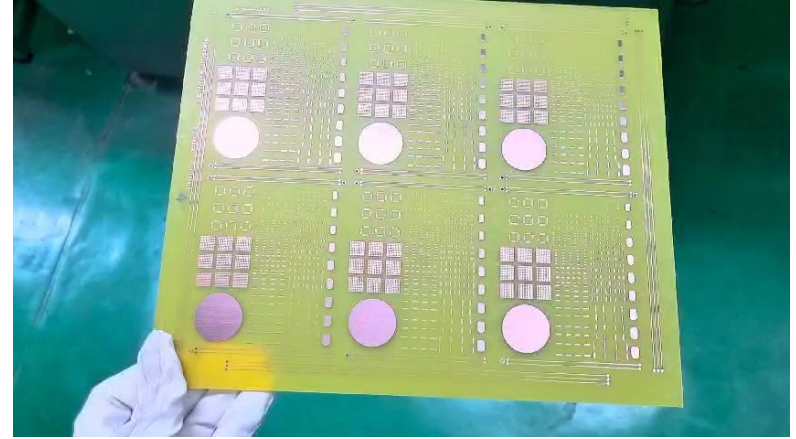
Double belt press  
Medium to large production scale

# Additive PCB manufacturing

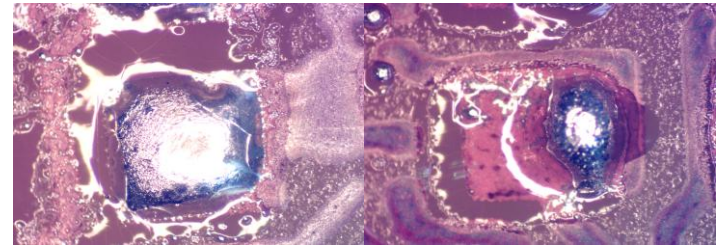
1. Printing
2. Drying and sintering
3. Cleaning and polishing



Water jets with  $H_2SO_4$  for removing residues and impurities, followed by gentle polishing to eliminate oxidized copper from the pattern.



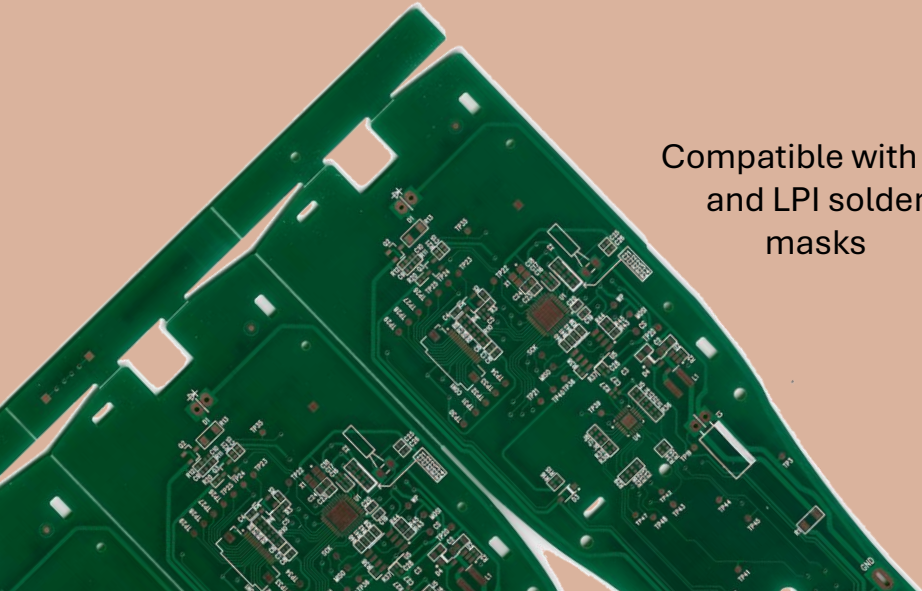
After cleaning and polishing, the pattern takes on a bright pinkish appearance.



