Mapping Technological Competence in Plastics Electronics in the UK and Germany

Supporting Documentation

1 Background

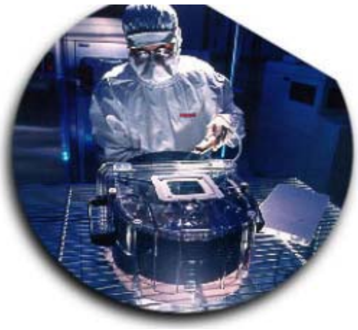
This document provides supporting documentation for the Competence Matrices for plastic electronics (PE) in the UK and Germany[1]. These matrices have been prepared by Cathy J Curling, an independent technical business consultant acting on behalf of the University of Reading. This supporting documentation has been written by Dr Zella King of the University of Reading, and Cathy J Curling. Any enquiries should be directed in the first instance to Dr Zella King at z.king@henley.reading.ac.uk

2 Background: Why look at Plastic Electronics?

Electronics is evolving beyond the rigid and fragile silicon wafers and glass-based displays that are pervasive in many conventional products (TVs, laptops, mobile phones). New products and processing techniques are envisaged, which make use of so-called 'plastic electronics'.

This new electronics industry is founded on devices processed on novel, flexible and robust substrates (e.g. plastic or stainless steel foils), with large area, low cost production techniques of additive printing processes with functional materials. Products with radically different price points, performance and functionality are anticipated, making possible applications and markets that are not accessible by conventional rigid electronics technologies.

Figure 1: Printing on plastic – a paradigm shift in electronics[2]



Conventional Processing	PE Processing
Subtractive batch processes (sheet deposition with photolithographic + etching layer definitions)	Additive continuous processes (printing material only in the required areas)
Controlled (e.g. vacuum) environment	Ambient (temperature and pressure) conditions
Fixed, long production runs of "same product"	Flexible, short production runs – "flexible" product functionality
High equipment, materials and infrastructure costs	Lower equipment, materials and infrastructure costs

[1] Acronyms in this document are defined in Section 8
[2] Photos sourced from http://www.chem.agilent.com/cag/ind/sm/clean_room_person_135.gif and https://www.ct.siemens.com/de/business/sta/index.html

Although this emerging industry has been considerably hyped, it is clear that disruptive developments in materials, device design and processing equipment are under way. A paradigm shift in the production of electronics is anticipated, as illustrated in Figure 1.

These new products and processing techniques offer significant market opportunities for many companies and national economies. However, bringing these products to market requires the resolution of many different challenges and uncertainties in materials development and formulation, device design and process design. Evolution in the ecosystem of companies, universities, funding sources and partnerships is necessary for economies that wish to capture value from these new technologies.

The UK government's Economic and Social Research Council (ESRC) has funded a project at the University of Reading, led by principal investigator Dr Zella King, to understand how the UK can best support collaboration within the emerging plastic electronics industry. For more information see www.printedelectronics.net. The competence matrices which this document supports are one of the outputs from that project.

3 What is plastic electronics?

Plastic electronics (PE) and printed electronics are general terms describing electronics based on semiconducting organic (i.e. carbon-based) polymers that are 'printed' (fabricated using printing techniques such as inkjet or screen printing) and/or 'plastic' (prepared on a flexible surface).

Innovation in plastic electronics is occurring alongside wider developments in organic and thin-film electronics, and hence it is not sensible to define 'printed', 'plastic', 'organic', 'polymer' or 'flexible' electronics as separate terms. They are different ways (often applied inconsistently in the literature) of describing a number of novel technologies and applications employing common sets of materials, processes, equipment and device architectures.

- Some **organic materials** are made from small molecules whilst others use long chain molecules (polymers). Polymers can be solution-based making it possible to print them, whilst small molecules have to be deposited using vacuum-based techniques[3]. Thus in **printed electronics,** liquid inks containing functional materials are deposited and defined using techniques familiar in conventional printing, such as inkjet, screen printing techniques.

- **Organic electronics** involves the inclusion (either through printing or some other technique) of an organic component within a transistor or other device. Some so-called "organic" devices make use of inorganic components such as metal contacts, together with an organic semiconductor. Organic components can be included in all sorts of different devices (including transistors and light-emitting diodes), which in turn can be found in a range of different applications, including displays, sensors and photovoltaic cells.

- **Flexible electronics** refers to devices and applications with the following main mechanical properties: robust, thin, light-weight, non-rigid. Not all so called "flexible" displays show full mechanical flexibility properties. Within the literature and market place, the term 'flexible' is used to refer to a range of different types of displays, including:

[3] For example, currently most polymer OLED materials are printed and small molecule versions are vacuum deposited, although material formulations for solution processible small molecule OLED materials are being developed.

- Flat displays made on plastic or other non-glass substrate, but only for the benefit of being thin and rugged (e.g. display on the lid of a laptop).

- Conformal (or formed) displays. Bent once to a given radius of curvature (RoC) and fixed there. For example, truly conformal displays integrated into the curved surfaces of vehicle dashboards.

- Flexible displays that can be bent or flexed to multiple radii of curvature (RoCs) and many times during use, but not over a range that includes a rollable format.

- Rollable displays – showing flexibility akin to thick fabric. For suitable viewing, some mechanical framework is typically required to keep the unrolled display taut and flat.

Plastic electronics – the term we use here – generally refers to devices built on flexible substrates making it possible to produce mechanically-flexible or bendable electronic products. Flexible substrates offer manufacturing efficiencies in that they can permit the use of reel-to-reel or reel-to-sheet production. However, flexible devices also create production challenges because of the need for the various component layers to remain intact and bonded together when the device is rolled or manipulated, exposed to heat or cold, air or water.

The terms ‘flexible’ and ‘plastic’ do not necessary imply that a device is **printed**; more usually, ‘flexible’ defines the mechanical and functionality properties of the final product. Electronics materials could be defined on a small flexible substrate using techniques familiar to conventional electronics, such as photolithography and wet/dry etching, rather than printing.

In summary, a range of intersecting terms is used to describe these new technologies, without a single clearly articulated definition. **Here we use the term ‘plastic electronics’ (PE) to refer to materials, processes or pieces of equipment that are intended to facilitate the development and fabrication of electronics products on flexible substrates.**

4 Why create Competence Matrices for plastic electronics?

Plastic electronics needs partnerships of a commercial or technical nature, between companies within the supply chain, and between companies and universities supplying new ideas at the top of the pipeline. The purpose of the Competence Matrices is to identify where areas of expertise currently lie in the UK and Germany, and to indicate where likely areas of compatibility (and incompatibility) lie between different potential partners. It is intended that the matrices will:

- Enable companies and university departments to identify potential partners in the UK and Germany. Technology fit is particularly important for the identification of partners, given the interdependencies that we note below

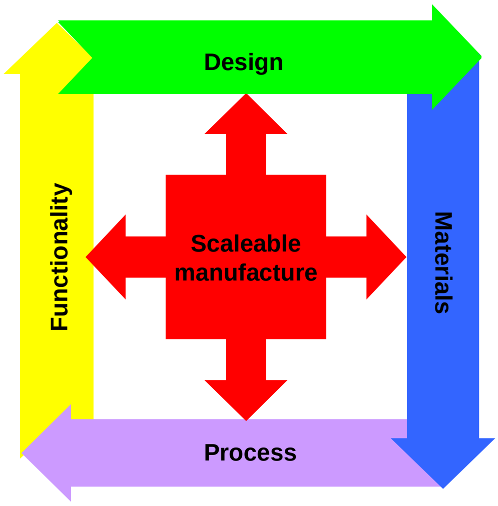
- Provide essential background to research on collaboration in plastic electronics by indicating where propensities to form partnerships are likely to lie. This is particularly important for the work being undertaken by Dr Zella King at the University of Reading. Her research concerns the inter-personal factors that are important in collaboration, once technology fit has been taken into account. For more information see www.printedelectronics.net

- Inform policy-makers of potential barriers to collaboration and areas of strength and weakness in the UK’s presence in the industry by analysing UK activity in its own right and in comparison with activity in Germany. Although Germany has come later to plastic electronics than the UK and has fewer innovative developers of materials, inks, technology or design, it has established considerable manufacturing capability, especially in the area around Dresden, and stands to capture significant value from innovation in equipment and in the manufacture of finished components. For these reasons, a comparison between Germany and the UK may be instructive for British policy-makers.

