Update on the National Printable Electronics Centre

Martin Walkinshaw
To IeMRC conference, 25 September 2013
The National Printable Electronics Centre

The National Printable Electronics Centre is operated by CPI (Centre for Process Innovation), from its site in Sedgefield, County Durham

From innovation to commercialisation
Role of Innovation Centres

"Research is the transformation of money into knowledge. Innovation is the transformation of knowledge into money"

G.L. Nicolson, Vice President of Technical Operations, 3M
Innovation Centres are there to help companies overcome the innovation “valley of death”

£1 spent here... needs £50-100 spent here..

Source: UCDavis Centre for Entrepreneurship
From innovation to commercialisation
### Industry Reasons for Engagement with Research / Innovation Centres

<table>
<thead>
<tr>
<th>Reason for Engagement</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant R&amp;D activities / facilities</td>
<td>78</td>
</tr>
<tr>
<td>KTP / Tech transfer</td>
<td>61</td>
</tr>
<tr>
<td>Reputation of the centre</td>
<td>41</td>
</tr>
<tr>
<td>Recruiting students</td>
<td>22</td>
</tr>
<tr>
<td>Financial leverage</td>
<td>22</td>
</tr>
</tbody>
</table>

Gray, DO, 2007, in “Science, Technology and Innovation Policy”
What is CPI?

- Founded in 2004, in recognition that University based research needs to be converted into manufacturing solutions, and this can require a different range of facilities and expertise
- CPI is an independent company limited by guarantee as a public/private partnership
- CPI helps companies to develop, scale up and take new products and processes to market
- Government investment of over £60m in assets and buildings, based around the process industry:
  - Sustainable processing facility £30m
  - Printable electronics facility £30m
  - Thermal technologies centre £2.5m
- Became part of the first Catapult (High Value Manufacturing) in October 2011
<table>
<thead>
<tr>
<th>Centre</th>
<th>Key Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Forming Research Centre (AFRC)</td>
<td>Billet forging; sheet forming; precision forging</td>
</tr>
<tr>
<td>Advanced Manufacturing Research Centre (AMRC)</td>
<td>Machining; materials and component testing; hybrid and metallic composites, assembly</td>
</tr>
<tr>
<td>Centre for Process Innovation (CPI)</td>
<td>Printable electronics; chemical processing; biotechnology</td>
</tr>
<tr>
<td>Manufacturing Technology Centre (MTC)</td>
<td>Automation and Tooling; fabrication, joining and assembly; additive and net shape, process modelling</td>
</tr>
<tr>
<td>National Composites Centre (NCC)</td>
<td>Composites design and manufacture</td>
</tr>
<tr>
<td>Nuclear Advanced Manufacturing Research Centre (NAMRC)</td>
<td>Fabrication of civil nuclear components</td>
</tr>
<tr>
<td>Warwick Manufacturing Group (WMG)</td>
<td>Lightweight product system optimisation; energy storage and management; digital verification and validation</td>
</tr>
</tbody>
</table>
Innovation in Printable Electronics
Manufacturing Readiness Levels (MRLs) Applied

MRL9 – Volume manufacturing
MRL8 – Pilot production established
MRL7 – Post-prototype of systems, sub-systems and components
MRL6 – Prototype systems and subsystems in relevant environment
MRL5 – Prototype components in production environment
MRL4 – Lab scale investigation towards manufacturing
MRL3 – First PoC Manufactured
MRL2 – Invention begins
MRL1 – Basic principals observed

From innovation to commercialisation
Innovation Challenges in Printable Electronics

- Scale up to large area
- Roll to roll processing
- Uniformity
- Integration with conventional electronics
- Barrier and encapsulation
- Cost of manufacturing
CPI Printable Electronics: Key Technology Areas

- Organic Thin Film Transistors (OTFTs) for Flexible Displays
- Solid State Lighting and Photovoltaics
- Ultra barrier: ALD
- Integrated Smart Systems (ISS) and Sensors

From innovation to commercialisation
CPI Printed Electronics Centre Progress Timeline

