Printed Electronics and Related Projects supported by the Innovative Electronics Manufacturing Research Centre (IeMRC)

Martin Goosey

IeMRC Industrial Director

Presentation Contents

- **Overview of the IeMRC**
- **Printed Electronics and the IeMRC's projects in this area**
- **Integrated Optical & Electrical Interconnect PCB Manufacturing**
- **Smart Microsystems**

The IeMRC

Innovative Electronics Manufacturing Research Centre

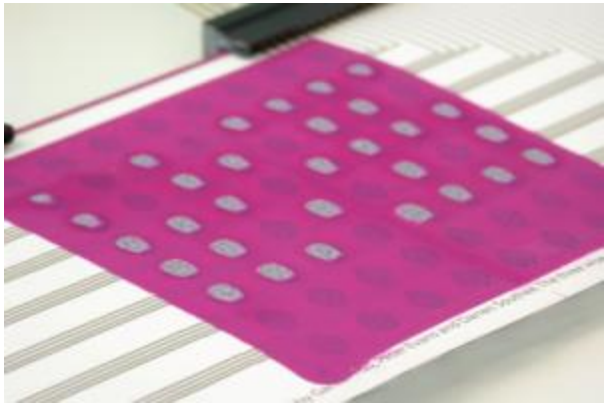
- The IeMRC is funded by EPSRC
- Part of the **I**nnovative **M**anufacturing **R**esearch **C**entre programme
- Initially awarded £5.5 million in funding over 5 years
- First period from 2005 to 2010
- Supporting electronics research in academia throughout the UK

IeMRC Vision Statement

The vision of the IeMRC is to be the UK's internationally recognised provider of world-class electronics manufacturing research. It will focus on sustaining and growing high value manufacturing in the UK by delivering innovative and exploitable new technologies, highly skilled people and strategic value to the electronics industry.

IeMRC – Industry Focus

- Aligned with the real future needs of the UK's electronics industry
- Strategy determined by an Industrial Steering Group with members form across the industry supply chain
- All projects have a strong industrial support
- Second five year period, started March 2010
- Additional tranche of funding ~£9 million
- Wide range of research projects



What is ‘Printed Electronics’?

- 'Printed electronics' and 'plastic electronics' are terms used to describe electronics based on semiconducting organic polymeric materials
- Deposited using additive or printing techniques
- Many applications offering a competitive or superior mix of novel performance and manufacturing economics
- Printing technologies offer lightweight and robust electronics at low cost on large area, flexible substrates eg advertising and clothing etc

Printed Electronics

- Printed electronics are being developed by by over 3,000 companies, universities and research institutes worldwide
- Market for printed electronics is beginning to emerge
- This year, the market for printed and thin film electronics is predicted to reach almost $2.0 billion
- Immediate applications in RFIDs and OLED displays manufactured using organic thin film transistor technology

IeMRC PE Projects

- The IeMRC research portfolio is broad and encompasses key areas from silicon processing through assembly to reliability and end of life issues
- It has supported, and continues to support activities, related to printed and plastic electronics eg;
  - Brunel - lithographic printing of conductors, components, displays
  - Surrey - ink jet/spin coating printing of conductive polymers, DTA
  - Oxford, Leeds, Manchester and Bangor - new flagship project

Printed Electronics at Brunel

Developed a wide range of printed electronics applications based on offset lithography eg

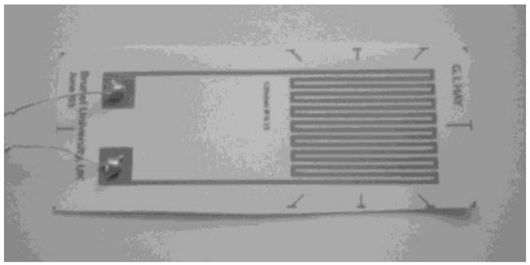
- conductive circuitry
- components
- batteries
- sensors
- displays

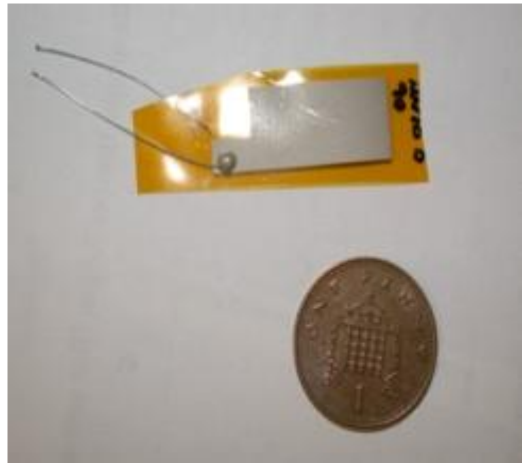
Dr. Darren Southee

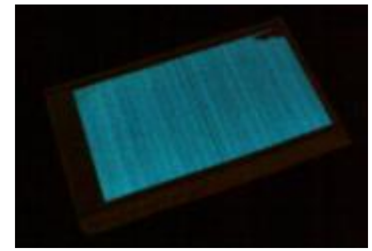
Cleaner Electronics Research Group

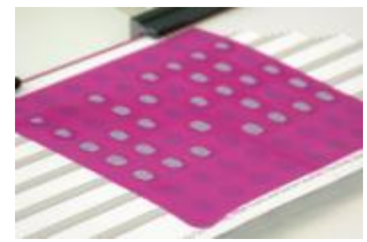
Email: Darren.Southee@brunel.ac.uk

Example Devices and Partners









Hallmark

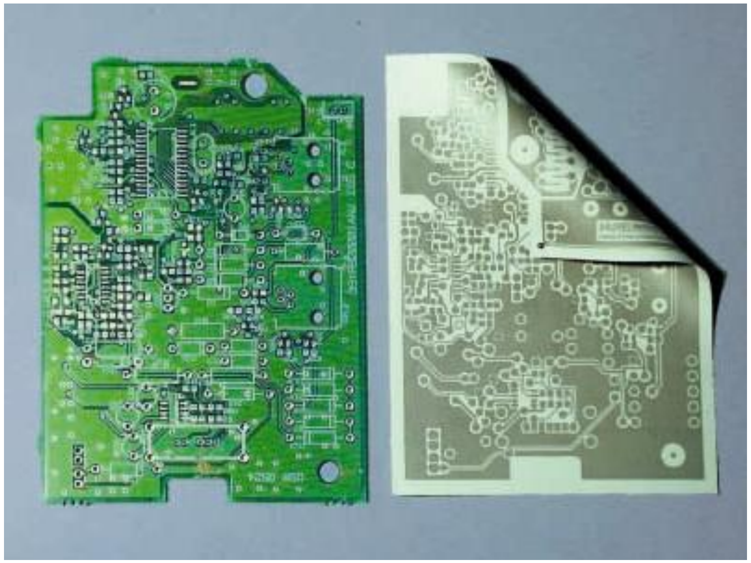
Arlex

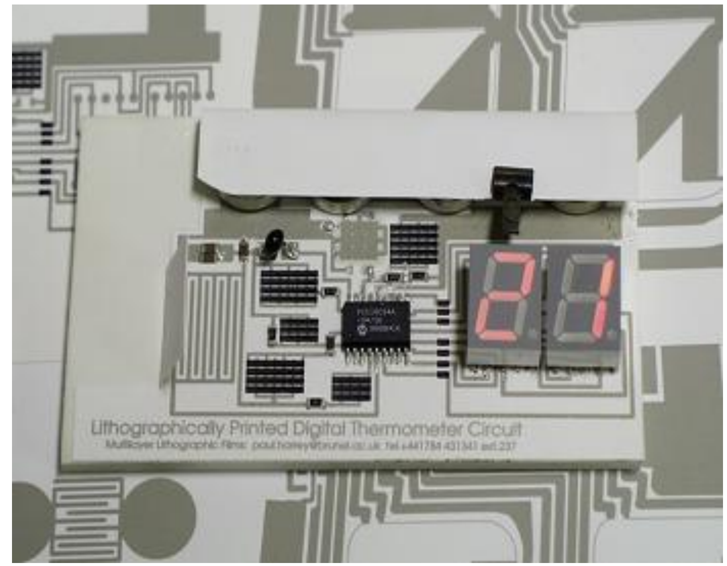
GEM

ArjoWiggins

DuPont Teijin Films

Printed Conductors



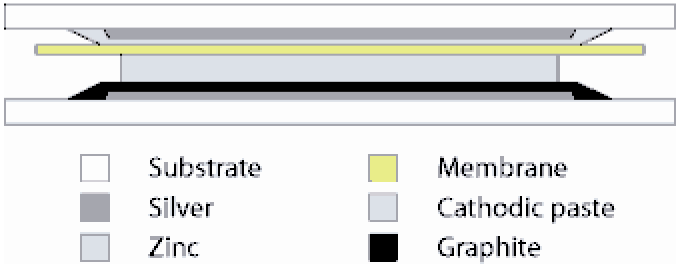


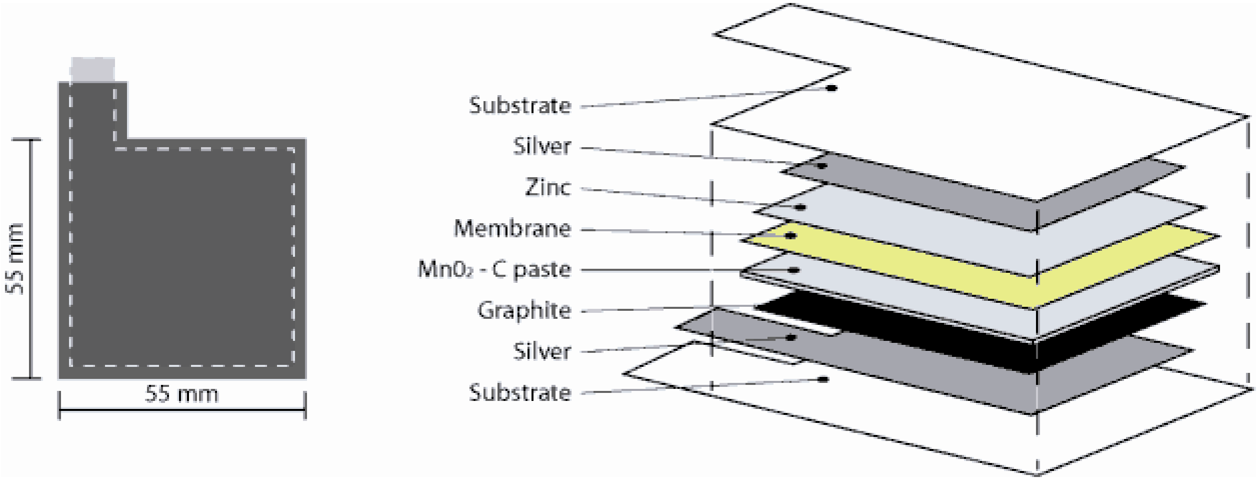
- Landline telephone mainboard
- Artwork taken from original resin laminate circuit board
- SMT passive components attached using conductive adhesive