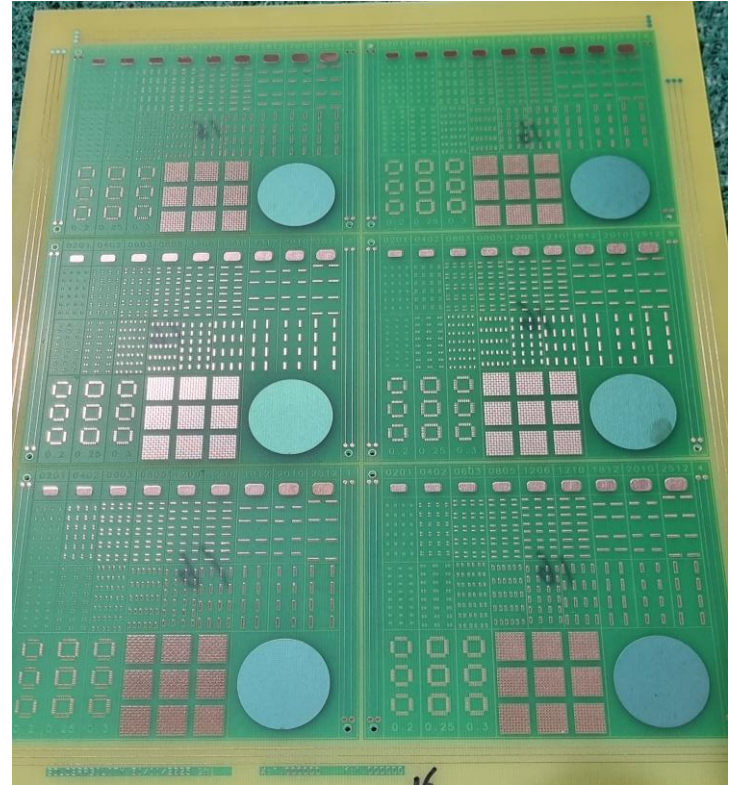
Reflow soldering, no cleaning and polishing (Right), with cleaning and polishing (Left)

# Additive PCB manufacturing

1. Printing
2. Drying and sintering
3. Cleaning and polishing
4. Solder mask and legends printing



Compatible with UV  
and LPI solder  
masks

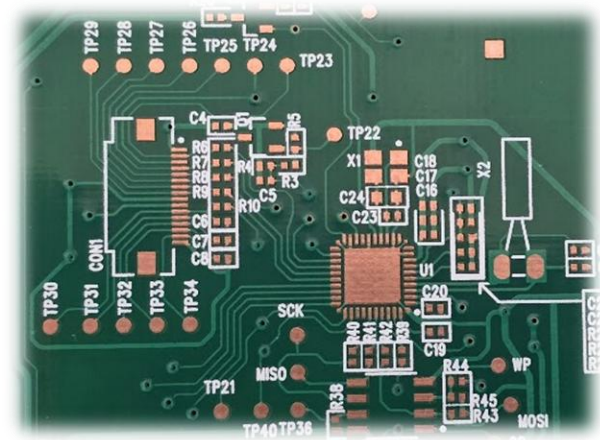


# Printed Circuit Boards Assembly

1. Printing
2. Drying and sintering
3. Cleaning and polishing
4. Solder mask and legends printing
5. Surface finishing- OSP

