

A Clear Advantage: Innovative transparent PCB materials for new markets

A-GAS[®]

Electronic Materials

CHASM[™]

TCF Industry Standard

- **ITO** (Indium TinOxide)
- Currently dominates both Glass & Flexible Substrate segments
- Will continue to dominate on Glass
- Will be displaced on Flexible Substrates (Plastic Films)
 - ITO is not flexible, formable or stretchable
 - ITO is not as transparent & conductive on Plastic
 - ITO can be costly to create circuit patterns on Plastic

Historically the patterning of ITO based TCF technologies has been dependent on high resolution laser ablation capabilities to enable pattern structures.

ITO Alternative Categories

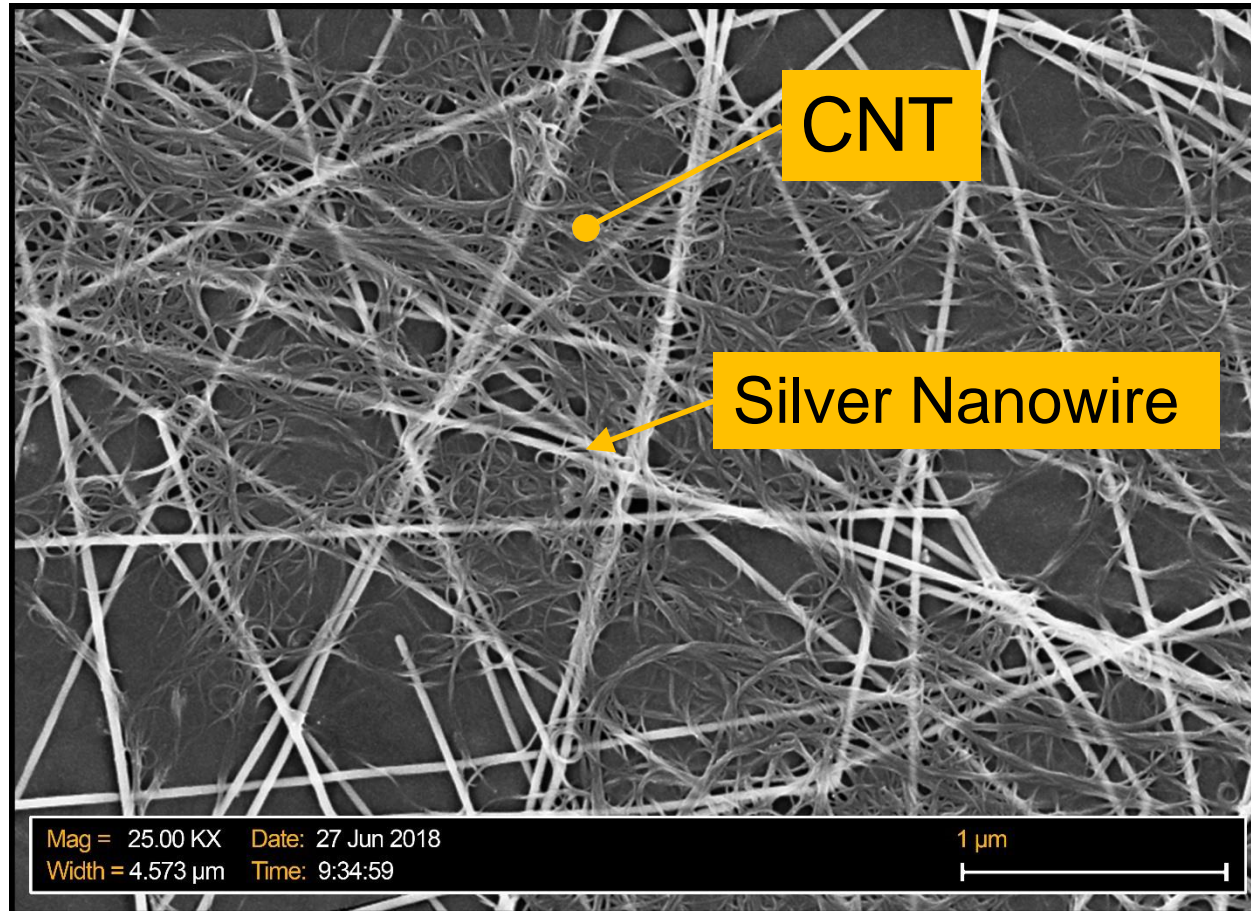
Market Needs

1. Transparency / Conductivity
