

Printed Electronics in HMI

Materials and Applications

November 2020

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a member of the DIC group




Color & Comfort

working for you.

The world's leading producer of inks, coatings and pigments

Sun Chemical's global presence, combined with our **parent company DIC Corporation**, allows for the delivery of local service and support customized to your market.

900 
Megatons
of ink/year

63 
Countries


20,000+
Employees

176 
Subsidiaries

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Sun Chemical Advanced Materials for Electronics

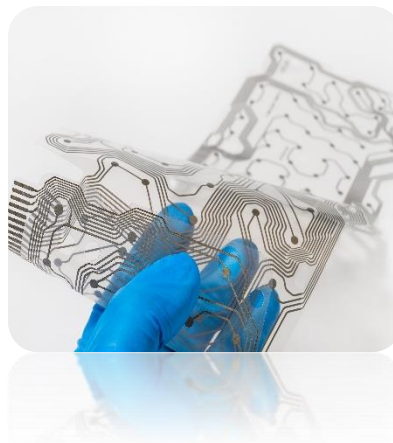
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Printed Electronics – Value Proposition


Lower Cost Alternative for Some Electronics Applications

The basic value proposition for printed electronics is that by using **additive processes**, instead of subtractive processes, you can **lower complexity** and **cost of manufacture** and **improve environmental impact**.

Enabling Technology for New Electronics Applications

PE also entails a lot of enabling technologies for **integration of electronics** and adding **new form factors** and **features** and therefore achieving things not readily possible or too expensive with more traditional PCB or FPC.

In addition to lower cost, PE can offer benefits like thin-form factor, 3D formability, mechanical flexibility, stretch-ability, portability/light weight, and rollability.

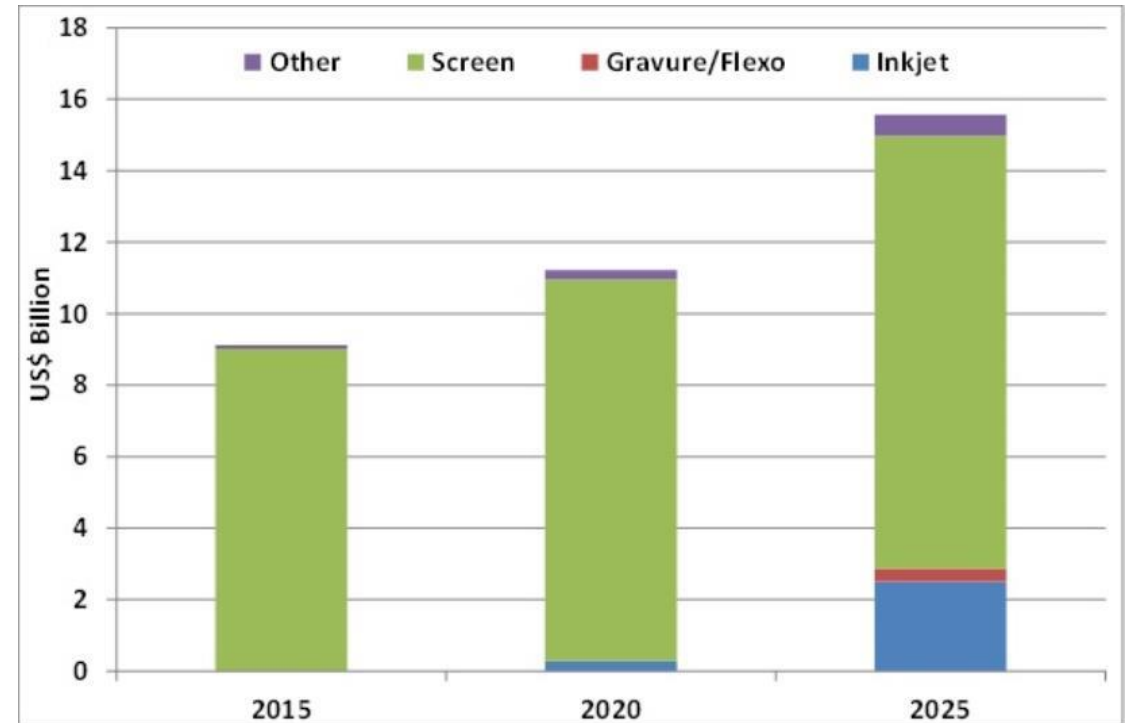


Trends in Printed Electronics Materials

Polymer Thick Film

- PTF is widely used technology for making printed circuits on plastic substrates using screen printing
- Typically processed at low temperatures (< 150 C)
- PTF inks found their commercial successful in membrane touch switches since the 70's

Total value of printed components split by printing technology type



Source: IDTechEx

Proven material technologies for printed circuits electronics.

PTF System

Conductive Silver Ink

- **Silver flake and powders** are dispersed in thermo-plastic or thermo-set resins and organic solvents
- Cost dependent on silver market price
- High conductivity interconnects and electrodes
- Solvent based, thermally cured

Conductive Carbon Ink

- **Conductive carbon black and graphite pigments** are dispersed in thermo-plastic or thermo-set resins in organic solvents
- Low cost
- Low conductivity interconnects, resistors, connector pads to prevent silver migration
- Solvent based, thermally cured

Dielectric/ Insulator Ink

- **Typically UV-curable filled with mineral pigments, but solvent based are also used in some apps**
- Crossover insulators for multilayer printed circuits
- Passivation layers
- Protective overprints/encapsulants, coverlays

Increasing Requirements for PTF Inks

- ✓ Better conductivity
 - ✓ Finer lines/pitch
 - ✓ Form factors
 - ✓ conform, stretch, 3D form
 - ✓ Increased reliability
 - ✓ Better environmental stability
 - ✓ Compatibility with SMT process
 - ✓ Faster speed printing
 - ✓ Faster drying time, lower T drying
 - ✓ Higher operational T
 - ✓ Expanding substrates
 - ✓ FDA compliant
 - ✓ Economical, lower cost
- And more...

Important to understand drivers behind the new requirements and properties critical to performance for a given application.



Human Machine Interface (HMI) Solutions

What is HMI?

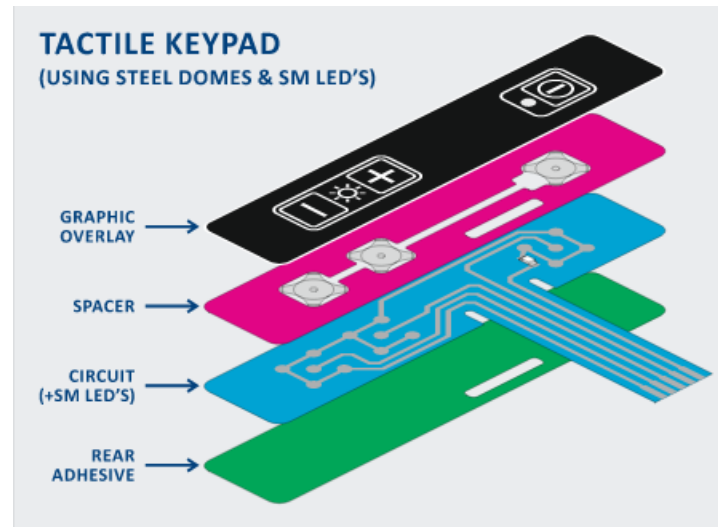
- Any device or software that allows you to interact with a machine
- Range from as simple as single **membrane touch switch, capacitive switches** to complex **multi-touch enabled control panels** or even smartphone can be considered an HMI technology.

Printed Switches - Membrane Touch Switch – MTS

Membrane switches function as a normally open, momentary contact, low-voltage pressure-sensitive circuit.

