Plastic Electronics: An Enabling Technology

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Abstract - Plastic Electronics, Organic Electronics, Printed or Polymer Electronics, is a branch of Materials Science dealing with Electrically-Conductive Polymers and conductive small molecules. It is called 'Organic' Electronics because the polymers and small molecules are carbon-based. This contrasts with traditional electronics, which relies on inorganic conductors and semiconductors, such as copper and silicon, respectively. In addition to organic charge transfer complexes, examples include polyacetylene, polyaniline (PANI), and polythiophene.

Keywords : organic semiconductors, conducting polymers .

I.INTRODUCTION

Plastic electronics represent a nascent and fast-growing industry, enabled by new carbon-based materials. These new organic materials - semiconductors, dielectrics etc. function very similarly to traditional inorganic materials with a major difference being that they are solution-processable - they can be dissolved into a solution or an "ink". The unique solution-processable property allows us to use organic materials differently from inorganic materials in two ways:

Printability. These materials allows electronic devices to be printed using ink-jet printing, gravure printing, and other roll-to-roll printing processes. In contrast, traditional fabrication processes require facilities that are extremely costly (multi-billion dollar fabs), and have limited throughput using inorganic materials. In addition, printing processes are easily scalable, i.e. it is relatively straight forward to accomplish large-area manufacturing.

Flexibility. These materials can be printed on flexible, light-weight substrates such as plastics, in contrast with traditional rigid substrates. This allows manufacturing of electronics with novel form factors such as roll-up displays and solar panels. In addition, flexibility provides robustness to impact since flexible things don't break easily when they get hit.
These 2 new abilities provide a host of unique and exciting benefits over traditional materials:

II.MATERIAL USE

1.DIELECTRIC POLYMERS

Insulating polymers in organic device are poly(methyl methacrylate), poly(vinyl phenol) and other polystyrenes, polyvinyl alcohol, polyimides, silicone network polymers, and parylene

2.CONDUCTIVE POLYMERS

Conductive polymers are preferred materials for leads and contacts in organic devices because of their suitability for printing. There are three main classes of conductive polymers used for printed electronics : polythiophenes (and related polypyrroles), polyanilines, and insulating polymers filled with conductive nanostructures

3.ORGANIC AND POLYMERIC SEMICONDUCTORS

Classes of *p*-Channel Organic Semiconductors
n-Channel Organic Semiconductors

Plastic electronics – is a technology that enables circuits to be printed onto a range of surfaces. This technology will lead to the creation of a whole new generation of innovative products that can be produced more cheaply and in a more environmentally-friendly way than previously viable. New products will include large area ultra-thin and ultra-efficient display and lighting panels; low-cost solar cells that can be integrated into buildings; and intelligent packaging that provides protection against counterfeiting or responds to changes in products that have exceeded their shelf life. The new technology has grown from expertise in various disciplines – thin film technology, organic chemistry, printing and circuit design.

The term 'Plastic Electronics' is becoming widely used within the electronics, printing and scientific communities to differentiate between the 'old' electronics' manufacturing materials and processes used around the globe since the 1950s and the 'new' technology platform of materials, device architectures and additive manufacturing processes that are emerging currently.

III.Moving from the old to the new

Conventional semiconductor electronic systems such as those used in TVs, brown and white goods, computers and mobile phones are mostly based around discrete passive electronic circuit devices (such as resistors, capacitors, inductors etc.) and active devices (diodes, transistors, integrated circuits). They are securely mounted onto rigid or flexible printed circuit substrate materials, usually by high-temperature soldering. The semiconductor elements are derived from crystalline wafers on which the circuits are fabricated then 'sliced and diced' and individually mounted into discrete plastic moulded, metal-leaded carrier devices.

The conventional semiconductor electronics market is characterised by needing high-cost design and fabrication processes to create the very high market volumes of complicated, high-resolution, high-density semiconductor devices, resulting in a few, high-investment, high-value companies manufacturing the vast bulk of global demand for semiconductor devices. After initial manufacture, these packaged semiconductors, together with the simpler and smaller passive circuit devices required to create functional electronic circuits, are mounted onto their pre-patterned metallised printed circuit substrates using solder paste that is then reflowed at high temperature to make solid, low impedance, mechanically sound connections. These substrate materials are usually rigid printed circuit boards or flexible, high-temperature metallised and patterned plastic films.

In both cases the electrical circuit traces onto which discrete components are to be mounted were usually created using a metal coating followed by photolithography and acid etching to remove the unwanted areas of metal. Conventional electronics manufacturing can be summarised by the following: High-temperature processes required for individual component manufacture and subsequent circuit assembly Subtractive 'coat, pattern and etch back' processes used to manufacture electrically conductive substrate materials, resulting in excessive waste materials with environmental implications High-investment manufacturing cost resulting in a limited number of global manufacturers dominating the production of electronic devices.

