Present Status and Contemporary Issues of Organic Electronics

J. R. Coley, A. A. Oram, and M. H. Rashid, Ph. D., Fellow IEEE
Department of Electrical and Computer Engineering
University of West Florida, Pensacola, FL 32514-5754
Tel: (850) 474-2976
e-mail: mrashid@uwf.edu

***Abstract*—**Researching the development and future of organic electronics shows a large variety of contemporary issues. Of the many contemporary issues found, this document is the examination of a few key contemporary issues. First, the issues concerning the production of standard and organic electronics are discussed while highlighting the advantages of producing organic electronics instead of inorganic electronics. Second, the present state of organic electronics is briefly mentioned. Third, two types of organic electronics are discussed. Fourth, the applications and ramifications of using organic electronics in engineering are discussed. Finally, the future of organic electronics and some key information to know for the future will be analyzed and discussed**.**

***Index Terms*—**Environment, OLED, Organic Electronics, OTFT, polymers.

I. Introduction

The evolution of electronics has led the worlds industries into developing machines that can perform amazing calculations and have allowed mankind to achieve amazing design feats. The application of electronics to develop and build computers has lead men to the moon. Now electronics are allowing for us to use electricity as the main power source for electric vehicles and hybrid cars. Modern electronics also affects society and our everyday life on a more dynamic way. Without electronics, automatic coffee makers, Large screen plasma TV's, personal computers, digital stereo systems, and many more personal electronic devises would not exist. However, the manufacturing process for both silicon and beryllium based electronics includes many chemicals that are known for the toxicity or difficulty to manufacture. However, new promising research in Organic Electronics will allow for the safe reduction of many toxic chemicals in the manufacturing process and will allow for the supplementation of preexisting electronics in ways that many would have foreseen.

II. Organic Electronics

Simply put, organic electronics are not based on silicon or beryllium semiconductors. They are polymer based, so many aspects of their production makes them as easy to manufacture as modern plastics.

A. Silicon production

Silicon based devices require the uses of toxic chemicals in the production or electronic devices. Silicon devices require very high temperatures, 300-500°C, to properly apply prepare silicon or to fix electronic devices onto the silicon substrate. Also, millions of gallons of water are required to properly dispose of the toxic chemicals used in the production process, such as arsenic (semiconductors production), phosphine (transistor production), and lead (CRT manufacturing) [5].

B. Organic Electronic Production

Organic electronics consisting of “conjugated organic molecules, short-chain oligomers, long-chain polymers, and organic-inorganic composites” allows for charge movement based on the pi-orbital overlap of molecules that in close proximity to each other. The charge movement can be allowed because of both p-type and/or n-type materials, and thus allows for the construction of semiconductors, light sources, and current conductors, with the majority being of the p-type materials [4].

To contrast the production of silicon based electronics, organic electronics don't require the same amount of heat as inorganic devise, typically about 90 – 150°C [3]-[5]. Since the organic components require lower temperatures, plastic can be substituted in place of Silicon substrates. With the organic components laid onto plastic substrates, costs of about $.01 per square centimeter can be achieved compared to silicon's rate of $1 per square centimeter [5].

During production, certain materials will align themselves to the substrate in a particular direction if predetermined conditions are met. This method of self aligning molecules allows for layers as thick as 3 nm, and can allow for the application of n-type and p-type materials to a substrate [3].

III. Present Status of Organic Electronics

At the present time, organic electronics are still being researched and developed. Currently, organic electronics, specifically the organic thin-film transistors (OTFTs), have low charge mobilities when compared to inorganic transistors [2]. However, light producing organic electronics have reached a state of maturity that will allow for the eventual replacement of LCD and CRT monitors and inorganic LEDs.

IV. Types of Organic Electronics

There are essentially 2 main types of organic electronics that are actively being researched and developed. Active organic electronics appear to be primarily taking shape in the organic equivalent of a MOSFET. The development of organic light-emitting diodes is driving the replacement of inorganic LEDs and the replacement of LCD screens and CRT devices.