- HMI panels
- Industrial controls
- Heavy machines
- Appliances – small and large
- Medical devices e.g. for monitoring patients or X-ray machines
- Access control systems
- Laboratory and analytical devices
- Cash dispensers
- Kiosk systems
- Etc.

Front-panel assembly of a typical Membrane Touch Switch



http://www.touchpanels.co.uk/custom_membrane_keypad.html



Source: Melsen Tech

Screen printing is dominant process today for printed switches and many other printed electronics.

Printed Switches - Capacitive Switch

Advantages:

- No moving mechanics
- Easier and thinner stack up
- Improved reliability
- Higher durability
- Easy cleaning
- Design flexibility and Aesthetics

Capacitive touch sensors can incorporate and combine multiple switch formats and layouts

- Discrete switches
- **Slide switches,**
- **Rotary wheels,**
- Combinations of tactile and non-tactile
- **Backlighting (transparent cap switch)**
- Haptics are possible

Advantages of cap switches make it a successful successor to MTS in multiple markets.



Source: GMNameplate, Quad Industries

Printed Switches

Transparent Capacitive Switch

TCS have becoming popular in many products from hand-held consumer products to appliances and now also automotive applications.

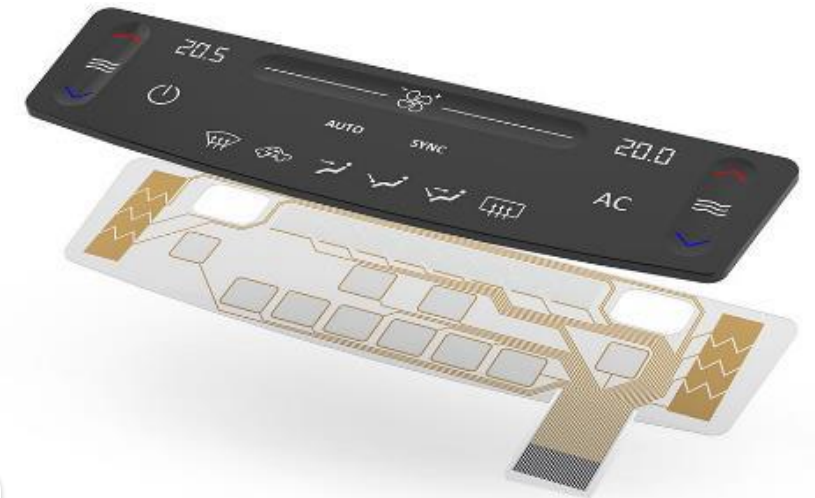
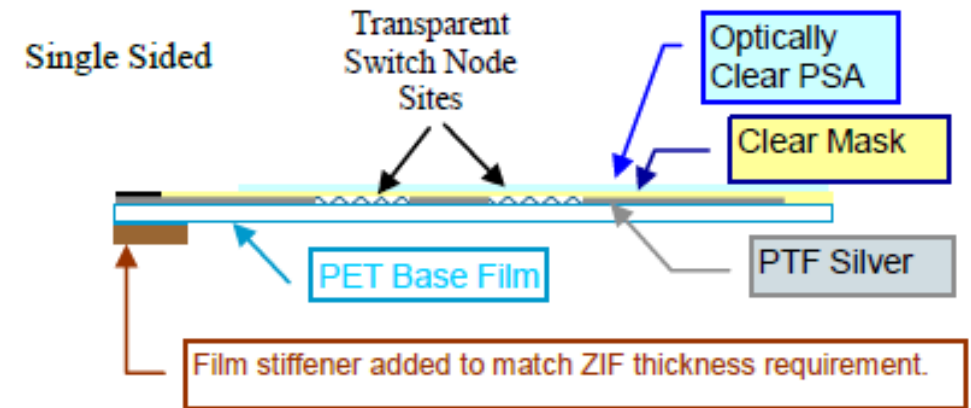
Transparent conductive polymer (PEDOT ink)

- Ideal for Self-Capacitance switch nodes with backlighting graphics.

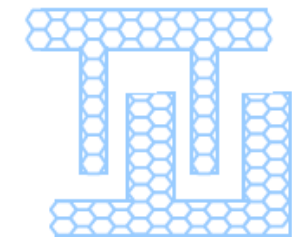
Micro Printed Silver

- Ideal for Mutual-Capacitance switch nodes with backlighting graphics.

TCS are growing in popularity and offer opportunity for new materials/suppliers



Self-Capacitance



Mutual-Capacitance

Materials for Printed Switches

- **Graphic inks** for decorative part (screen, inkjet) – SunTech Graphics
- **Pressure sensitive adhesives** – Daitac PSA tapes
- **Materials for flex Circuit** – Suntronic Printed electronics materials



While we offer PTF solutions, competitive solutions with other on the market, we always try to increase the value proposition by adding value by offering advanced materials and customization services.

- **Silver conductive** inks for interconnects and switch electrodes, solvent based, thermal cure
 - Generic purpose PTF silvers
 - Economical silver – low silver loading
 - High performance inks – high conductivity
 - Fine line printable for TCS switches
- **Carbon/graphite conductive** inks for resistors, connector pad protection, silver migration inhibition for connectors, solvent based, thermal cure
- **Dielectrics** for crossovers, passivation, and protection, 100% solids, UV and UV-LED curable
- **UV Protective Clears and Diffusers** for TCS switches, 100% solids, UV curable

Standard Products for HMI Switch (MTS/Cap Touch)

Print Method	Product Type	Drying Mechanism	Pigment or Color	Product Name	Features	Performance Metrics
General Purpose Package						
Screen	Conductive Silver	Thermal	Silver	AST6200	General purpose PTF silver, vinyl based	<15 mΩ/sq/mil
Screen	Conductive Silver	Thermal	Silver	AST6320	General Purpose, lower silver loading PTF silver, vinyl based	<13 mΩ/sq/mil
Screen	Conductive Carbon	Thermal	Graphite/ Carbon	GST4300	General purpose PTF Carbon, vinyl based	<25 Ω/sq/mil
Screen	Dielectric	UV	Green/Clear/Blue	DSU4606	Excellent flexibility and adhesion to various substrates	<10 ¹³ Ω/mm
Screen	Dielectric	UV	Green/Clear/Blue	DSU4601	Excellent dielectric properties	<10 ¹³ Ω/mm
Halogen Free Package						
Screen	Conductive Silver	Thermal	Silver	AST6000	General purpose PTF silver	<18 mΩ/sq/mil
Screen	Conductive Silver	Thermal	Silver	AST6000-HV	High viscosity version AST6000, higher definition	<15 mΩ/sq/mil
Screen	Conductive Carbon	Thermal	Graphite/ Carbon	GST4200	General purpose, miscible with AST6000 and AST6000-HV	<30 Ω/sq/mil
Screen	Dielectric	UV	Green/Clear/Blue	DSU4606	Excellent flexibility and adhesion to various substrates	<10 ¹³ Ω/mm

