Introduction to the PETEC Printed Electronics Centre and Technology Challenges

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Abstract

This paper describes the growth of the emerging flexible electronics industry within the UK and discusses the role of the newly established PETEC Centre in supporting the growth of this fledgling industry, reviewing the key technology sectors and current technology challenges.

INTRODUCTION

For the past forty years, inorganic silicon and gallium arsenide semiconductors, silicon dioxide insulators, and metals such as aluminum and copper have been the backbone of the semiconductor industry. However, in recent years, there has been a growing research effort in organic electronics to improve the semiconducting, conducting, and light emitting properties of organics (polymers, oligomers) and hybrids (organic–inorganic composites)

This combination of new materials coupled with cost-effective, large area production processes has enabled the emergence of a promising new technology sector, organic or printed electronics. Intelligent packaging, rollable displays, flexible solar cells, energy efficient lighting, are just a few examples of the promising fields of application for organic and printed electronics based on these new large scale processable, electrically conductive and semiconducting materials.

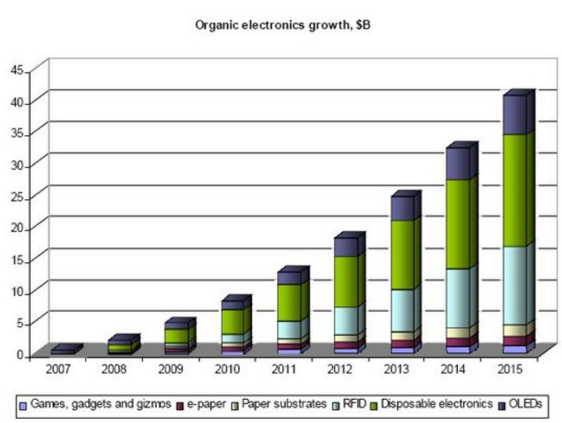

Figure 1: Market Potential for Organic Electronics

The Market potential for this new sector is predicted to reach in excess of £40 billion by the year 2015 (Figure 1) In order to accelerate the development and commercialization of this new emerging technology within the UK, PETEC – the UK's first design, development and prototyping facility specifically for the printed electronics sector has been established. The centre offers a unique blend of materials, process and people capabilities, whose primary aim is to help bring new printable electronic products to market quickly by offering facilities and expertise that are rarely available in-house, reducing the client's level and risk of capital investment.

WHAT IS PRINTABLE ELECTRONICS?

Printable Electronics is essentially a system of mass-producing technologies using traditional printing methods in a low-cost, high-efficiency environment. Printable Electronics (PE) combines a new class of materials and large area, high volume deposition and patterning techniques [1]

PE is often referred to as plastic, flexible, organic, polymer or thin film electronics and attracts acronyms such as OLAE or FOLAE (Flexible and/or Organic Large Area Electronics), but they all refer to the same processes and this ambiguity should not detract from the importance of these technologies.

Printable electronics is the general term to describe electronics based on semiconducting organic materials as opposed to silicon semiconductors. Production costs are greatly reduced, which enables the evolution of a new wave of technologies and products which are lightweight, flexible and cheap to produce.

APPLICATIONS AND TECHNOLOGY BENEFITS

The list of potential benefits that PE technologies could bring is vast. These include, but are not limited to:

- Reduction in cost of materials, design and manufacturing.
- A faster production turnaround time.
- Circuits produced on flexible substrates such as plastics give massive potential for alternate applications.

- Lightweight potential leading to new applications, installations and zero maintenance (where applicable).
- Increased environmental credentials
- Superior fault tolerance.

One of the main benefits of PE production techniques is that by using what's known as electronic inks and a flexible substrate (plastic, for example), production can take place on a roll-to-roll basis. This combines traditional printing techniques with cutting edge technology to provide the products of tomorrow today.

The potential global market for PE is huge, with applications ranging from point-of-care medical diagnostic devices, smart packaging, novel drug delivery devices to real-time newspapers, smart clothing, flexible solar cells (photovoltaic's) and displays.

THE PETEC CENTRE

Based in the North of England, and opened in 2008 the PETEC centre is home to some of the world's most advanced prototyping equipment and laboratories for developing printed electronics (Figure 2) The facility originally comprised of a 600m^2 class 1000 clean room (class 100 lithography area) This has been extended in the past 12 months with the addition of a new building hosting a Class 100 clean room (official opening April 2011) In addition to the clean room area, the facility is supported by a fully equipped formulations laboratory for the development of the organic polymers and an electrical test laboratory.