Mid 2012 – High performance OSCs

Late 2012 – OLED on glass

Early 2013 – Inks on ISS

Summer 2013 – Flexible OLEDs

Mid 2012 – Pragmatic Print Pilot line

2010 – Display Backplane project

Early 2012 – LACE line arrives

2011 – Integrated systems opens

2008 – First transistor backplane projects complete

2008 – 600m2 clean room facility opens

2009 – Barrier deposition

2011 – Gen2 clean room facility opens

2010 – Northern Way PE demonstrators

Autumn 2013 – R2R Spool

2014 – R2R Atomic Layer Deposition Barrier

2014 – R2R Digital Patterning

From innovation to commercialisation
Update on Activities - Optoelectronics
LACE line – full system view
SSL Development – range of prototypes

Small molecule “multi pixel” OLED
Low efficiency, short lifetime application

From innovation to commercialisation
SSL Development – assessing defectivity challenge!

Large Area “single pixel”
SSL Development – targeting lighting!

“White” POLED - Emissive Area 155 cm$^2$
# Flexible OLED Development

## Voltage, Current, Luminance Table

<table>
<thead>
<tr>
<th>Voltage (Volts)</th>
<th>Current (µA)</th>
<th>Luminance (cd/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8</td>
<td>58</td>
<td>15</td>
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<tr>
<td>3</td>
<td>122</td>
<td>32</td>
</tr>
<tr>
<td>3.5</td>
<td>407</td>
<td>105</td>
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<tr>
<td>4</td>
<td>842</td>
<td>208</td>
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<tr>
<td>4.5</td>
<td>1400</td>
<td>339</td>
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<tr>
<td>5</td>
<td>2100</td>
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<td>9</td>
<td>12760</td>
<td>2646</td>
</tr>
<tr>
<td>9.5</td>
<td>14800</td>
<td>3015</td>
</tr>
</tbody>
</table>

## Graph

- **Voltage (Volts)**
- **Luminance (cd/m²)**
- **Current (µA)**

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*From innovation to commercialisation*
Organic Photovoltaic Technology Development

Polymer Photovoltaic Architectural Glass

Collaborative programme with European materials/glass supplier
Excellent Results / IP generated. World’s largest OPV single cell.
Ongoing Development Work

• Solution based “large” single pixel (> 240 sq.cm) White OLED
• Flexible “smaller area” OLED (evap and solution)
• Slot Die experimental programme – strong material dependence
  – Establish coating performance for range of aqueous/solvent based electronic materials
  – Impact of viscosity / solids content / wettability etc
  – Assess performance on sheet and R2R
• Air stable / longer lifetime OPV materials
Update on Activities – Integrated Systems
Layout of ISS Line

- Conductive adhesive screen printer
- Pick and Place
- Oven UV Cure
- Digital Cut & Crease
- Laser Engraver/Cutter

From innovation to completion...
Examples of ISS Projects

• Working with Peratech on developing new formulations for R2R printing processes
• Conductive ink characterisation for packaging films
• Testing of gravure security inks
• Printed connections for novel lighting application
• Printed antenna for flex circuits
• Printed electronics in toys and games
• Creation of a UK supply chain to enable the widespread adoption of low cost, near field communication (NFC) devices using printed electronics
INTELLICO aims to develop highly innovative ambient intelligence (AmI) software components to increase significantly the observability and traceability of systems, human operators (HO's) and environments within the automotive and electronics manufacturing supply chains leading to more effective control & monitoring throughout the product supply chain and operational lifecycle based upon higher levels of intelligence.

This knowledge generation capability requires the deployment of a network of integrated, embedded (within the product and processes) RF components with robust reliable sensors, autonomous operation, proactive reasoning, learning and social abilities (e.g. communication, co-operation, conflict resolution and negotiation). The objective of INTELLICO is to demonstrate a prototype generic network at automotive and electronics manufacturing end users.