Advanced Electronic Material Solutions for HMI

Print Method	Product Type	Drying Mechanism	Pigment or Color	Product Name	Features	Performance Metrics
Next Gen Silvers						
Screen	Conductive Silver	Thermal	Silver	AST6010	High conductivity, good for UHF RFID antenna	<11 mΩ/sq/mil
Screen	Conductive Silver *NEW*	Thermal	Silver	AST6202	Highest conductivity, low solids, high cost effectiveness	5-7 mΩ/sq/mil
Screen	Conductive Silver	Thermal	Silver	AST6025	Fine line printable, high conductivity, thick deposit	<10 mΩ/sq/mil
Screen	Conductive Silver	Thermal	Silver	AST600-HV	Solderable with low T solder paste	<15 mΩ/sq/mil
Screen	Conductive Silver *NEW*	Thermal	Silver	CXT-0644	Fine line printable, high solids, solderable with low T solder paste	<10 mΩ/sq/mil
Additional Materials for HMI						
Screen	Transparent Conductive Ink	Thermal	PEDOT:PSS	C2100629D1	Water based conductive polymer ink for transparent electrodes and conductive films	500-700 Ohms/sq
Screen	Protective Ink *NEW*	UV	Transparent Clear	DXT-2978	Specially designed protective transparent clear for use with backlit transparent capacitive switches	N/A
Screen	Protective Ink *NEW*	UV	Translucent Clear	DXT-3033	Specially designed protective translucent clear for use with backlit transparent capacitive switches	N/A
Screen	Light Diffusing Ink *NEW*	UV	Diffusing Clear	DXT-2991	Specially designed light diffuser ink for use with backlit transparent capacitive switches	N/A

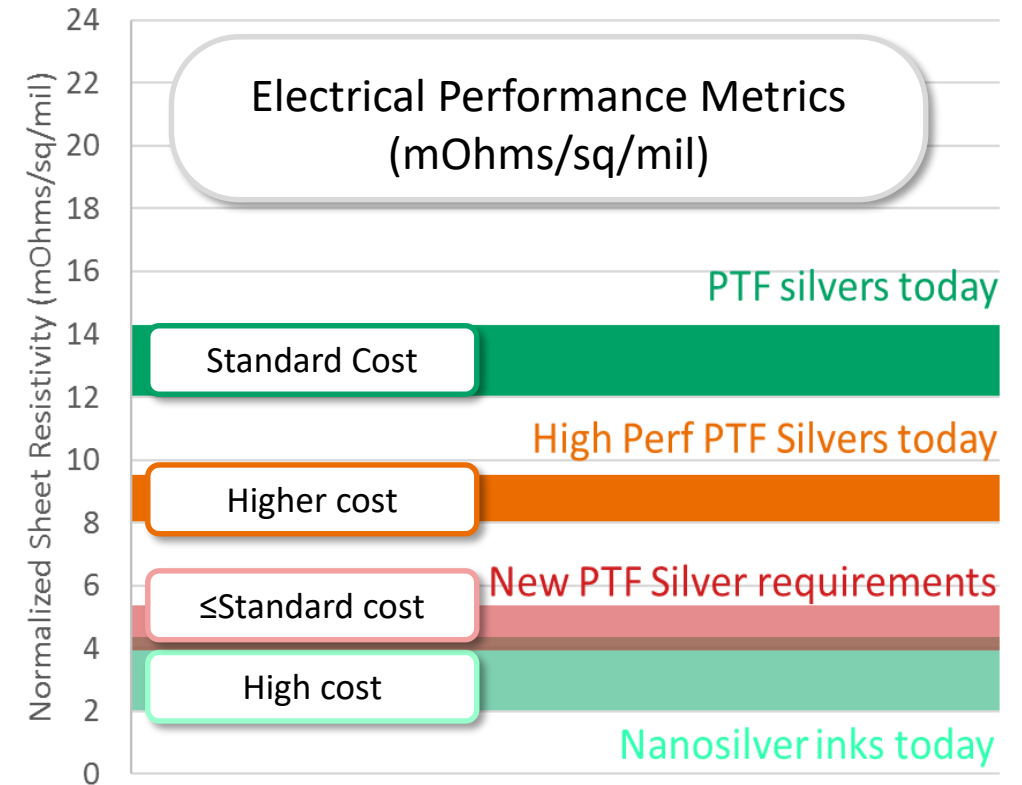
Advanced materials address new performance or cost requirements, thus paving a more successful path to commercialization. Working in close collaboration with printed electronics manufacturers enable Sun Chemical to develop materials that meet the market needs.

Better Conductivity

- Best PTF silver inks are still **~10 x higher resistance** than bulk metals (copper, silver)
- Nanoparticle based inks were demonstrated as low **3x bulk silver resistance**, but still challenged to meet all CTPs for some PE applications and usually require special handling and processing.

Drivers for better conductivity silver inks

- Lower cost (higher mileage of conductive ink for low power applications)
- Higher current carrying capacity for finer and denser circuits
- Enable additive manufacturing for large area sensors, heaters, connectors, etc.