- Microprocessor controlled thermometer
- Circuit interconnect, resistors, capacitors and switch actuator, all printed by offset lithography
- Uses glazed paper as the circuit substrate

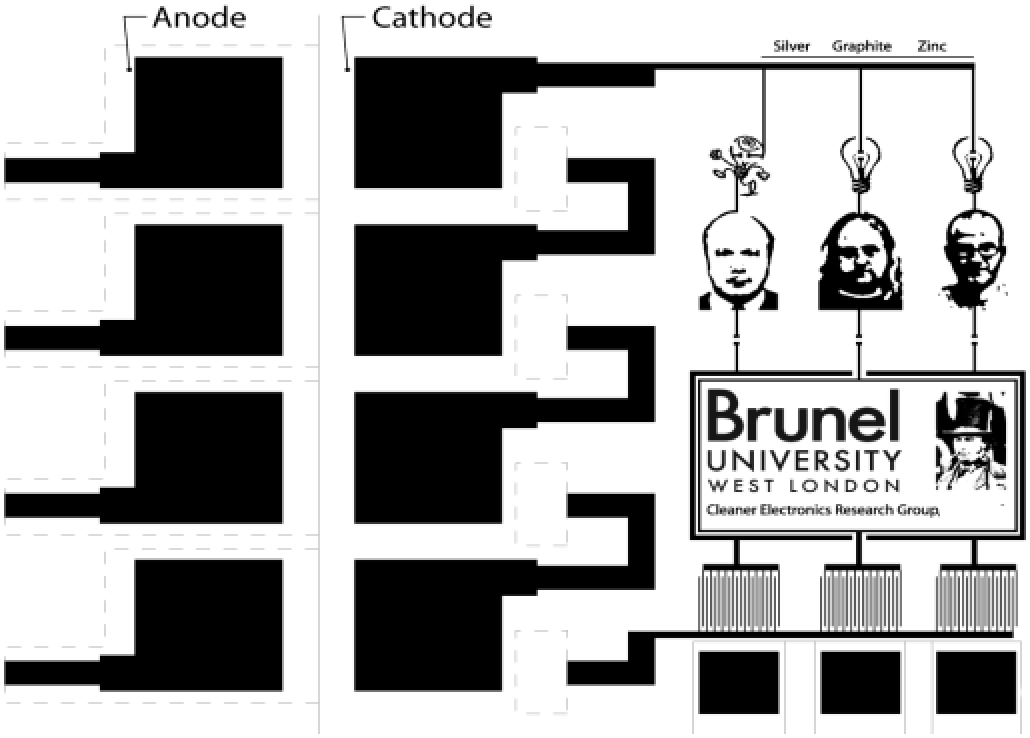
Lithographically Printed Batteries

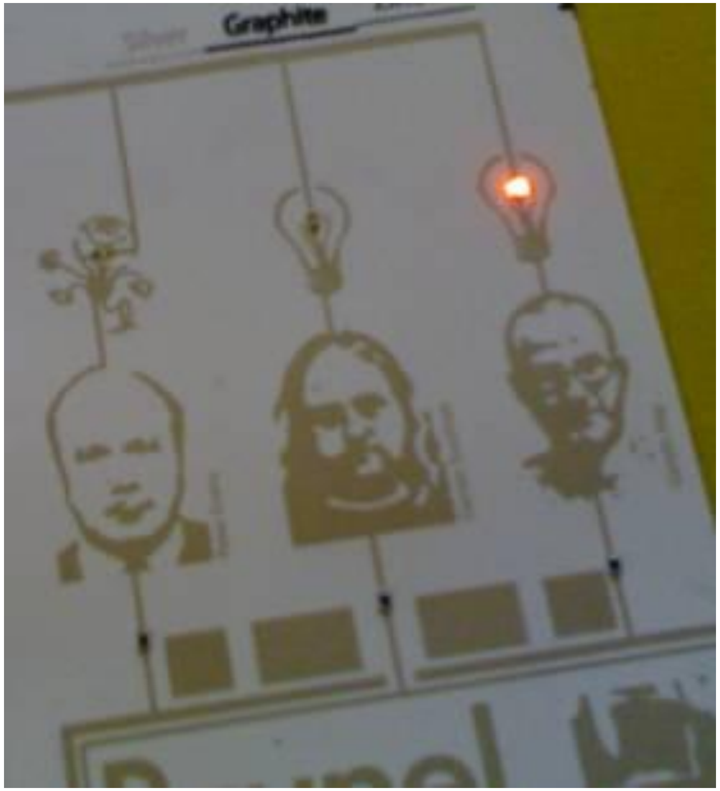
- Printed on a non-porous substrate material
- Use silver current collectors
- Manganese dioxide





Lithographically Printed Batteries

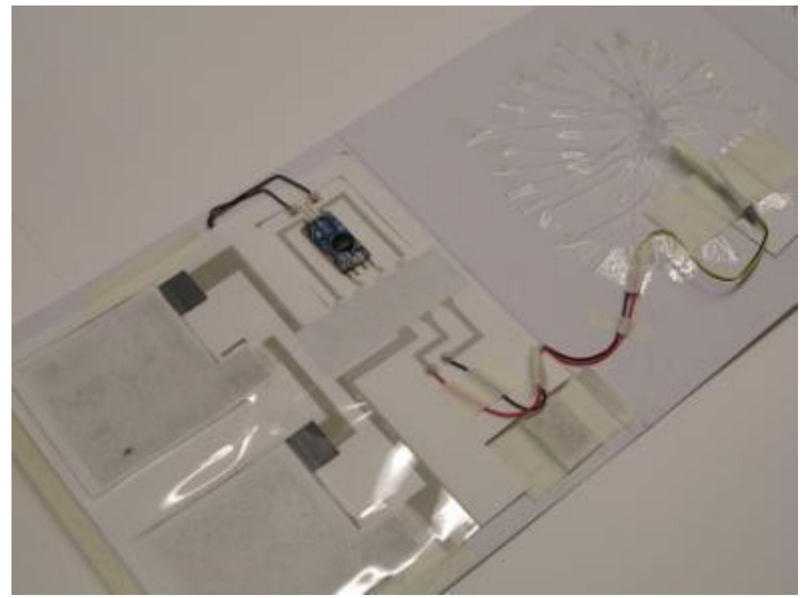




Includes four cells producing a potential of 6.0 to 6.5V

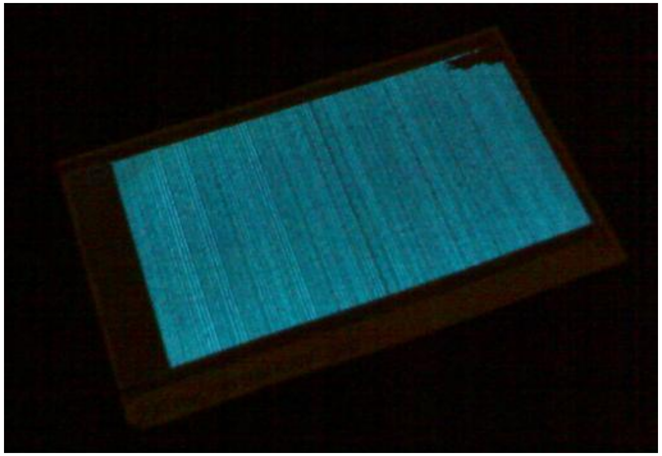
Lithographically Printed Batteries

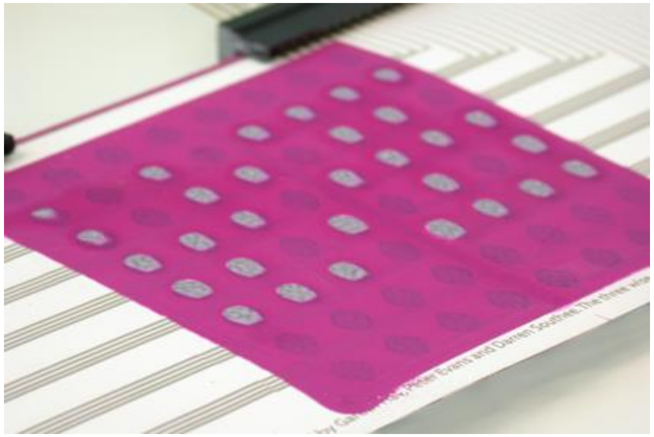
‘Amplified Experience Greetings Cards’ (Hallmark/Tigerprint)
powered by printed battery structures