A. Organic Thin-Film Transistors

OTFTs, or organic thin-film transistors, offer two unique advantages over inorganic transistors. First, the transistor can be produced on flexible substrates, which allows for them to be used in applications where silicon would have never been considered [3]. Second, they are cheaper to produce. The sole problem with OTFTs is their low charge mobilities, which makes them inappropriate for situations that require high switching frequencies [2].

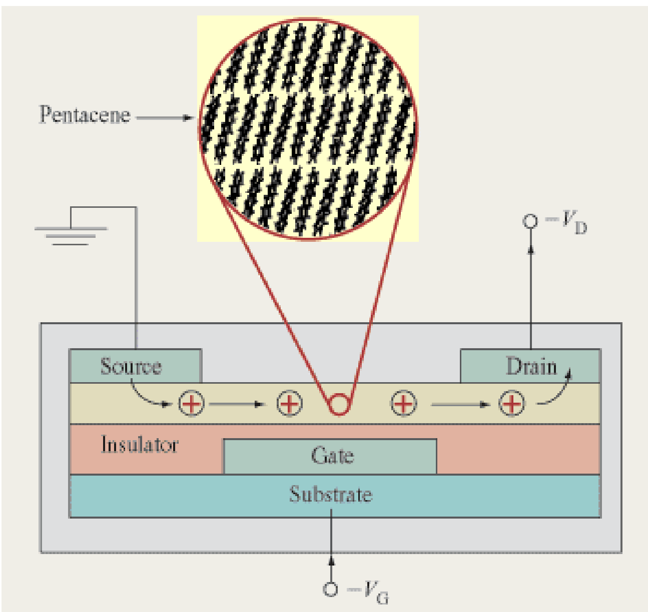


Fig. 1: A diagram depicting the current through a p-type OTFT. Pentacene is an organic polymer [4].

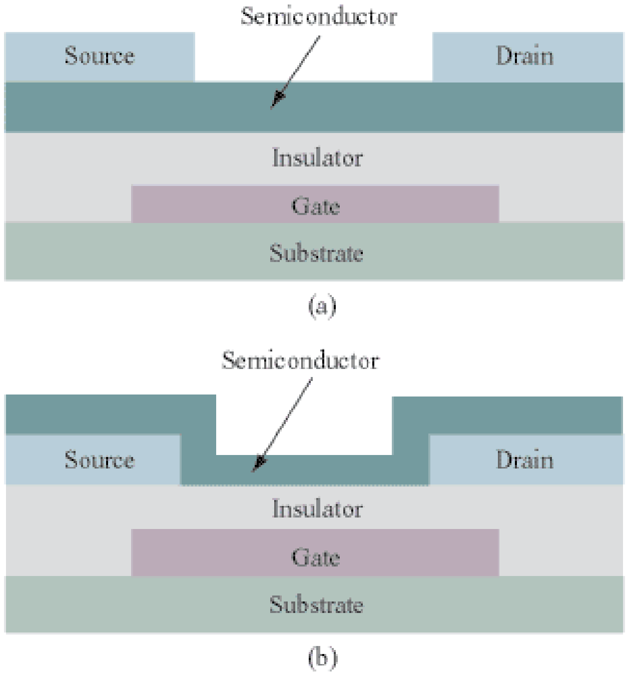
Fig. 1 shows that the performance of the p-channel OTFT is vary similar to that of a p-channel MOSFET. This familiarity of MOSFETS should allow for the easy adaptation to OTFTS.

Fig. 2 shows two highly possible manufacturing techniques for producing OTFTs. Fig. 2 (a) shows how the organic semiconductor can be placed on top of the gate terminals and then have the drain and source terminals placed on top of the organic semiconductor. For this approach, the drain and the source terminals are both "evaporated" onto the organic semiconductor [2].

In fig. 2 (b), the gate, drain, and source terminals are first built onto the substrate with the insulation for the gate. Then the substrate with the completed terminals and insulation has the organic semiconductor applied to it.

Because OTFTs have such low charge mobilities, they will typically have currents in the range of a few micro-Amps [2]. Since these currents are so low, the devices will consume very little power [3]. For applications where high switching speeds are not required, the OTFTs can provide very energy efficient devices.

As discussed in the production of organic electronics, some of the organic semiconductors will self align during their application to the substrate.