The first of these objectives is likely to be of primary interest to most readers of this document and the Matrices. The identification of technology fit is very important in any collaboration. All development of new technology in electronics involves complex interdependencies between material sets, processes, device design and the resulting functionality of the product. Changing the materials used in a device will affect the functionality of that device, changing its design will affect the process by which it is made and so on.

As a product is scaled up from single-unit lab-scale work to production in small volumes (we refer to this as 'process scale-up'), the materials, design, functionality and process all need to be developed in step, so that the product can ultimately be manufactured at suitable cost points and production yield values. These interdependencies are illustrated in Figure 2.

Figure 2: The interrelation between Design, Materials, Process and Functionality for PE technology development and scalable manufacture[4]



These challenges are particularly acute when many aspects of the materials, design, process or functionality are novel, which is likely to be the case in all but the most basic developments in plastic electronics. Where companies and universities partner to develop new technologies, they have to grapple with the difficulties of keeping their developments in step. Finding the right partners is an important factor in this process.

5 How did we categorise companies and university departments in our Competence Matrices of plastic electronics?

We wanted to find a way to examine this interdependency in the Competence Matrices. We therefore sought to characterise each entity with respect to its core technology areas. We identified five technology areas which we refer to in the first part of the each Competence Matrix headed "(1) Main Classification". These are described in more detail below, illustrating each area using cooking analogies:

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[4] Figure sourced from the slides presented at the Women's Engineering Society (WES) 2007 Daphne Jackson Memorial Lecture "Plastic Fantastic: The dawn of a new printable electronics revolution" by CJ Curling. London, February 8th 2007 http://wes.org.uk/?q=content/daphne-jackson-memorial-lecture

5.1 Technology areas

5.1.1 Materials and/or Inks: Ingredients list in a cooking recipe

These are the base functional material sets and formulations that make up the layers on a PE substrate. A given material can have one or more functionalities including electrical, optical, geometric, surface energy level etc. A material can be inorganic/organic or a hybrid material (e.g. an inorganic element in an organic matrix carrier solution – e.g. silver nanoparticles dispersed within a fluid-based organic ink formulation).

5.1.2 Technology and Design: Instructions in the recipe: weights and measures of each ingredient, how and when to combine them

This covers two elements: (a) the design of the electronics itself: e.g. feature/pattern sizes of the active and passive electronics elements on the substrate, and hence their electrical properties and characteristics, such as:

- active element selection – e.g. TFT or diode
- logic circuit design elements for RFIDs – e.g. transponders, logic gates, comparators
- AM backplane display driver design – row and column widths and layer thicknesses, pixel sizes, pixel capacitor sizes
- OLED sizes for the RGB sub-pixel elements

and (b) the technology and methods used to deposit and define the elements on the substrate. For example:

- vapour deposition with mechanical masking
- solution deposition into pre-defined OLED RGB wells

5.1.3 Equipment: What cooking utensils to use

This refers to the machines and substrate handling kit that takes the “Materials and/or Inks” and the “Technology and Design” recipe, and makes the required electronic layers, patterns and devices on the PE substrate. These can include ink printers and coaters, as well as for example, machines to load and unload sheet to sheet substrates in and out of processing equipment, cleaning steps, test equipment (electrical, geometric, chemical or optical), R2R continuous and stop-start machines.

5.1.4 Process Scale-up and/or early Prototyping: Optimising a recipe for making more than one test batch – e.g. best “eating”/storage lifetime analysis; optimising for lowest cost base ingredients

At this stage the technology has moved on from proof-of-concept demonstrators to proof-of-product. Typically this involves scale-up of processes and equipment, and early stage assessment of quality, yield, statistical process control (SPC) etc., with multiple “same process” batch working and increasing use of automated equipment, as opposed to manual handling/”hand crafting”. Process scale-up aims to demonstrate (internally to the company, or externally to investors or customers) that the technology can in principle be ramped up from making a few batches per week to 10-100's batches[5] of validated components.

Output from this stage includes engineering samples (prototypes) suitable for sharing with potential customers, so that field trials, focus groups, user trials and tests at the customer's site can be undertaken. At this stage, engineering samples will typically have no warranty or CE marking. Contractual arrangements under which samples are shared will thus reflect such uncertainties - including restricted use by in-house engineers; no deconstruction/reverse engineering of component elements and materials, for example.

Process scale-up often takes place through Joint Development Agreement (JDAs) or early Joint Venture (JV) arrangements between an entity that intends to supply the PE product's technology capability, and the intended customer or product integrator. Note that the customer here is not the end-consumer; this is a B2B type relationship where the customer might ultimately incorporate the supplier's (and other's) components into their final product assembly (e.g. a flexible display unit combined with Bluetooth hardware for a mobile electronic reader product). We refer to such a customer as a plastic electronics 'end-user'. The IP arrangements are tightly specified, but the final price and business conditions (e.g. royalties; licensing agreements etc.) at which the PE supplier's technology will be provided to the end-user for mass market entry is still mostly open to final contract negotiations.

5.1.5 Components: Selling a fruit cake base for someone else to ice for final wedding cake product. Services: Altering a cake's recipe/ingredients for a specific allergy requirement

Components and Services are separate models, but they share the characteristic that they furnish a final product or service to a customer, which may be provided for a fixed price.

- **Components** are finished items that are sold with data sheets covering all aspects of their formulation, processing and usage. For example display backplane driver array elements might be supplied as finished components to a customer who then adds e-paper display media layer on top, or substrates might be supplied as a finished component to the maker of backplane driver arrays.

- **Services** covers co-development addressing specific needs for designs, materials, equipment etc. This can range from the provision of a relatively standardised measurement or testing service undertaken to meet specific customer needs, to a consultative-style/partnering relationship (a form of early JDA) arrangement to develop bespoke solutions to PE problems, or to develop new opportunities. Typically the latter starts with a short initial assessment project, and can follow on with a development programme tailored to the specific needs (payments, timeline, IP ownership etc.) of the (paying) customer.

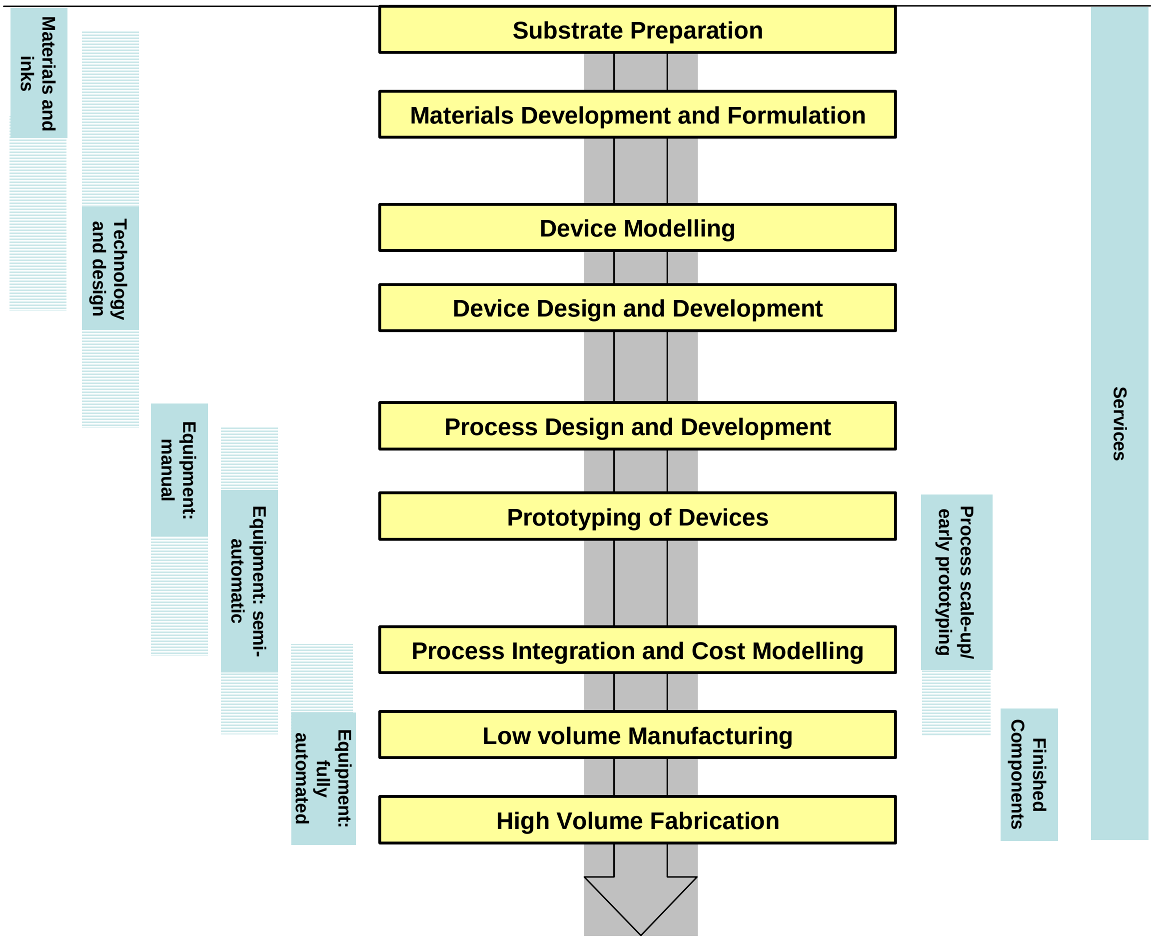
Now let's consider the route to market for a single innovation in PE, such as a display backplane driver array element, or a photovoltaic cell structure. From inception to market, a number of steps through this value chain are required as shown in Figure 3.