(www.intellico.org.uk)
Update on Activities - Leverage
Partners

A Finland, Oulu: VTT/PrintoCent
B France, Lyon: Plastipolis
C France, Grenoble: CEA
D Germany, Dresden: OES
E Germany, Heidelberg: InnovationLab
F Germany, Munich: Fraunhofer/EMFT
G Netherlands, Eindhoven: TNO/Holst
H Netherlands, Eindhoven: KMC/Innovation Fab
I UK, Cambridge: CIKC
J UK, Sedgefield: CPI
K Switzerland, Basel: CSEM
L Spain, Barcelona: CETEMMSA/PEC4
M Greece, Thessaloniki: AUTH
N Sweden, Norrkoping: Acreo
O Portugal, Famalicao: Centi
P Austria, Weiz: StOLAE
Q Belgium, Gent: IMSC

www.colae.eu
What we believe and set out to do

Digital Fabrication: towards ‘Industry 2.0’

Influence/coordinate EU programs towards new sustainable economic growth
- Clarify economic & societal relevance of ‘Digital Fabrication’ for Europe
- Deliver a strong roadmap, aiming for high impact and wide support
- Focus on both business value and technology

Connect to & involve others. Deliver common framework.

Connect to existing EU programs, research agendas, roadmaps
- Maximize impact
- Mobilize & build eco-systems

Seminar on Digital Fabrication in bio fabrication – CPI, 6th Nov
www.diginova-eu.org
Diginova: partner overview

From innovation to commercialisation
Update on Activities – OSCs for Displays
High mobility Organic Semiconductors

- Novel materials sets developed to help control and maximise OTFT performance
- Key attribute is combination of high permittivity binders and high mobility small molecule
- Gives control of wetting and phase separation on a range of surfaces
- Using this approach can achieve high mobility at short channel with excellent uniformity
Printing techniques – IJ and slot die

<table>
<thead>
<tr>
<th>Channel Length / µm</th>
<th>Linear Mobility / cm²/Vs</th>
<th>s.d. / %</th>
<th>No. of transistors</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2.9</td>
<td>12.2</td>
<td>12</td>
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<td>3.5</td>
<td>17</td>
<td>36</td>
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</table>

Prepare SD electrodes and bank structures by photolithography
IJ print OSC layer and dry in air (using Dimatix DMP2800)
Hotplate bake

W = 100 µm, 12 dpp

Slot die

From innovation to commercialisation
Update on Activities – Roll to Roll processing
R2R challenges for displays

- Front to backside contact of soft or wet coatings on plastic film
- High resolution patterning and management of severe pattern distortion
Roll vs Spool processing of film

Typical monolithic R2R processing: long machine path, single rate, film must be complete at rewind.

Spool based processing: short machine paths (process splits), flexible processing, variable rates processes in different locations, oven bake possible.

Roll – front to back-side contact (damage, scratches)

Spool – back-side contact only (low defectivity, winding of soft/tacky/wet films)
Prototype system design

Process to be applied here (slot die, print, expose, metallise, etc)

Robot for automatic connection and separation of process film with support film

Clean Spool Cassette (CSC)
Prototype system trials

**Full system**

- Process film on support
- Film being spooled up

**Slot die head**

- Full spool of film in the cassette (kept under tension for safe transport or storage)

Non-drying fluorescent marker material slot die coated - used to detect any contamination issues

**Note:** Early detected fault, now corrected

From innovation to commercialisation
Digital Lithography project

2 year proof of principle project to develop digital lithography on freestanding plastic film (started Q2 2013)

Heidelberg – world leading supplier of direct write mask exposure tools for up to 1.6m x 1.4m substrates

CPI – UK National Printable Electronics Centre, leading capability in low temperature, high performance OTFT backplanes

Demo system will be installed at CPI to trial capabilities vs mask based projection lithography

From innovation to commercialisation
Conclusions – Update on the National Printable Electronics Centre
Summary

• CPI’s National Printable Electronics Centre addresses innovation challenges in the mid TRL/MRL development stages

• We provide services to industry and academia aligned with the requirements of an innovation centre

• The centre has progressed rapidly since its creation in 2007.

• Over the next few years our work will progress towards developing roll-to-roll manufacturing capability for the UK / EU
Thank you!