Currently collaborating on applications with a pharmaceutical company

Printed Electronics at Brunel





Hallmark

GEM

ArjoWiggins

arlex

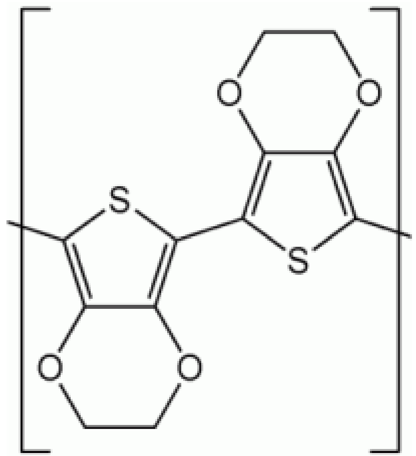
DuPont Teijin Films

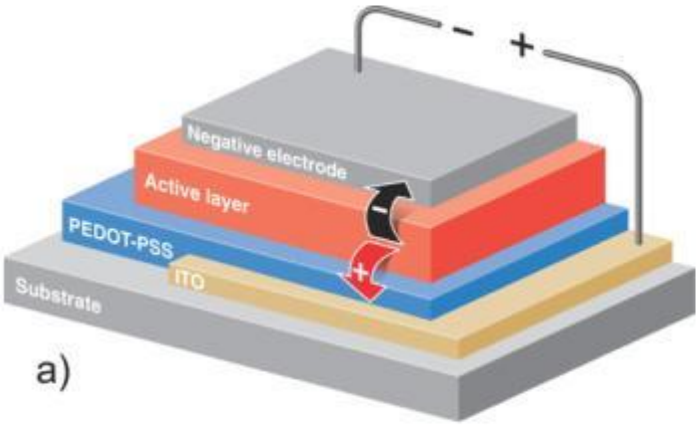
Brunel UNIVERSITY WEST LONDON

Ink Jet Printing and Spin-Coating of Electrically Conductive Polymers

Peter Wilson, Constantina Lekakou and John Watts

Performance of PEDOT





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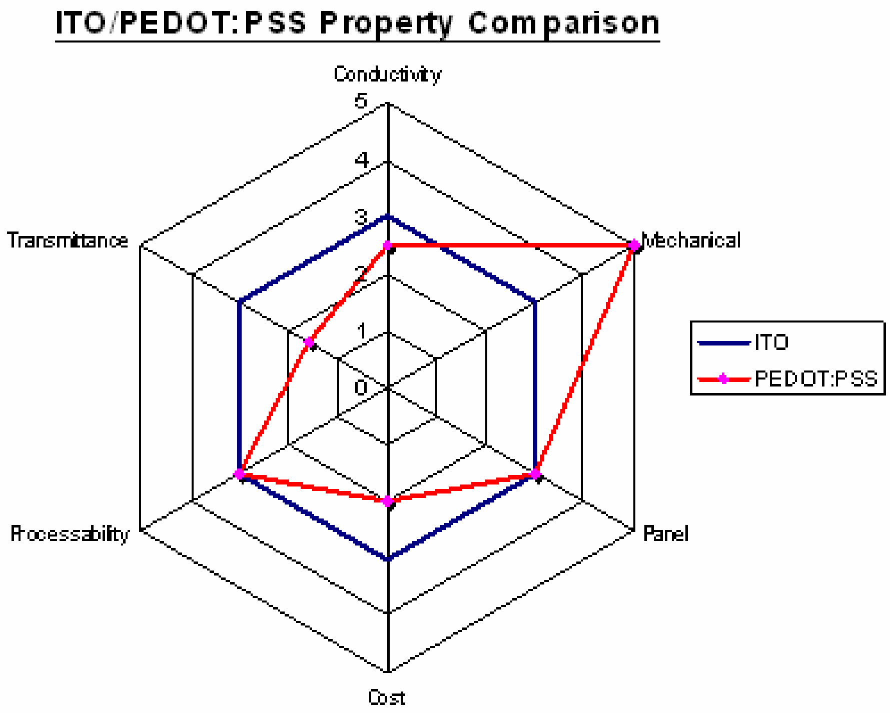
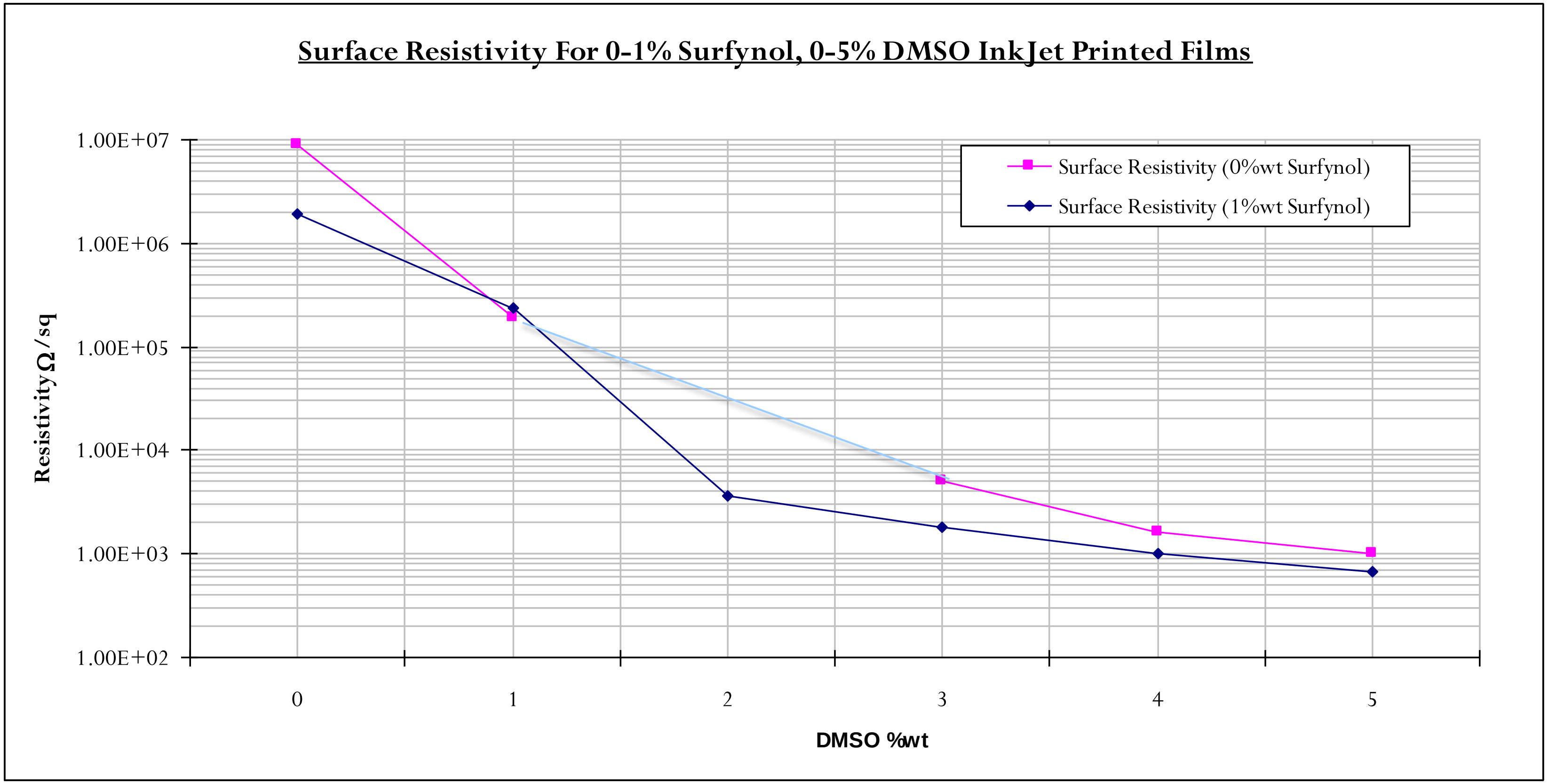


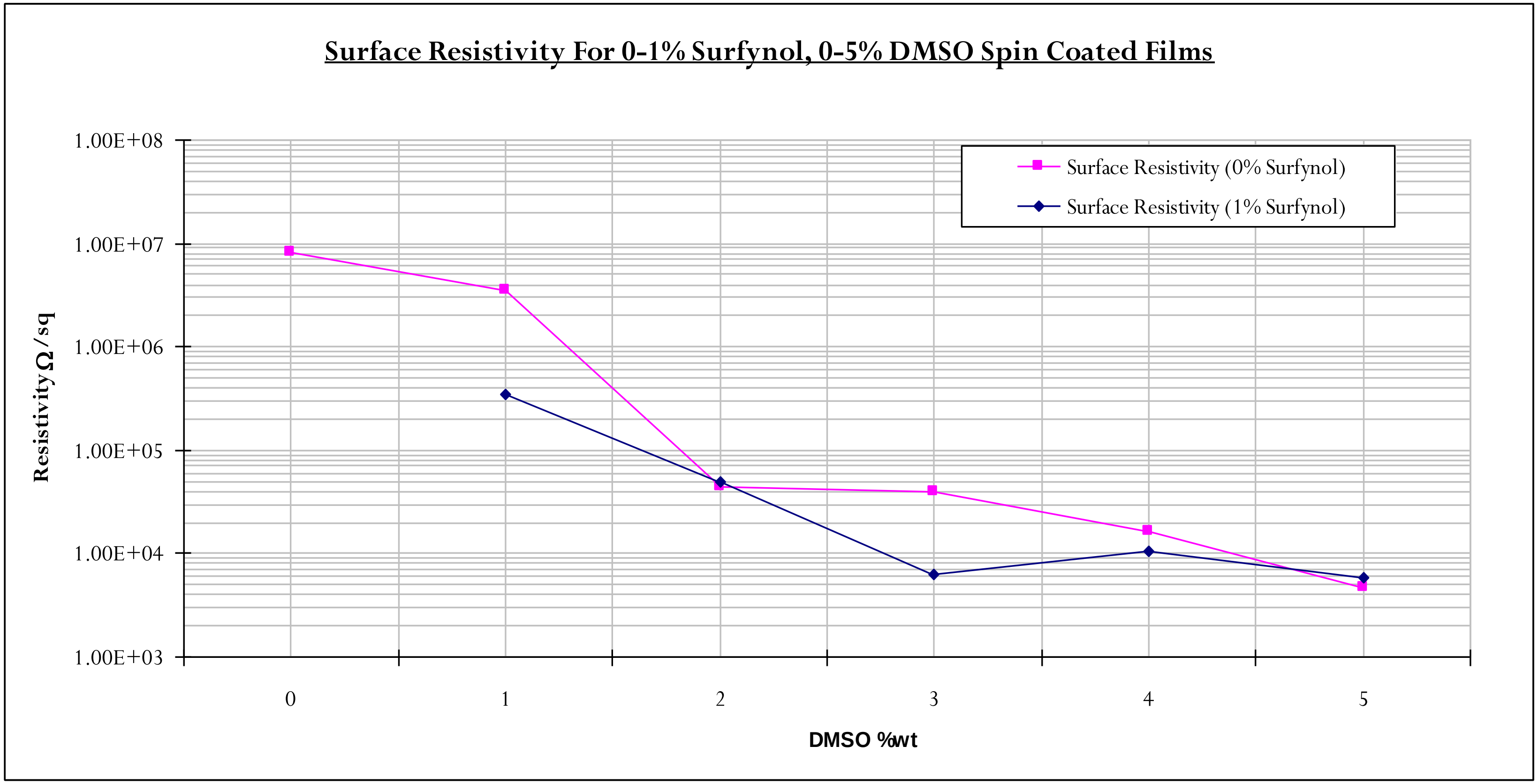
Comparative assessment of PEDOT:PSS films compared to ITO layers