Because of this unique property, experts at the Max Plank Institute for Solid State Research in Stuttgrat in association with the Universities of Stuttgrat and Erlangen have discovered a process for producing complementary circuits [3]. Complementary circuits are composed of one p-channel transistor in series with a n-channel transistor. Complementary circuits are an important part of many circuits [3]. One important example of a complimentary circuit is the current supply found in many op-amps, including the uA741.

Fig. 2: (a) The OTFT with the drain and source evaporated onto the organic semiconductor. (b) The OTFT with the organic semiconductor applied to the substrate with the drain, source, and gate terminals already applied to the substrate [2]

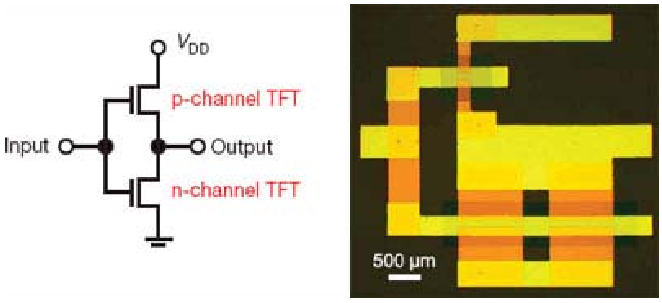


Fig. 3: The circuit schematic and picture of a complimentary inverter composed of p-channel and n-channel OTFTs.

B. Organic Light Emitting Diodes

Organic light emitting diodes (OLEDs) are produced by two methods. The first method is to sandwich the two different organic semiconductors between two conductors [6]. One organic layer acts as the light emitter, and the other layer acts as the conductive layer [7]. The second method requires preparing a substrate with both the anode and cathode. Once the substrate is prepared, then the light emitting organic semiconductor can be "laminated" onto the substrate, and a transparent protective surface is laid on top of the laminated semiconductor [1]. The lamination process utilizes organic crystals, most of which can be removed and reapplied to without damaging the organic structure, something that can't be done with other OLED manufacturing techniques [7].

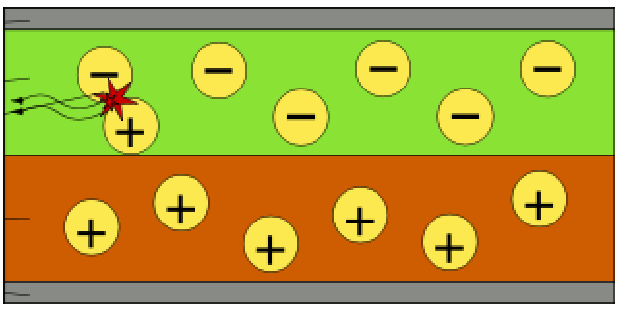


Fig 4: The sandwiched OLED. The top grey layer is the anode. The green layer is the emitter layer. The brown layer acts as the conducting layer. The bottom grey layer is the cathode of the OLED.

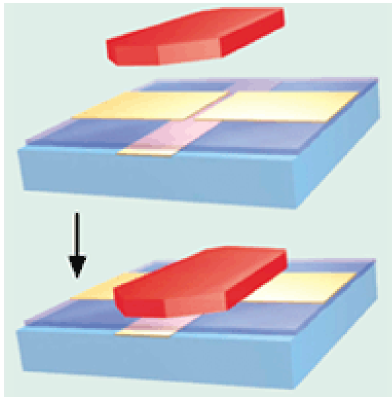
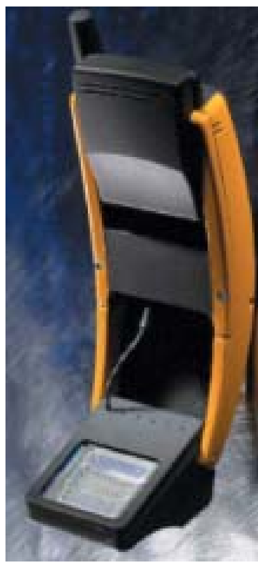


Fig. 5: The lamination process on a single OLED, the red structure is the crystal. The yellow and pink structures are either the anode or the cathode (which ever is appropriate during the initial design stage). The top picture depicts the OLED before the crystal is mounted to the prepared substrate. The bottom picture depicts the completion of the OLED cell.

