Northern Way
Printable Electronics Supply Chain Project

Project Overview &
Materials Work Packages
Dr Bev Brown, 16th March 2011

Northern Way Printed Electronics Project

- £ 6M business-focused development project between academia, PETEC & commercial organisations based in the North of England
- 2 year project, funded by the NWDA as part of the Northern Way initiative
- Development of close to market opportunities

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Some of the Key challenges

The project attempted to start to address the following:

- How can the UK benefit from the growth in Printed Electronics
- How to bridge the gap between research and commercialisation
- How to establish a supply chain and 'link-in' the UK's commercial organisations
- How to capture a significant share of a high value market for UK companies

Some of the perceived barriers to entry for Northern Way companies, what they said before the project began:

- In general, lack of knowledge about the PE market
- Unclear about suitability/adequacy of printers for PE market
- Chemical companies unclear about which OSC molecules to synthesise
- Technical know-how was fragmented and organisations were not engaging with HEIs
- Lacked understanding of patent landscape
- Unclear about customer base and technical requirements
- Unclear about access to the supply chain and end users
- Unclear about how to have their 'products' validated
- Required a fabrication option to make product demonstrators
- Unclear about routes to market, especially in cases where the end-user may be an Asian electronics company

Structure of the Northern Way Project

WP1
Design & synthesis of novel OSCs

WP2 (a)
Scale up OSCs

WP2(b)
Develop ink formulations for printing

WP4
Fabrication OTFT backplanes

WP5
Organic circuit modelling

WP6
Held a Demonstrator Competition

WP3
Substrate development

WP5
Integration of OTFTs into flexible EPD displays
ASU & PETEC

WP7
Implemented 8 Demonstrator Projects

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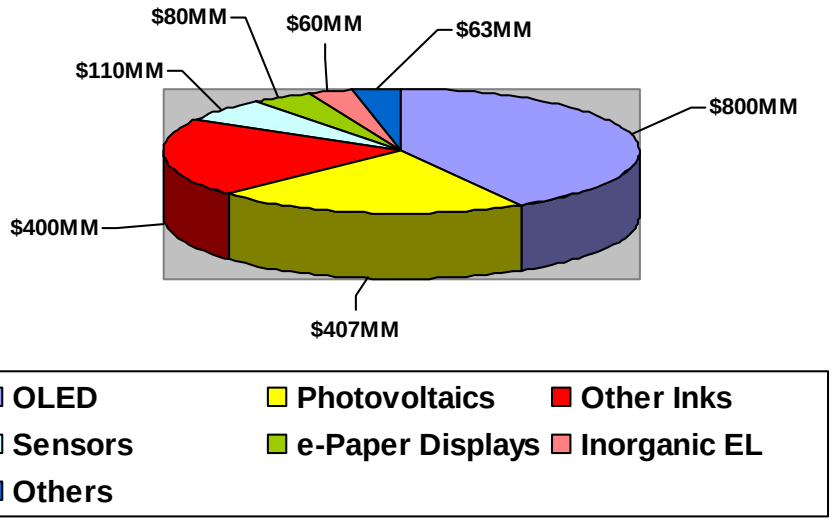
Printed Electronics is potentially a large market

Source	Date	Size ($Bn)	Market
IdTechEx (UK)	2019	54	Printed Electronics
Displaybank (Korea)	2020	50	Flexible Displays
DisplaySearch (US)	2018	8.2	Flexible Displays

Plastic Electronics 2009 Market Forecast (IdTechEx 2009)



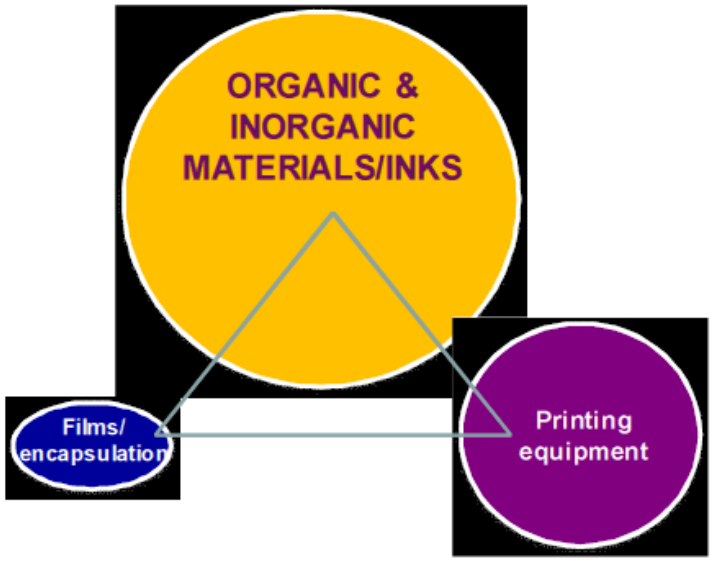
Market forecast by component type: Printed organic, inorganic and composite