Room for innovation to further increase conductivity

New High Performance PTF Silver AST6202

New PTF Silver Ink
AST6202

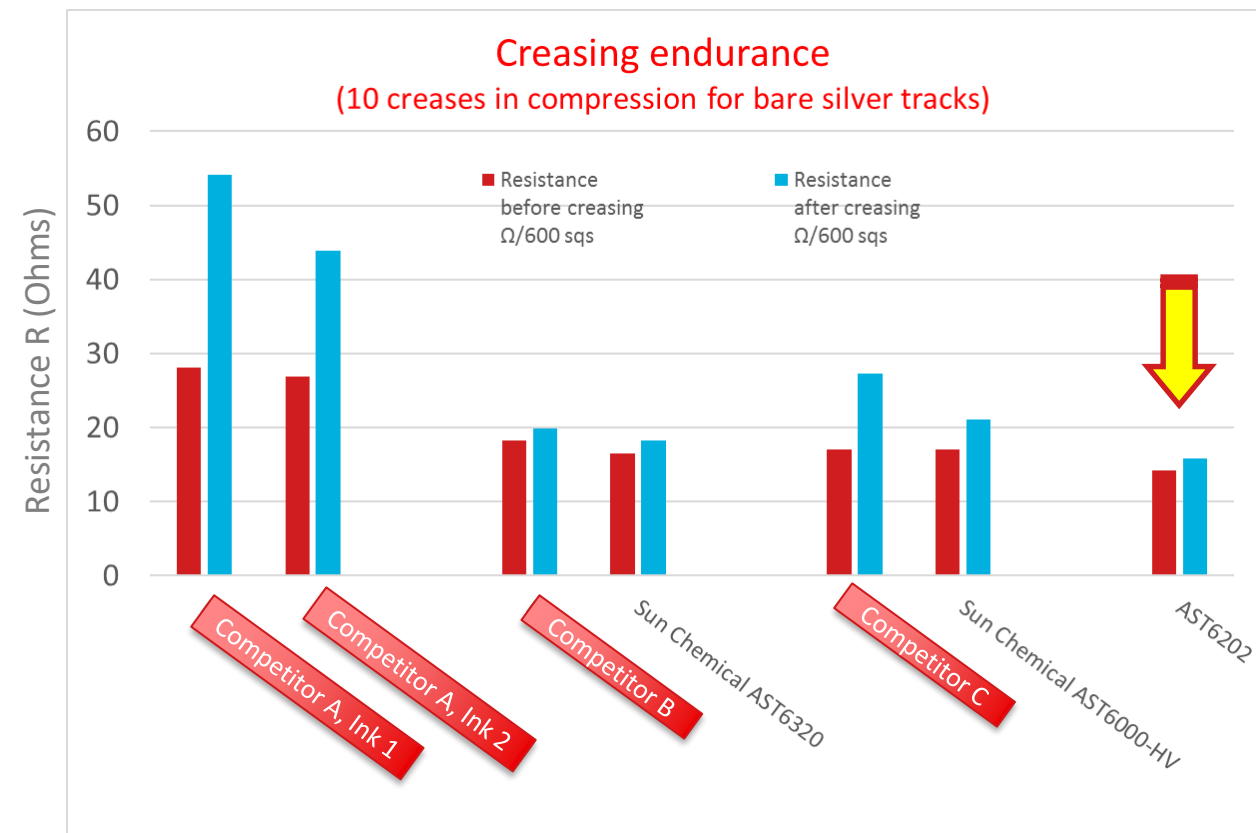
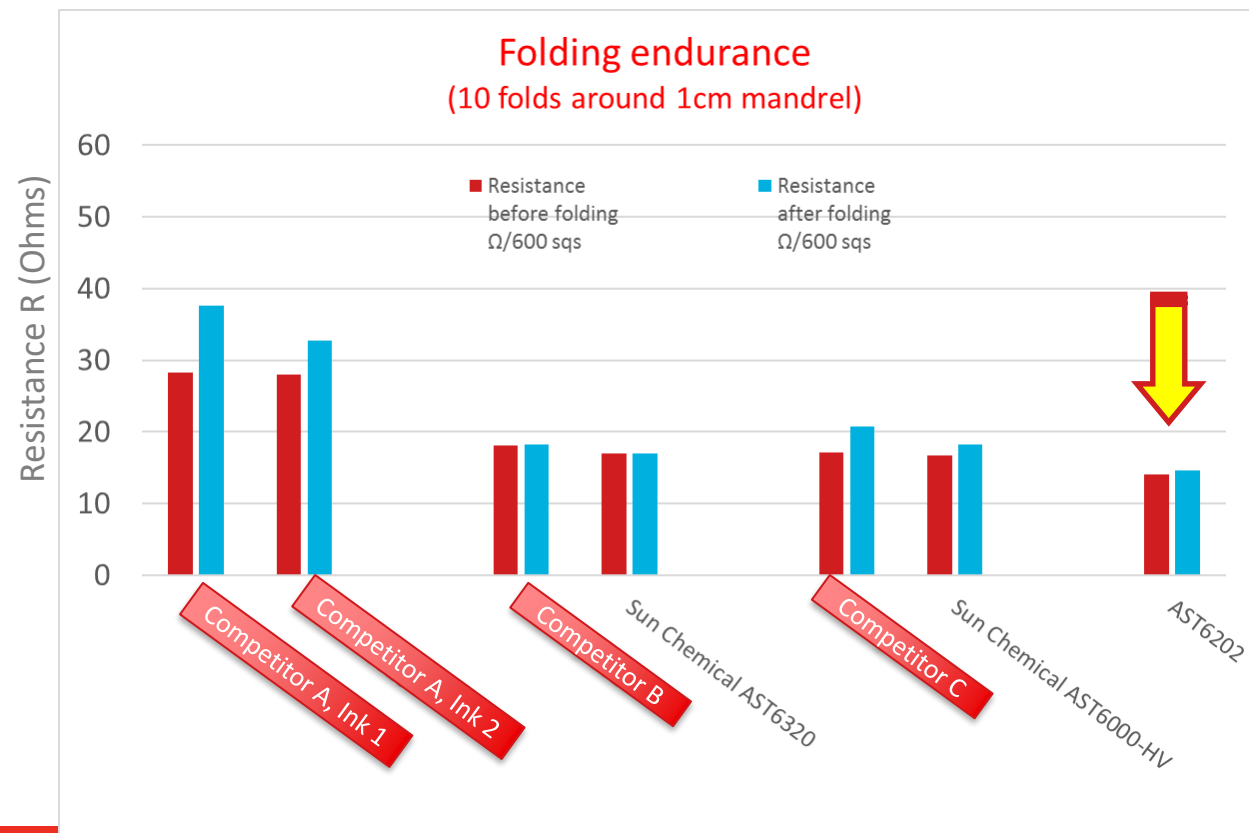
Features

- Lower silver content than traditional PTF silvers
- Low sheet resistivity: 4-6 mΩ/sq/mil
- Low density – more volume per kg
- Excellent mileage (high coverage)
 - 40-60% more cost effective than generic PTF inks
- Excellent adhesion on multiple flexible substrates used for printed electronics
- Not containing halogenated materials
- Excellent enviro stability
- Compatible with PTF carbons and dielectrics

Properties		General PTF Ink	Low cost PTF silver	High conductivity/ low cost ink
Ink Properties	Example Product codes	Henkel: 479 SS Sun: AST6000-HV	ECM: CI1001 Sun: AST6320	Sun: AST6202
	Viscosity	180 Poise, 50RPM	260 Poise, 20RPM	124 Poise, 50 RPM
	Density (g/cm ³)	2.68	2.2	2.07 ★
	Solids (150 °C, 1h)	79%	66%	58% ★
Printing Properties (325SS mesh on Melinex ST505)	Volume Resistivity (mΩ/sq/mil)	13-15	13-15	4-6 ★
	Thickness (um)	~10	~10	~5 ★
	Cross Cut Test (ASTM3359B)	Class 5B	Class 5B	Class 5B
	Pencil hardness	5H	5H	5H

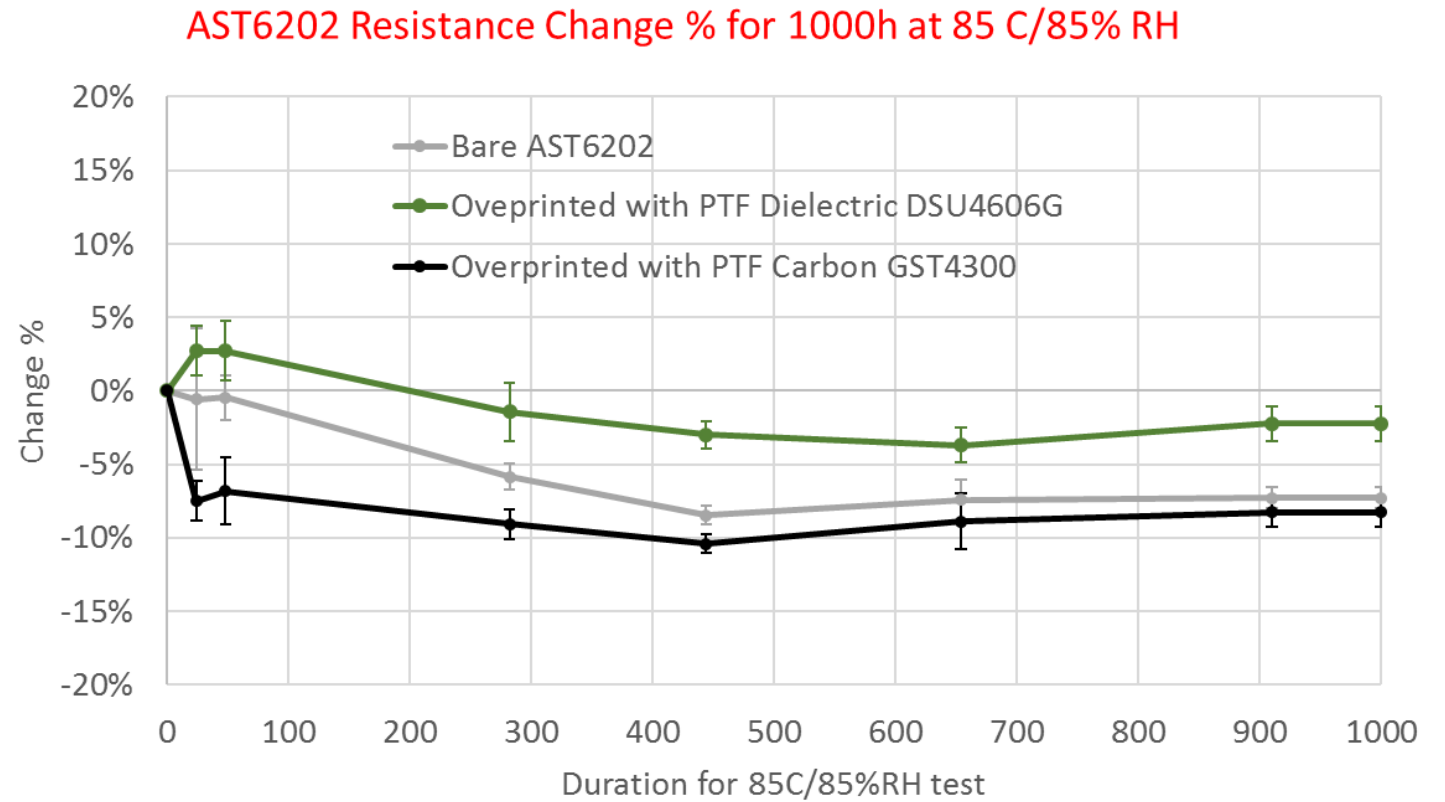
Mechanical Properties

Printed with 325SS mesh on ST505 and dried at 250 F for 30 min, results for bare silver tracks



Printing thinner layers lead to better mechanical properties. Mechanical properties of the new ink are comparable or better than leading PTF inks on the market.