Plastic electronics introduces a new, exciting platform of organic and inorganic material sets that can be matched with a new paradigm in manufacturing processes. The revolutionary impact of plastic electronics is that individual circuit devices, whether passive elements (resistors, capacitors) or active elements (diodes, transistors, transistor arrays, etc.) can now be fabricated at the point of circuit manufacture using new solution-processed materials and delivery methods. Active circuit elements can be printed using carbon-based semi-conductive inks, offering different performance criteria as an alternative to the use of old, conventional, discretely-packaged silicon wafer-based devices.

Circuit designer can now design the basic architecture of the components he or she wishes to use. He or she can modify the designs to adapt to the performance levels achievable from the available functional inks and pastes required in the new, simpler manufacturing processes. Existing designs can be easily updated as higher performance materials become available. For total design flexibility, he or she can place the electrical circuitry exactly where the functions are required on the substrate material. Plus, previous limitations on available substrate size can be considerably relaxed for the simpler circuit requirements, allowing functional electrical and electronic circuits to be fabricated on very large sheets of suitable material, and even in continuous fabrication using large area roll-to-roll manufacturing techniques. Plastic electronics is a wide-ranging technology platform that radically challenges how electrical and electronic circuits in the future could and should be designed and fabricated. The cost of entering volume manufacturing of plastic electronic devices is very modest compared to that of comparable large-area silicon-based electronic systems.

IV.THE PLASTIC ELECTRONICS PLATFORM

Plastic electronic devices can vary in design and fabrication complexity from being extremely simple to exceptionally complex. In the simplest design case, where a few circuit elements are to be attached to a substrate to form the finished electrical circuit, the conductive traces are printed onto the substrate material to create the required circuit layout. Discrete passive elements (sensors, resistors, capacitors, inductors, switch elements) can then be printed as required. Active circuit elements such as discrete conventional diodes, LEDs, transistors and integrated circuits can be directly attached to the substrate using conductive adhesives. Alternatively, where limited low-power active circuitry is required, a fully plastic electronic design can be considered whereby the active circuit elements are fabricated as thin film (diodes or transistors) by depositing additional layers of organic solution-processed materials directly onto fine resolution conductive traces printed on the substrate, with the architecture of the active device created by a printing or stamping process.

V.COMPARISON

- Basic operation of OTFT similar to MOSFET
- Manufacturing equipment is similar to FPD fab (materials are different)
- Plastic circuits will not replace silicon…
- Low temperature processing (>200^{o}C for a:SiH, >800^{o}C for silicon)
- Flexible substrates on large scale

Enable new products: Thin, ultra-light, robust, flexible and conformal Opens the door to wide range of customizable fabrication techniques But will allow innovative new applications where inorganic transistors can not be used due to their poor mechanical properties and cost.

VI.ADVANTAGES

Higher Throughput : Traditional manufacturing technologies such as photolithography have material throughputs around 0.1m^2/s. In contrast, printing technologies such as gravure printing have throughputs close to 60m^2/s, nearly 600 times faster.

Lower Cost. Because of the lower cost of plastic substrates and the lower cost of manufacturing plants (a fab can cost $1-3 billion), printed and flexible electronic devices produced using organic materials are orders-of-magnitude cheaper than conventional electronics.

Lighter Weight. Because these materials can be applied to light-weight, plastic substrates, the weight profile of the devices are significantly reduced.

Robustness. In contrast with inorganic materials and substrates, both organic materials and plastic substrates they are deposited on are flexible, durable, and shock-resistant.

Large-area Production. The ability of the materials to be printed allows for the manufacture of large-area devices, such as sheets of solar-cells and large-area displays.

Rapid development cycles. Because circuits can be printed easily by a number of lab-scale devices, device designs can be prototyped, tested, and modified quickly, resulting in quicker commercialization.

VII.DISADVANTAGES

There are also limitations with printed and flexible electronic devices. In particular, inorganic materials allow for higher-resolution fabrication (and thus smaller feature size), meaning that more circuitry can be packed into a given area. Furthermore, inorganic materials often have better performance characteristics such as higher mobility for transistors and higher efficiency for solar cells. The differences are summarized in the table below:

	Conventional Electronics	Printed / Flexible Electronics
Advantage / Disadvantage	High performance	Low performance
	Small area / feature size	Large area / feature size
	High cost/unit area	Low cost/unit area
	High capital investment	Low capital investment
	Long production run	Short production run
	Rigid	Flexible

For this reason, it is not the aim of printed and flexible electronics to replace every conventional devices. While it is true that new devices are likely to displace conventional ones in some areas (e.g. displays), the most exciting opportunities come from their ability to open up new types of applications that are not practical with current materials.

VIII. APPLICATION

Organic Thin-Film Transistors (OTFTs) . Often used in logic circuits, they act as "switches" that can turn voltage or current on and off based upon an applied voltage. They also function as amplifiers in analog circuits.

Organic Photovoltaic (OPVs) . They generate electric currents when exposed to a light source. They are most often used in solar cells, and in sensors and other applications.

Display Backplanes. In most displays, the application is divided into two parts: the front plane and the backplane. The front plane creates the image you see, while the backplane regulates the flow of current to each individual pixel, turning it on or off as necessary. For electrophoretic displays (EPVs) or OLED displays, the front planes are made from flexible materials. However, the backplanes are still made from non-flexible, traditional materials. The creation of flexible backplanes will allow, for the first time, the production of truly flexible displays.