6. Reflow soldering
7. Hand soldering
8. Wave soldering

Boards Assembly



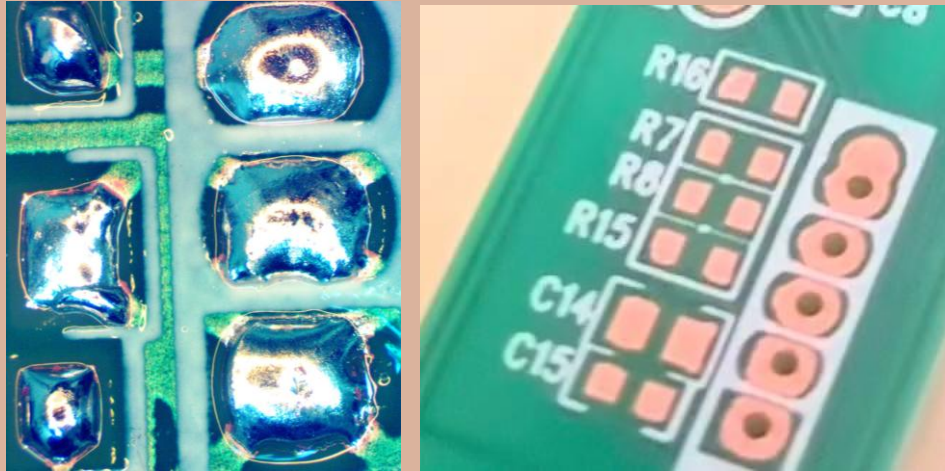
OSP surface finishing has been found to be compatible with Copprint pastes. We are working to approve additional surface finish processes.

## Surface finishing main benefits

- **Oxidation protection:** Prevents copper layer exposure, extending board lifespan.
- **Soldering Aid:** Provides a smooth surface for better component attachment, reducing detachment risks

# Printed Circuit Boards Assembly

- Hand Soldering

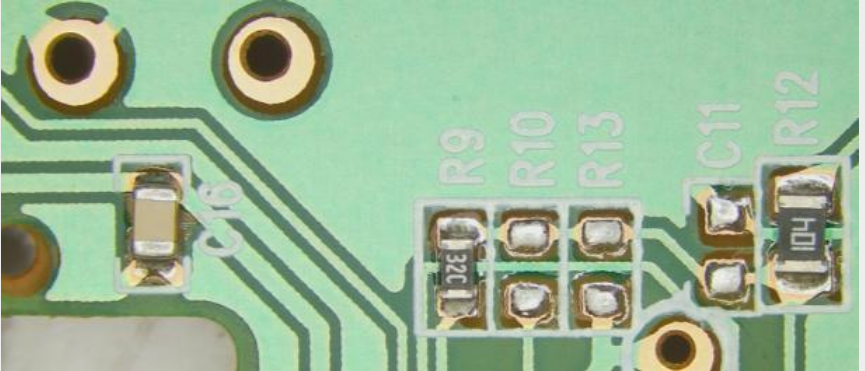
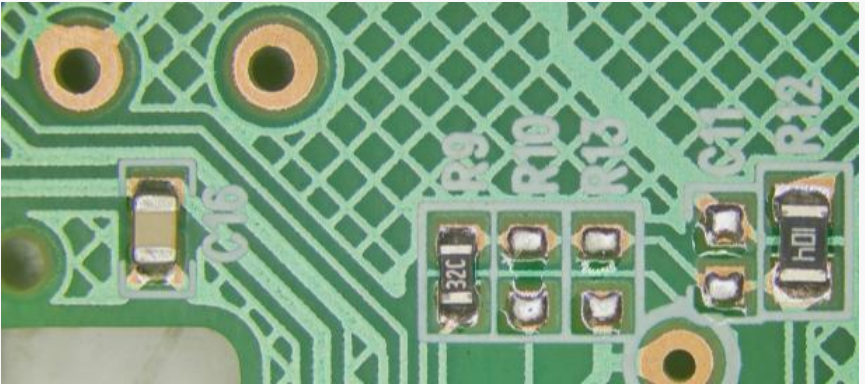


Hand Soldering, SAC 305,  
280°C  
covering >95%



Hand Soldering, SnCu, 280°C  
covering >95%

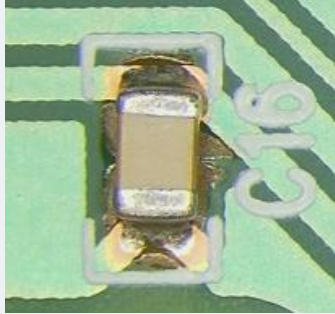
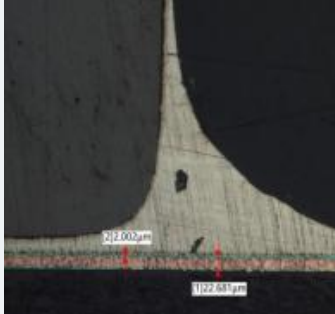