Figure 2: PETEC printed electronics centre

To satisfy the UK market, the services that the PETEC centre offers are:

- Contract R&D projects for commercial organisations and public funded projects
- Expertise in materials formulation and processing
- Manufacturing expertise and scale-up knowledge
- Access to adaptable tool set for R&D/Pilot Manufacturing
- Clean room space and laboratories available for client use
- Electrical testing of fabricated devices

PETEC staff work on both European and UK funded government collaborative projects as well as commercial projects. The primary focus of work within the facility is the development of printed transistor backplanes for flexible displays. In addition, the versatile equipment set allows proof of concept products to be made in the areas of Solid State Lighting (SSL) and Organic Photovoltaic's (OPV)

Process development is performed on both glass substrates up to 300mm diameter and on plastic film, typically PET (polyethylene terephthalate) to demonstrate the feasibility of flexible processing. Roll to Roll vacuum and wet coating capability at 390mm web width is utilized to demonstrate process scalability.

The development of state of the art solution processable organic semiconductor materials has currently demonstrated electron mobilities in excess of 1 $cm2.sec^{-1}.V^{-1}$. A significant benefit of these materials being solution based, and therefore able to be processed under ambient, low temperature conditions means the offer of lower cost production techniques is realized. For a suitable display backplane, the challenge is to develop a fabrication process to make transistor arrays with good uniformity, repeatability and stability. PETEC is actively engaged with the Flexible Display Centre at Arizona State University to develop printed backplanes for use in active matrix OTFT displays.

TECHNOLOGY CHALLENGES

Current challenges for the development of solid state lighting and organic photovoltaic applications centre on optimizing efficiency, cost and device lifetime. Improving the lifetime of a flexible device can only be achieved by the incorporation of a suitable barrier layer to prevent the ingress of water into the sensitive organic electronic components. This challenge needs to be overcome if the technology is to move to commercialization. Water Vapor Transmission Rate (WVTR) and currently measured in units of g H20/m2/day is said to require a barrier with a WVTR level of 1E-4 for photovoltaic applications and 1E-6 for OLED technology in order to achieve a 15-20 year lifetime. PETEC is currently in a collaborative project with a major UK Company developing barrier technology and measurement capability to be utilized within a building integrated photovoltaic (BIPV) application.

OLED TECHNOLOGY DEVELOPMENT

Organic Light Emitting Diodes (OLEDs) consist of a set of thin organic layers positioned between two electrodes, at least one of which is transparent or semi-transparent (Figure 3) There are two basic types of OLEDs—those where the organic layers are deposited by vacuum thermal evaporation, and those where the organic layers are solution processible. Typically, the vacuum deposited variants are based on small-molecule materials and the solution processible variants are based on polymer materials. In both cases the underlying physics of device operation is the same. In a manner similar to LEDs, charge carriers are injected from the electrodes into the organic layers where they recombine and emit light that escapes the device through a transparent electrode. Since the active layers of the device are very thin, ~100 nm, OLED devices are generally not freestanding, but are fabricated on a glass or polymer substrate [2]

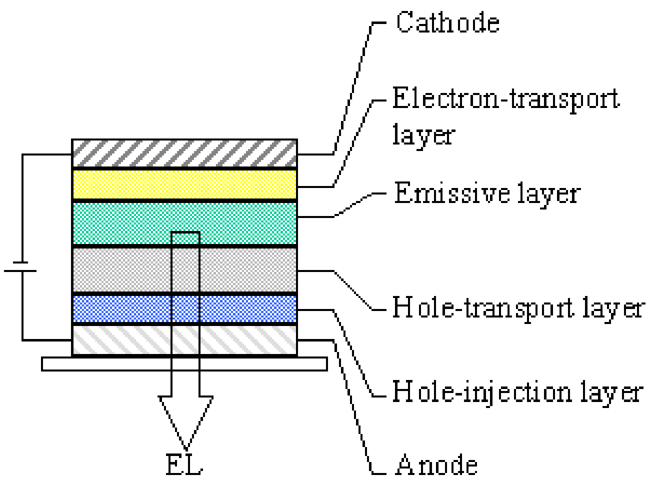

Figure 3: Typical OLED device structure

In order to support the development of OLED and OPV technology within the UK, PETEC have installed a £4.5 million fully automated batch production system in a new state of the art Class 100 clean room. The line is known as the LACE line (large area coating equipment) (Figure 4)