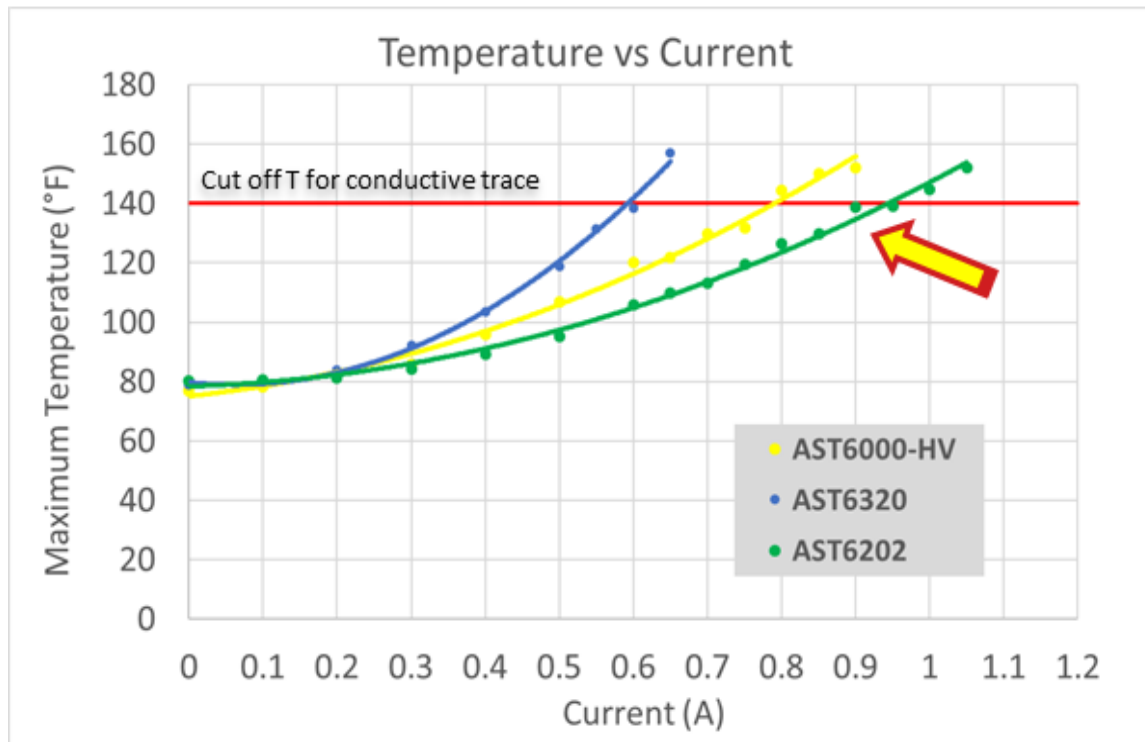
Environmental Stability



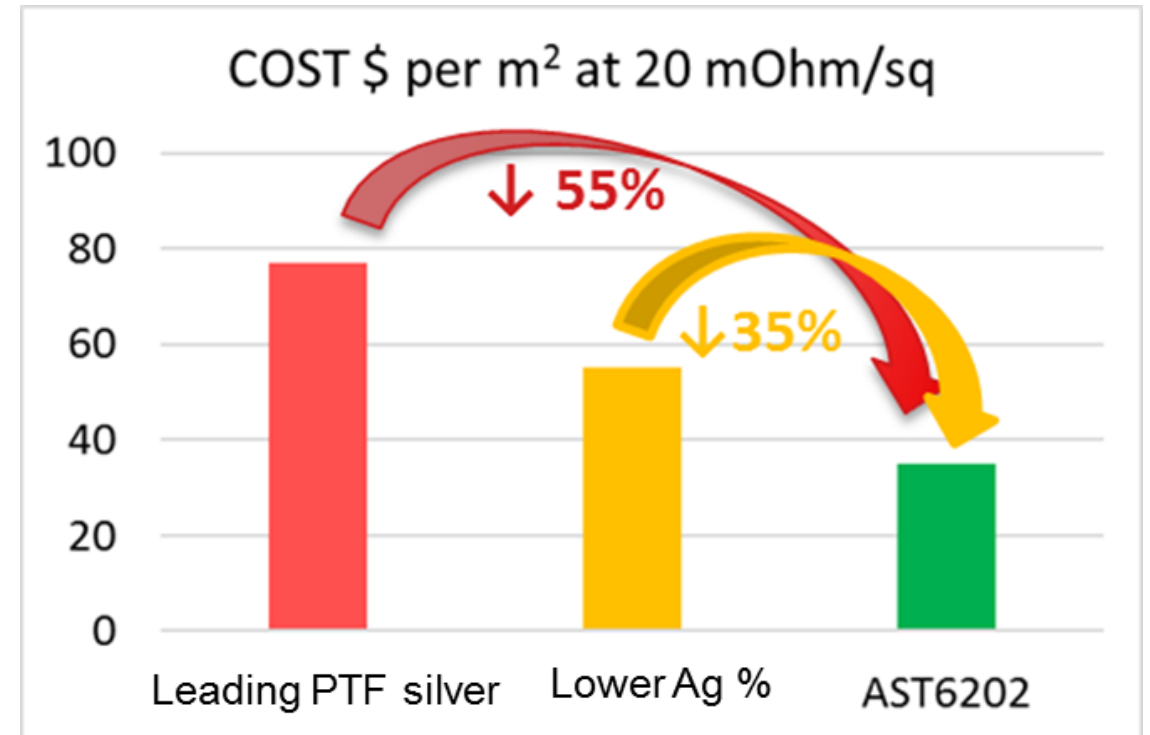
Environmental stability within targets ($\pm 10\%$) for printed interconnects reliability

AST6202 - Added Value

Higher conductivity allows to build larger parts or higher amperage circuits



Higher conductivity allows to achieve same sheet R at thinner deposit, improved mileage and therefore the cost



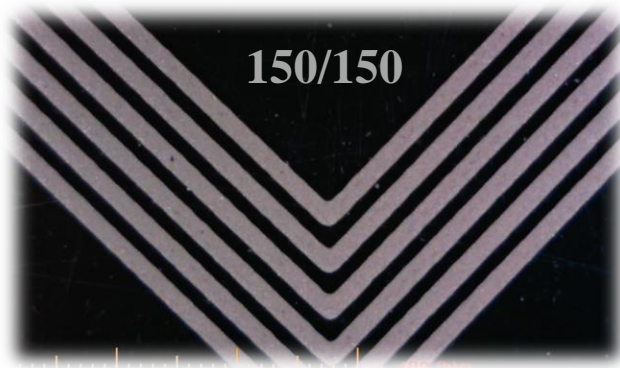
Drivers for Higher Resolution Functional Printing

