FLEXIBLE DISPLAYS: RIGID SETBACKS TO BENDABLE TECHNOLOGY

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Abstract *— With the advent of flexible organic light emitting diode (OLED) displays, electronics producers can market a new innovative product, that of flexible devices [1]. These advancements create an opportunity to analyze the display technology in use, and research past applications and current advancements of OLEDs, while illuminating the factors that are holding up its production in flexible applications. In reporting on the outlook for the future of flexible technology, the concept of OLEDs was explored greatly, and the other applications in which they could be applied, such as lighting. OLED lighting panels classify as unique due to their lack of high energy consumption as well as thin design, thus providing a sustainable source of light.*

A flexible display is essentially an array of OLEDs on a flexible substrate, such as plastic or metal [2]. The light and thin OLEDs are more favorable for practice in flexible technology due to the nature of their construction, as well as the fact that they do not require a backlight as common LCD displays do [1]. This helps them retain a smaller form factor, allowing companies to produce a thinner product.

With recent advances in research of OLED display panels, companies are beginning to produce more cost effective displays with higher pixel count and improved life span with efficiency in mind [3]. It is rumored that consumers can look forward to being able to purchase devices utilizing flexible displays within the next few years [4]. Prototypes for roll out, curved sided, and strikingly thin cell phones with the flexibility of a credit card have been designed. However, a multitude of obstacles stand in the way of having these products on the market for retail use [5]. This paper will investigate factors currently restricting mass production while reporting on possible solutions in the works to eventually allow the technology to find itself in the hands of consumers around the globe.

Key Words **—** *OLED Displays, Flexible Devices, Display Research, Electronic Developments, OLED Sustainability, OLED Lighting, Display Alternatives*

BENDING PERCEPTIONS

Consider current consumer electronic products such as the iPhone, Amazon Kindle, and numerous Android devices. These products, among many others found in most consumer households, all utilize relatively dated technology in terms of their displays. The use of liquid crystal displays (LCDs) in many common electronics poses a few setbacks, most of which can be overcome with the implementation of organic light emitting diode (OLED) displays. In recent publications by popular news outlets, such as *USA Today*, discussion has been focused around the possibilities of flexible technology [6]. These products would be made possible by the aforementioned OLED displays, utilizing no backlight or rigid design causing them to retain a set form, thus allowing the display to bend, flex, and even fold. This may sound unrealistic to the average consumer, but the technology behind it is close to making products such as these attainable to everyday people [6]. Research has been conducted since the 1960s relating to OLEDs, finally reaching a state in which it can work its way into the ever-changing technological market through flexible technology [1].

Flexible technology aims to change how all consumers use their devices, much in the same way that touch screen phones aimed to replace flip phones. It poses the same type of market-changing impact upon its release. The possibilities for devices taking advantage of this technology are essentially limitless, ranging from wearable wristbands to home appliances with contoured displays. Powerful electronics companies like LG and Samsung are even beginning to develop radical prototypes [5]. Fully flexible devices may not yet pose the user-friendliest interfaces, however their semi-rigid counterparts could be the next big things hitting shelves across the globe. These devices could use either design allowing for some flexibility from the user or built in curvature. For example, a display that wraps around the edge of a phone for viewing while placed on a countertop adds a convenience that no other technology can currently provide [2]. To understand the technological leaps that will be made, it is best to first examine previous generations of display technologies encompassing the market today.

PREVIOUS GENERATIONS OF DISPLAYS

Reflecting on previous generations of displays utilized in various technical applications, one will find a common factor: the LCD display. LCD displays must be able to "convert backlight emission to uniform area emission and switch on and off the light with a liquid crystal shutter that is located between two polarizers." However, an LCD display does not produce light pixels on its own; a backlight is required to illuminate the image being displayed [1]. Most make use of a cold-cathode fluorescent tube (CCFL) or multiple light emitting diodes (LED) as their backlight source. Two main types of LEDs are present in LCD displays, one in which short wavelengths of light are converted to longer wavelengths, as well as an LED to emit the three RGB colors (red, green, and blue). Multiples of these LED point lights or a CCFL tube contribute to the common backlight for an LCD display [1].