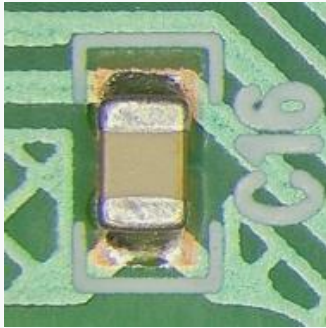
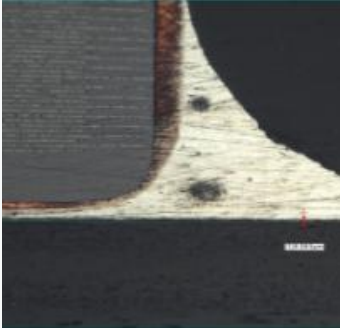
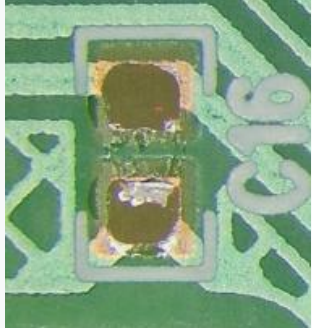
# SAC305 Reflowed PCBA

<p>Copper etched PCBA FR1, subtractive</p>	
<p>Copper printed PCBA FR4, additive</p>	

# Printed Circuit Boards Assembly

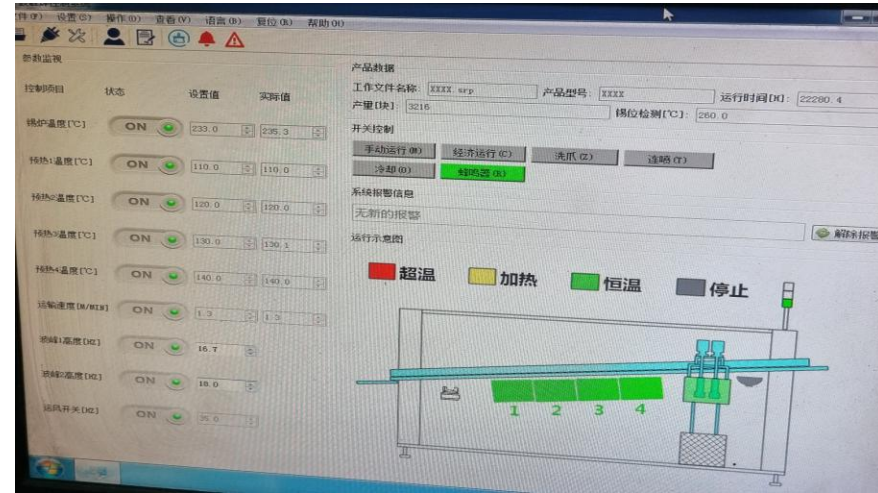
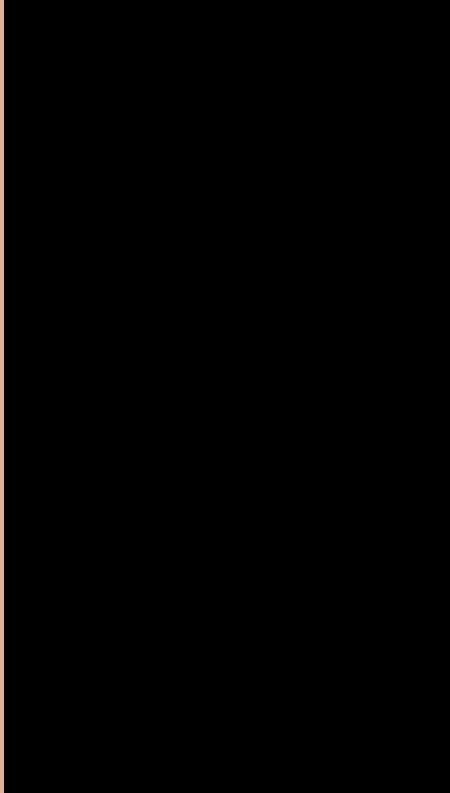
- Reflow Soldering