Drivers for higher resolution

- Narrower traces lead to lower cost
- Higher density interconnects
- Transparency
- RF performance

State of Art

- Production >6 mils (150 μm) traces and spacing are common
- Early production looking at 4 mils (100 μm) for traces and 2 mils (50 μm) for transparent apps)
- Development targeting <1 mil (<25 μm)

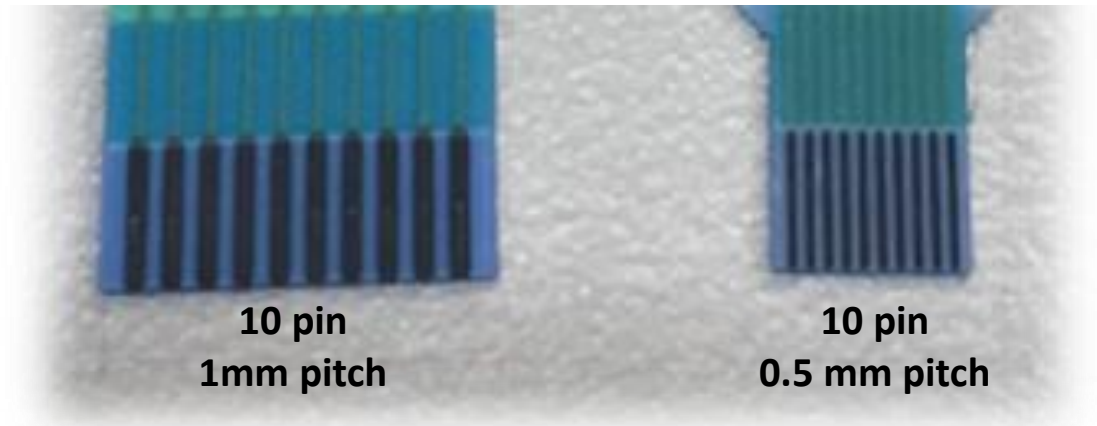


Opportunities for innovation not only in materials but also in processes and practices

Higher Density Printed Silver Circuits

- Finer widths fit **more components in a smaller area** and can accommodate **unique functionality** in the printed circuit.
- **Reduce the circuit layer count** and route traces in and around narrow clearance sections of the layout.
- Utilize designs that require **fine pitch connectors**

Ability to integrate smaller components and make more complex circuits increases competitiveness of silver circuits on PET vs. traditional copper flex on PI film.

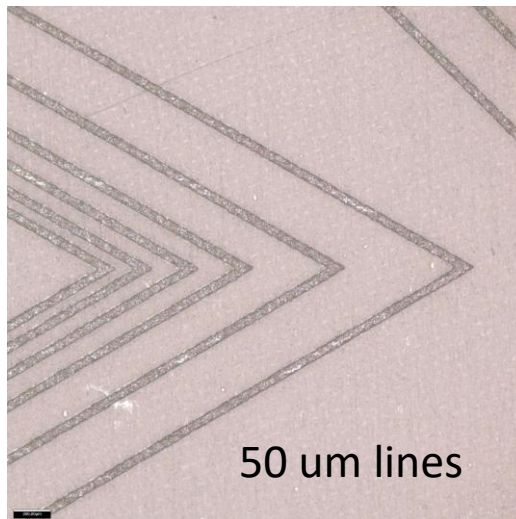


Connector Pitch	Example Applications
0.3 mm	Mobile devices (phones), wireless consumer electronics
0.5 mm	Larger mobile devices (GPS, cameras, tablets), medical and consumer electronics, monitors and multimedia electronics in car
1 mm	Medical controls, other HMI, white and brown appliances, printers, gas pumps, ATMs
2.5 mm	Larger automotive sensors (occupancy, car seat), heaters, larger appliances, keyboards, various control panels and switches

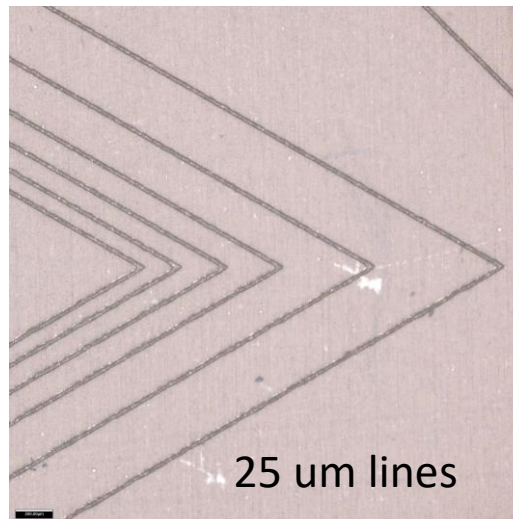
Micro Printed Silver for Transparent Cap Switches

- Many companies are trying to develop fine line TCS.
- Current limitation is how fine can PTF ink print on production level. Finer lines will provide better transparency. Ideally <50 microns, better to be at <30 microns.
- For now, only high end application are targeted.

Transparent fine
line mesh
50 um fine lines

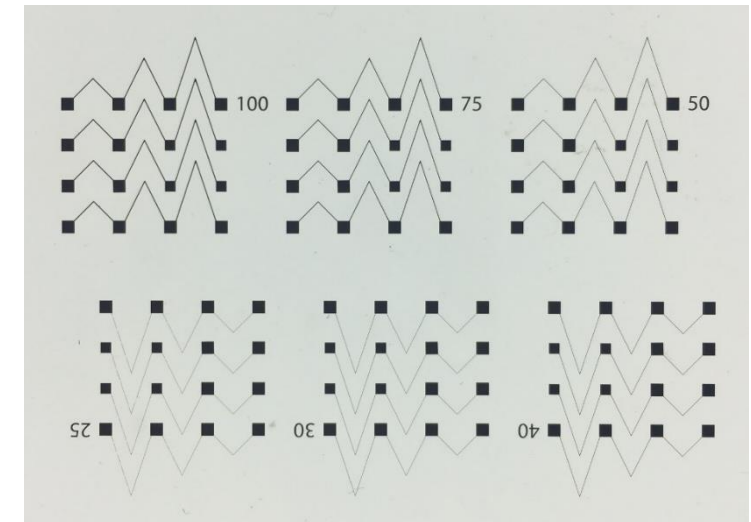


50 um lines



25 um lines




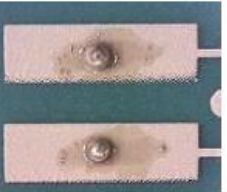
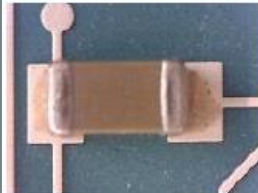



powders tend to be the most difficult to
duce.
Optimum silver inks are obtained by blending
right balance of flakes and particles. Flake
vides improved conductivity by allowing
imum contact. The goal is to allow the
e-like particles to overlap one another like so



Screen printed using Sun Chemical AST6025
Silver Ink, Asada Mesh SS mesh and Ikonics
Alpha FlexTrace PET substrate

SMT Compatibility for Printed Electronics

- Majority of printed electronics applications are using **ECAs for component attachment**
- Demand for higher density, finer pitch and higher reliability circuits sometimes requires to use **solder paste**
- New developments in **flexible ECAs** are enabling highly formable and flexible applications in stretchable and wearable electronics
- Compatibility of silver PTF inks with **low T solder** enables to expand applications of silver flex circuits.

				
Ink	AST-6025	CXT-0644	AST-6000HV	AST-6310
Pad				
	Solder Wettability Poor	Good	Good	Poor
Chip (3216 size)				
	Solder Wettability Poor	Good	Good	Poor

Opportunity for innovation in the component attachment and integration of flexible hybrid electronic circuits.