2. Affordability
3. Environmental Stability
4. Flexibility / Formability

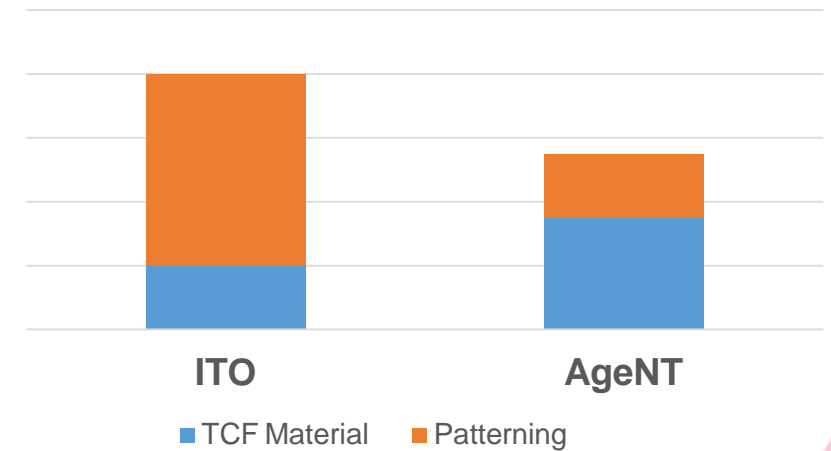
	SIGNIS™		AgeNT™		
	PEDOT	CNT	AgNW	MM	CNT Hybrid
1. Transparency / Conductivity	○ Limited	○ Limited	✓ Excellent	✓ Excellent	✓ Excellent
2. Affordability	✓ Excellent	✓ Excellent	○ Limited	○ Limited	✓ Good
3. Environmental Stability	○ Limited	✓ Excellent	✓ Good	✓ Excellent	✓ Excellent
4. Flexibility / Formability	✓ Excellent	✓ Excellent	○ Limited	○ Limited	✓ Excellent

AgeNT™ *CNT Hybrid TCF Materials*

The best flexible printed electronics you'll never see

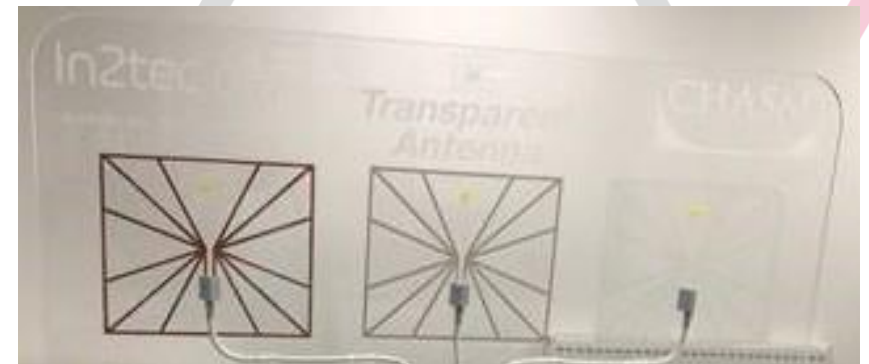
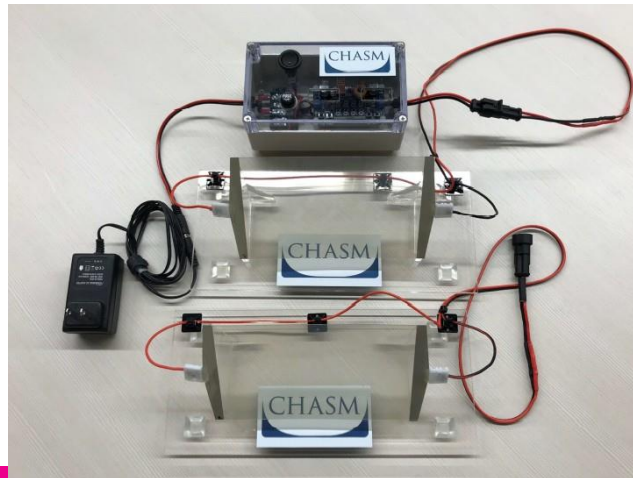
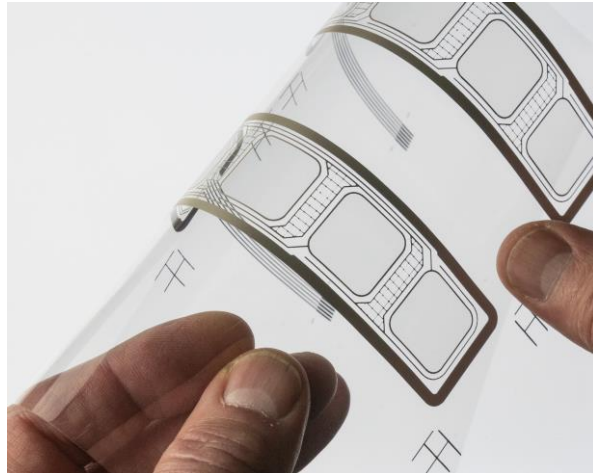
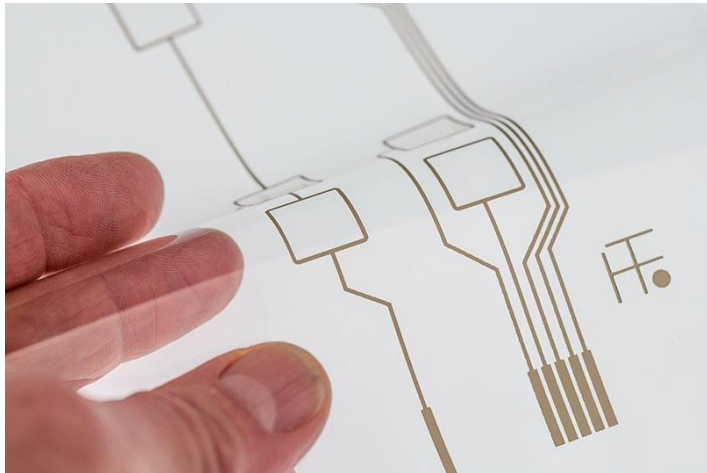