In contrast, OLED displays consist of only an OLED device placed on the surface of a substrate (usually glass). In all applications of OLEDs, there are fewer components than any LCD display. The most prominent difference between OLED displays and LCD displays is the use of the backlight. OLED displays have the advantage of being self-illuminating and thus are not restricted to set enclosures requiring an additional light source. This allows OLEDs to be presented on a more flexible substrate, as they are not limited to the rigid backing required for a lighted backdrop.

DISSECTING OLEDS

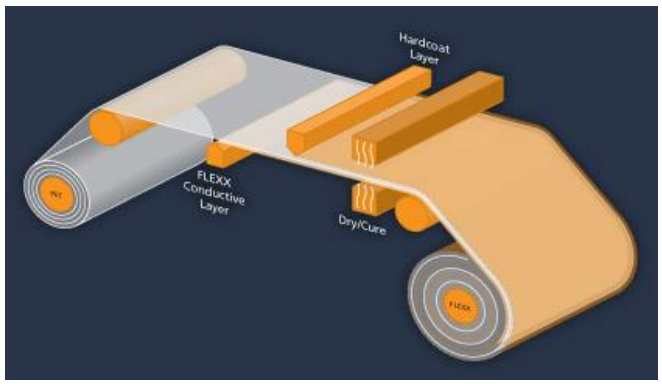
A flexible display is essentially an array of OLEDs on a flexible substrate such as plastic, glass or metal which can then move as freely as the user desires. This technology has been projected as much lighter and more user friendly than current glass panel displays on the market today, for the screen would be essentially shatterproof [2]. OLEDs originated in the 1960s and have experienced many improvements over the decades, making them now suitable for consumer use. OLEDs are more favorable for practice in flexible technology due to the fact that they can be applied to malleable substrates, as well as the fact that they do not require a backlight as common LCD displays do [1]. This helps them retain a small form factor and save on weight allowing companies to produce a thinner product to keep up with current technological trends, while giving the OLEDs the potential to be mounted on bendable surfaces, thus creating new prospects in the upcoming development of flexible technology.

It is easy for one to believe that flexible displays are a futuristic concept and will not be obtainable by consumers for a number of years. However, there is remarkable research being done to allow for these devices to make their way into products one step at a time. The first OLEDs implemented in consumer goods came from Kodak. The Kodak LS633 digital camera was the first consumer product to feature an active matrix organic light emitting diode display (AMOLED) [1]. This display was not flexible, or even visually appealing, but it did prove the marketability and plausibility of this technology. The Kodak LS633, released in 2003, set the path for the next generations of displays. Now with over 10 years of continued research, products are finally being prepared for market with breathtaking advancements on the OLED display.

SOUNDS GREAT, BUT HOW DOES IT ALL WORK?

The process for the production of OLEDs is relatively more straightforward than other modern displays such as LCDs because there is no backlight required; however, production of OLEDs is not necessarily an easy task. The most common way current OLEDs are being produced is by compiling multiple layers of substrates, then printing or etching circuits onto those surfaces and finally sealing the product to protect it from dust, oxygen, and outside contaminants [7]. A more advanced take on this method is called roll-to-roll manufacturing, a process that is not truly unique to OLEDs and has previously been applied to photovoltaic panel production [8]. This roll-to-roll method for production creates electronic components by applying treatments to a continuous roll of substrate. The idea behind this can best be described with a real world scenario. Imagine a modern plotter commonly used for printing large images or AutoCAD files to scale: this is essentially a large inkjet printer that feeds off a spool of paper. In the scenario of roll-to-roll processing the paper would pass through the print head and then be rolled onto an empty spool. From that point in the production, the spool could be printed on again and again by various different devices building up different layers of work. That is essentially how roll-to-roll production works but instead of printing images on the flexible substrates of flexible OLEDs, transistors and other components would be etched into the material [2]. A good visual representation of this process can be seen below in Figure 1, where substrate is being processed from one roll to another roll.