Development and formulation of Materials/Inks is the primary concern in the initial stages, with iterations around Technology and Design as noted in Figure 3. At this stage, the interaction between a given materials component and other elements of the device is important (for example, ensuring that the layers of a device can be added without affecting the functionality of the underlying layers.)

[5] N.B. This exact number of batches, size of a batch etc. depends on the technology complexity and novelty of the process – hence these are indicators of typical volumes and not exact metrics that can be applied universally.

Equipment is relevant at all stages, but development of equipment features more prominently as the device reaches the Prototyping stage, with kit evolving from a manually-operated, "hand-crafted" operation carried out with considerable human intervention, to greater automation as the volume of items and batch sizes produced increases. Process scale-up is only undertaken when the basic parameters and processes for the device are in place, and requires attention to the relationships between costs and scale of production. Often at the Process-scale-up stage, issues relating to materials or design are identified, requiring further iterations through previous steps. In the final stages, the process culminates in a finished component or product that can be manufactured in high volumes for sale to a product integrator or customer. At any stage in the process, Services may be provided (such as measurement and testing of optical, geometric or chemical properties).

Figure 3: Process flow chain for the development of new plastic electronics technologies



Route to market for PE technologies

5.2 Position in the value chain

The process flow chain described in the previous section will rarely be undertaken by a single company; more typically there is a chain of innovation beginning with basic science (chemistry and physics) in universities, and ending with companies of sufficient scale to manufacture at high volumes. In the intervening stages, small companies owning IP relating to the technology and/or its application are often involved.

It is clear from the above discussion that an entity (a company or university department) could be a customer for one aspect of an emerging technology (e.g. materials), and a developer of another (e.g. process scale-up). In effect, in a given technology area, there are mini-value chains running from innovation through production to commercialisation.

To capture position in the value chain in our Competence Matrices, we developed the following categories:

5.2.1 Innovative developer of plastic electronics

These are early stage technology innovators, often owning the base IP surrounding a new PE technology. Entities in these categories are typically universities or research institutes, with base research funded from the public purse, or small companies (funded through equity finance) with an IP portfolio in the technology area. Increasingly, universities are seeking to protect IP in core technologies.

5.2.2 Supplier/manufacturer of plastic electronics

These are entities (usually companies) that make PE items – bottles of material/ink, technology equipment, consumables, printing mechanical masks for OLEDs etc – and finished components. Given that the PE industry is still in its infancy, being a supplier or manufacturer does not necessarily imply high volume to supply global markets with guaranteed supply agreements (as one may find as for example silicon chip supply and manufacture). In plastic electronics, being a supplier or manufacturer typically involves low volume, bespoke/"not yet ready for public usage" product manufacture.

5.2.3 End-user/customers deploying plastic electronics

End-users, as defined in this project, are companies that sell complete products and systems (not components) in large volumes (millions+ of units) as a revenue-generating standalone business. In the conventional silicon-based AMLCD industry for example, AUO in Taiwan makes LCD cells which are then supplied to module manufacturers (such as LG, Samsung – end users selling standalone products and systems) to make into display monitors for personal computers[6].

In PE, an end-user is likely to purchase a finished component (such as a flexible display), with the objective of adding to its value though assembly or incorporation with other components (e.g. hardware for mobile data access to a flexible display peripheral through Bluetooth) in order to generate a finished standalone mobile product/system, ready for release into the public retail space.

An entity is not an end-user if it is:

- Seeding an early market from first production factories funded by equity finance (as per the current activities of Polymer Vision and Plastic Logic).
- Making engineering prototypes as part of a JDA (very different financial and contractual arrangements to selling volume product).

5.3 Analysis opportunities in the Competence Matrices

Combining the classification of Technology Areas (described in Section 5.1) and Value Chain position (covered in Section 5.2), with the Process flow chain in Figure 3, gives an insight into the extent to which each of the countries of interest are active across the value chain in PE. We illustrate this on the first page of each Competence Matrix headed "(1) Main classification" using a set of classifications as shown in Figure 4.

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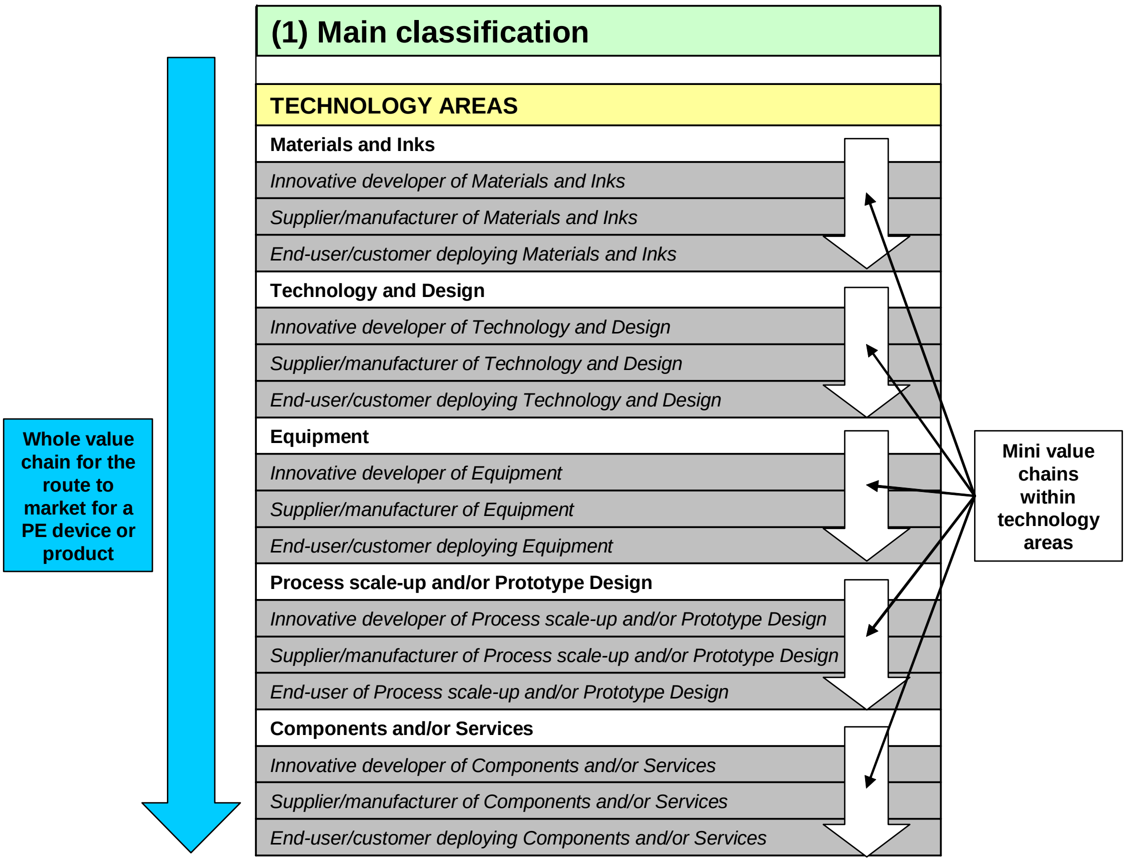
[6] http://www.digitalcamerainfo.com/content/Samsung-LG-to-Strike-Deal-with-Taiwan-LCD-Suppliers.htm

Figure 4: Mapping classifications used in the Competence Matrices to the various value chains for PE



Route to market for PE devices and products

In Part 2 of each Competence Matrix headed "(2) Materials and Technologies" sub-categories have been selected in order to identify common groups of users and customers across separate interests of technology (independent of product). In Part 3 headed "(3) Applications and/or Products", sub-categories have been selected in order to identify common groups of users and customers across products (independent of technology). Examples of this are given below.