Device life-time is ~ 7 x ITO

Conductivity of PEDOT

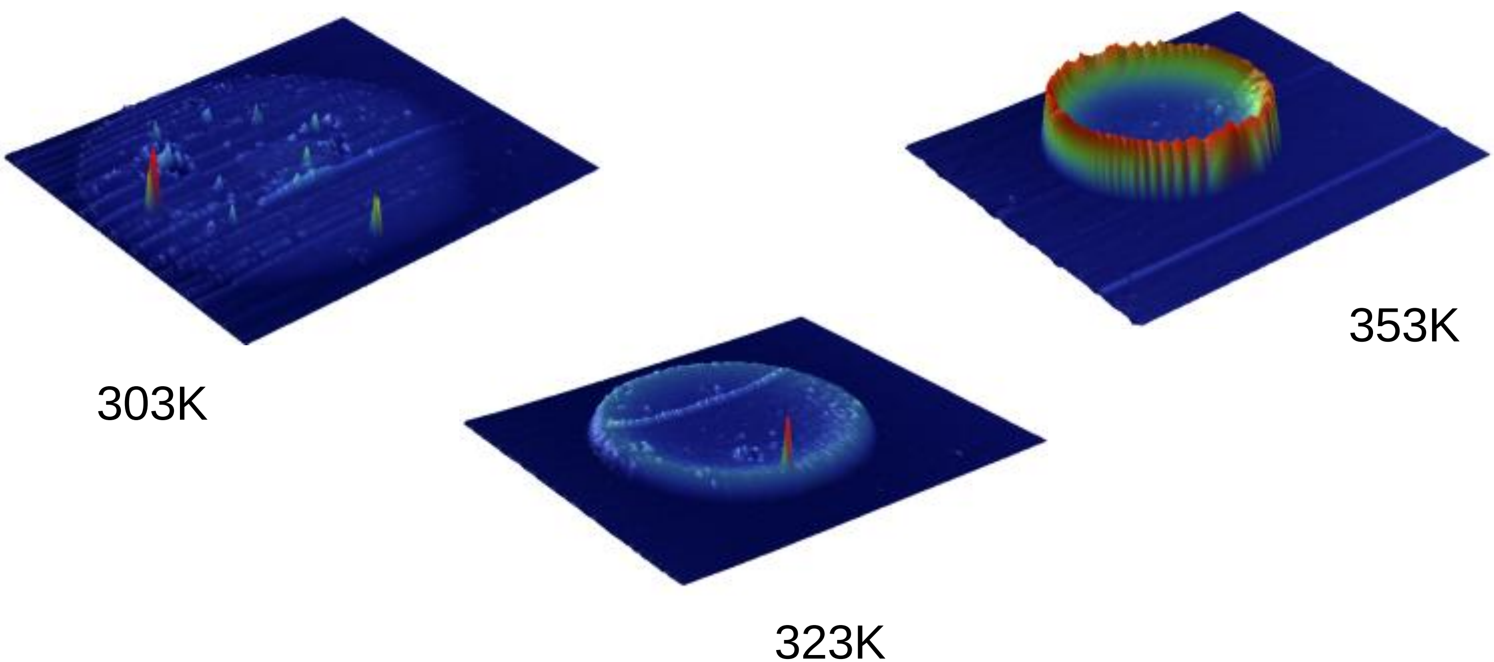


Conductivity of PEDOT



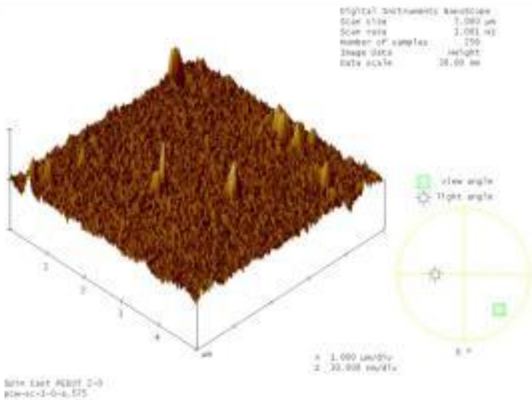
Effect of Shape on Conductivity

Drop profilometry demonstrating drop shape evolution due to redistributive ‘Marangoni’ flow as a result of increased substrate to drop solution temperature ratio

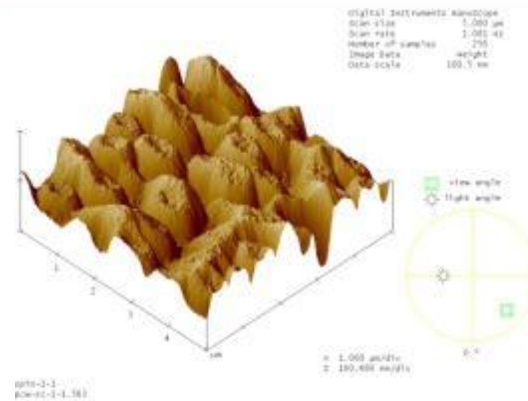


Single Drop Profilometry for Identical Inks at 3 Substrate Temperatures

Topography of PEDOT



5 µm x 5 µm topographic
Spin Coated (1% DMSO, 0% Surfynol)



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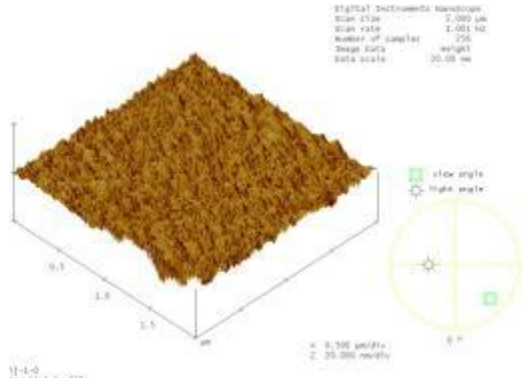
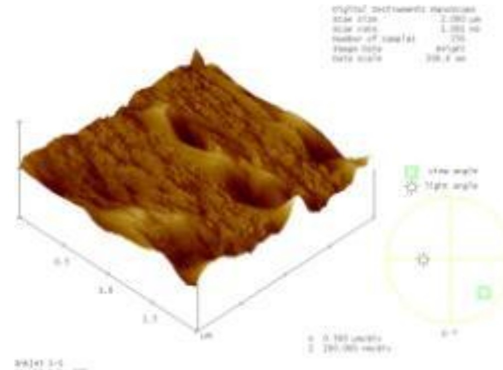


2 µm x 2 µm topographic
InkJet (1% DMSO, 0%Surfynol)

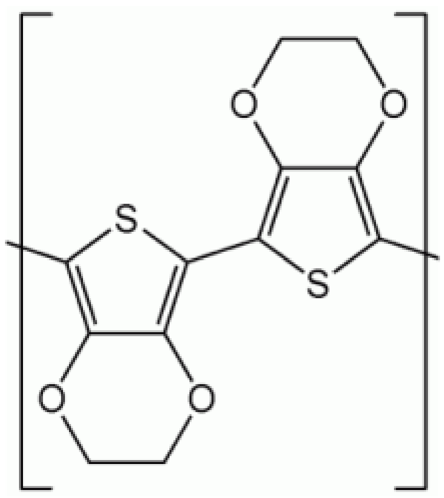


2 µm x 2 µm topographic
InkJet (1% DMSO, 1%Surfynol)

Printed Electronics at Surrey

Inkjetting of PEDOT can provide comparable films to spin coated whilst also offering;

- lower waste
- increased deposition accuracy
- greater selection of patterns & shapes
- a wider range of applications



IeMRC Flagship Project - RoVaCBE

Roll-to-roll Vacuum-processed

Carbon Based Electronics

AXESS TECHNOLOGIES LTD
SCOTT BADER
CAMVAC
M.Y. Healthcare
DALMATIAN TECHNOLOGY
SILVACO
GENERAL
parkside FLEXIBLES NORMANTON
PRIFYSGOL BANGOR UNIVERSITY
UNIVERSITY OF LEEDS
MANCHESTER 1824
UNIVERSITY OF OXFORD

The RoVACBE Flagship Project

Key Objectives

- Processing devices and device arrays for properties and high yield
- Link manufacturing parameters and materials with circuit design
- Exploitation of new materials
- Create 2D semiconductor and insulator patterning within a vacuum R2R process
- Address the mechanical and electrical robustness of the devices

Vacuum Deposition of Electronics

- Used for very low-cost simple electronics devices eg
  - tagging devices on packaging
  - brand protection, product tracking
  - anti-counterfeiting for consumer goods
- Extending the existing high-value manufacturing technology
- Vacuum deposition is widely used by the food packaging industry
- Roll-to-roll process with high webspeed (e.g. 50 m/min)
- Low environmental impact process (solventless)

Roll to Roll Processing

Industry (Camvac Ltd)

Oxford

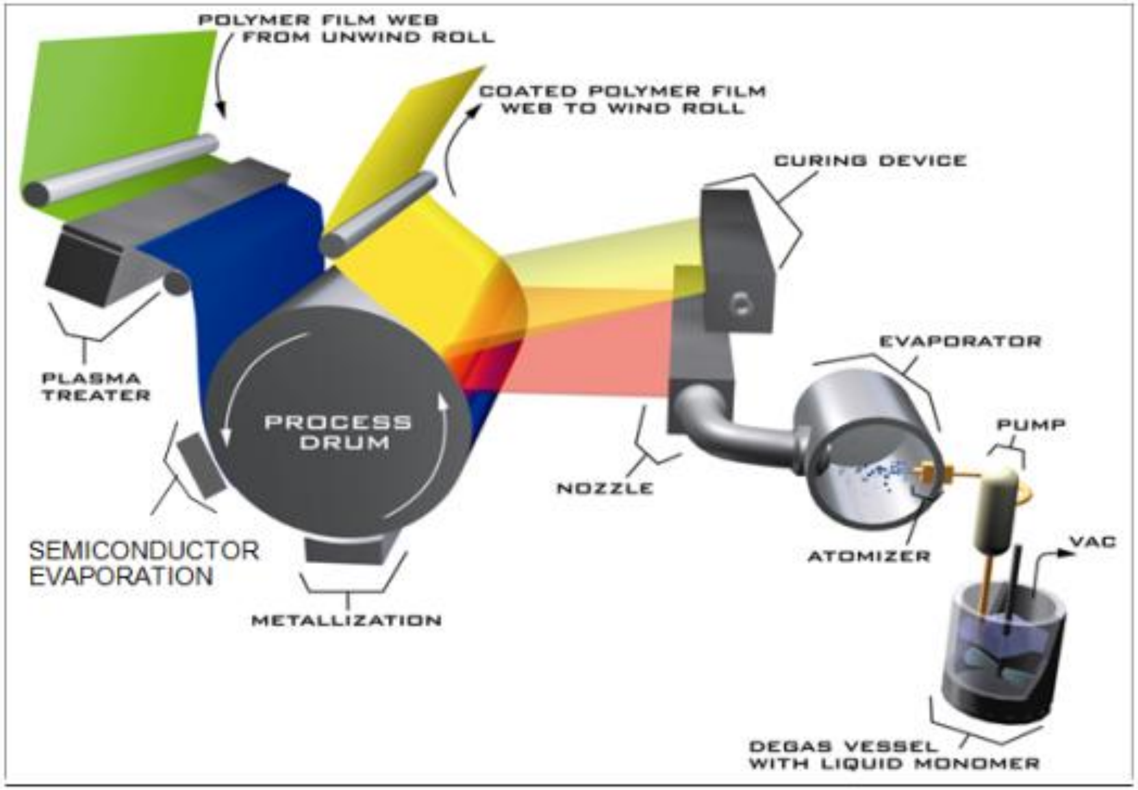
vacuum web coating

Manufacturing Transistors

Evaporated molecular semiconductor

Flash-evaporated and e-beam cured polymer dielectric layer

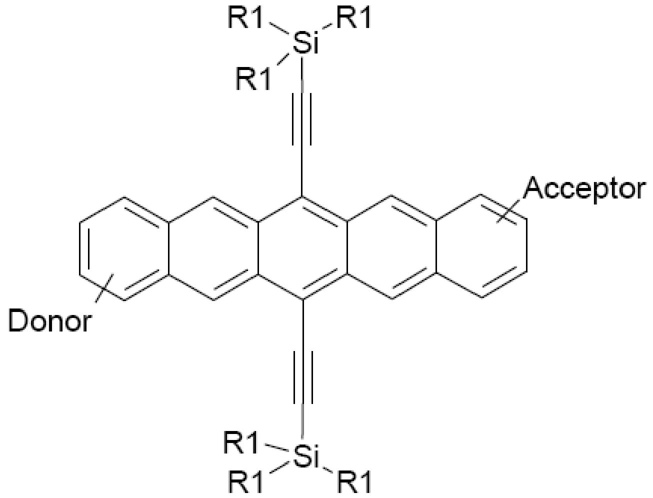
In-line evaporation of metal contacts also possible