Advancements in PTF Dielectrics

- Transition from traditional UV to **UV-LED Curing**
- Fast adoption of UV-LED in graphics printing, making its way into electronics manufacturing
- **Advancements in PI chemistries and UV-LED curing equipment** enable formulation high reliability PTF dielectrics
- Sun Chemical recently developed a **new line of UV-LED cross-over dielectrics specifically for PE**

	LED Curing System	Arc Lamps
Lifetime	> 20,000 hours	500 - 2000 hours bulb life
Environmental	Mercury-free Ozone-free	Mercury waste Ozone generating
Input Power	Small (~half)	Large
Maintenance	Maintenance-free	Bulb replacement & cleaning
On/Off	Instant	Minutes
Heat	60°C	~350°C

Increasing viability of new technologies and applications by designing more cost effective and more enviro friendly solutions.

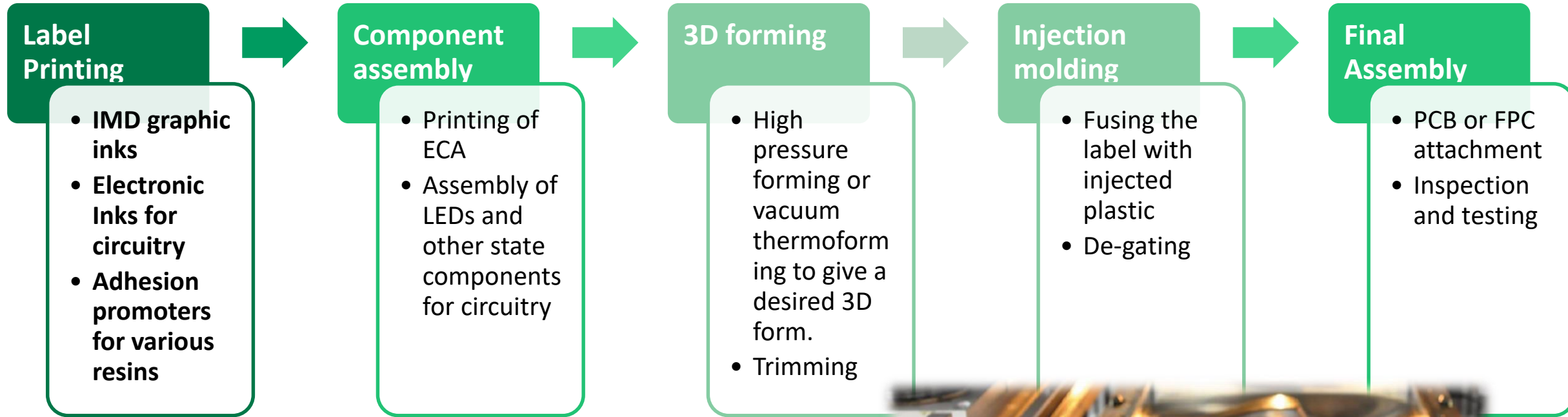


In-mold Electronics

Enabling technology for adding electronic functionality **and** 3D form to “still” surfaces

Disruptive manufacturing approach for some electronics applications

Process Flow for Decorated IME and Material Requirements



SunTronic™ IME
Solutions^{Tailor Made}

New suite of materials was needed to meet the requirements for the whole IME process.



Source: Niebling

IME Targeted Industries



Automotive

Appliance

Consumer (home)
electronics

Medical HMI

Industrial HMI

Aerospace

Wearables



Trends

- Information technology focus
- Connectivity and interactivity
- Touch, voice, gesture
- Illumination
- Seamless and light weight designs
- Differentiation and branding
- Streamlined manufacturing
- Lower cost
- Increased reliability



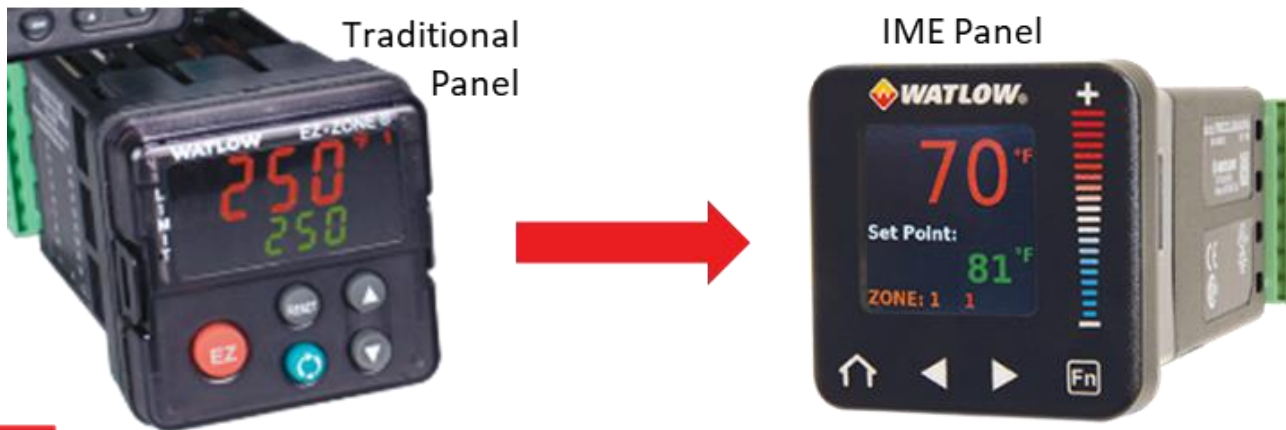
IME Advantage

- ↔ New way of electronics integration
- ↔ Embedded electronic functions (antenna, switches, sensors)
- ↔ Innovative backlighting of plastics
- ↔ 70% thinner and 50% lighter parts are possible
- ↔ 3D form and design freedom
- ↔ Reduced cost via simplified process, less assembly/tooling
- ↔ Circuits over molded in plastic

In-mold electronics approach addresses multiple market/application trends.

Added Value of IME in HMI (Cap Touch)