FIGURE 1 [2]



Example of the roll-to-roll manufacturing process where material is processed and then re-spooled for transfer to the next machine

What truly makes an OLED function unique is the property of electroluminescence. Two main properties of electroluminescence that apply to OLEDs are the acceleration of electrons causing light emission and luminescence due to electric hole recombination [1]. The structure that allows for this excitement of molecules includes a pair of conducting panels, one anode (positive charge) and one cathode (negative charge). In between these two panels is an organic layer, whose particles will become excited from the flow of electricity and display colors. This excitement is what causes the OLED to produce color and vibrancy, setting itself apart from previous generations of displays which could not self-illuminate. There are also transistors in different types of arrays depending on the type of display being examined (such as AMOLED vs PMOLED) [1]. AMOLEDs or active matrix organic light-emitting diodes differ from PMOLEDs, passive matrix light-emitting diodes, by their functions within units. PMOLEDs can only alter one row of display output at a time, as opposed to AMOLEDs which can handle more operations and can distribute the power needed to run themselves more efficiently. This is why AMOLEDs are used in the current generations of devices opposed to the less powerful PMOLEDs of previous generations [2].

RESTRICTIONS

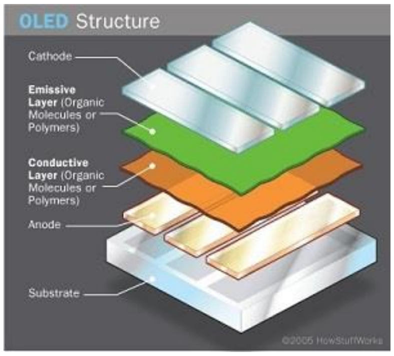
In reality, making a perfectly flexible device is much more complicated than just the display. While the technology can be compiled to make a very flexible screen, there are not yet flexible components to all parts of most electronic devices. In addition, cost hinders the production of OLEDs, as they are very expensive to manufacture.

Obstructions in Manufacturing

Flat panel display in today's gadgets is essentially multiple layers of different materials, and to make that complex flexible, all parts that show rigid qualities must be removed, which is quite difficult to do. Often, glass is placed in displays for protection and durability, yet shows very few flexible tendencies in that application. This is exactly where the implementation of flexible plastic as an alternative to glass comes into play. However, plastic comes with an array of problems of its own [5]. Glass has a thermal capacity, optical transmission and tough barrier properties that plastic lacks concerning electronics high performance and extended lifetime [7]. While consumers are interested in the newest of trends and technological advances, they also expect a product of high durability and long lifespan as products evolve. While many are claiming that the flexible plastic can be essentially shatter proof and thus indestructible, there has been no long term research done on the wear and tear of a flexible display [9]. After a few thousand bends, will the plastic display still appear as sleek, smooth and stable as the first day?

In addition, a major modern trend in technology is the touch screen. Only recently did companies such as PolyIC in Germany start looking into flexible touch screens to accompany the displays on flexible devices. PolyIC flexible touch screens in particular are helpful in that they can be used in a roll-to-roll manufacturing process. This process is believed to be the only way that flexible displays will be able to be produced on a large scale at a reasonable price and in a timely manner [6]. Manufacturing costs limit the creation of OLED panels over a certain size, which suggests that roll-to-roll manufacturing OLEDs on plastic substrates could prove highly beneficial [3]. OLEDs themselves can prove costly in a consumer application because they are highly susceptible to damage from oxygen and water without a hermetic seal that often comes at a hefty price. Figure 2 shows the inner layers of an OLED display: these different layers must be kept out of harsh conditions for if any are exposed then the whole display is prone to failure. Until a seal of a lower cost can be fashioned, considerable funds must be put towards the protection of the OLEDs [5].

FIGURE 2 [2]



This shows all of the inner layers of a OLEDs construction, if any of these were to be exposed to outside elements there would be device failure

Never before have we had the need to print transistors on flexible surfaces. Since there is now this need, the process for recreating transistors onto flexible substrates is being researched. The first of two methods involves material bonding to a rigid carrier panel, and then releasing a flexible film containing transistors after their fabrication while bonded to the rigid panel. The second process is more advanced and unique approach that involves roll-to-roll handling of the substrate. While this technique is promising, there is still much work to be done to prove its true practicality and effectiveness in a large-scale assembly application [8]. During the process of printing transistors, it is proven that higher temperatures yield the highest performing transistors. That being said, the flexible plastic substrates required to make flexible displays run the risk of melting at these high temperatures [5]. This problem has proven to be a large one as the pursuit of flexible displays continues. Materials to withstand these production stresses are needed, and thus first generation flexible devices may be limited by the capabilities of the current materials available.