Organic Materials for RoVaCBE

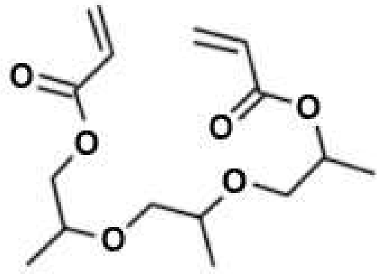
Organic semiconductor

- molecular materials can have higher mobility than polymers (e.g. 5 $cm^2/(Vs)$)
- without the requirement for solubility, can design for high stability product

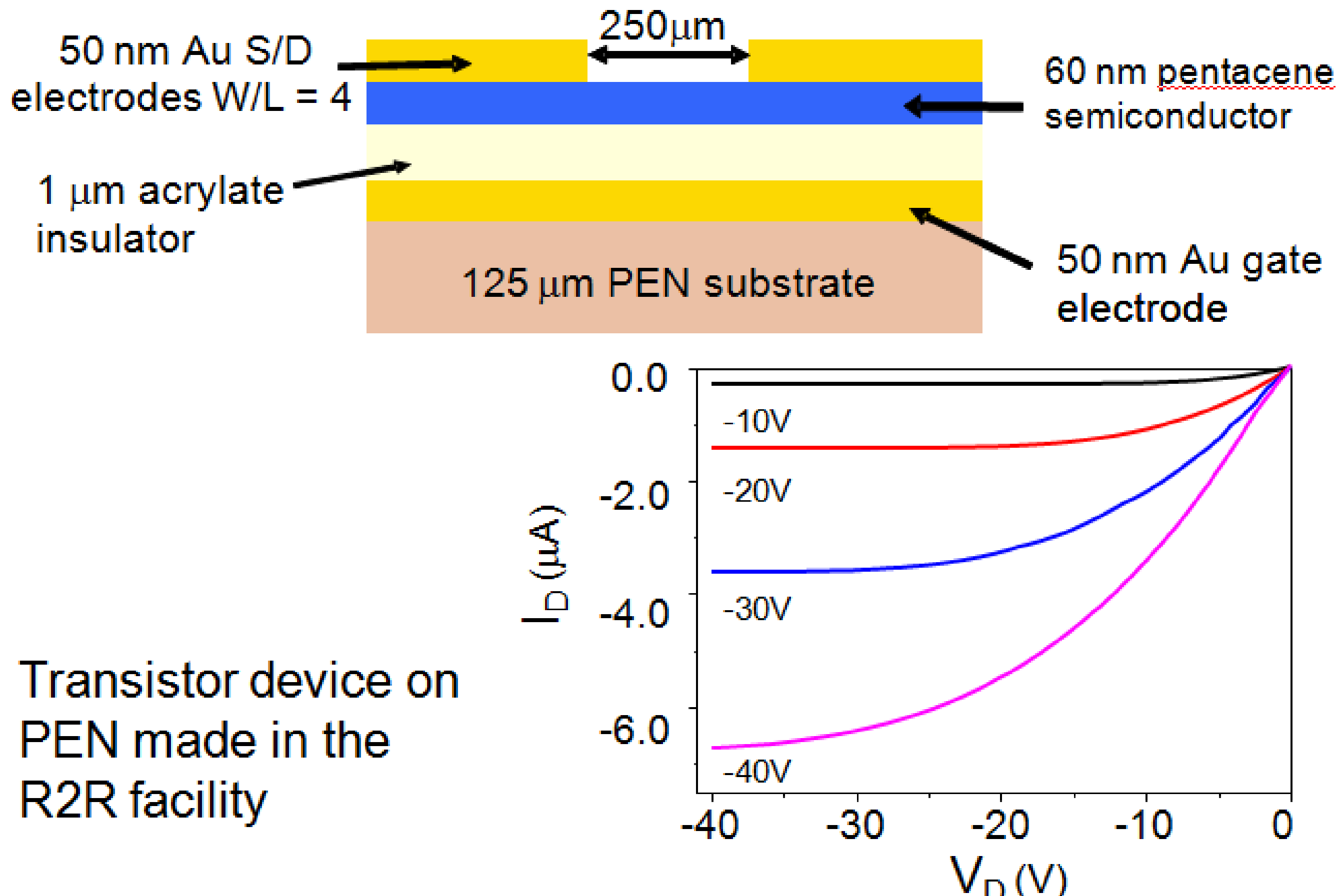


Organic dielectric

- flash evaporation
- high speed process
- already used for capacitor technology
- free of pin-holes over large area
- explore modification to curing process and monomers



Manufacturing Transistors



Transistor device on PEN made in the R2R facility

RoVaCBE Summary

Already able to fabricate transistors in a R2R environment

- high yield (>90%)
- using solventless, high-speed processes
- close interface between circuit design, choice of materials and manufacture
- additionally need to develop tailored patterning methods and assess circuit mechanical/thermal properties

Integrated Optical & Electrical Interconnect PCB Manufacturing

David Selviah, David Hutt, Andy Walker

UCL, Loughborough & Heriot Watt Universities

plus

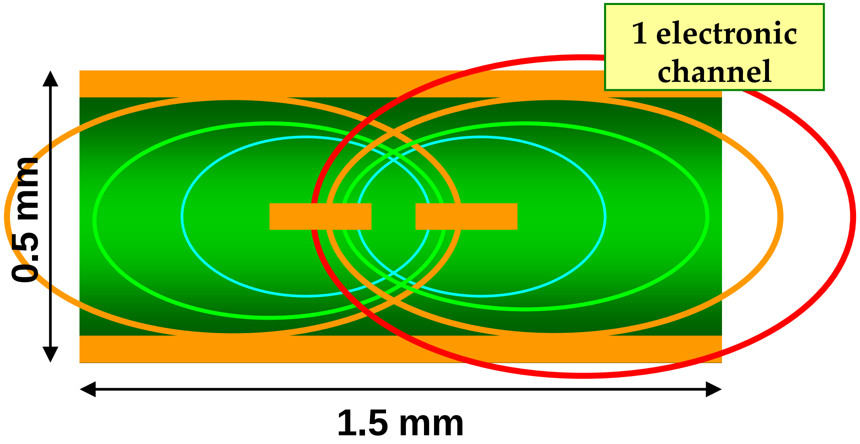
nine industrial partners including Bae, NPL, Stevenage Circuits and Xyratex

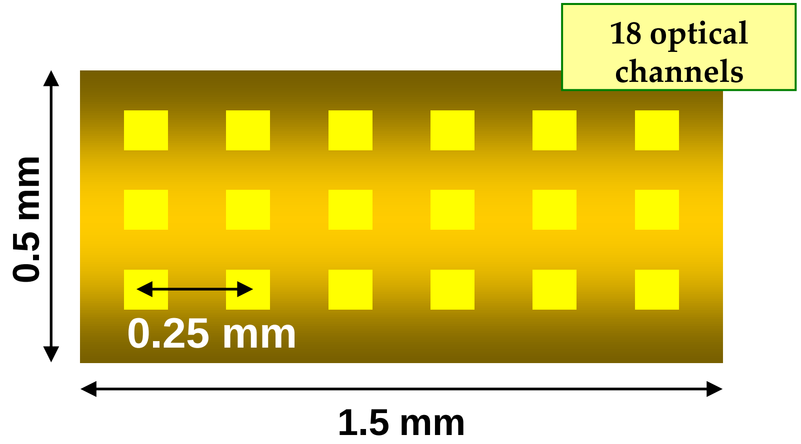
Project Rationale

Copper conductors corrupt high speed signals:

- crosstalk
- reflections
- signal dissipation
- skin effects
- ‘electromagnetic compatibility’ issues

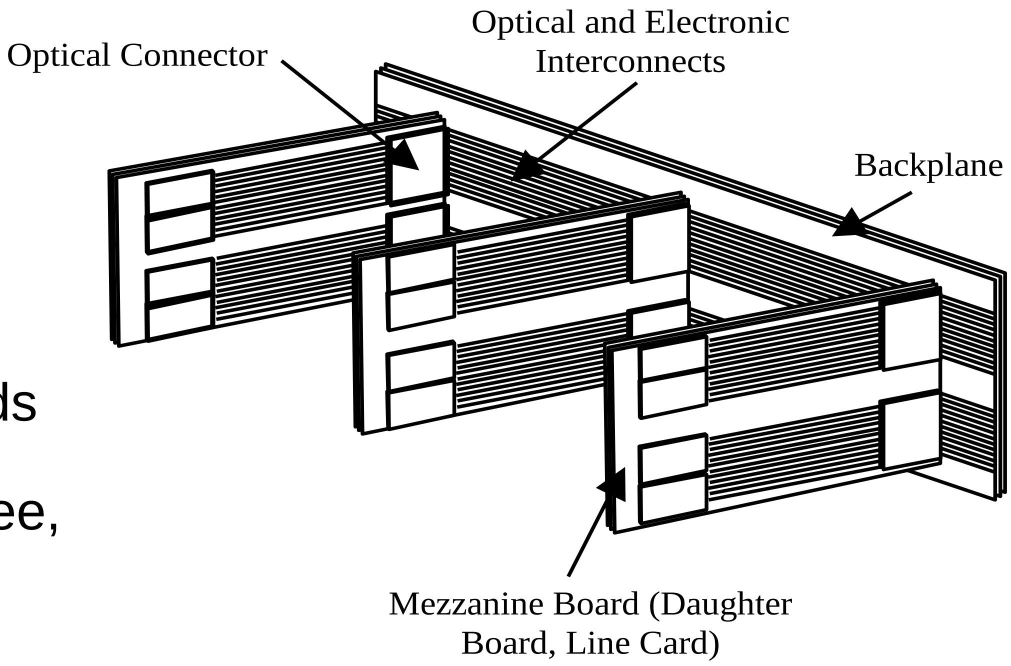
- optical signal pipelines possible
- more optical channels on a board
- send data faster down each optical ‘pipeline’
- send optical data further
- no interfering radiation leaking outside the box





