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Conductive Materials – Market Uses and Experiences

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www.hvm-uk.com

INNOVATIVEADDITIVECIRCUITTECHNOLOGY

Overview

- Outline of some applications in printed electronics and where graphene sits
- Very small section of potential applications of graphene
  - Those where CIT is active
  - CIT is not currently working with graphene
- Mainly using data based on available materials not hero results

About CIT

- Part of Carclo plc, £250m business on London stock exchange
- Carclo is a manufacturer
  - Medical device and disposables
  - LED lighting for super cars
  - Specialist Aerospace parts
- CIT is subsidiary based in Cambridge, England
  - Focussed on catalyst and metallisation processes

CIT Business

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- Licensor of Touch screen sensor circuits
  - In partnership with Atmel Corporation
- Manufacturer of inkjet based flex circuits
  - Wide range of applications including sensors & antennas
- Developer of innovative solutions for wide range of applications across Printed Electronics
  - Developing full assembly processes for low-cost electronics
- R&D Partnered with several companies across the Organic semi-conductor sector
  - Focus on lighting and Photovoltaics

CIT Process

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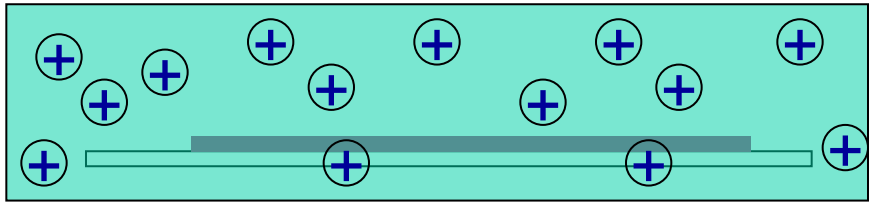
Digitally Print Catalytic Ink

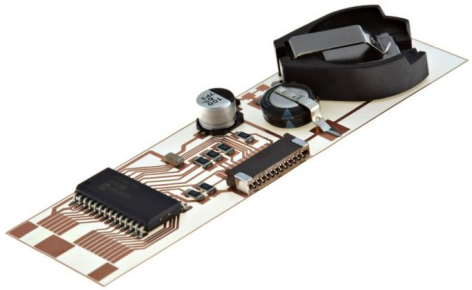
Immerse in solution of
Metal Ions



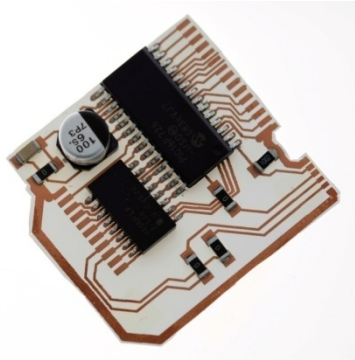
Metal film is grown by
Autocatalytic deposition