The single-crystal approach as shown in Fig. 5 makes it clear that OLEDs can be achieved in incredibly



small sizes. OLEDs can be employed in sizes down to a few molecules, in which case they are called small-molecule OLEDs [7].

V. Potential Applications of Organic Electronic

Like all things that have been invented before, the inventions must be able to serve a noticeable application to society or to the well being of human kind before it will be produced and used. In today's technology standards, new technology must be able to either greatly supplement the current technology or be able to effectively replace current technology.

A. OTFT Applications

The current generation of OTFTs, though experimental, can potentially be used in products that require low switching speeds and high efficiency. Most likely, this could include applications that involve controlling OLEDS. With the ability to make complementary circuits, almost any application that involves transistors can potentially be implemented with OTFTs.

B. OLED Applications

The most promising Organic electronic is undoubtedly the advanced usage of OLEDs. Because they can be implemented on the molecular level, it is theoretically possible to produce large organic screens that would provide clearer images and higher detail then is possible with the current generation of LCD screens [7]-[3]-[5]

Currently, many small devices are using OLED screens in place of LCD screens. Because OLED screens generate their own light, OLEDs are currently about 50% more efficient than LCDs. This efficiency makes them perfect for applications requiring extended battery times [5]. OLEDs are now being used in consumer electronics, including cellular phones, PDAs, digital camera, and portable audio-visual systems [6].

A promising market for OLED screens is their application as microdisplays. With the correct combination of OLED screen size and a special lens, a large virtual image can be produced. This virtual image can have same proportions as a 72 inch TV viewed from 72 inches away. Or the microdisplay could provided the same information as a 19 inch computer monitor viewed from about 20 inches away [9]. Microdisplays can be potentially applied to all applications.

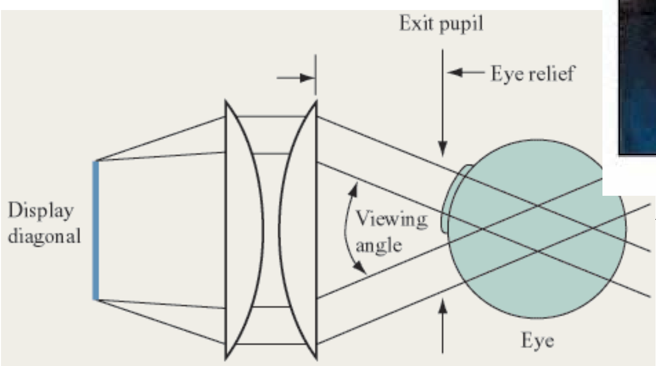


Fig. 6: Microdisplay diagram. The lens allows for the OLED screen to be simulated as a much larger screen [9].

Fig 7: Concept of a 3rd generation cell phone that incorporates a microdisplay for accessing the internet [9].

(a)

(b)

Fig 7: Two examples of microdisplays designed for the use as computer monitors. (a) is an example IBM, and (b) is an example from Virtual Vision [9].

One feature unique to OLED screens compared to LCD or CRT monitors is the ability to be use flexible plastics as the substrate [5]. By producing flexible OLED screens, products can feature roll-up screens that would allow for easy transport of unique, large screen PDAs, such as Philips new Polymer Vision Readius [8], shown in fig. 8.

Fig. 8: Polymer Vision, a PDA with a folding screen. Here, the screen is unfolded unfolded [8].

Fig. 9: Universal Display Corp.'s example of flexible and impact resistant [5].

VI. Future of Organic Electronics

The future of organic electronics is currently at a breaking point. With efforts to give OTFTs better charge mobilities, we will see OTFTs become better suited for high frequency switching applications. When OTFTs are capable of high frequency switching, we will most like see them deployed as high speed processors in computers. High speed OTFTs would have a unique advantage over current computer processors, they would run as fast as current processors, be more efficient, and operate at cooler temperatures.

The future development of OLEDs is also an area of development to watch closely. OLEDs are currently restricted to the small sizes needed by hand-held devices, but manufacturers want to begin using them to replace LCD screens currently used for laptop and desktop computers. However, the production of large OLED screens is currently very difficult and expensive. Sony has made an announcement that it will begin production of an 11 inch TV in 2007; however the product is expected to be very expensive [6].