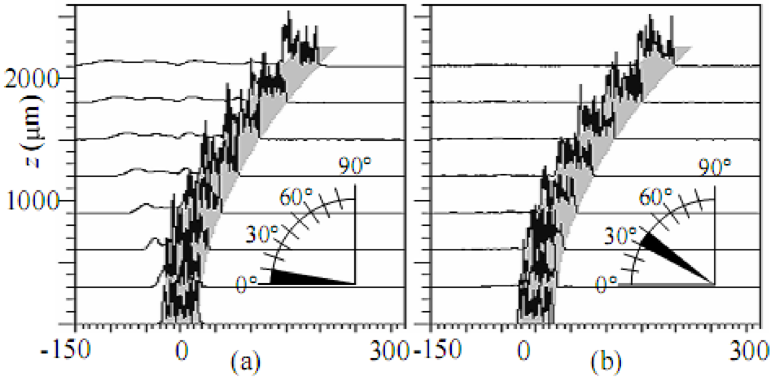
Opto PCB Flagship Overview

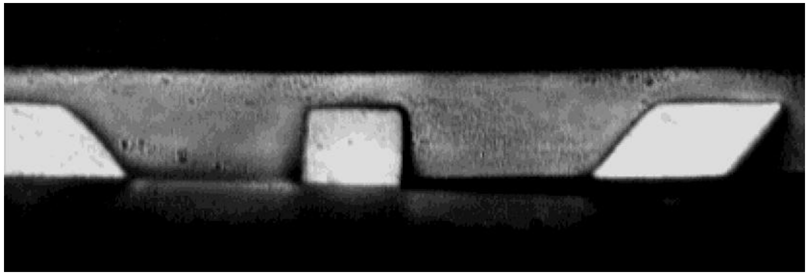
- Integration of optical waveguides with electrical printed circuit boards
- Integrated optical & electrically interconnected PCB (OPCB) for backplanes & daughter cards
- High bit rate (10 Gb/s), error-free, reliable, dense connections
- CAD design tools, fabrication techniques, optical-electrical connectors



Formation of Waveguides

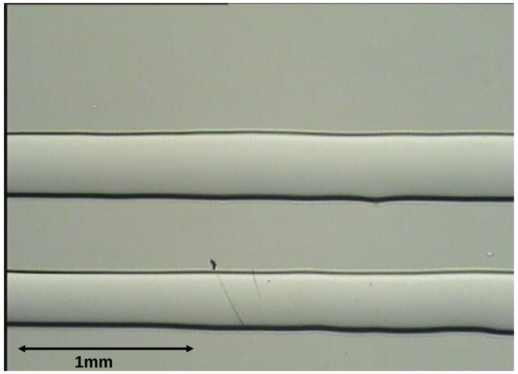
- Modelling & Characterisation – UCL



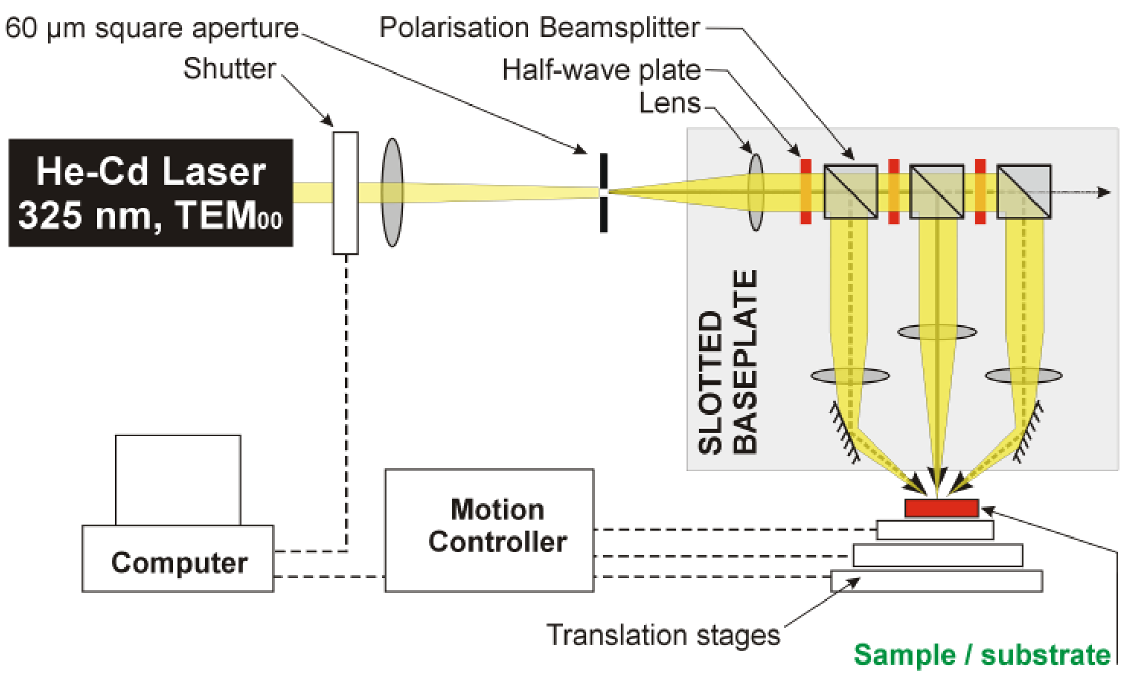


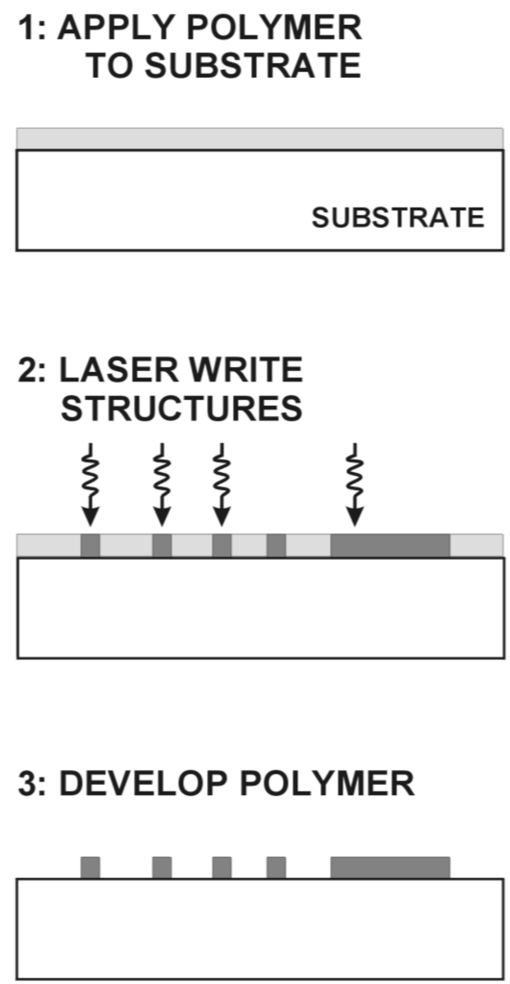
- Laser direct writing of waveguides – Heriot Watt

- Laser ablation and inkjet printing of waveguides - Loughborough



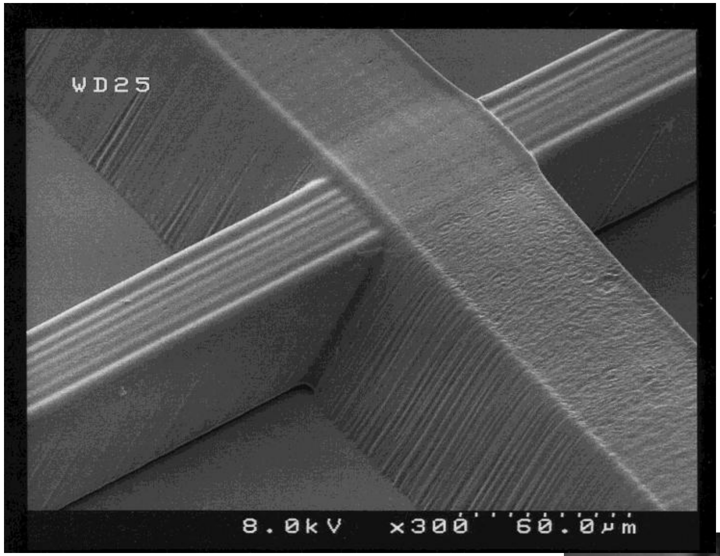
Heriot-Watt – Direct Laser Writing

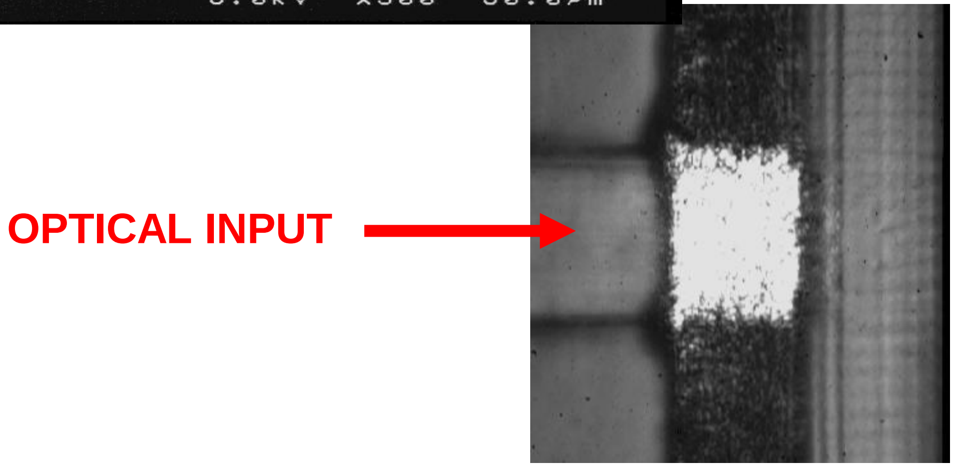


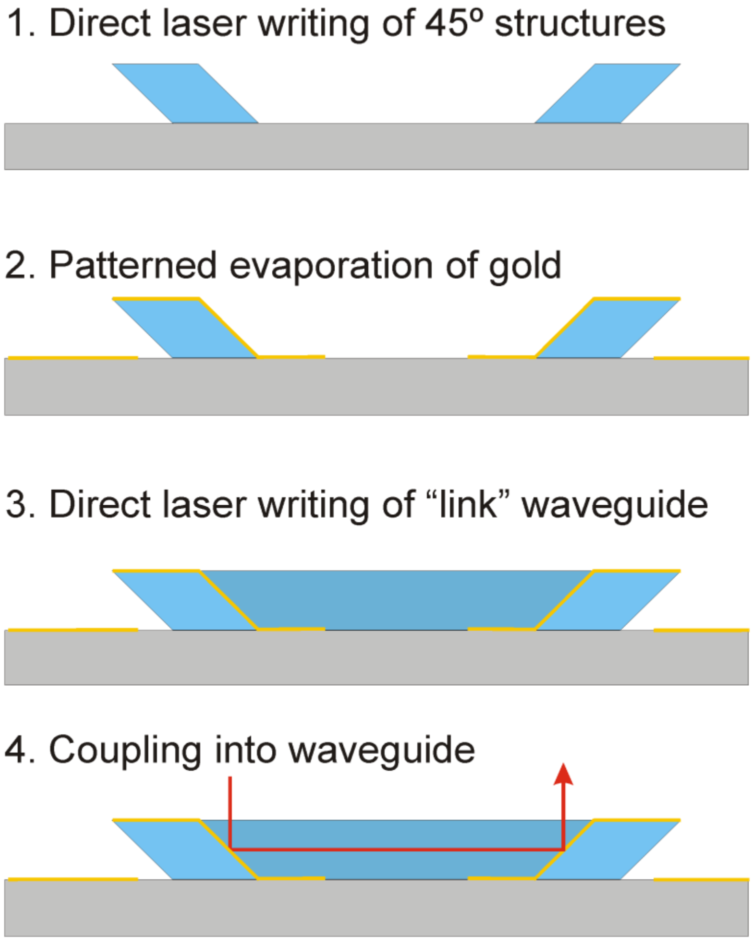


By using two opposing 45º beams the amount of substrate rotation needed is minimised