Lifespan, Durability and Construction

Another challenge facing OLEDs is the differential aging of colors. While the light is only emitted when accessed, the rate at which each of the different emissive colors age is different. One would not be able to keep the quality of light for each color constant as they will fade at different paces [3]. For a real world application, consider a modern cell phone. If an OLED display was to be used, one could expect fading to occur more quickly in an area of constant illumination, say the top menu bar found on most smartphones. This spot may be one of the first to start to fade, possibly from a crisp white to a yellowish hue, or other color possibilities depending on the application. One could easily find this annoying if more than 13-20% of luminance is lost [10]. This contributes to another one of OLED displays setbacks, the illumination of specific regions and the associated variable lifespan for each pixel. This is a problem not seen in standard LCD display applications, due in fact that these displays use a uniform backlight to project their image instead of the individual illumination of pixels.

Another factor that proves to hold up the development of fully flexible devices is that of internal components that have yet to be produced in a flexible form. One of the most notable of these is the battery found in all mobile phones that may one day hope to utilize a flexible display. A fully-flexible battery or even semi-flexible battery is something that has never been produced, nor has much research been done for the development of flexible batteries. This causes a current inability to produce a fully flexible cell-phone, but workarounds could allow for the production of a semi-ridged cell phone, such as ones showcased at trade shows like CES [5]. These prototypes take on different designs but ultimately have the same similar idea, keeping the rigid portions together, such as motherboards and batteries, and allowing for the display to be flexible to the users' preference. Features ranging from a display with a roll-out functionality or a folding construction, there have been designs made so that the flexibility can be retained while allowing for rigid components [5].

One final limiting feature of OLED displays is their lack of ruggedness and ability to handle outside forces. OLEDs are very fragile when it comes to water and other debris damage, thus presenting a major problem. If OLEDs are not properly sealed or encased when released in a public product, they could become damaged very easily by water exposure or perforation. If either of these occurs it would be nearly impossible to repair the display: an entire new display would have to replace the damaged one. This may not pose a detrimental threat with the continued advancements of materials comprising these display advances, but currently this setback creates a large problem. For a product to reach the consumer market it would have to be sturdy enough to handle transportation after production and then the wear and tear associated with daily use. In its current state the OLED would not hold up to what other displays on the market are dealing with, and this is not purely limited by the lack of ruggedness. As stated earlier, the different lifespans of individual pixels is another problem associated with the lifespan on these devices. If these and other restrictions can be overcome in the next few years through continued research and interest, then it is hard to rule them out as a market-changing product.

WHAT IS HAPPENING RIGHT NOW?

Achievements of the Technology

With the technology finally working well enough to show off to the public, many companies are now racing to have registered firsts in the field of flexible technology. The largest electronic powerhouse empires are working hard to create products utilizing OLEDs in a flexible manner, even with all the setbacks in place. For a few years now, the Amazon Kindle has used an OLED display construction. However, due to the pricey costs of research to make all the components of a Kindle flexible, Amazon is just using the OLEDs for screen display, and not making use of their flexible attributes [4].

Since there are still many obstacles to making a 100% flexible object, the products that have been and will be released within the next few years are expected to not necessarily be flexible to the user, but rather have flexible components that may have been bent at one point and then mounted to rigid components by the creator. The displays' flexible qualities may be apparent in the form of a curved screen, despite the product retaining a non-flexible form. It is still expected that we are quite some time from devices that users will be able to bend, flex, and maybe even stretch [2].

Flexible technology can essentially open up a limitless world of new technological goods; products that will be able to be rolled, folded, or flexed and used for almost anything. While it is predicted that tablets, televisions, and mobile phones will be the first to take advantage of the technology, for they are effectively the biggest ticket items, there are also other possible applications. Beyond typical electronics, flexible displays can be used for a multitude of other functions, such as candy wrappers, living room wallpaper, kitchen countertops, or even military wristband computers [6]. If the launch into an era of flexible technology is as successful as analysts are predicting, we could see an increase in flexible display sales from $85 million to $8.2 billion between 2008 and 2018 [6].

What can be Purchased Today?