Radio-frequency identification (RFID) Tags. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader. Currently limited in usefulness due to cost constraints, the much lower costs promised by printed electronics stands to unlock the power of this technology by making it ubiquitous on retail goods and novel applications.

Solar Cells. Organic photovoltaic devices, thanks to lower cost and faster manufacturing on a large scale, allows the possibility to make inexpensive solar cells to produce cheap, renewable energy all over the world. Sensors. Printed and flexible circuits can be designed to detect a variety of stimuli, including temperature, pressure, radiation, and chemical identity.

End-User Applications

With just these few building-block devices, the potential number of applications is significant:

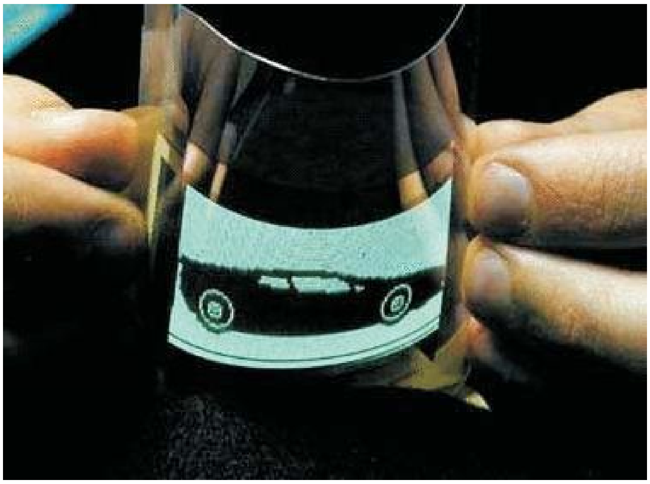

FIG.A FLEXIBLE DISPLAY

FIG.B OLED TV

FIG.C OLED DISPLAY

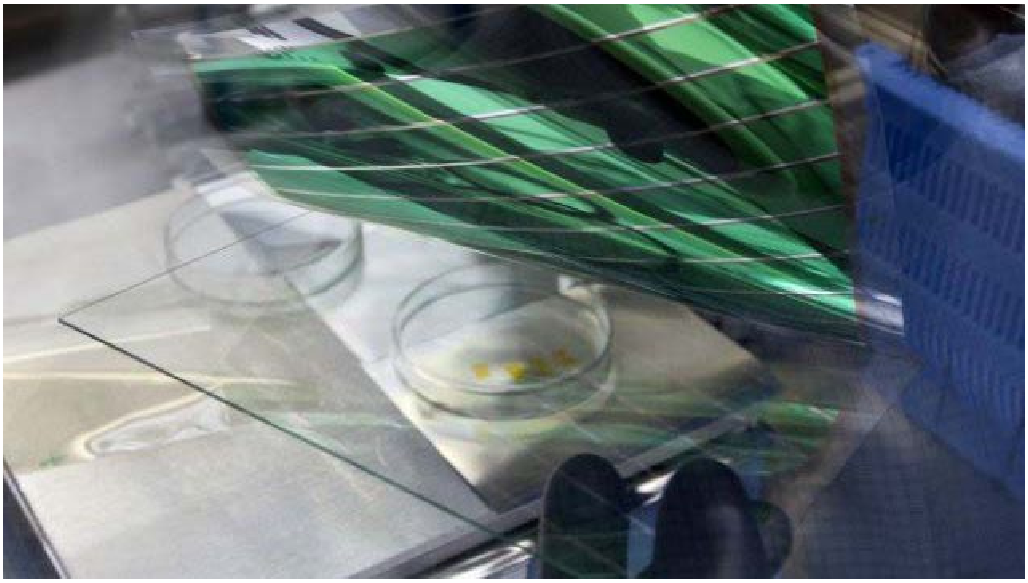

FIG.D FLEXIBLE SOLAR PANELS

IX.FUTURE SCOPE

Plastic electronics can add value in many diverse markets. In one sense the technology is complementary to conventional silicon electronics, displays and enabling new concepts such as electronic labels, intelligent bio-sensors, disposable electronics, flexible e-paper and electro-textiles, as well as novelty applications - gadgets, gizmos and games. It is likely that the biggest applications for plastic electronics are yet to be discovered.

X.CONCLUSION

The vast bulk (estimated at ~94%) of the products around which these predictions are based for 2012 – OLED mobile displays, photovoltaic cells, sensors, e-paper displays, inorganic electroluminescent displays and other miscellaneous products will be fabricated on glass or other rigid substrates, and the PE materials are used for cost and performance improvements.It is estimated that more than 70% of the devices made are based on existing fabrication techniques used at the companies, with only 30% having additive printing as a primary manufacturing activity, so further improvements are likely as new deposition and patterning technologies are adopted.By 2020, a much higher percentage of theglobal production of products will be exclusively based around the new PE platform manufacturing processes as these move into the commercial domain, with estimates of greater than 40% being predominately printed, and greater than 33% being fabricated on non-rigid substrates, with the overall plastic electronics market predicted to rise to a value in excess of US$ 45 billion.

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