Typical Applications

- Antennas
  - UHF RFID antennas
  - Suited to many other antenna applications



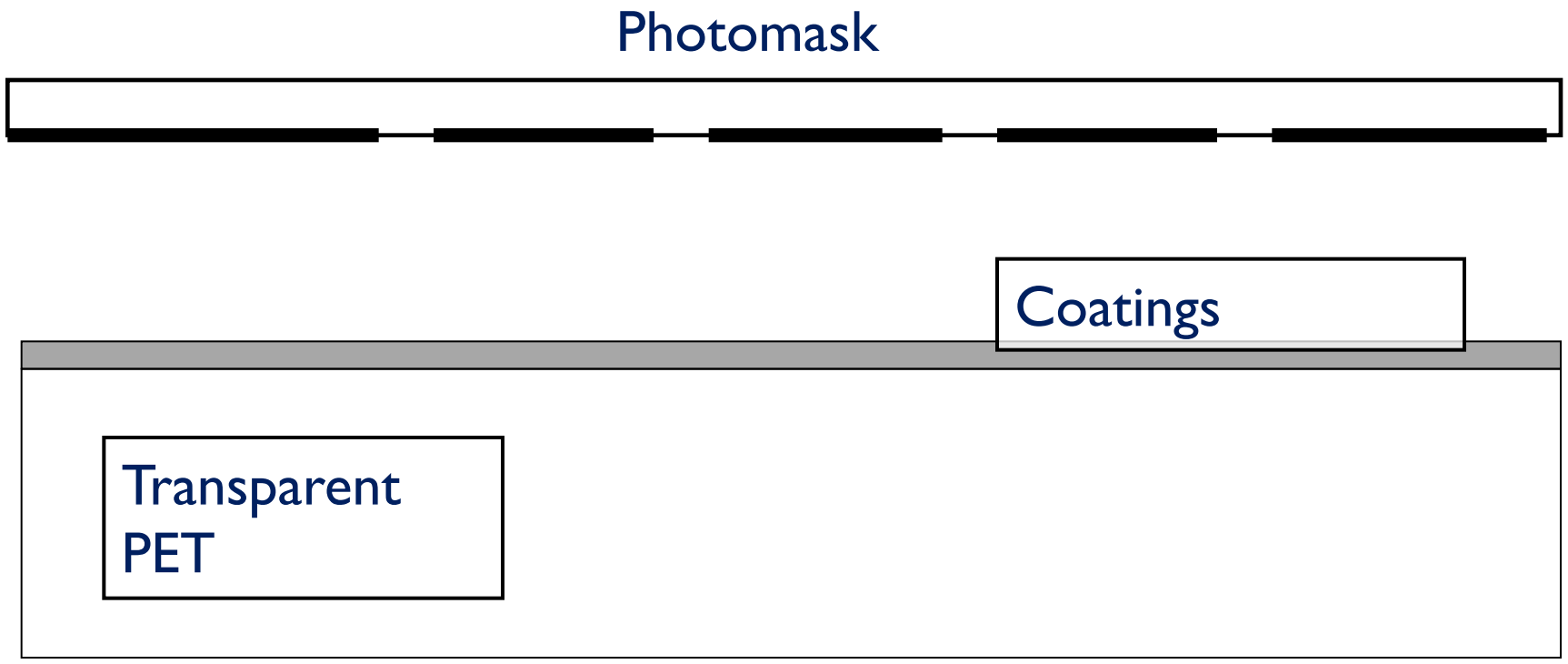
- Low current Sensors and Transducers
  - Cost effective for disposable applications
  - Flexible for easy implementation
  - Solderable - allowing surface mount components to be attached on standard equipment
- LED Circuits and Arrays
  - Thin copper on PET ideal for Surface mounted LEDs
  - Limited power requirements



Transparent Conductor Solutions

- Metal Mesh as alternative to ITO
  - Currently largest CIT application
  - Touch sensors for mobile devices
  - Partnership with Atmel Semiconductor
- Front electrode materials for OLED and OPV devices
  - In combination with field filler