5.3.1 "Main thin film process steps" sub-category under Part 2: Materials and Technologies

The deposition and patterning of a PE device architecture can utilise a number of technologies including photolithography, vapour phase deposition, printing/additive processes (e.g. inkjet; gravure; screen; flexography). Their selection depends on the required performance, characteristics and functionality of the device in question.

For example, the selection of a printing technique depends on a number of factors including:

- Compatibility of the functional ink (e.g. its formulation; properties such as viscosity, drying behaviour etc.) with a given printing technology
- Capability to print the desired feature sizes (e.g. resolution; layer-to-layer alignments; final ink thickness; surface characteristics such as roughness etc.) onto the underlying layer and/or initial substrate
- Product process throughput or so-called TAC time

Thus in each Competence Matrix under “Printing/additive processing”, entities are marked as to whether they are *Low resolution/comparatively thick layers, higher-throughput (e.g. flexo, gravure or offset)* or *High resolution/comparatively thin layers, lower throughput (e.g. inkjet, soft lithography..)*, in order to identify potential partners with a common core competence in printing technology types, but with product application independence.

5.3.2 “Displays: Applications and mechanical metrics” sub-category under Part 3: Specific Applications and/or Products

At a basic level, a display is a device that converts electrical signals into a light output (an image). Depending on the display media selected and combined with a given driving display backplane, the display can have a number of types of light output such as reflective (reflects the ambient light – e.g. electrophoretic e-paper displays), emissive (light generated internally to the display – e.g. OLED, PDP) or transmissive (a backlight’s light output is modulated by the display cell – e.g. LCD).

Within PE, flexible displays are being developed across a number of display media types, with mechanical metrics from “rigid only” through to “rollable”. Thus in each Competence Matrix under “Displays”, entities are marked as to whether they are concerned with *Rigid only; Conformal (fixed RoC); Flexible/bendable (multiple RoCs) and Rollable (full mechanical flexibility to minimum RoCs)*, in order to link PE networking partners into common interests of backplane driver technology developments of *rigid* through to *rollable*, but with, for example, independence of specific display media type.

6 How did we select companies and university departments for inclusion in our Competence Matrices?

We wanted to include companies and university departments located in the UK and Germany that are publicly known to be developing material, processes or equipment for the fabrication of electronics products on flexible substrates. That includes any university for which plastic electronics research is a key competence or aim, and every company for whom plastic electronics is part of its remit or mission. We hoped that this would give us an overall sense of the emerging eco-system in the UK and Germany. We therefore included both entities whose primary focus is flexible end-products, and those whose core focus lies elsewhere (e.g. conventional printing equipment or thick film inks), but who nonetheless have tools or material sets that are relevant to the design or fabrication of PE devices and components, or their measurement or validation once fabricated.

The data were prepared from information that is in the public domain, and written in English. It is therefore possible that some universities or institutes in Germany may have been missed where they only have German language version of their websites. Each matrix reports only on the activities of the entity in the relevant country. Thus Plastic Logic is listed as a supplier/manufacturer of process scale-up and/or prototype design in the Germany matrix but not in the UK matrix, reflecting the fact that its production activities are in Dresden. Likewise, NANOIDENT’s entry is limited to its activities in Germany, excluding the wider extent of R&D and production being undertaken in Austria.

We exclude

- Entities that are focussed on rigid glass-based thin-film electronics or active in conventional electronics components and/or systems. Thus Light Blue Optics, which develops miniature projection systems using liquid crystal on silicon (LCoS) microdisplay display drivers with RGB laser light sources, is excluded from the UK matrix.

- Entities that are active in PE in other countries, but which have no major R&D or manufacturing in the country of interest. Thus iTi, which is headquartered in Boulder, Colorado and with a sales office in Cambridge, UK, is excluded from the UK matrix.

- Final product integrators – e.g. mobile phone companies, display set makers – as they form part of the existing “channel to market” for any electronics products

- Entities providing high-level support to the PE industry, such as venture capitalists, angel investors; funders from the public purse (e.g. UK Government’s Technology Strategy Board, EPSRC)

- Entities providing market intelligence/data, conferences etc. (e.g. cintelliq, IDTechEx) and trade associations (such as VDD, VDI and VDMA in Germany).

- Corporate entities with a business focus on scouting for new business investments/spin-ins (e.g. Kodak Cambridge)

The following table gives some further reasoning for why entities have been excluded from the UK Matrix. Similar reasoning was applied in the preparation of the German matrix.

Entity	**Reason they are not in the Competence Matrix for the UK**	**Evidence for this reasoning**
FUJIFILM Imaging Colorants	Business focus does not include PE applications	“FUJIFILM Imaging Colorants (FFIC) is a world leader in the development and supply of innovative, high performance colorants for the global digital printing market. • Colorants for inkjet printers • Coloured chemical toners for laser printers & photocopiers • Infrared absorbers for a range of specialty applications” http://www.fujifilmic.com/ The business was formed in February 2006 following the acquisition of Avecia’s electronic materials businesses by Fuji Photo Film Co. Ltd. http://www.fujifilmic.com/news_art2.html
GE Aviation Systems	Focus is not on PE technologies and applications	“GE Aviation specialises in the design, manufacture and testing of custom electronic components and sub-systems, including Application Specific Integrated Circuits, Custom Electronic Modules, Standard Components, Packaging of Microsystems and Ruggedised Displays.” http://www.electroniccomponents.geaviationsystems.com/About-Us/index.asp
Inca Digital Printers	Focus is not on PE technologies and applications. (Any displays-related PE technology development is likely to be based in Japan under the Japanese DNS parent.)	“Inca's main products are flatbed inkjet printers aimed at companies wanting to efficiently respond to market needs for short run prints, particularly high quality, full colour images onto a variety of rigid or flexible substrates”. http://www.incadigital.com/company/index.php Their focus is still centred on classical graphics pigment ink printing. Dainippon Screen (DNS) of Japan acquired Inca in 2005 - for assess to inkjet technologies for display manufacture (outside of the UK). http://www.incadigital.com/company/dainippon.php
iTi - imaging	Sales office only in	“imaging Technology international Corporation (iTi), based in

Technology international	the UK	Boulder, CO since 1992, designs, develops and manufactures digital systems that incorporate inkjet technology for industrial applications". http://www.iticorp.com/sales/sales_contacts.php In January 2006 they opened a Cambridge UK sales office. http://www.imagingtechnology-corp.com/pressroom/PR_European_Office.pdf
Oerlikon Optics UK Ltd	They only have a sales office in the UK	"Oerlikon Optics is your partner for innovative optical solutions. The division possesses a comprehensive know-how in optical thin films, glass processing, lithography and the production of optical subassemblies" http://www.oerlikon.com/ecomaXL/index.php?site=OPTICS_EN_contact_worldwide_locations
PRP Optoelectronics	Not a PE technology remit	Focus is on conventional LEDs and packaging for robust application requirements - hence not a PE focus. http://www.prpopto.com/technology.html
QinetiQ	Unclear whether there is any remaining focus on PE, given the recent MoD sell off to new business stakeholders	Developer of novel materials and devices - e.g. the ZBD display technology was spin out of the UK's Defence Evaluation and Research Agency (DERA) in Malvern (now QinetiQ) in July 2000. However, recently the Ministry of Defence (MoD) sold off the R&D labs in the UK (mostly to private equity firms): "Privatisation of the country's top-secret defence research labs and facilities as Qinetiq" http://www.theregister.co.uk/2007/11/23/qinetiq_stealth_piracy_pillow_bite_deal/ and http://news.bbc.co.uk/1/hi/business/4592238.stm .. and hence the focus on PE for this "leading international defence and security technology company.. developing innovative technology-based solutions and products and provide technology-rich support services for government organisations, such as the UK MoD and the US DoD, and for commercial customers around the world" is unclear.
Cambridge Display Technology	CDT ***is in*** the Competence Matrix as post the Sumitomo (Japanese chemical company) acquisition, they have retained R&D labs in Cambridge UK. http://www.cdtltd.co.uk/news/642.asp	