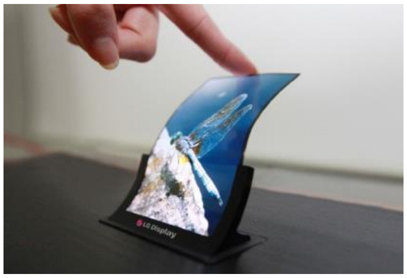
Some of the major technology companies releasing OLED flexible display gadgets include LG and Samsung. These two companies have both released cell phones in the last year that take advantage of flexible OLED displays, in the form of curved screens, with flexibility that the phone does not break when pressure is placed on its curved surface. The LG *G Flex* and the Samsung *Galaxy Round* both received great reviews, yet the prices are quite high for both. It appears that both LG and Samsung do not have high budgets just yet for creating mass quantities of these phones, and thus the prices are quite high. It is believed that they wish to see the impact these phones have on consumers and gauge how the people perceive this technology before they proceed much further [2]. In addition to the mobile phones, LG and Samsung have both released curved glass televisions making use of OLEDs. While these TVs are of a curved display, they do not flex at all beyond their curved screen. Again, these products are extremely high in price, but the reviews for them appear to be some of the best, with witnesses claiming it as the greatest viewing experience in their life [2]. While the products out on the market are quite the spectacle, the biggest spotlight is on what is still to come from these electronic powerhouse companies.

Prototypes in the Spotlight

At numerous electronics shows since the mid-2000s, companies such as Nokia, Philips, Samsung, and LG have unveiled products using flexible technology that are not yet in circulation to the public for everyday use. Other notable corporations working on flexible technology include Sony, Toshiba and AUO, but they are a bit behind the others at this point [6].

Of the technology showcased thus far, Nokia unveiled one of the most remarkable devices in 2011, utilizing the bending of the flexible OLED phone for execution of actions within applications. For example the ability to bend the phone to flip to the next page of a book, or capture a picture. [9]. At the Consumer's Electronics Show (CES) in January of 2013, Samsung fired back with multiple prototypes of flexible devices. The Senior Vice President of Samsung, Brian Berkeley, showed off the flexible technology with smartphones that open like a book or even a screen that rolls out, using solely OLEDs [5]. To make these phones, even just for show purposes, malleable plastic had to be used extensively in place of glass, while the question of touch screens that flexed was also in question. Luckily, Atmel, a large contributor in touch screen technology, developed a new product, XSense, that uses touch sensors in the form of a flexible film that can be wrapped around curved surfaces of phones [9]. Many of these proof of concept designs feature radical styling and design that could possibly one day make its way into the homes of consumers. One of these uniquely designed products produced by LG can be seen in Figure 3.

FIGURE 3 [2]



This is a prototype created by LG that was unveiled at a Society for Information Display (SID) event in 2013

In the most recent advance for flexible technology, LG has released not only a curved, but actually flexible television. At the CES in Las Vegas this past January, this astonishing product was announced. Made of flexible OLEDs, and after being put through a slew of testing for reliably and durability, this product received extremely high reviews from critics. While LG was one of the first to provide a flat OLED TV, and then a curved OLED TV for consumers to purchase, it is now the very first giving the public a look into its newest project, an OLED TV in which one can actually adjust the curvature to the users desire for viewing [11]. While this product, among many others discussed in this section, is not available to the public yet, it provides the suspense as to what is to come in the area of flexible technology. Many companies are hard at work to perfect the idea of flexible products, and while they are doing so, consumers are getting excited to see what will come of it all.

Just Rumors or Real Products?

Many times each year, companies will make statements on what projects they are working on or the products they will be releasing soon. The same goes for flexible technology where company representatives hint at products in the works. Such examples include insinuating the idea of a smartphone that can be worn as a bracelet as something that will be common in the future. It has been rumored that Hewlett-Packard is working with the United States Military to create an item along these lines. They are supposedly developing wristband computers to be used by deployed soldiers that would provide numerous functions for them, including GPS, radio, and important information transmitting. They would be extremely ideal due to the fact that they would not add to the already heavy pack weight that the US Army soldiers must endure. In addition, they are presumed to be solar powered and thus not require an external power source. Similar products are considered for use in the National Football League, to be given to quarterbacks to aid them in calling plays. Digital hospital bracelets could also prove a useful advance for the medical world from flexible displays. Janos Veres of the printed electronics team at the Palo Alto Research Center (PARC) is also working on other applications of flexible technology in the medical world, in the form of digital sensor patches to be worn by patients to record heart rate, blood pressure, and temperature. The PARC is exploring flexible technology in smaller applications than smart TVs and phones, but rather smart security tags, shelf and food labels, and loyalty cards with memory [6].