Cost of Patterned TCF (\$/m²)



- Better Performance
- More Affordable

Transparent Flex Printed Circuits



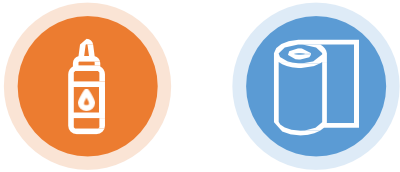
Fabrication and Process requirements

Fabrication and Process requirements

- Systems already present in industries such as a PCB shops or a Printed Electronics manufacturer – minimal equipment capital cost to open new markets
- Hybrid material structure – combination of ink and film to form a hybrid material
- Ink acts as pattern mask and is a functional part of end product, therefore no mask removal stage

Processing Equipment

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INK + FILM

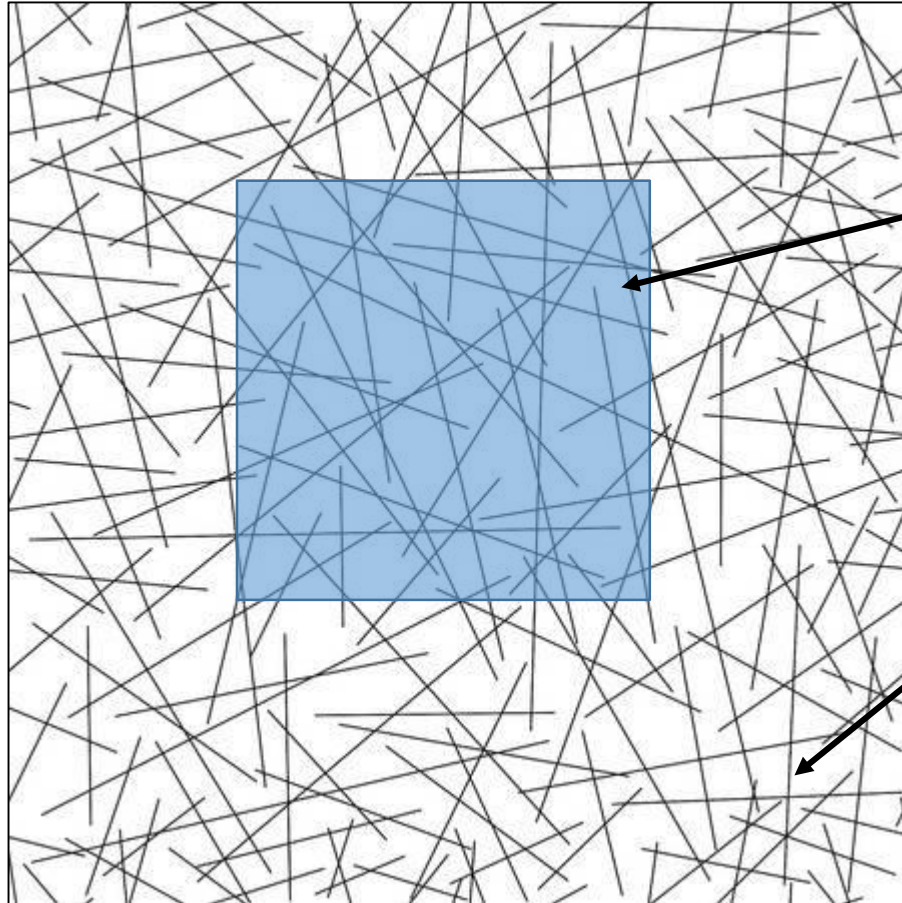


- Screen Printing Press
- Convection Oven
- Ventilation Systems

- Conveyorized Etcher



AgeNT[™] *Low-cost Patterning*



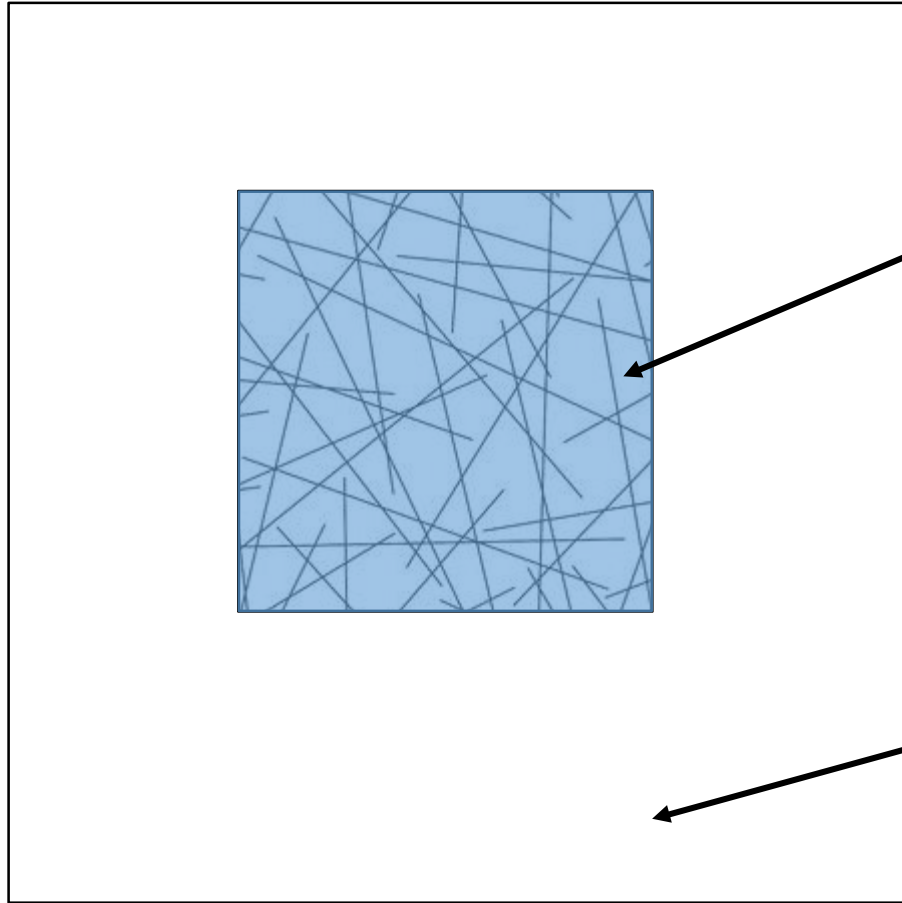
CNT ink

AgNW film

CNT ink is screen printed onto R2R coated AgNW film

Exposed AgNW areas are etched away to create Patterned TCF

AgeNT™ *Low-cost Patterning*



CNT Hybrid TCF

AgNW etched away (Ferric Nitrate)

Three versions:

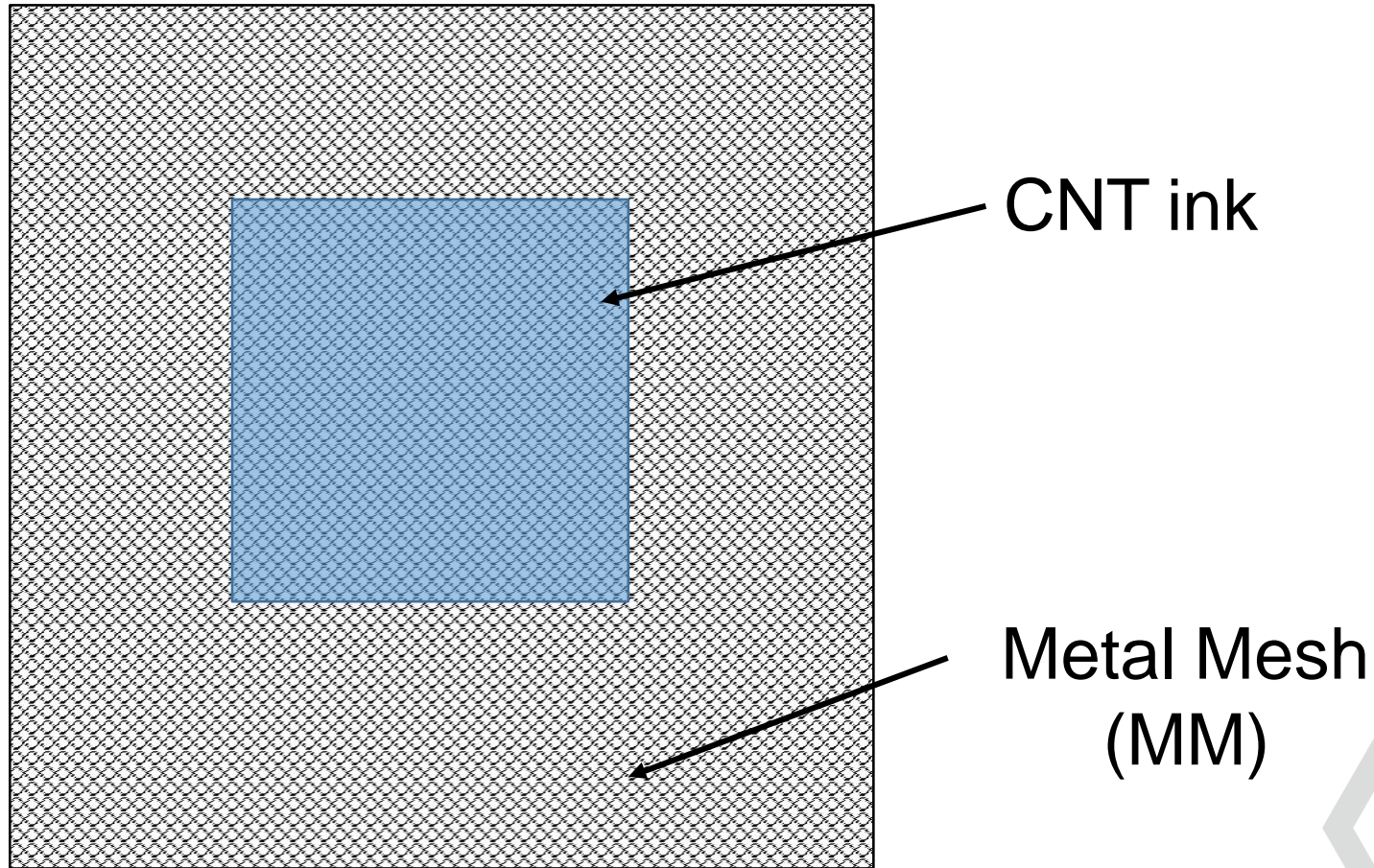
75 Ω/\square
98% VLT

30 Ω/\square
95% VLT

10 Ω/\square
90% VLT



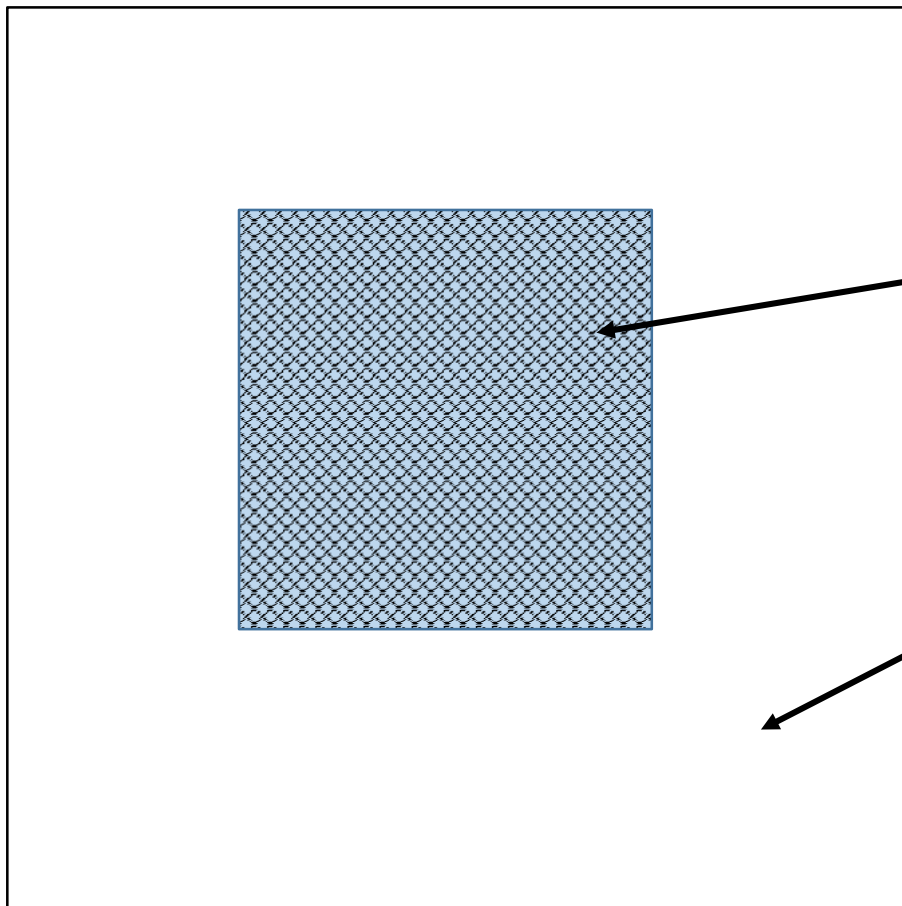
AgeNT™ *Low-cost Patterning*



CNT ink is screen printed onto MM Film made from Cu mesh

Exposed MM areas are then etched away to create Patterned TCF

AgeNT™ *Low-cost Patterning*



CNT Hybrid TCF

Metal Mesh etched away
(Ferric Nitrate)
(Ferric / Cupric Chloride)

1 Ω/\square
>94% VLT



APPLICATIONS SPOTLIGHT: TRANSPARENT HEATERS

Applications

Numerous application areas and opportunities for growth and application diversification:

1. Transparent Heaters
2. Transparent Antennas (IoT, 5G etc)