7 Rationale for classifications of example entities

Three examples from the UK matrix are used as illustrations in the tables below, with the "Notes" column explaining the reasoning that has been applied in filling in the black boxes. These entities (which have been selected for illustrative purposes) are:

- Conductive Inkjet Technology (CIT)
- Polymer Vision (including the Innos acquisition)
- University of Abertay, Dundee - the EPICentre

7.1 Conductive Inkjet Technology (CIT)

(1) Main classification		
TECHNOLOGY AREAS		Downloads on the technology and equipment sets: http://www.conductiveinkjet.com/downloads.html
Materials and Inks		
Innovative developer of Materials and Inks		Ink tailored for highly reliable jetting and optimal metal deposition. Enables low temperature deposition of dense films Supply of UV cured catalyst ink and metallisation fluid under a technology licence.
Supplier/manufacturer of Materials and Inks		
End-user/customer deploying Materials and Inks		
Technology and Design		
Innovative developer of Technology and Design		Low cost process for metallisation with UV curable inks designed specifically for inkjet. Optimised for print quality and print head reliability
Supplier/manufacturer of Technology and Design		
End-user/customer deploying Technology and Design		
Equipment		
Innovative developer of Equipment		
Supplier/manufacturer of Equipment		Digital printing of a variety of metals. Through approved partners Preco Inc and Xennia, integrated technology platforms are available – reel-to-reel narrow web and A4 lab systems through to A0 sheet fed
End-user/customer deploying Equipment		
Process scale-up and/or Prototype Design		
Innovative developer of Process scale-up and/or Prototype Design		For example, Print2Chip™ for copper interconnect printing – RFID chip attachment. MetalJet 5000 and MetalJet 6000 systems are installed in a clean manufacturing facility in Cambridge.
Supplier/manufacturer of Process scale-up and/or Prototype Design		
End-user of Process scale-up and/or Prototype Design		
Components and/or Services		
Innovative developer of Components and/or Services		
Supplier/manufacturer of Components and/or Services		Supply of UV cured catalyst ink and metallisation fluid under a technology licence.
End-user/customer deploying Components and/or Services		
(2) Materials and Technologies		
THIN FILM PROCESSING FACILITIES AND STATUS		
(Cleanroom) facilities and main activities:		
R&D (lab-scale processes; exploratory stage; core technology developer)		Both lab-scale and industrial printing processes are developed in-house/through approved partners.
Prototype Line (engineering sample volumes; yield and SPC control)		
Production line (fully-balanced production line; shift systems and volume production output)		
SUBSTRATE TYPE AND PREPARATION		
Plastic:		Processes have been optimised for the direct writing of conductive metals onto non-porous substrates (specifically plastics)
Other "flexible":		
Stainless steel/metal foil		
Paper		
Applicable to rigid substrates		
Substrate barrier/encapsulation/planarisation layers		
MAIN THIN FILM PROCESSING STEPS		
Printing/Additive processing:		
Low resolution, comparatively thick layers (e.g. screen, gravure, offset...)		
High resolution, comparatively thin layers (e.g. inkjet, soft lithography...)		Inks and processes surrounding inkjet technologies

Mechanical masking		
Direct write/materials modification (e.g. laser ...)	■	Laser-assisted inkjet technologies are being developed to create small/precise features
Sheet deposition of materials from solution - e.g. slit coating, spin coating...		
Vacuum-based sheet materials deposition		
Conventional photolithography with wet/dry etch for material definition		
Other (pls specify)		
Process Type:		
S2S/batch processing	■	Integrated technology platforms are available – reel-to-reel narrow web and A4 lab systems through to A0 sheet fed
R2R/continuous processing	■	
MATERIALS AND DEVICES		
Main Device Type classification		
Active device elements (e.g. (O)TFTs, diodes, PV, PLED...)		
Passive device elements (e.g. antennas, interconnect, electrodes...)	■	Ink developments for conductive metals e.g. antenna coils, interconnect.
Generic PE applications		
Main Material Type classification		
Semiconductor		
Dielectric/Passivation layers		
Matrices and interconnect; transparent conductors	■	UV curable catalyst inks plus electroless plating processes
Bio/pharma/medical materials		
Nanotechnology (e.g. tubes, wires...)		
Phosphors, light emitters, lasers		
Surface modification, surface energy patterning...		
Coatings, release films...		
Generic Materials base Research/know-how - suitable for PE devices		
ENCAPSULATION LAYERS FOR		
Backplane/active driving elements:		
Frontplane (e.g. display media, sensor elements...):		
Generic encapsulation layers for PE applications		
DISPLAY EFFECTS		
OLED - emissive:		
Small molecule OLED		
Polymeric OLED		
Electrophoretic - reflective		
Electroluminescent/phosphor-based		
LC-based		
Generic display effects		
SIMULATION AND MODELLING		
Materials structure and chemical performance simulation		
Materials/device simulation and architecture design (at elemental device and/or pixel level)		
Circuit simulation and architecture design (e.g. backplane array, RFID circuit)		
Thin-film processes (e.g. printing and coating rheology...)		
Manufacturing processes		
BACK-END INTEGRATION		
Electrical contacting to e.g. discrete Si IC drivers via flex-foils		
Electronics packaging and integration (e.g. module assembly...)		
FAILURE ANALYSIS, TEST, METROLOGY ETC.		
Development of core testing techniques		
Test and Measurement:		
Electrical		
Optical/Geometric		

Chemical		
Lifetime/environmental/mechanical		
Level of testing:		
Single/few devices only		
Component/prototype line/production level		
(3) Specific Applications and/or Products being addressed		
Generic "flexible displays/electronics"	■	Applications are noted on the CIT web site http://www.conductiveinkjet.com/app-universe.html
DISPLAYS	■	
Component Level:		
Backplane AM drivers		
Display biplanes (backplane + display media)		
Applications and Mechanical metrics:		
High end (greyscale/colour...)		
Low end (signage, PoP, ESL, indicator displays...)		
Rigid only		
Conformal (fixed RoC)		
Flexible/bendable (multiple RoCs)		
Rollable (full mechanical flexibility to minimum RoCs)		
RFID	■	
Antennas only	■	
SMART CARDS/PACKAGING	■	
NOVELTIES/GAMES/DISPOSABLE ELECTRONICS	■	
PHARMA/MEDICAL/BIO APPLICATIONS		
LARGE AREA SOLID STATE LIGHTING	■	
Emissive element based on … materials:		
Inorganic		
Organic		
BATTERIES/FUEL CELLS	■	
PHOTOVOLTAICS	■	
SENSORS	■	
Optical/light		
Chemical/Biological/Pharma		
Touch		
FASHION/WEARABLE ELECTRONICS		
(4) Component Manufacture and Supply		
Substrates:		
Plastic		
Functional inks:		
Organic-based inks	■	CIT ink contains a catalyst as the base for a subsequent electroless metal deposition from solution
Inorganic-based inks		
Active elements (e.g. display driving backplanes, solar cells..)		
Passive elements (e.g. antennas, light guides..)	■	
Thin-film/printing/post processing manufacturing equipment and consumables:	■	Equipment sets supply with approved partner Xennia - "Xennia's new range of MetalJet® platforms makes CIT technology readily available as part of an integrated package of printer, UV lamp and plating station."
R&D/lab scale	■	
Prototype/manufacturing scale	■	
Display media (e.g. EP, OLED..)		
Simulation and modelling packages		
Discrete Si driver ICs		
Back-end integration/flex foils/electronics packaging		
Test and analysis equipment/service		
Complete systems (in relatively low volumes/market sizes)		
(5) Business Model and Financing Status		
Funding:		
VC/angel funded (equity finance)	■	CIT was set up as a joint venture between Xennia and Carclo. Having