The talk of all these great products is surely appealing to the public and those who anticipate the flexible era of technology being ultra-useful and revolutionizing to technology. However, there are still many factors in the way of transforming into a time where flexible devices are the norm. While advances in the technology are being made, there are still high costs in mass manufacturing that are holding things back. As said by the materials scientist Andrea Ferrari of the University of Cambridge, "there is a huge gap between the lab and the devices on the market," and people who read about the gadget prototypes of the major technology companies must keep that in mind [5]. Flexible technology is not quite in our grasp yet, but one can presume it is not too far off with developments and improvements in the last few years.

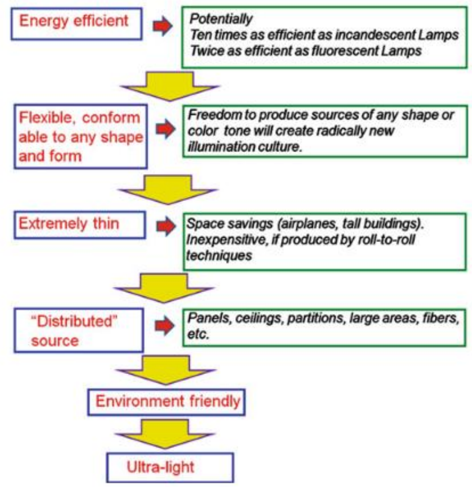
IMPACT ON SOCIETY AND THE FUTURE OF TECHNOLOGY

Despite the previously mentioned restrictions plaguing the production of OLED utilizing devices, they still are poised to cause a major stir in the current market. This could be seen in much the same way that smart phones took over the cellular device market in previous years; a possibly market changing technology making its way into the homes of people across the globe. That being said, some of the largest impacts from this technology do not affect people or lifestyles, but change markets and ways individuals interact with their devices. This impact may not happen instantly but over a period of time which may seem to just flow with newly occurring trends in electronics. This poses an interesting question of what the future of cellphones and televisions may look like, or even other products integrating OLED technology.

OLEDs for Sustainability and Alternative Use

As mentioned, there are in fact other applications being investigated in the field of OLEDs, one of the more interesting applications being researched is the use of OLED panels for lighting. These panels offer many benefits compared to current lighting techniques, including energy efficiency, thin design, and environmentally friendly construction. Other benefits of OLED panels verses current lighting technology can be seen in Figure 4. OLED panels absorb 70% less energy as compared to conventional light sources, ultimately reducing the energy consumption as well as carbon dioxide emissions associated with the production of electricity [12].

FIGURE 4 [12]



This flow chart displays benefits of OLED lighting alternatives when opposed to traditional lighting sources

The benefits associated with OLED panels also include their ability to produce light in different shades thanks in part to their RGB filter, but also their ability to be dimmed throughout the panel. These panels, however, differ in construction from the previously mentioned OLED displays discussed through the majority of this paper. Instead of relying on active matrix OLED (AMOLED) construction to display different colors at every LED, these panels can use simpler constructions. For applications of OLED lighting, passive matrix OLEDs offer many benefits include simpler circuits and more straightforward designs, this is due to their major difference when compared to AMOLED panels. This difference is that AMOLEDs have dedicated transistors that control every LED within an array, whereas passive matrix OLEDs work as a single unit being controlled. The benefits associated with this can range from, decreased manufacturing cost to easier manufacturing processes and affordability of final product [12]. Some examples of possible applications for OLED lighting include, under-cabinet flat mounted lighting solutions, traditional lighting fixtures featuring high efficiency OLEDs, or even entire ceiling coverings which can be dimmed to supply the perfect amount of light throughout an entire room or office space. The opportunities to implement OLED panels into lighting solutions is virtually limitless due to their construction and low voltage requirements. This allows for radical designs to be used and allowing for beautiful lighting fixtures to be sold. One of these modern designs in lighting fixtures can be seen in Figure 5.