3. Transparent Lighting Films
4. Transparent Touch Sensors

Some applications to be covered in a future presentation so stay tuned.....



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Transparent Heaters Opportunities

Automotive industry opportunity for transparent heater solutions, driven by growth in:

1. Advanced Driver-Assistance Systems (ADAS) and autonomous vehicles for improved safety.

Increased number of sensors in the vehicle which need to be kept clear of frost and mist to function properly

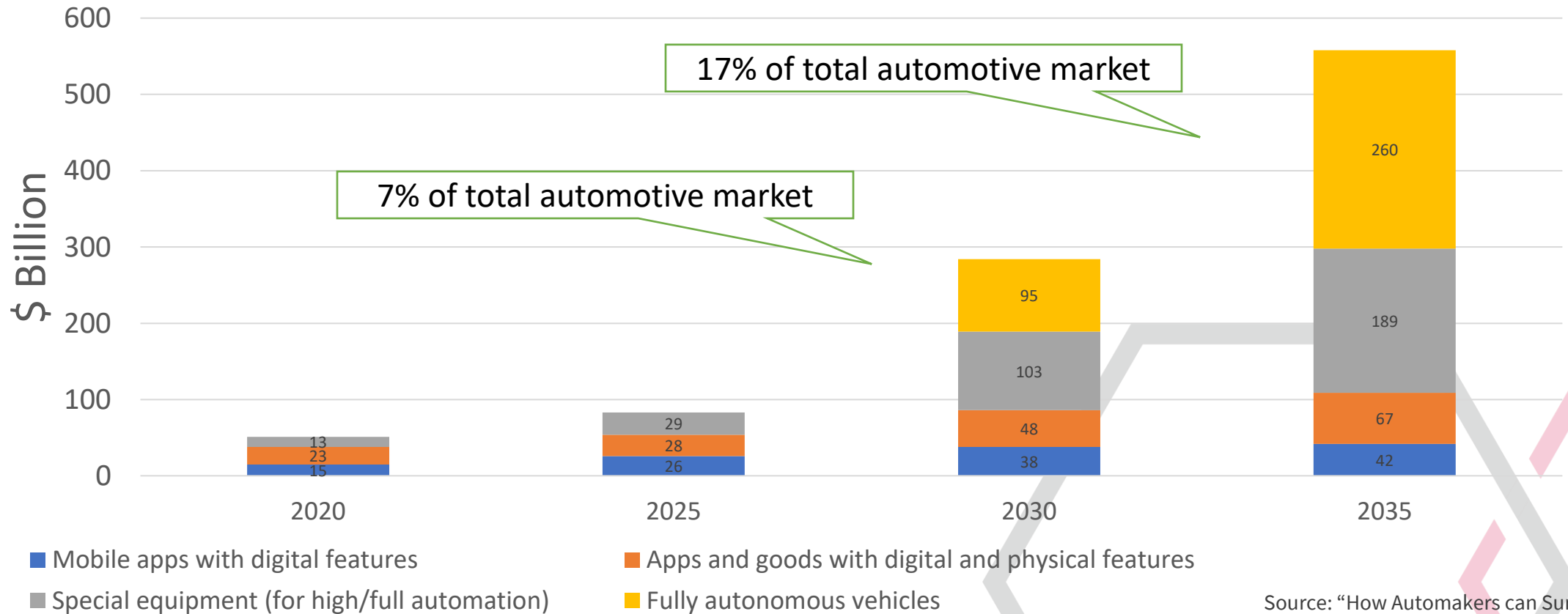
2. LED lighting replacing halogen or xenon light, for brighter more energy efficient systems.