VII. Things to Know

Though OTFTs are currently being researched and improved, we can expect to see them creeping into our future design either because of their efficiency and/or cheapness. Currently, the behavior of OTFTs is similar to that seen in MOSFETs, except they are much more energy efficient. Refer to Reference [2] for more in depth information on the mathematical modeling of OTFT behavior.

For applications that require a small view screen, like those in cell phones, the OLED screens are more energy efficient than back-lit LCD screen [5]. Replacing back-lit LCD screens will allow for the device to have a longer battery life.

VIII. Conclusion

Organic Electronics are here, and they will only be getting better. This new era of electronics will most likely not see the speeds currently being achieved by inorganic processors, but that does not neglect the value of organic electronics. Because organic electronics can be more easily produced, they will begin to replace inorganic electronics where possible based solely on their manufacturing price.

The current trend for OLED screens has already shown that the potential for OTFTs to become a major component in most new designs is very likely. As OLED screens continue to develop, they will eventually become the new standard for the entertainment and computer industries as the visual system of choice. OLEDs and OTFTs are here to stay, and they will either actively supplement inorganic electronics or allow for the complete replacement of inorganic electronics where possible.

IX. References

Periodicals:

[1] B. Halford, "Toward Better, Colorful Devices," Chemical and Engineering News, vol. 82, no. 15, March 2004 [online]. Available: http://pubs.acs.org/cen/topstory/8211/8211notw1.html

[2] C. D. Dimitrakopoulos, and D. J. Mascaro, "Organic Thin-film Transistors: A review of Recent Advance," IBM J. Res. & Dev., vol. 45, no. 1, Jan. 2001 [Online]. Available: http://researchweb.watson.ibm.com/journal/rd/451/dimitrakopoulos.pdf

[3] "Complementary Circuits Made from Organic Materials," Nanowerk, March 2007 [online]. Available: http://www.nanowerk.com/news/newsid=1556.php

[4] J. M. Shaw, and P. F. Seidler, "Organic Electronics: Introduction," IBM J. Res. & Dev., vol 45, no. 1, Jan. 2001 [Online]. Avaiable: http://www.research.ibm.com/journal/rd/451/shaw.pdf

[5] L. Frazer, "Organic Electronics, A Cleaner Substitute to Silicon," Environmental Health Perspectives, vol. 111, no. 5, pp. A288-A291 May 2003 [online]. Available: http://www.ehponline.org/members/2003/111-5/innovations.html

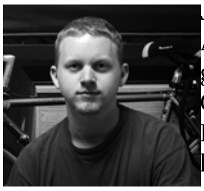
[6] OLED-info.com, "Introduction," OLED-info.com, June 2006 [Online]. Available: http://www.oled-info.com/introduction

[7] "Organic Light-emitting Diode" Wikipedia, Apr. 2007 [Onlin]. Available: http://en.wikipedia.org/wiki/Organic_light-emitting_diode

[8] Philips Corp. "Readius," Polymer Vision, 2007 [Online], Available: http://www.polymervision.com/ProductsApplications/Readius/Index.html

[9] W. E. Howard, and O. F. Prache, "Microdisplays Based Upon Organic Light-Emitting Diodes," IBM J. Res. & Dev., vol. 45, no. 1, pp. 115-127, Jan. 2001 [Online]. Available: http://researchweb.watson.ibm.com/journal/rd/451/howard.pdf

X. Biographies



Jimmy Coley was born in Mobile, Alabama on April 5th, 1984. He graduated from the Okaloosa-Walton Community College's Collegiate High School in 2003 with both his high school diploma and his general AA degree.

His previous employment was with Pizza Hut, and he drew motivation to earn his degree from seeing how people of lesser opportunities approached life as a failure. He has been a full time student at the University of West Florida since 2004 and is expecting to graduate in the fall of 2008.

Ashley Oram was born in Pensacola, FL on June 23rd, 1986. She graduated Pace High School with honors in 2004. She is currently a full time student at the University of West Florida and is expecting to graduate in the spring of 2009.