SAC 305

Process	Before test	Cross section	After test	Push force Kg*f
Etched copper FR1,subtractive				Avg:5.4 Min:4.5
Printed copper FR4				Avg:5.4 Min: 4.5

# Printed Circuit Boards Assembly

- Wave Soldering

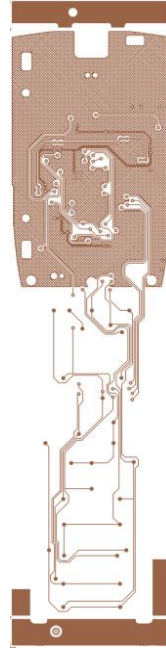


Wave soldering, SAC 305,  
235°C  
covering>95%

**Wave soldering is not approved yet. The process window is narrow, and we work to stabilize this process.**

# Etching vs. Printing

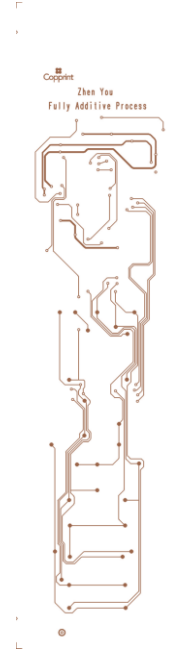
Etching process



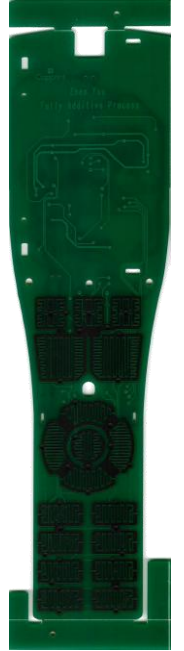
100%

33.9% coverage  
66.1% waste

Designing for printing:



5% coverage



# Rethinking design of PCB

- >70 years of design for etching
- Design for Additive Manufacturing – DfAM
- Reducing costs, using less materials and improving sustainability
- Make thinner lines - Line width should depend on functionality
- Reduce traces height – you can print less than  $4\mu\text{m}$
- No need for wide grounding areas.