Energy efficient bulbs do not produce as much heat and are susceptible to frosting over with ice and snow



Transparent Heaters Opportunities

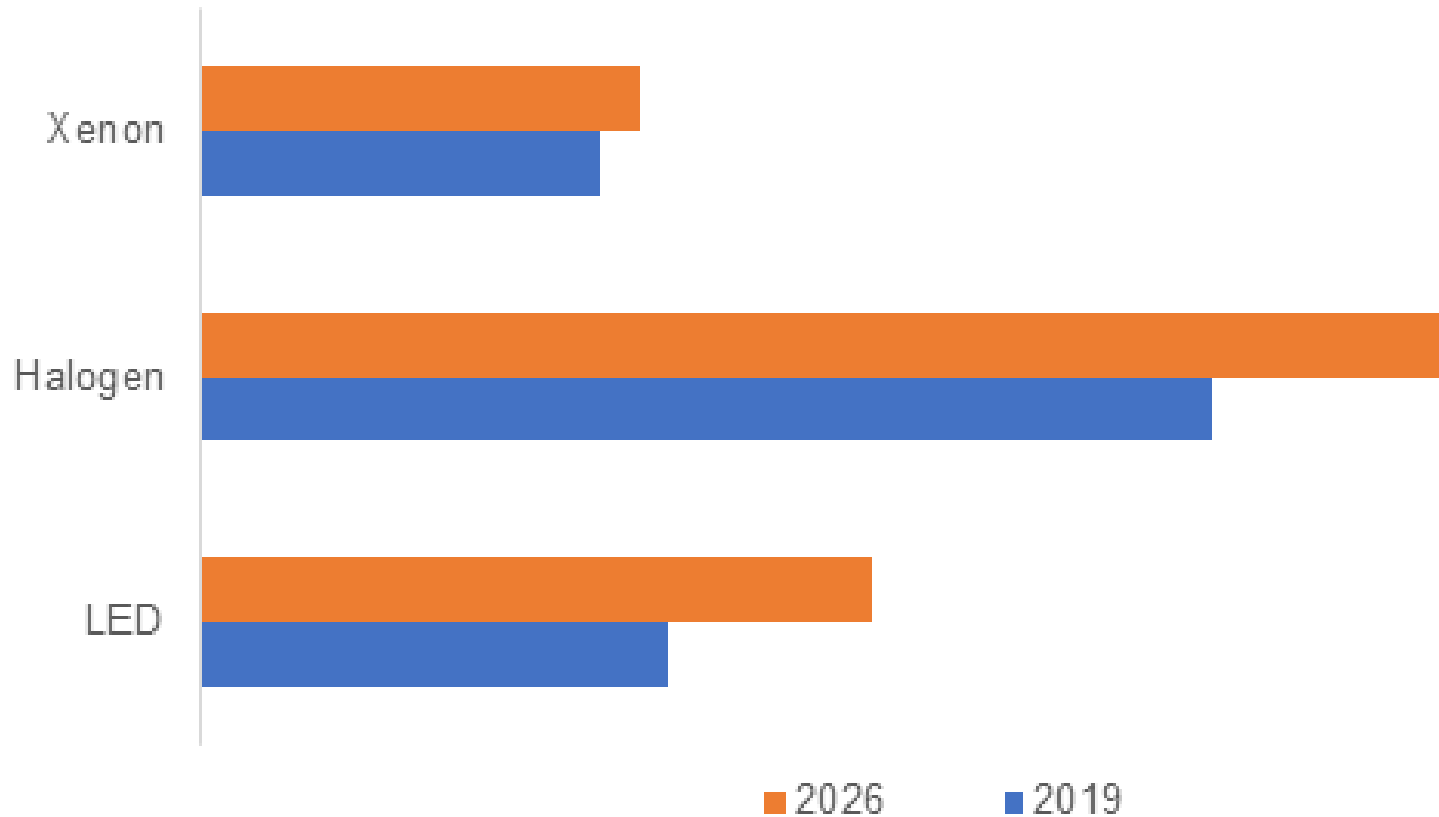
Global Market for Automated and Autonomous Driving, Including Related Services