The system built by MBraun GMBH offer material companies and device developers the opportunity to optimize material sets and device designs within this growing sector

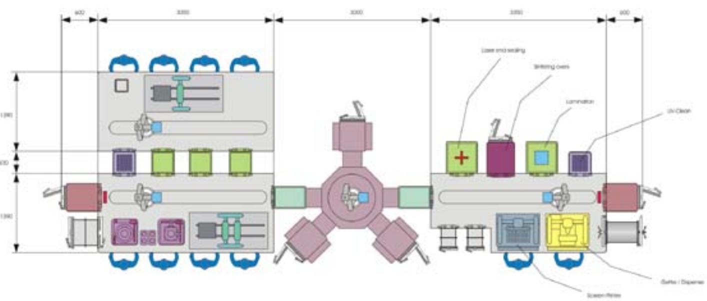

Figure 4: LACE OLED prototyping line

The system offers the user the option to run a range of substrate sizes from 4” to 8”, cassette-cassette operation, full automation and data logging. The fully integrated batch system is designed to minimize manual intervention and maximize product yield.

The system is configured with both conventional spin coating capability, in addition to precision slot die coating. Vacuum evaporation for both metals and organics provides versatility to produce a range of device architectures. An encapsulation module provides full encapsulation of the lighting or photovoltaic tile to maximize lifetime (Figure 5)

Figure 5: LACE encapsulation module

TYPICAL OLED PROCESS FLOW

The process flow for the manufacture of an OLED device through the LACE system commences with the baking of up to 20 pre-patterned substrates in a convection oven to remove moisture. The substrates are then transferred into a buffer cassette which acts as a holding station.

Typically, glass substrates are pre-patterned with an ITO (Indium Tin Oxide) layer that provides an output for the emitted light as well as serving as the anode metallization.

A UV ozone clean is performed to provide a suitably treated surface for the subsequent wet coating of the hole transport layer, typically a PEDOT: PSS formulation.

Following an appropriate bake to stabilize the film, the substrates are transferred into a glove box nitrogen environment for the coating of the emissive layer. The glove box environment is necessary due to the air sensitive nature of the polymer species.

The substrates are the transferred into an evaporator to deposit the cathode metalisation. The final stage of the process involves the encapsulation of the device to prevent the ingress of moisture to maximize device efficiency and lifetime. A fully automated x-y dispenser places the encapsulation glue in a pre-defined pattern. Moisture getters are placed in an etched cavity to provide additional removal of low levels of moisture. A mechanical press seals the substrate to the cavity glass, whilst curing the adhesive under UV light. The cycle time for each substrate is < 10 minutes.

Production of prototype devices is expected to commence in May 2011, and will give device designers and material companies a unique opportunity to develop their technology knowledge base in a controlled, automated environment.

CONCLUSIONS

The organic or printed electronics market is predicted to exceed $300 billion in about 20 years, due to the technology offering a range of benefits, most notably lower cost, performance, robustness and flexibility. The technology will impact many different markets from displacing existing technologies, such as conventional displays and silicon based photovoltaic’s, to creating new markets, such as ultra low cost “Disposable electronics” on retail packaging, large area sensors and much more [3] The PETEC centre has been set up and supported by UK Government funding in order to support the research, growth and ultimately the commercialization of this emerging technology.

REFERENCES

[1] OE-A roadmap for Organic and Printed Electronics 3rd Edition 2009
[2] IDTechEx Printed Electronics Reports 2009
[3] Encyclopedia of Printed Electronics April 2001 Raghu Das, Peter Harrup

ACRONYMS

LACE: Large Area Coating Equipment
OLED: Organic Light Emitting Diode
OPV: Organic Photovoltaic
WVTR: Water Vapor Transmission Rate
SSL: Solid State Lighting
PEDOT: Poly (3, 4-ethylenedioxythiophene)
PSS: Poly (styrenesulfonate