	■	become 100% owned by Carclo, all CIT activity has been consolidated in Cambridge UK. http://www.conductiveinkjet.com/pdfs/October-News.pdf
Private funding (bank, friends-and-family or own business revenues)		
Majority Govt-funded/public sector entity		
Involved with Govt grant funded projects (TSB Collaborative R&D, EU FP6/7 etc.)	■	For example, CIT have partnered with CDT in a DTI programme for laser-cured fine lines.
Current status:		
University - focus on Base Technology Research		
University - Looking to also spin-out/technology transfer opportunities		
Small start-up/SME	■	
Larger corporate/international organisation/established company		
Main Business Model(s):		
Open access/Open innovation/Partnership working	■	"Our business model is to supply our patented UV curable catalyst inks directly to our customers under a licence agreement. With our partners we have designed a range of inkjet equipment which spans laboratory test equipment right up to a high speed reel to reel full production press. Having become 100% owned by Carclo plc, the decision has been made to consolidate all CIT activity at Cambridge. This will involve installing both the MetalJet 5000 and MetalJet 6000 systems in a newly created clean manufacturing facility. CIT will now be offering a Contract Manufacturing Service for both sheet material and reels – particularly for those customers who want to qualify the product before acquiring their own equipment. Finally, we also work with customers on feasibility programmes to integrate our technology into their processes. In these situations we work with a range of equipment manufacturers to provide optimum solutions to our customers." http://www.conductiveinkjet.com/about-us.html
Licensing business model (e.g. IP..)	■	
Direct manufacture/supply to customers	■	
Currently involved with JDAs/JVs		

7.2 Polymer Vision (including the Innos acquisition)

(1) Main classification		
TECHNOLOGY AREAS		
Technology and Design		
Innovative developer of Technology and Design	■	Developer of OTFT backplane technologies for rollable electrophoretic displays
Supplier/manufacturer of Technology and Design		
End-user/customer deploying Technology and Design		
Process scale-up and/or Prototype Design		
Innovative developer of Process scale-up and/or Prototype Design	■	Through Polymer Vision's acquisition of Innos, they have access to first manufacturing facilities, as well as R&D facilities in Eindhoven, NL through MiPlaza at the High Tech Campus.
Supplier/manufacturer of Process scale-up and/or Prototype Design		
End-user of Process scale-up and/or Prototype Design		
Components and/or Services		
Innovative developer of Components and/or Services		
Supplier/manufacturer of Components and/or Services	■	The Readius® product will be commercially launched by mid 2008 Telecom Italy will co-develop and market with TIM in Italy on an exclusive basis, while Polymer Vision will market the device in the rest of the world
End-user/customer deploying Components and/or Services		
(2) Materials and Technologies		
THIN FILM PROCESSING FACILITIES AND STATUS		
(Cleanroom) facilities and main activities:		
R&D (lab-scale processes; exploratory stage; core technology developer)	■	In 2007, Polymer Vision acquired the whole of the Innos Ltd UK business activities (Innos had been the manufacturing subcontractor of the company's rollable displays). This acquisition occurred within a year of Polymer Vision's spin out from Royal Philips Electronics.
Prototype Line (engineering sample volumes; yield and SPC control)	■	
Production line (fully-balanced production line; shift systems and volume production output)	■	With the facilities at Innos in Southampton (an ex-Philips Si IC fab) "*Polymer Vision are vertically integrating the (first) manufacturing of their rollable Readius displays*" http://www.polymervision.com/site/news/16/46/Press_releases/25/Polymer_Vision_acquires_Innos_business_to_integrate_vertically_the_manufacturing_of_rollable_displays. These facilities are based on conventional Si IC wafer processing equipment sets. Polymer Vision also has access to R&D facilities in Eindhoven, NL through MiPlaza at the High Tech Campus http://www.futuretechnologycenter.nl/downloads/KIVI/Miplaza.pdf and the Holst Centre relationship.
SUBSTRATE TYPE AND PREPARATION		
Plastic:	■	The flexible plastic OTFT backplane substrate is laminated to a rigid carrier during processing, with subsequent release and lamination to e-paper display media to form a flexible e-paper display
Other "flexible":		
Stainless steel/metal foil		
Paper		
Applicable to rigid substrates		
Substrate barrier/encapsulation/planarisation layers		
MAIN THIN FILM PROCESSING STEPS		
Printing/Additive processing:		
Low resolution, comparatively thick layers (e.g. screen, gravure, offset...)		
High resolution, comparatively thin layers (e.g. inkjet, soft lithography...)		
Mechanical masking		
Direct write/materials modification (e.g. laser ...)		
Sheet deposition of materials from solution - e.g. slit coating, spin coating...	■	The Polymer Vision 5" diagonal rollable OTFT backplane technology is based around conventional sheet vacuum depositions and conventional wet/dry layer

Vacuum-based sheet materials deposition	■	patterning. The OTFT bottom-gate p-type semiconductor layer is produced from a soluble precursor route: http://www.polymervision.com/site/page/15/26/38/How_to_make_a_rollable_display
Conventional photolithography with wet/dry etch for material definition	■	
Other (pls specify)		
Process Type:		
S2S/batch processing	■	Plastic substrate processing on rigid Si wafer 'carriers'
R2R/continuous processing		
MATERIALS AND DEVICES		
Main Device Type classification		
Active device elements (e.g. (O)TFTs, diodes, PV, PLED...)	■	Polymer Vision's focus is on rollable e-paper displays, using E Ink media. Their OTFT backplane array drivers are also being developed for other applications through partnerships – e.g. RFID with the Holst Centre Eindhoven NL http://www.holstcentre.com/index.php?id=54&news=345
Passive device elements (e.g. antennas, interconnect, electrodes...)	■	
Generic PE applications	■	
Main Material Type classification		
Semiconductor		
Dielectric/Passivation layers		
Matrices and interconnect; transparent conductors		
Bio/pharma/medical materials		
Nanotechnology (e.g. tubes, wires...)		
Phosphors, light emitters, lasers		
Surface modification, surface energy patterning...		
Coatings, release films...		
Generic Materials base Research/know-how - suitable for PE devices		
ENCAPSULATION LAYERS FOR		
Backplane/active driving elements:		
Frontplane (e.g. display media, sensor elements...):		
Generic encapsulation layers for PE applications		
DISPLAY EFFECTS		
OLED - emissive:		
Small molecule OLED		
Polymeric OLED		
Electrophoretic - reflective	■	Their first rollable colour display was demonstrated at SID'08: http://www.polymervision.com/site/news/16/46/Press_releases/61/Introducing_the_first_rollable_display_prototype_in_full_color
Electroluminescent/phosphor-based		
LC-based		
Generic display effects		
SIMULATION AND MODELLING		
Materials structure and chemical performance simulation		
Materials/device simulation and architecture design (at elemental device and/or pixel level)	■	Device and circuit/backplane array-level simulation activities are core to the development of the technology into production
Circuit simulation and architecture design (e.g. backplane array, RFID circuit)	■	
Thin-film processes (e.g. printing and coating rheology...)		
Manufacturing processes		
BACK-END INTEGRATION		
Electrical contacting to e.g. discrete Si IC drivers via flex-foils	■	
Electronics packaging and integration (e.g. module assembly...)		
FAILURE ANALYSIS, TEST, METROLOGY ETC.		
Development of core testing techniques		
Test and Measurement:	■	Essential capabilities and tasks for an entity working to manufacturing scale-up
Electrical	■	
Optical/Geometric	■	
Chemical	■	
Lifetime/environmental/mechanical	■	
Level of testing:		
Single/few devices only	■	Testing facilities and protocols across both R&D and manufacturing-levels (MiPlaza, Holst Centre; Innos manufacturing line)
Component/prototype line/production level	■	