FIGURE 5 [2]

An example of a lighting fixture taking advantage of OLED panels, notice that it still can take advantage of slim design

These OLED lighting alternatives also pair very nicely with solar applications, due to their low voltage requirements, making OLED lighting solutions a great way to utilize the current generation of solar panels but could make an even larger in the coming years. As OLEDs are produced in a roll-to-roll fashion, research is showing that photovoltaic solar panels can be produced in much the same way. This opens up the possibility for fully self-sustainable street lights and various other outdoor lighting applications. The design could implement upward facing solar panels manufactured on top of downward projecting OLED light panels, thus producing an extremely thin, light, and efficient alternative to modern outdoor lighting.

This, however, is not the only possible application that OLEDs could have in changing the homes of people across the globe. With the use of AMOLEDs previously discussed, producers would be able to create OLED wallpaper integrating an entire home into a "Smart House". Imagine all of the media viewed in one day but covering the walls of a home, no need for televisions or other secondary displays, as your walls could not only change in patterns day by day, but also act as a computer display with the world at your fingertips. This may seem like something out of a science fiction book, but as early as 2010 companies have been testing the validity of this application [12].

In terms of sustainability, The United States Department of Energy (DOE) is always looking for new ideas to improve the energy consumption among the American people. Since 2010, the DOE has teamed up with Pittsburgh Plate Glass Industries (PPG) to promote the usage of OLED lighting technology through commercialization and mass production. In tests comparing the new float glass substrates with OLEDs with indium tin oxide substrates, conclusions have shown significant advantages to the technology in terms of cost and performance [13]. In addition, it is said that OLED lights have the ability to emit four times as much light per watt as common incandescent bulbs. PPG was the only company honored in terms of OLED technology at the 2013 Annual Solid State Lighting Research and Development Workshop, out of over 300 researchers, manufacturers and industry personnel present. All people present took a part in working hard to promote and monitor advanced lighting technology, with specific concentration on making energy usage in our society more sustainable. However, the OLED technology in particular received great recognition as an extremely promising lighting source in the eyes of the DOE [13].

Human Factors

The factors associated with the production of these devices cannot be ignored. In recent years Apple Inc. has made headlines due to the result of events at their largest production plant Foxconn, including deaths and low wages. This is a side of consumer electronics that is often ignored but one that does play a part as market trends shape the production models and methods associated with the products. Be it the pursuit of lower prices at time of sale or an increase in units produced for period of time, thought must be given to the individuals that are on the production end of these devices. Having said that, it is important to retain quality of life for the individuals working within these plants.

THE OUTLOOK

Reflecting back, LCD displays have been used in most electronics with a screen for quite some time, but now there is new technology to consider. OLED displays prove more effective in many aspects, in addition to the fact that they possess flexible qualities. These qualities can be utilized because of groundbreaking research being conducted on both flexible substrates as well as the production of the interworking of the OLEDs themselves. This allows consumer electronics powerhouses, such as LG and Samsung, to race a flexible product to the market, in hopes of changing the ways consumers interact with their devices. The introduction of these flexible devices to the market has the potential to change the way individuals view consumer electronics, much in the same way touchscreens phased out tactile interfaces.

While significant advancements have been made to OLED technology and their implementation into electronic displays, many obstacles still exist before perfectly flexible devices can make it into the hands of consumers. Such setbacks include: high manufacturing costs, hardware limitations, durability, and performance. Thus putting flexible OLED devices in a state of limbo due to the limitations posed by current production standards accompanied with producers' interest to rush flexible devices to markets. This can leave the consumer confused as to what the future may hold for flexible devices. Current research, supplemented with the prototypes released at various trade shows allow one to establish that trends lead to a flexible future. That being said, it is uncertain when technology utilizing full flexible capabilities of OLED devices will be available at a moderate price point to consumers. This leaves flexible OLED devices in a beta phase where they must first prove themselves viable and marketable before the next generation of smart phones, televisions, and various other technologies comprised of flexible OLEDs can penetrate the wallets of consumers.

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