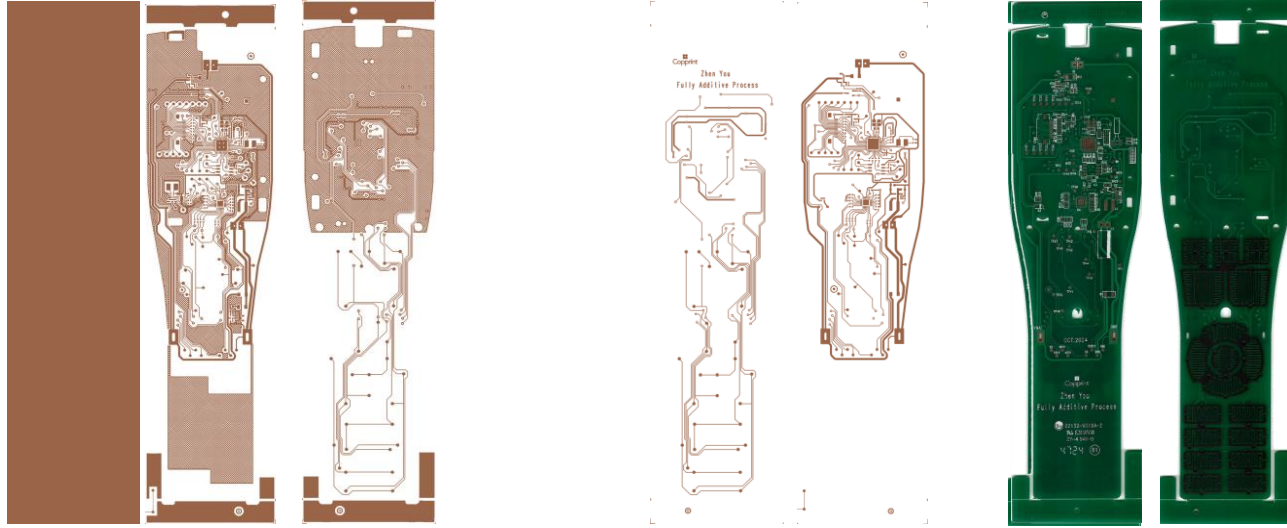
# Another DfAM example

Etched RFID antenna  
Aluminum on PET  
(800-900 MHz)



Printed RFID antenna  
Copper on paper

# DfAm – implications – both sides



	Foil (pre-etched)	Design for additive manufacturing
Coverage	100% -> 33.9,41.3%	7.5%
Layer height	25µm	12µm
Copper	5.2gr	<b>0.14gr</b>
Cu Waste	3.4gr	0.007gr

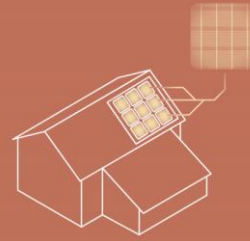
# Technology comparison

	Standard Etched PCB	Fully additive PCB
Description	FR4+Plated Through Hole+Copper etching	FR4+CPTH+Surface Copper Printing
Laminate	FR4 copper clad laminate	FR4 laminate <u>without copper</u>
Manufacturing method	Subtractive process	Additive process
Process flow	CNC→Desmear→Deburr→Electroless Plating→Panel and T/H Plating→Dry film application →Developing→Etching→Stripping→Solder Mask...→OSP	CNC→Copper Through Hole Printing→Baking→Surface Copper Silkscreen Printing→Sintering→Solder Mask...→OSP
Capability	<ul style="list-style-type: none"> <li>• PTH hole 0.3mm, pad 0.6mm;</li> <li>• Trace spacing/width 0.075mm</li> </ul>	<ul style="list-style-type: none"> <li>• CPTH hole 0.4mm, copper pad 1.1mm;</li> <li>• Trace spacing/width 0.15mm</li> <li>• Thin copper layers are possible – down to 5μm – <b>material cost-saving</b></li> <li>• <b>Manufacture anywhere</b></li> </ul>
Limitation	<ul style="list-style-type: none"> <li>• <b>Toxic waste</b></li> <li>• <b>High CO<sub>2</sub>e</b></li> <li>• <b>High energy consumption</b></li> <li>• <b>Large footprint of equipment</b></li> </ul>	<ul style="list-style-type: none"> <li>• Through Hole q'ty ≤ 20K/M<sup>2</sup></li> <li>• T/H rated current ≤ 500mA</li> <li>• Silkscreen accuracy ±0.15mm</li> </ul>
CO <sub>2</sub> e (relative to etched pcb)	100%	~40%

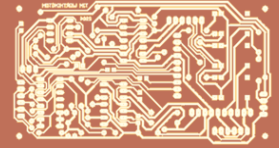
# Let's Make Greener PCBs Together!!!

- ✓ Proven & protected technology
- ✓ Adoption by top customers
- ✓ Significant pipeline
- ✓ Enabling new markets
- ✓ Lower costs & sustainable
- ✓ >50% PCB CO<sub>2</sub>e savings

*on every roof...*



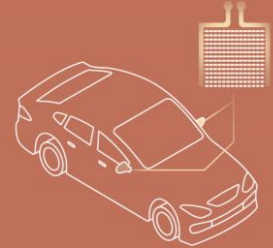
*in every circuit board...*



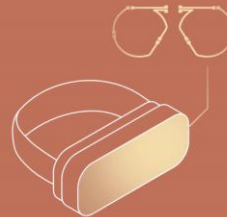
*on every tag...*



*in every car...*



*in every device...*



*in every IOT sensor...*