US $ (bn)	2010	2015	2019	2029
Logic/ memory	0.02	1.0	**8**	**110**
OLED Displays (*includes TFT back plane and OLED front plane)	0.90	7.8	**16**	**95**
OLED lighting (Front plane only)	0.01	0.4	2	20
Electrophoretic displays	0.11	1.4	5	14
Photovoltaics (includes all thin film PV e.g. CIGS but excludes all CdTe & Si-types)	0.70	6.3	**19**	**70**
Batteries	0.02	0.17	0.9	5
Sensors	0.12	0.5	1.5	6
Conductive inks	0.40	1.0	2	4
Total	2.3	18.6	54.4	**324**

Source IdTechEx Report, 2010

Materials for Printed Electronics: potentially a large opportunity

Relative investments from the key areas of printed electronics development



Source IdTechEx Report, 2010

Source IDTechEx

Sales Revenue ($bn)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2029
Materials value	0.54	0.74	1.45	2.69	4.57	6.89	9.44	12.55	17.95	24.00	33.15	217.75
Other (production, services etc)	1.38	1.72	2.18	3.56	4.96	7.17	9.83	12.55	15.91	20.44	24.01	117.25
Total	1.92	2.46	3.64	6.25	9.53	14.06	19.27	25.09	33.86	44.44	57.16	335

- View that maximum value will be generated through sales of materials

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Some recent examples of OLED Displays

DuPont Displays with Dainippon Printing

LG Displays

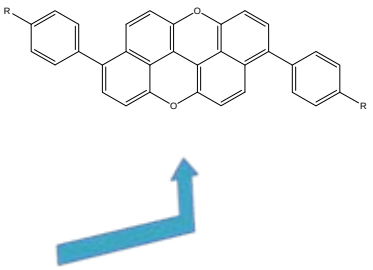
Some recent examples of OLED Displays

AUO, Dec 2010 claim world's largest 3D TV

LG Displays OLED Smart TV, Sept 2010, product launch 2011

- Need for cost effective, electrically stable, TFT backplane driver for flexible OLED

Sony's low temperature solution printing approach to flex OLED

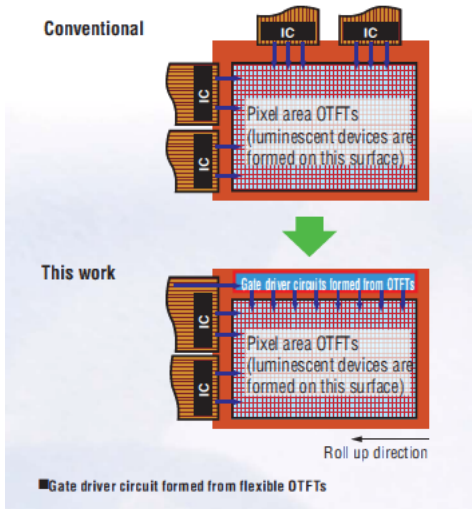


Specifications of the Prototyped OTFT

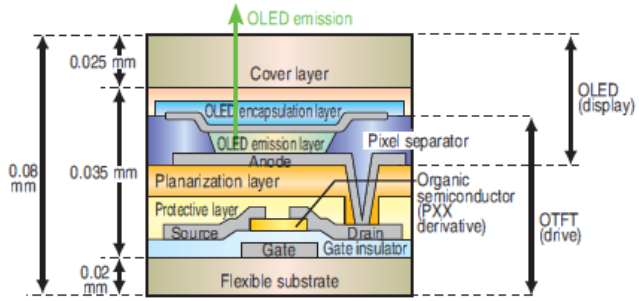
Organic semiconductor material	*peri*-Xanthenoxanthene (PXX) derivative
Hole mobility	0.4 cm^2/Vs
Current on/off ratio	10^6
Channel length	5 μm
Threshold voltage	−5 V

Specifications of the Rollable OTFT-driven OLED Display

Panel size	4.1-inch wide
Number of pixels	432 × 240 × RGB pixels
Pixel size	210 μm × 210 μm
Resolution	121 ppi (pixels per inch)
Number of colors	16,777,216 colors
Peak luminance	> 100 cd/m^2
Contrast ratio	> 1000 : 1
Minimum bending radius	4 mm
Drive type	2T-1C voltage drive using OTFTs
Panel thickness	0.08 mm