(3) Specific Applications and/or Products being addressed		
Generic "flexible displays/electronics"		Applications under consideration through co-development partnerships include RFID
DISPLAYS		
Component Level:		
Backplane AM drivers		OTFT flexible display backplane drivers on a plastic substrate
Display biplanes (backplane + display media)		
Applications and Mechanical metrics:		
High end (greyscale/colour...)		Their first rollable colour display was demonstrated at SID'08: http://www.polymervision.com/site/news/16/46/Press_releases/61/Introducing_the_first_rollable_display_prototype_in_full_color
Low end (signage, PoP, ESL, indicator displays...)		
Rigid only		
Conformal (fixed RoC)		
Flexible/bendable (multiple RoCs)		
Rollable (full mechanical flexibility to minimum RoCs)		As "*the rollable display company*", applications are focussed on this flexible mechanical format – as demonstrated by the Readius e-reader http://www.readius.com/
RFID		(RFID is not included in the business remit of Polymer Vision, hence no black box fill here. Other applications of the base OTFT technology such as RFID, are being pursued through partnerships – e.g. Holst Centre)
Antennas only		
SMART CARDS/PACKAGING		
NOVELTIES/GAMES/DISPOSABLE ELECTRONICS		
PHARMA/MEDICAL/BIO APPLICATIONS		
LARGE AREA SOLID STATE LIGHTING		
Emissive element based on … materials:		
Inorganic		
Organic		
BATTERIES/FUEL CELLS		
PHOTOVOLTAICS		
SENSORS		
Optical/light		
Chemical/Biological/Pharma		
Touch		
FASHION/WEARABLE ELECTRONICS		
(4) Component Manufacture and Supply		
Substrates:		
Plastic		
Functional inks:		
Organic-based inks		
Inorganic-based inks		
Active elements (e.g. display driving backplanes, solar cells..)		
Passive elements (e.g. antennas, light guides..)		
Thin-film/printing/post processing manufacturing equipment and consumables:		
R&D/lab scale		
Prototype/manufacturing scale		
Display media (e.g. EP, OLED..)		
Simulation and modelling packages		
Discrete Si driver ICs		
Back-end integration/flex foils/electronics packaging		
Test and analysis equipment/service		
Complete systems (in relatively low volumes/market sizes)		Manufacture of rollable displays (E Ink media) from the (ex-)Innos cleanroom facilities - the Readius® product will be commercially launched by mid 2008 http://www.polymervision.com/site/news/16/46/Press_releases/46/Readius%AE_commercial_product_brings_e-reading_comfort_to_mobile_phones_using_rollable_displays Production of the Cellular Book for TIM market entry: http://www.polymervision.com/site/news/16/46/pressreleases/34

		Telecom Italy will co-develop and market with TIM in Italy on an exclusive basis, while Polymer Vision will market the device in the rest of the world. http://www.polymervision.com/site/news/16/46/Press_releases/34/Telecom_Italia_and_Polymer_Vision_announce_the_'CELLULAR-BOOK'
(5) Business Model and Financing Status		
Funding:		
VC/angel funded (equity finance)		Spun out of Philips Research Eindhoven, NL activities. Equity funders include NVP http://www.research.philips.com/newscenter/archive/2007/070425-siliconhive.html?x=rss and Technology Capital SA.
Private funding (bank, friends-and-family or own business revenues)		
Majority Govt-funded/public sector entity		
Involved with Govt grant funded projects (TSB Collaborative R&D, EU FP6/7 etc.)		For example, Polymer Vision's partnering within the FP6 FlexiDis program https://share.philips.com/QuickPlace/flexidis/Main.nsf/h_Toc/8c01b07342cd2fe7c12571d90052f8a4/?OpenDocument
Current status:		
University - focus on Base Technology Research		
University - Looking to also spin-out/technology transfer opportunities		
Small start-up/SME		Spun out of Philips Research Eindhoven, NL – core technology and IP is based on more than 10 years of R&D in organic electronics.
Larger corporate/international organisation/established company		
Main Business Model(s):		
Open access/Open innovation/Partnership working		For example, Polymer Vision has a partnership covering the research and development of organic transistor technologies and patterning processes in the open-innovation setting of Holst Centre. http://www.holstcentre.com/index.php?id=54&news=345
Licensing business model (e.g. IP..)		Applications outside of displays include RFID applications – the logic circuit technology is based on Polymer Vision's OTFT technology core competence using organic bottom-gate p-type Pentacene TFTs from soluble precursor route. http://counterfeitdrug.wordpress.com/2008/02/19/holst-center-reports-breakthrough-in-organic-rfid/
Direct manufacture/supply to customers		Manufacture of rollable displays (E Ink media) from the (ex-)Innos cleanroom facilities - the Readius® product will be commercially launched by mid 2008 http://www.polymervision.com/site/news/16/46/Press_releases/46/Readius%AE_commercial_product_brings_e-reading_comfort_to_mobile_phones_using_rollable_displays Production of the Cellular Book for TIM market entry: http://www.polymervision.com/site/news/16/46/pressreleases/34
Currently involved with JDAs/JVs		"*E Ink has a number of flexible display initiatives under development, including partnerships with Polymer Vision*" http://www.eink.com/technology/flexible.html

7.3 University of Abertay, Dundee - the EPICentre

(1) Main classification		
TECHNOLOGY AREAS		
Components and/or Services		
Innovative developer of Components and/or Services		Focus of this entity is on man-machine interfaces – including PE display usability. "Epicentre's Display Measurement Labs are equipped for usability studies in which subjects are asked to perform a series of realistic tasks with a proposed user interface (prototyped with advanced visualisation tools such as VAPS if required) under strict experimental conditions. In this way a user interface can be evaluated and improved at an early stage of development before substantial resources have been committed." Covers human-machine interface design.
Supplier of manufacturer of Components and/or Services		
End-user/customer deploying Components and/or Services		
(2) Materials and Technologies		No filled boxes in this Section 2 as they do not have thin-film/PE device processing in their remit.
THIN FILM PROCESSING FACILITIES AND STATUS		
(Cleanroom) facilities and main activities:		
R&D (lab-scale processes; exploratory stage; core technology developer)		
Prototype Line (engineering sample volumes; yield and SPC control)		
Production line (fully-balanced production line; shift systems and volume production output)		
SUBSTRATE TYPE AND PREPARATION		
Plastic:		
Other "flexible":		
Stainless steel/metal foil		
Paper		
Applicable to rigid substrates		
Substrate barrier/encapsulation/planarisation layers		
MAIN THIN FILM PROCESSING STEPS		
Printing/Additive processing:		
Low resolution, comparatively thick layers (e.g. screen, gravure, offset..)		
High resolution, comparatively thin layers (e.g. inkjet, soft lithography..)		
Mechanical masking		
Direct write/materials modification (e.g. laser ..)		
Sheet deposition of materials from solution - e.g. slit coating, spin coating..		
Vacuum-based sheet materials deposition		
Conventional photolithography with wet/dry etch for material definition		
Other (pls specify)		
Process Type:		
S2S/batch processing		
R2R/continuous processing		
MATERIALS AND DEVICES		
Main Device Type classification		
Active device elements (e.g. (O)TFTs, diodes, PV, PLED..)		
Passive device elements (e.g. antennas, interconnect, electrodes..)		
Generic PE applications		
Main Material Type classification		
Semiconductor		
Dielectric/Passivation layers		
Matrices and interconnect; transparent conductors		
Bio/pharma/medical materials		
Nanotechnology (e.g. tubes, wires..)		
Phosphors, light emitters, lasers		

Surface modification, surface energy patterning..		
Coatings, release films..		
Generic Materials base Research/know-how - suitable for PE devices		
ENCAPSULATION LAYERS FOR ..		
Backplane/active driving elements:		
Frontplane (e.g. display media, sensor elements..):		
Generic encapsulation layers for PE applications		
DISPLAY EFFECTS		
OLED - emissive:		
Small molecule OLED		
Polymeric OLED		
Electrophoretic - reflective		
Electroluminescent/phosphor-based		
LC-based		
Generic display effects		
SIMULATION AND MODELLING		
Materials structure and chemical performance simulation		
Materials/device simulation and architecture design (at elemental device and/or pixel level)		
Circuit simulation and architecture design (e.g. backplane array, RFID circuit)		
Thin-film processes (e.g. printing and coating rheology..)		
Manufacturing processes		
BACK-END INTEGRATION		
Electrical contacting to e.g. discrete Si IC drivers via flex-foils		
Electronics packaging and integration (e.g. module assembly..)		
FAILURE ANALYSIS, TEST, METROLOGY ETC.		
Development of core testing techniques		Covers the readability and usability ***of displays in general***: human/machine interfaces
Test and Measurement:		
Electrical		
Optical/Geometric		Covers e.g. optical assessments of displays
Chemical		
Lifetime/environmental/mechanical		
Level of testing:		
Single/few devices only		Test facility only – no production level facilities
Component/prototype line/production level		
(3) Specific Applications and/or Products being addressed		
Generic "flexible displays/electronics"		Applicable to PE man-machine interfaces in general
DISPLAYS		
Component Level:		
Backplane AM drivers		
Display biplanes (backplane + display media)		
Applications and Mechanical metrics:		
High end (greyscale/colour..)		
Low end (signage, PoP, ESL, indicator displays..)		
Rigid only		
Conformal (fixed RoC)		
Flexible/bendable (multiple RoCs)		
Rollable (full mechanical flexibility to minimum RoCs)		
RFID		
Antennas only		
SMART CARDS/PACKAGING		
NOVELTIES/GAMES/DISPOSABLE ELECTRONICS		
PHARMA/MEDICAL/BIO APPLICATIONS		
LARGE AREA SOLID STATE LIGHTING		