CIT Photo-lithographic Process



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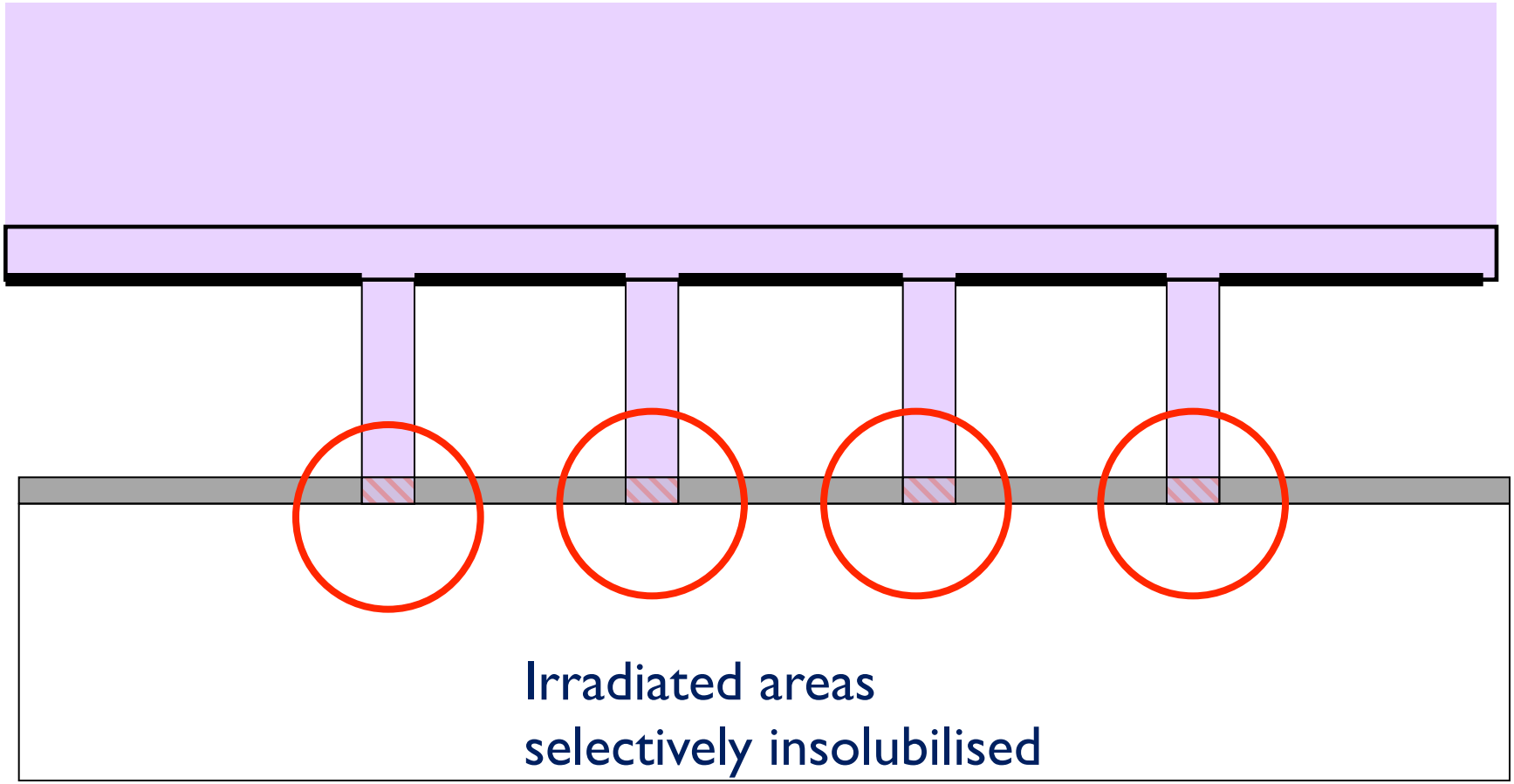
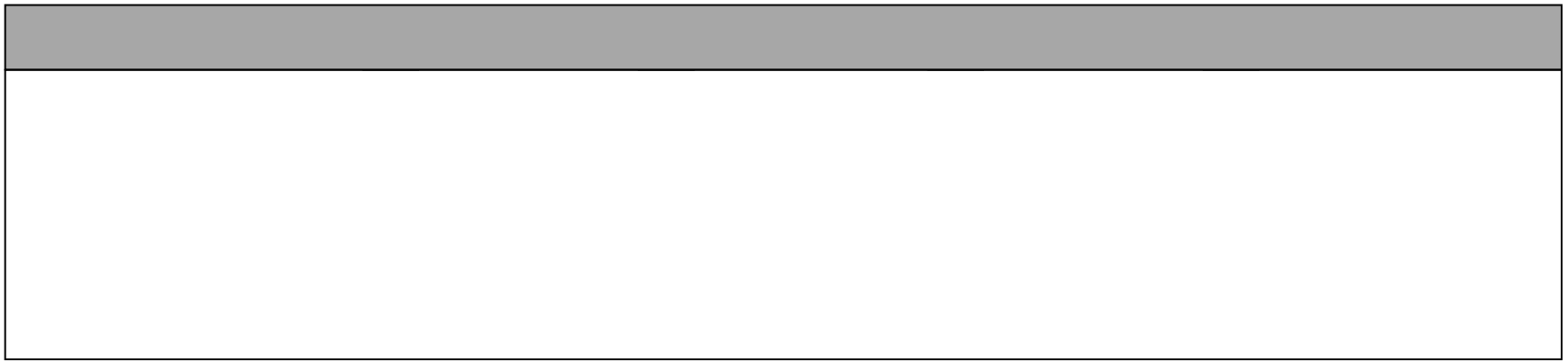
UV exposure