Gate driver circuit formed from flexible OTFTs



OTFT and OLED devices are integrated on an ultrathin 0.02 mm flexible substrate

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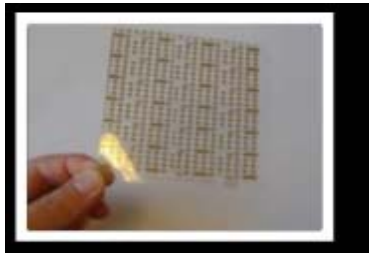
As a result of an in-depth techno-commercial analysis: WPs 1-5 focussed on devt. of Materials & Processes for OTFT backplanes

PETEC & OMIC Design novel OSCs

Chemical Companies manufacture OSCs 10g, then 100g & finally 1kg

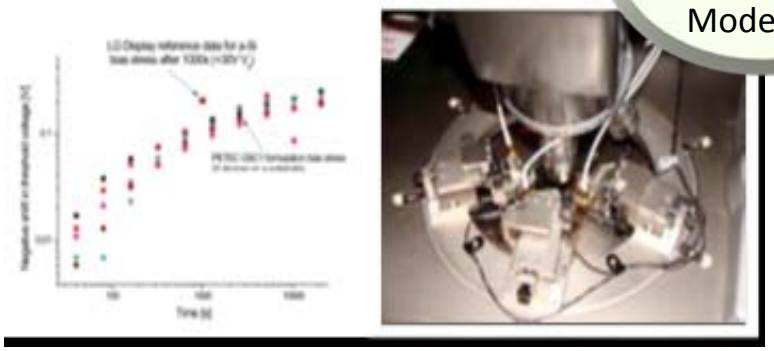
CIC

PETEC formulate OSC inks Test OSC batch to batch performance in TFTS



PETEC develop process & fabricate prototypes

UoL Organic Circuit Modelling



Extensive device testing

Collaborate with end -users

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Key Collaborators in WPs 1 &2

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Objectives of WPs 1 & 2

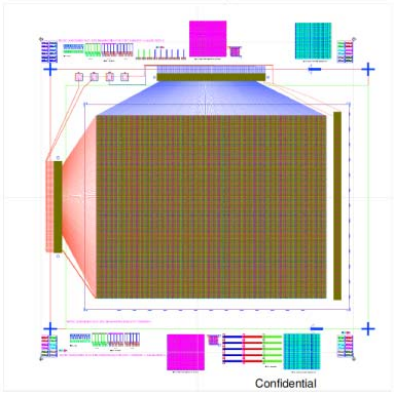
Aim to transfer knowledge from academia and PETEC to Northern Way chemical companies, namely:

- Design rules for the preferred OSC molecules
- Chemical purity required and characterisation techniques
- Purification methods
- Assessment of batch to batch repeatability
- Understanding of how to validate the OSC material in end-use TFT testing

- Develop range of OSCs capable of driving E-paper, UHD LCD and OLED

OSC Materials Developed in Northern Way project could drive any of these displays

- WP 1 and 2 aimed to develop materials and processes for OTFTs for the flexible Display market



PETEC OTFT

- The materials and processes developed will also be relevant and transferable to printed organic circuits: RfId, ISS and printed logic

What we have achieved in WPs 1&2

- Chemical companies to develop processes to scale up the synthesis of the leading OSCs to 1 kilo scale by 31.03.11.

- Develop understanding of comparative cost benefit analysis for ease of synthesis and technical performance of the OSC (Yes)

- Develop formulated OSC inks having strong FTO position (Yes)

- File IP for molecules, ink formulations, synthesis routes and any novel processing (Yes and still more IP being drafted)

- Secure commercial interest from major FPD companies (Yes)
  - leading to material sales
  - Validation of materials by FPD companies

- Competition has engaged with Printing Industry to help to understand what can be produced on existing printing equipment
- Overall, the project has incorporated ~ 40 organisations (>90% SMEs)

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Strong Technology Pull for the OSC inks

- UK printed electronics company testing Northern Way OSCs
- Asian company has validated PETEC's TFT data for leading OSC
  - Collaborative project started Q1 2011.
- In discussions with large Asian FPD companies re projects
- Polymeric OSCs are being used in ink programme with Japanese company from Oct 2010-March 2011.
  - Follow on project expected.
- Small scale commercial ink samples dispatched to 4 Tier 1 Asian companies in Q1 2011
- In the UK, OSCs from the project are being incorporated into TSB programmes and FP7 programmes

Northern Way Supply Chain Materials Project: What does the future hold?

- Commercial Exploitation of the outputs is now the focus
- Relationship between PETEC and materials companies will continue
- There will be an ongoing requirement for supply of OSCs developed in the project
- Confident that the materials companies will develop further improvements in the design of the OSC molecules and in the process chemistry

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And finally…..

- Many thanks to the Northern way for funding the project
- Thanks to the project partners for their excellent participation
- Thanks for your attention

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