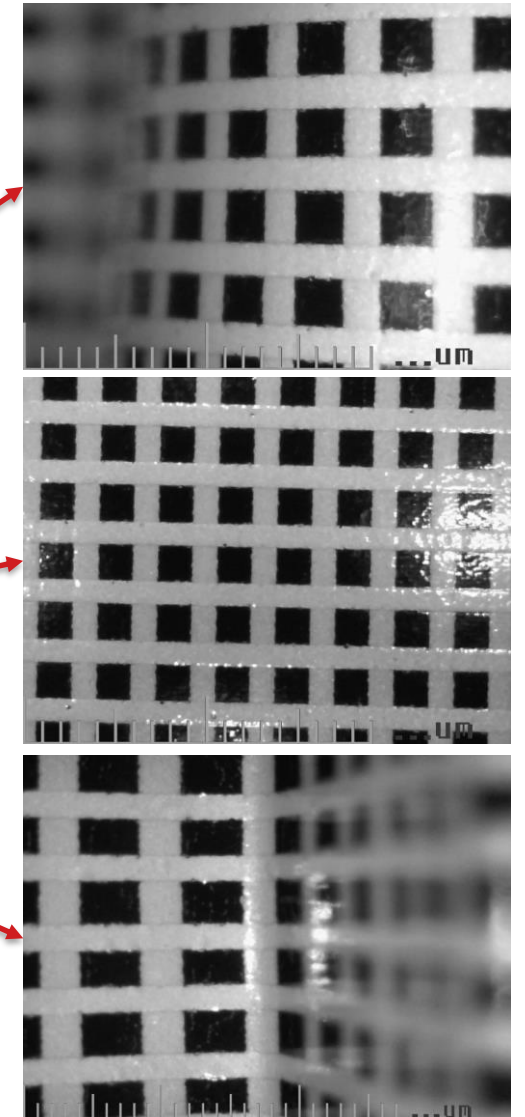
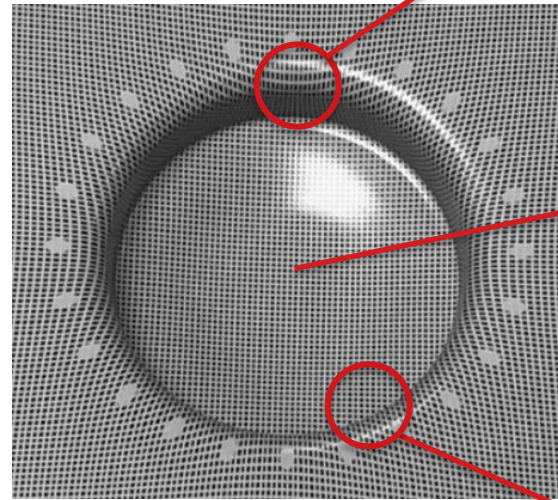
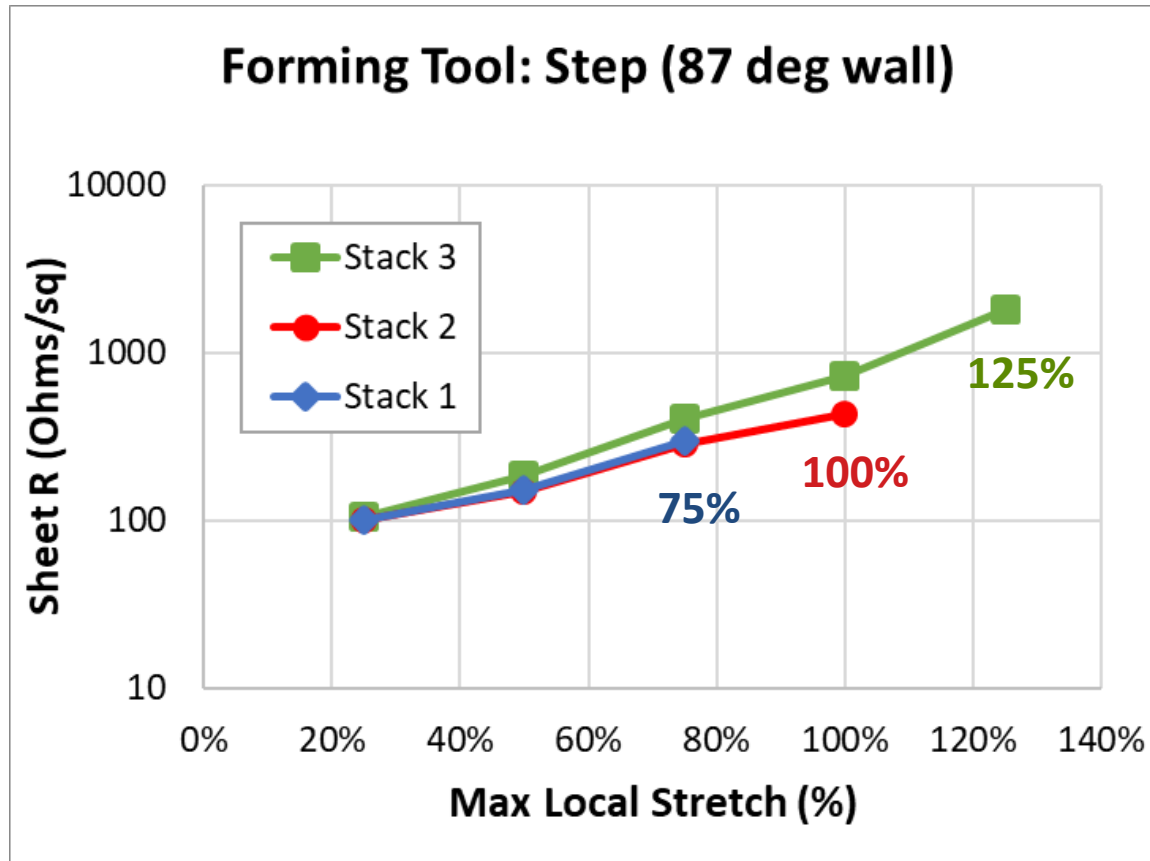
- Improved cap touch functionality - bringing the touch sensor closer to the finger
- 3D form and design freedom, landmarks for “no-look” operations
- Eliminates contamination points, can be totally sealed from dust and liquids



<https://www.watlow.com/about-watlow/News/PM-PLUS-Launch>



Optimization of Functional Ink Stack to Maximize Formability



The maximum stretch capability for a given silver ink can be improved by designing the overall ink stack for better forming performance.

Gen3 IME Inks

Product Category	Product Name	Description	Features
Conductive Silver	CXT-0886	IME Silver Ink	7-8 mOhms/sq/mil, lowest resistance, minimal 3D forming, good for flat interconnects, antenna or heaters
	CXT-0869	IME Silver Ink	10-12 mOhms/sq/mil, some 3D forming, good for slightly curved for interconnects, antenna and heaters
	CXT-0873	IME Silver Ink	15-20 mOhms/sq/mil, good 3D forming, good for moderate stretch areas or medium curvature radii
	CXT-0872	IME Silver Ink	25-30 mOhms/sq/mil, excellent 3D forming, best for higher stretch areas or sharper angles
	CXT-0887	IME Silver Ink	30-35 mOhms/sq/mil, slower drying version of high formable ink, excellent screen stability (down to 100 um)
	CXT-0877	IME Silver Ink - Fine line	25-30 mOhms/sq/mil, formable silver for direct patterning of fine traces (<100 um)
Conductive Carbons	GST4500	Cond. Graphite Ink	Not formable, Good for pad protection/cushion for better drop-in solid header connector
	GST4700	Cond. Graphite Ink	Not formable, good scratch resistance, good for silver pad protection for flex tail connectors
	TBD	IME Graphite Ink	Formable carbon ink for formable high resistance interconnects
Dielectrics/ Cross-over Insulators	CXT-0874-C	IME SB Dielectric Clear	Solvent based dielectrics, excellent forming, gate wash resistance and very good adhesion when molding to PC resins, also can be used as a planarizing barrier for UV IMD graphic labels or as a passivation if using carbon black decorative inks. Higher solids white version delivers cross-over insulation with less printing passes than clear.
	CXT-0874-G	IME SB Dielectric Green	
	CXT-0874-W	IME SB Dielectric White	
	CXT-0874-TC	IME SB Dielectric Transparent Clear	
	CXT-0890-W	IME SB Dielectric White	High solids white solvent based dielectric, slower drying than CXT-0874 type
	DXT-2973	IME UV Dielectric Clear	UV-curable dielectric clear, excellent forming, good adhesion to co-polyester molding resin
Adhesion Promoters	MTC1000	IME Adhesion Layer	Adhesion promoter for co-polyester molding resins, low haze
	CXT-0874-TC	IME Adhesion Layer	Adhesion promoter for polycarbonate resins, low haze, can be used as planarizing layer between IMD graphics and IME inks and to improve forming of silver

In Closing...

- Embracing the added value (enabler factor) of new technologies is more likely to lead to successful commercialization
- There are many opportunities for innovation in flex circuits technologies
- Advancements in materials for PE are addressing market needs and already show commercial successes
- Collaboration is key - identify key stakeholders and partner strategically
 - **Sun Chemical Corp – a partner that transforms with you**

SunTronic™
Electronic Materials *Solutions* *Tailor Made*



Thank You!

Questions?

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