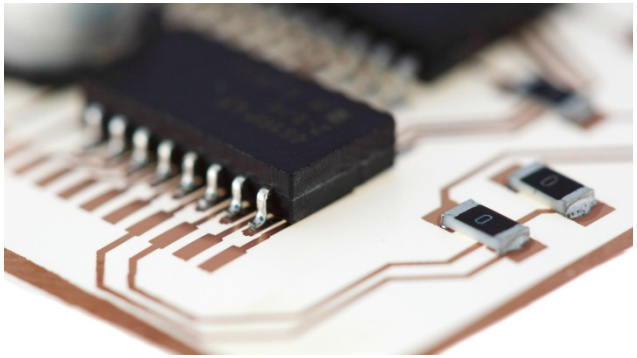
Development and Metallisation

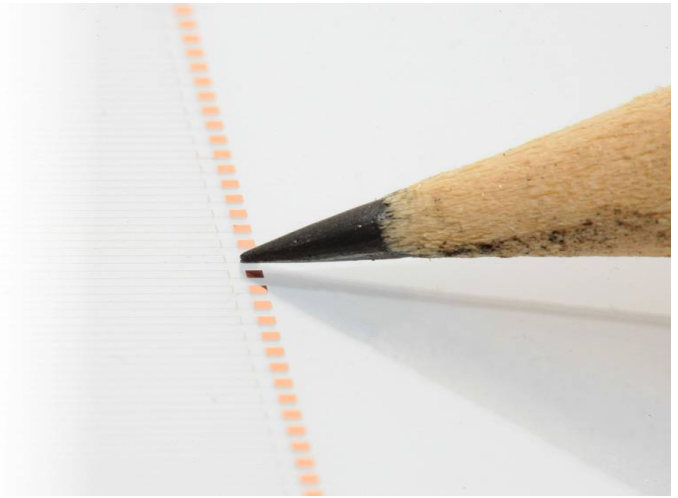
- Wet Development dissolves unexposed coatings
- Wet metallisation step builds copper on patterned coating