Source: "How Automakers can Survive the Self-Driving Era" – AT Kearney

Transparent Heaters Opportunities

Automotive Lighting Market Size, by Technology, 2019 & 2026, (USD Million)



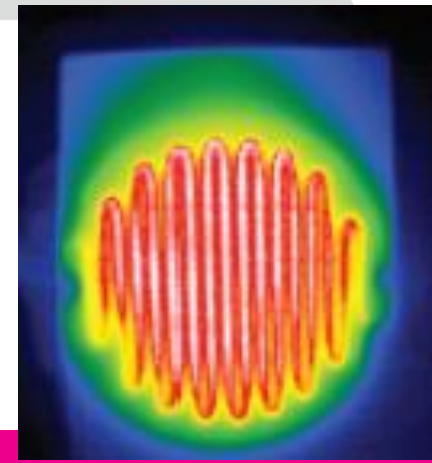
Source: www.gminsights.com

Conventional “Transparent” Heaters

Conventional automotive solution for “transparent heaters”:

Printed heating stripes or embedded conductive wires

- Uneven heat distribution (less effective de-icing)
- Visible wires (impact to camera sensor function and/or aesthetics, regulatory controls over wires structures and visibility)
- Single point of failure (if wire is broken in any part, system no longer functions)

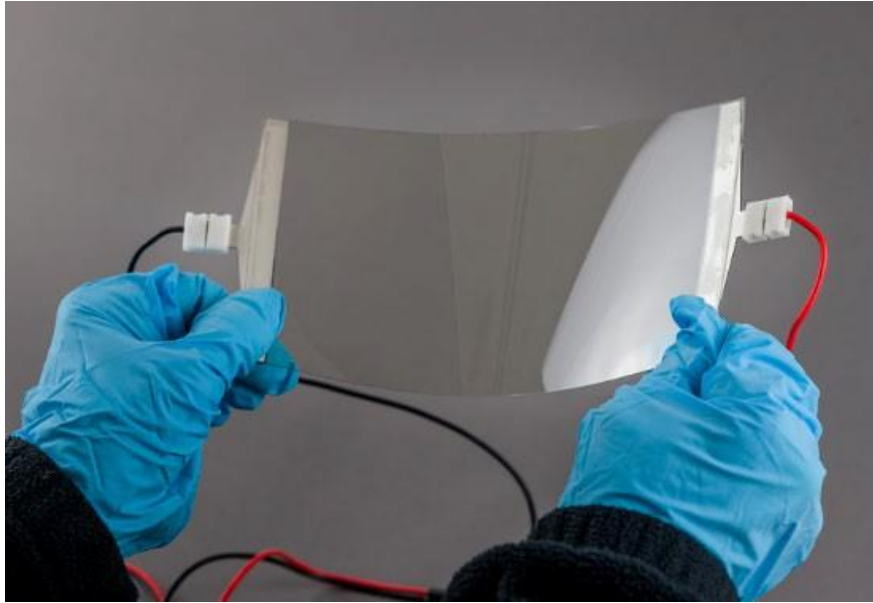


The Next Step in Transparent Heaters

AgeNT transparent heaters

Suitable for most demanding customer specifications.

Can be laminated between glass or applied onto plastic and glass lenses by adhesive film or overmolding.



- Power Density > 3,000 W/m²
- Temperatures > 120°C (248°F)
- Highly Flexible
- Highly Transparent
- Uniform Heating



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Summary

- AgeNT hybrid technologies offer a solution to the issues of ITO for flexible applications
- Ease of processing route for large scale manufacturing
- Low capital cost possibilities for current PCB manufacturers and Printed Electronics manufacturers
- Options for diversification of product and application portfolios
- Potential for diversification of the existing customer base

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You can also join us on LinkedIn by searching for "Dr. David Shaw" and "A-Gas Electronic Materials" to continue the conversation.