Heriot-Watt – Direct Laser Writing

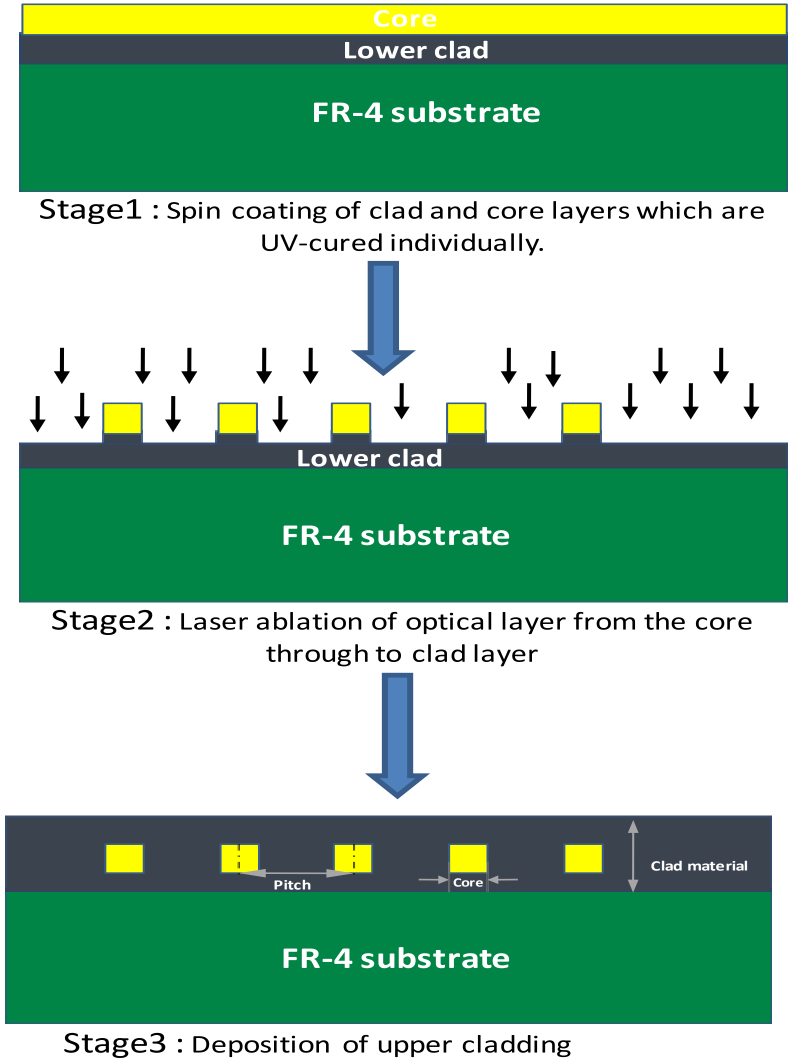






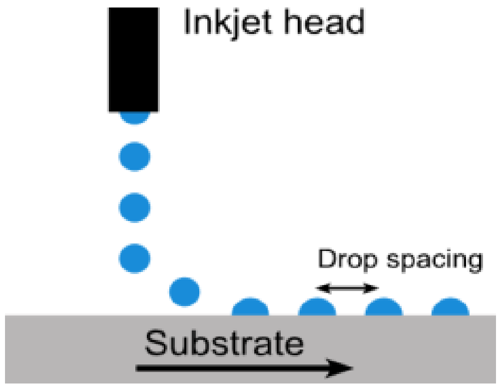
Loughborough – Laser Ablation

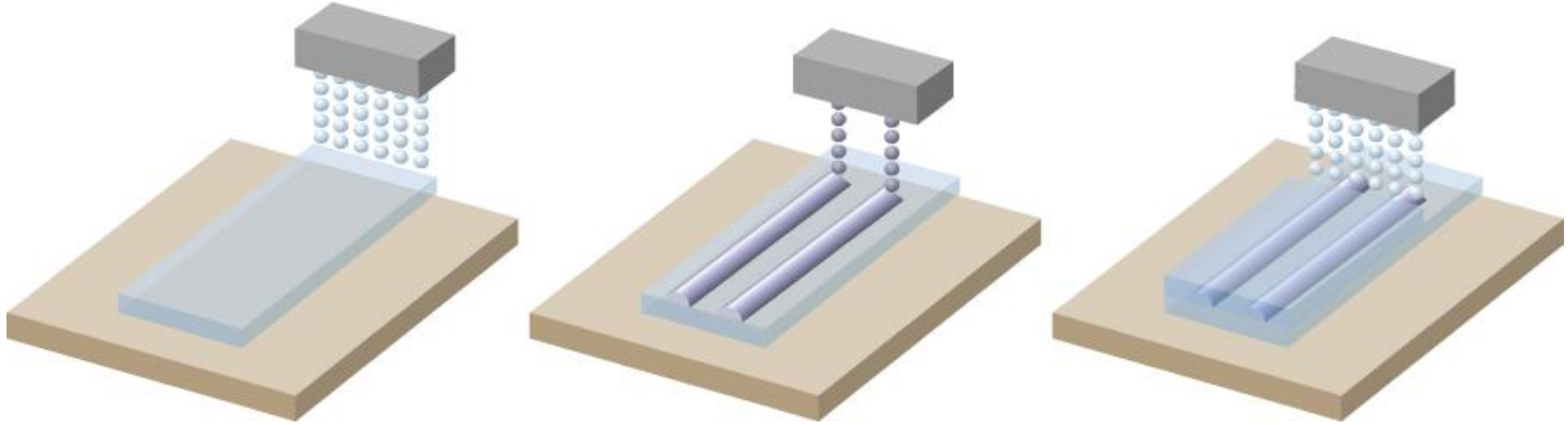
- Research
  - Straight waveguides
  - 2D & 3D integrated mirrors
- Approach
  - Excimer laser – Loughborough
  - CO_2 laser – Loughborough
  - UV Nd:YAG – Stevenage Circuits
- Optical polymer
  - Truemode® – Exxelis
  - Polysiloxane – Dow Corning



Loughborough – Ink Jet Printing

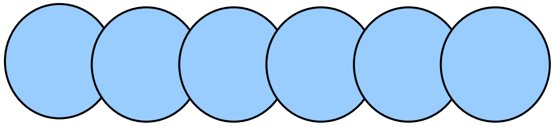
- Print polymer then UV cure
- Advantages:
  - controlled, selective deposition
  - less wastage, uses picolitre volumes
  - large area printing
  - low cost



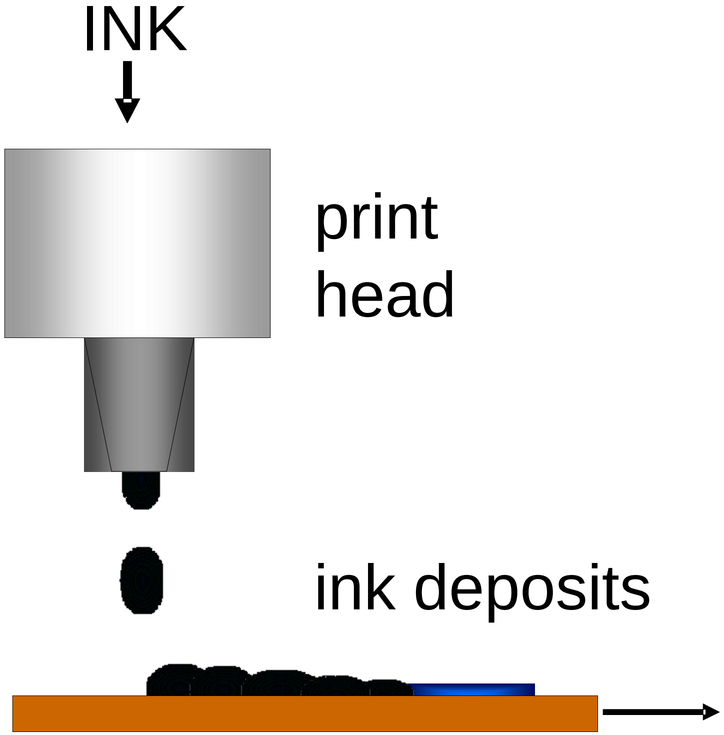


Loughborough – Ink Jet

- Inkjet Deposition
  - ink formulation
    - viscosity, surface tension
  - drying effects
    - coffee stain
  - wall roughness caused by multiple droplets
  - wetting and droplet spread