Emissive element based on … materials:		
Inorganic		
Organic		
BATTERIES/FUEL CELLS		
PHOTOVOLTAICS		
SENSORS		
Optical/light		
Chemical/Biological/Pharma		
Touch		
FASHION/WEARABLE ELECTRONICS		
(4) Component Manufacture and Supply		
Substrates:		
Plastic		
Functional inks:		
Organic-based inks		
Inorganic-based inks		
Active elements (e.g. display driving backplanes, solar cells..)		
Passive elements (e.g. antennas, light guides..)		
Thin-film/printing/post processing manufacturing equipment and consumables:		
R&D/lab scale		
Prototype/manufacturing scale		
Display media (e.g. EP, OLED..)		
Simulation and modelling packages		
Discrete Si driver ICs		
Back-end integration/flex foils/electronics packaging		
Test and analysis equipment/service		
Complete systems (in relatively low volumes/market sizes)		
(5) Business Model and Financing Status		
Funding:		
VC/angel funded (equity finance)		
Private funding (bank, friends-and-family or own business revenues)		
Majority Govt-funded/public sector entity		UK university funded from the public purse
Involved with Govt grant funded projects (TSB Collaborative R&D, EU FP6/7 etc.)		For example, partner in 2006 ENDSENSE DTI project - coatings for more readable displays, with Colin Cartwright of the School of Computing and Creative Technologies
Current status:		
University - focus on Base Technology Research		Focus on base development of testing methodologies. Facilities are open to the scientific community.
University - Looking to also spin-out/technology transfer opportunities		Not looking for specific PE spin-outs
Small start-up/SME		
Larger corporate/international organisation/established company		
Main Business Model(s):		
Open access/Open innovation/Partnership working		Looking to collaborate with other R&D entities on analysing the man-machine interface
Licensing business model (e.g. IP..)		
Direct manufacture/supply to customers		
Currently involved with JDAs/JVs		

8 Glossary of terms

A

Additive processing*/printing/direct write*
New thin film processing technologies where only material required in the final device is deposited/defined. Typically processes akin to the graphic printing industry – only the pigment inks for the final e.g. words in a book product, are deposited on the paper substrate. C.f. Subtractive processing

AM
Active matrix

AMLCD
Active matrix liquid crystal display

a-Si
Amorphous silicon

B

B2B
Business to business

BLU
Backlight (for an LCD)

C

CE marking
This is a mandatory conformity mark on products placed on the single market in the European Economic Area (EEA). The CE marking (an acronym for the French "*Conformité Européenne*") certifies that a product has met EU health, safety, and environmental requirements, which ensure consumer safety.

D

Deposit/ion
Applying a layer of a material onto a substrate

DERA
Defence Evaluation and Research Agency (now QinetiQ)

DoD
Department of Defence (USA)

E

EL
electroluminescence/t

EP (display media)/electrophoretic
An electrophoretic display is an information display that forms visible images by rearranging charged pigment particles using an applied electric field. Such paper-like display media is available from e.g. E Ink or SiPix.
Analogous to the LC in an LCD or OLED layers in an OLED display

E-paper
Electronic paper

ESL
Electronic shelf-edge label e.g. for supermarkets

Etching
Etching is the process of using attacking chemicals (wet etching: acids or alkalis in

solution, or dry etching: elements in the gas phase) to cut into unprotected parts of a layer. Also see Subtractive processing

EU
European Union

F

Fab

Factory or fabrication facility

FPD
Flat panel display

FP6/7
Framework 6 or 7 programmes. These are a series of programmes for Research and Technological Development in Europe, partly funded by the EU.
http://ec.europa.eu/research/fp6/index_en.cfm and
http://ec.europa.eu/research/fp7/index_en.cfm

Functional materials
Materials that have properties beyond a geometric/dimensional definition - such as width, thickness, length etc.
Functions can include light emitting, light sensing, electrical (resistive, capacitive, inductive; conductor, insulator, semiconductor) etc.

G, H

I

IC
Integrated circuit

IJP
Inkjet printing

IP
Intellectual property

J

JDA
Joint development agreement

JV
Joint venture

K

L

Lab
Laboratory
LC
Liquid crystal

LCD
Liquid crystal display

LCoS
Liquid crystal on silicon

M

MoD
Ministry of Defence (UK)

N

O

OE
Organic electronics

OLED
Organic light emitting diode (PLED is a form of OLED). Organic materials produce light through electrical stimulation. The term OLED includes PLED, sm-OLED and dendrimer technologies

P

PDP
Plasma display

PE
Generic acronym in the literature covering plastic/printed/polymer/polymer electronics. In this project, PE refers to plastic electronics, which is defined as: materials, processes or pieces of equipment that are intended to facilitate the development and fabrication of electronics products on flexible substrates

Phosphorescent
Specific type of luminescence related to fluorescence

Photolithography
See Subtractive processing

PLED
Polymeric/polymer light emitting diode. Solution-processible organic polymers which emit light when stimulated electrically. LEP, LEP-OLED, P-OLED are alternative terms

PM
Passive matrix

PoP
Point of purchase

Polymers
Long chain organic molecules

Printable Electronics
Generic term covering electronic components manufactured with additive printing technologies as per newspapers, books posters etc. For paper books, pigment-based inks are used. For printed electronics, these are replaced by functional materials (conductors, dielectrics, semiconductors) within a solution format.

PV
photovoltaic

Q

R

R&D
Research and Development

R2R
Roll-to-roll processing

R2S
Roll-to-sheet processing

RFID
Radio Frequency Identification Device

RGB
Red, green blue

Rheology
Properties concerned with the flow of matter e.g. liquid flow on a substrate or through a printer head

RoC
Radius or radii of curvature

S

S2S
Sheet-to-sheet processing

SME
Small to medium-sized enterprise

SPC
Statistical process control

Subtractive processing
Conventional vacuum deposition, photolithography and etching technologies originally developed for the silicon IC industry. Here a sheet material layer is deposited, prior to defining an in-situ positive resist etch mask, wet/dry etching to remove the unwanted material and resist strip clean. C.f. Additive processing

Substrate
Base material upon which processing is conducted to produce new films or layers of materials, and thus the required final devices

T

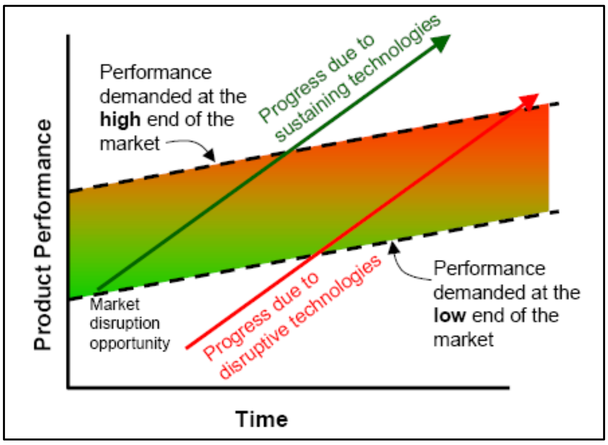
TACT
The time needed to manufacture one unit of a product, measured as the elapsed time between the completion of one unit and the completion of the next (derived from the German word taktzeit which translates to clock cycle)

Technology definition – Evolutionary (or sustaining) vs. Revolutionary (or disruptive)

- *Sustaining or Evolutionary*: Improving performance of existing products with reference to current customers' performance measures.

  Product/service offering into incumbent markets and applications
- *Disruptive or Revolutionary*: Product performance may be initially worse but presents new value proposition

  Product/service offering into new markets and applications



Ref: Christensen, 1997

TFT
Thin film transistor. For example, switching elements in an AM display driving backplane

TSB
Technology Strategy Board

TV
Television

U

V

VC
Venture capital/ist

W, X, Y, Z