Applications

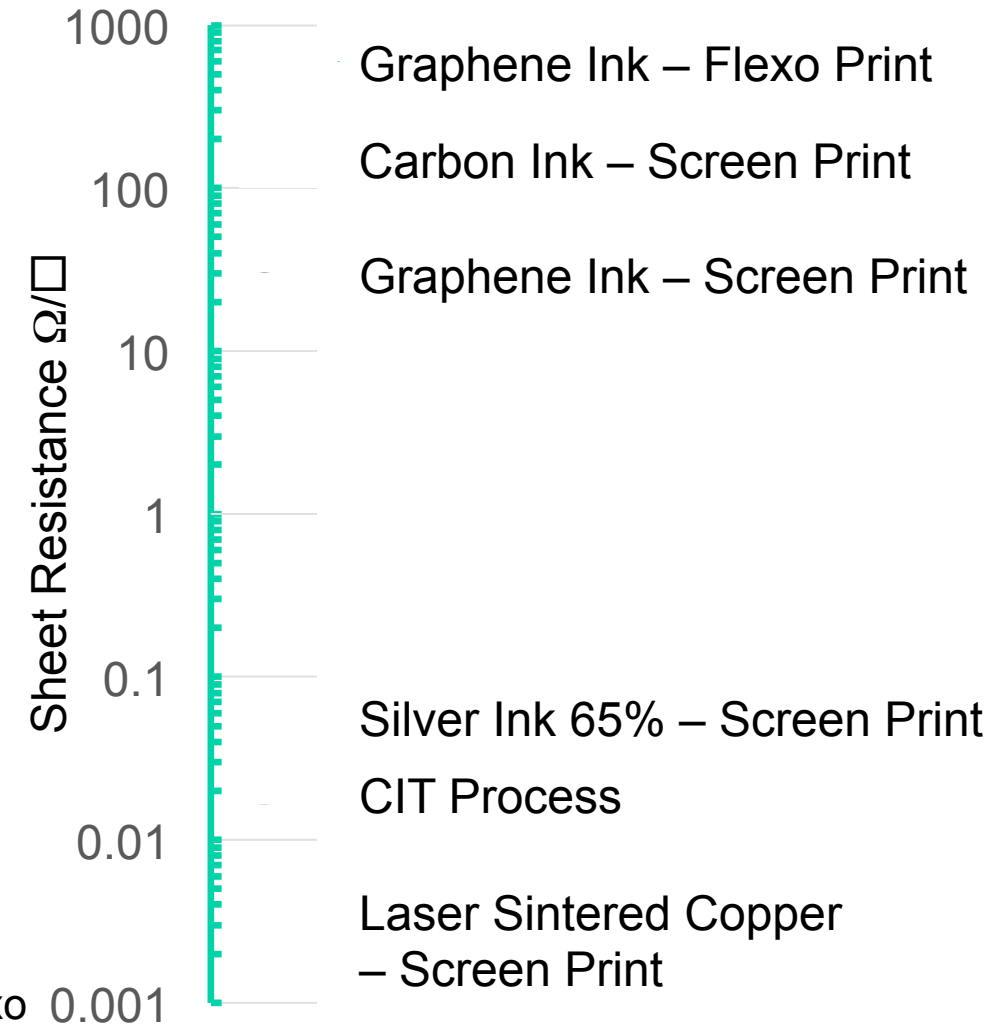
- Consider two separate areas
  - Those traditionally served by conductive Inks
  - Those requiring transparent conductors





Conductive Inks

- Different applications require different levels of conductivity
- Membrane keypads and passive sensors tolerate higher
- Antennas and current carrying applications <50 mΩ/☐



Data sourced from Gwent Group
Assumes 10 μm screen print and 1 μm flexo

Requirements For Transparent Conductors

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Competition

- ITO
  - Typical: 270 Ω/♦ - ~90% T
  - Available 100 Ω/♦, 10 Ω/♦ and less
- Metal Mesh Technology
  - CIT, Cambrios ~ 10 Ω/♦ at 2-4% blocking
- Larger area devices pushing for lower sheet resistance and higher transmission

Graphene

- Theoretical Undoped
  - 97.7% T ~ 6k Ω/♦
- Typical doping 3.2 x 10^{12} cm^{-2}
  - 90% T ~ 20 Ω/♦
- CVD Films approach this
  - GRAPHENEA >97% 170 Ω/♦
- Large area coating techniques not so promising numbers
  - Typically > k Ω/♦ < 90% T

Typical data from:
Graphene photonics and optoelectronics
F. Bonaccorso, Z. Sun, T. Hasan & A. C. Ferrari
Nature Photonics 4, 611 - 622 (2010) Published online: 31/8/2010

Cost Targets and Other Considerations

Conductive Inks

- Need methods to make connections and assemble components
- Patterning techniques and processing speeds need to be considered
- Generally <$2 /sqft printed circuit including substrate (Volume product)
- Lower conductivity applications tend to be lower cost (e.g. where carbon inks would be used instead of silver)

Transparent Conductors

- For most applications TCF will require patterning
- Devices usually require connection to outside world via higher conductivity medium
  - Silver printed bus lines on ITO film
  - Ideally <1 Ω/☐
  - Bus lines built in for CIT process
- Applications demanding large area devices
  - >16” diagonal already sought
  - Higher conductivity enables larger area devices
- Typical cost ~$0.5-$1 per diagonal inch for **finished** component

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Thank You!

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