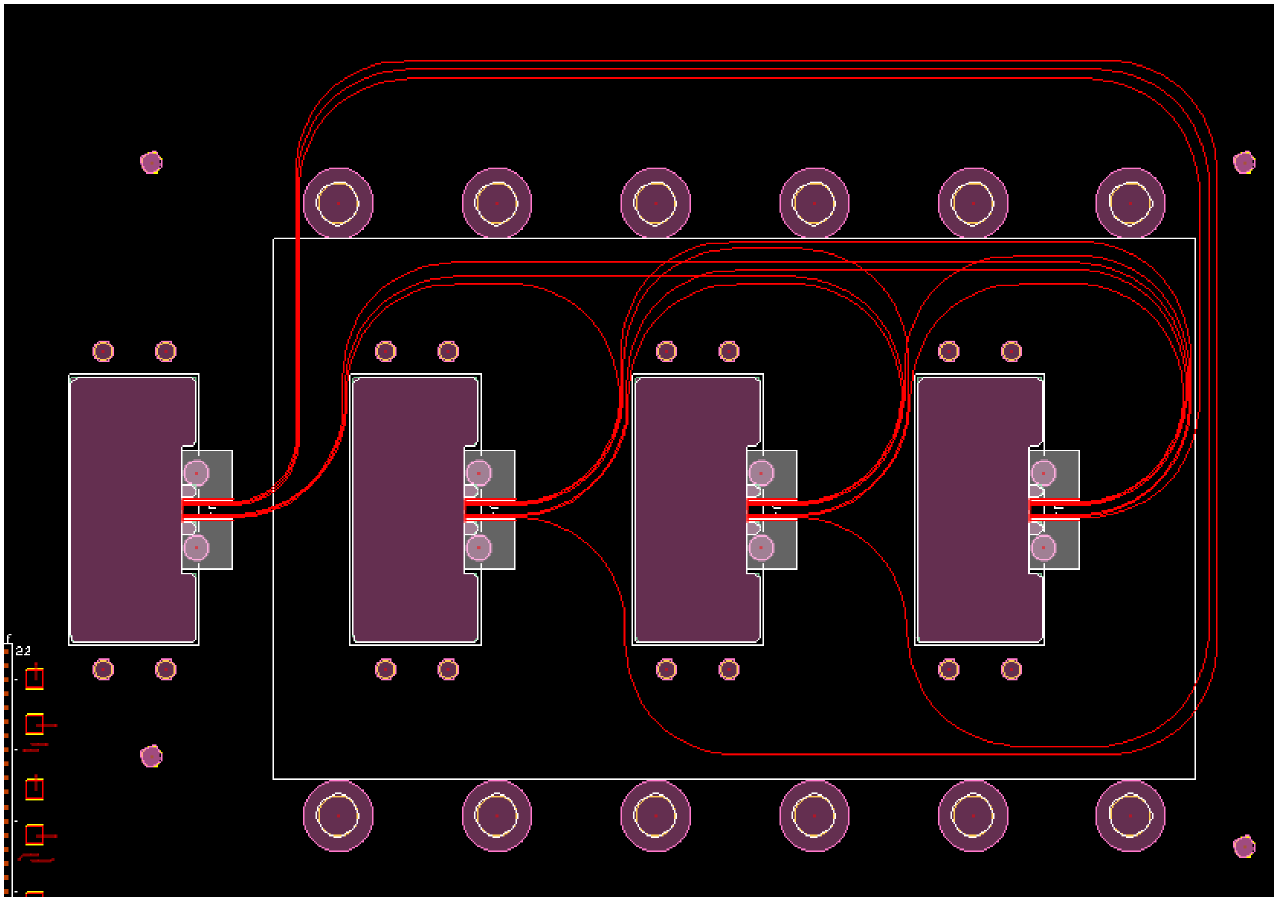


Droplet merging, effect on wall roughness



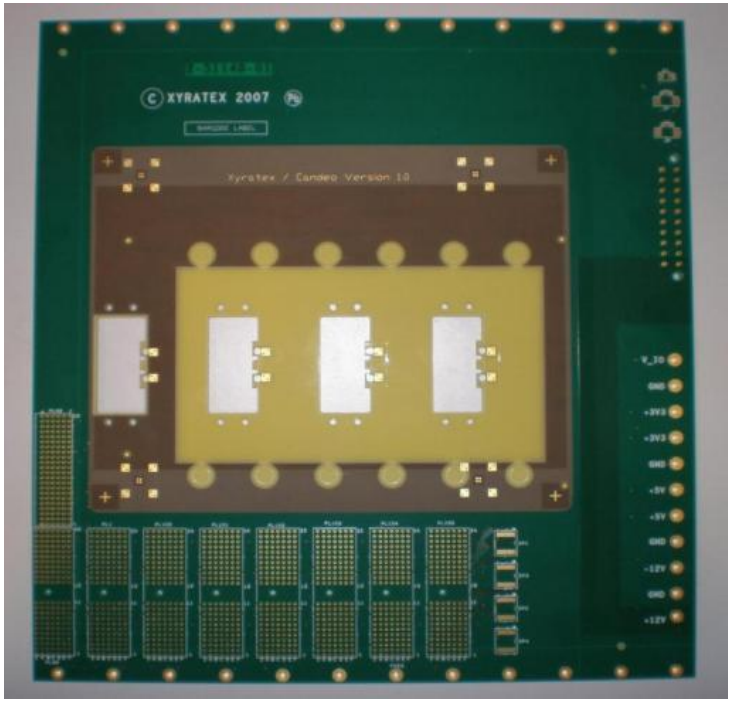
Substrate positioning - CAD data

Opto PCB Demonstrator



Fully connected waveguide layout using design rules

Opto PCB Demonstrator



Active optical backplane connector

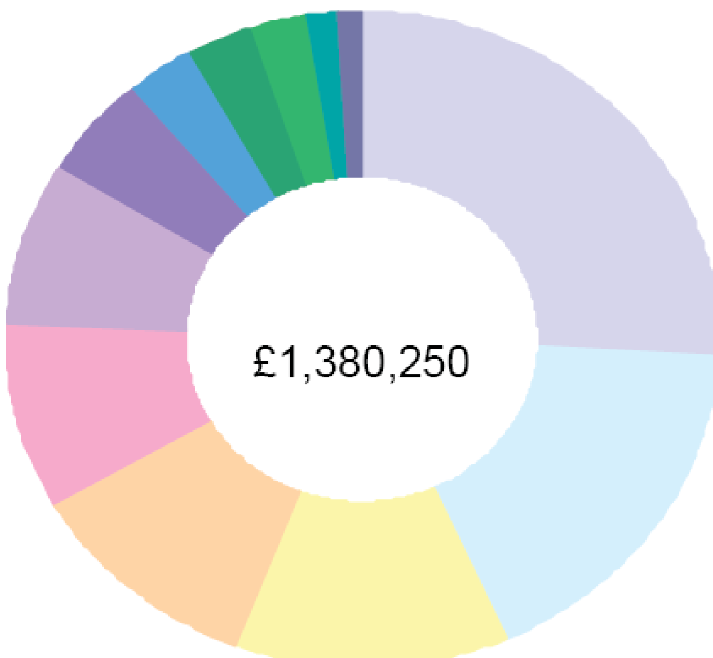
SMART MICROSYSTEMS

High added value products through innovative manufacturing

Professor Anthony Walton

HERIOT WATT UNIVERSITY
IIS Institute for Integrated Systems
THE UNIVERSITY OF EDINBURGH

Smart MicroSystems Flagship



7 multinational companies,
6 SMEs, 2 trade organisations

- National Semiconductor
- Wolfson Microelectronics
- ST Microelectronics
- SELEX Galileo
- Memsstar
- Ceimig
- Qinetiq
- Pyreos
- Renishaw
- NMI
- Semefab
- Microstencil

Smart Microsystems – IeMRC Sept 2010

Institute for Integrated Systems

Rationale for the Project

"Many companies cannot afford investment to keep up with road map technologies"

Companies are asking the following questions

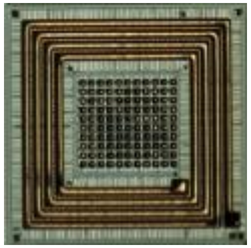
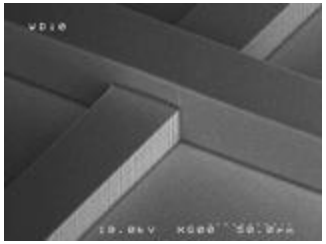
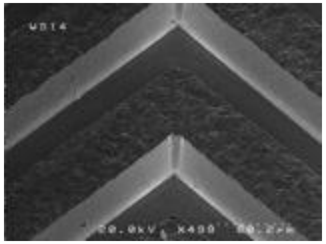
- Is there a market for IC technology from older fabs?
- Can we differentiate our product?
- What can we do with "old" fabs?
- Are there opportunities to integrate technologies with foundry (state-of-the-art) CMOS?

Example Workpackages – WP1

Novel Magnetic Materials & Integration

- National Semiconductor , Greenock have invested £12 million in MEMS equipment for enhancing their product offering
- Flagship will help establish this operation as the NS MEMS centre
- Technology challenges:
  - – controlled deposition of thick Permalloy, piezoelectric and magnetostrictive
  - – sensing elements alongside magnetic components
  - – demonstration of industry relevant prototypes



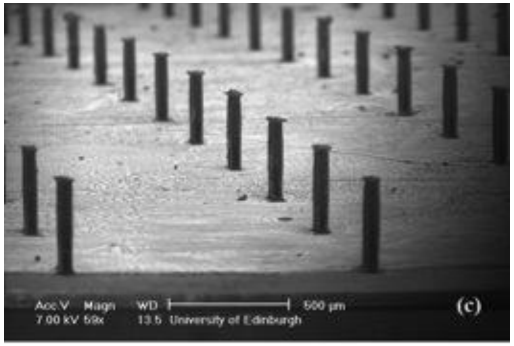




Example Workpackages – WP3

Novel Printing Technologies & 3D Integration

- Non-conventional CMOS technologies
  - screen printing
  - inkjet printing
  - powder blasting (after electroplating vias)
  - cold spray deposition
  - photo-sensitive organometallic films
- Photoresist-free patterning of Pt
- Electrodes integrated with CMOS for electrochemical bio-sensing
  - critical wound care (ITI)
  - cancer monitoring (Metoxia)

Section through a plated via

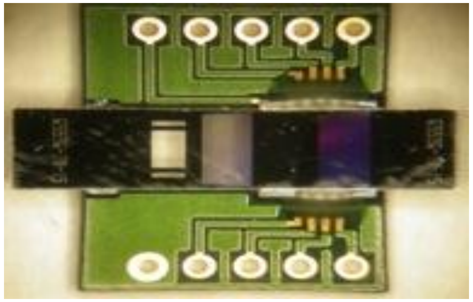


Vias with silicon removed

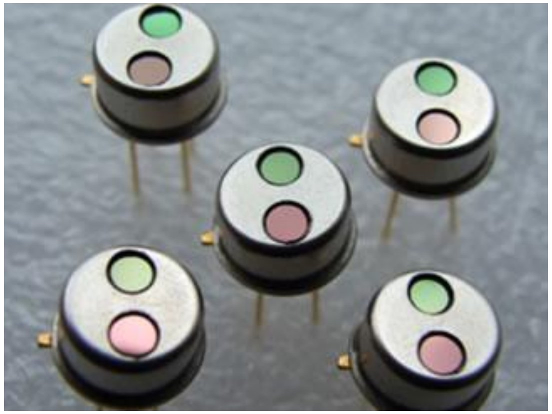
Example Workpackages – WP5

Integration of Sensors with IC Technology

- CMOS based optical encoders
  - accurate placement of post-processed structures for mounting LED devices
  - possibility of using MEMS actuators or surface tension to automatically align device



- Pyroelectric IR sensor technology on CMOS
  - piezoelectric film requires high temperatures (> 550^{o}C)
  - use a novel wafer bonding film transfer technology developed in-house



- Microphone technology integrated with CMOS

Summary

- The IeMRC is supporting electronics research in UK Universities
- This research aims to meet the needs of the UK electronics industry
- The IeMRC's research includes work on printed & plastic electronics
- Printed electronics offers huge growth potential and has potential applications in many new and exciting areas
- Also supporting a wide range of other research from silicon processing to end of life and business issues.

More Information

- The IeMRC is at www.iemrc.org or contact; m.goosey@lboro.ac.uk
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The

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