A

Seminar report

On

Interferometric Modulator

Submitted in partial fulfillment of the requirement for the award of degree of Bachelor of Technology in Computer Science

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

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Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Preface

I have made this report file on the topic **Interferometric Modulator**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

1. INTRODUCTION

Wireless communications are an essential and continuously expanding part of modern life. Smart phones presents a number of challenging requirements on the display module, such as low power consumption, video quality speed, and viewability in a broad range of lighting conditions.

The Interferometric Modulator (IMOD) is an electrically switched light modulator comprising a micro-machined cavity that is switched on and off using driver ICs similar to those used to address LCDs. An IMOD based reflective flat panel display can comprise hundreds of thousands of individually addressable IMOD elements. IMOD displays represent one of the largest examples of a **micro electro mechanical systems** (MEMS) based device. In one state an IMOD reflects light at a specific wavelength and gives pure, bright colors while in a second state it absorbs incident light and appears black to the viewer. As clear as an image on paper, IMOD displays can be viewed in any lighting condition including direct sunlight. Two to three times as bright as other technology

The IMOD displays minimize eye strain, and their wide viewing cones are free of the inversion effects that plague polarization-based displays. Qualcomm's new media FLO technology will enable user to watch high performance video on portable device and applications such as this need a display offering superior viewability and less power consumption. The Qualcomm's IMOD display technology will overcome all above mentioned requirements

Fig 1: First Qualcomm's display device

Fig 2 a: Common mobile display

Fig 2 b: Mirasol mobile display

Fig 3: IMOD LCD.

Fig 4: Application of IMOD in communication devices

2. COMPETATIVE TECHNOLOGY

There are four primary approaches to flat-panel displays as shown in Figure 5. Transmissive displays work by modulating a source of light, such as a backlight, using an optically active material such as a liquid-crystal mixture. Emissive displays such as OLEDs make use of organic materials to generate light when exposed to a current source. Reflective displays work by modulating ambient light entering the display and reflecting it off of a mirror-like surface. Until recently, this modulation has typically been accomplished using liquid-crystal mixtures or electrophoretic mixtures. Finally, transflective displays are a hybrid combination of a transmissive and reflective display. This technology was developed to provide sunlight viewability for transmissive displays. Being a compromise however, this type of display technology offers a compromised viewing experience. Reflective displays were invented primarily to address the shortcomings of transmissive and emissive displays, namely power consumption and poor readability in bright environments. Since transmissive LCDs require a power-hungry backlight and OLEDs require a constant power source to generate light, it makes it difficult for designers of these technologies to reach one of the ultimate goals of mobile display technology: reducing power consumption. This is especially important for battery-powered portable devices such as mobile phones, PDAs, digital music players, digital cameras, GPS units and mobile gaming devices. With efficient use of ambient light, reflective displays eliminate the backlight unit and offer both significant power savings and a thinner display module. Battery-powered devices with 10-inch or smaller diagonal displays comprise the fastest-growing segment of the $92 billion (2006) display market. According to Display Search, this segment is expected to reach $29 billion in 2009. Given that the small-display market has huge potential and even greater demands for technological refinement, it’s no surprise that it is crowded with various solutions by companies large and small. Figure 6 shows where mirasol displays reside among the many technologies that are in use or in development for the portable phone and PDA industries alone.

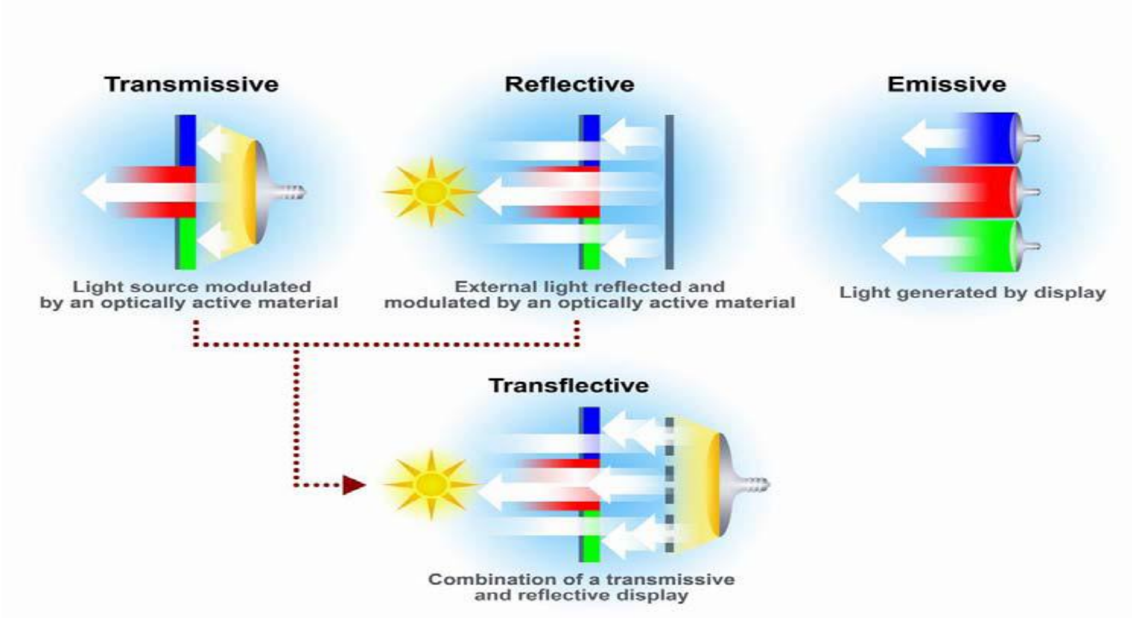

Fig 5: Primary Approaches to Flat Panel Electronic Displays

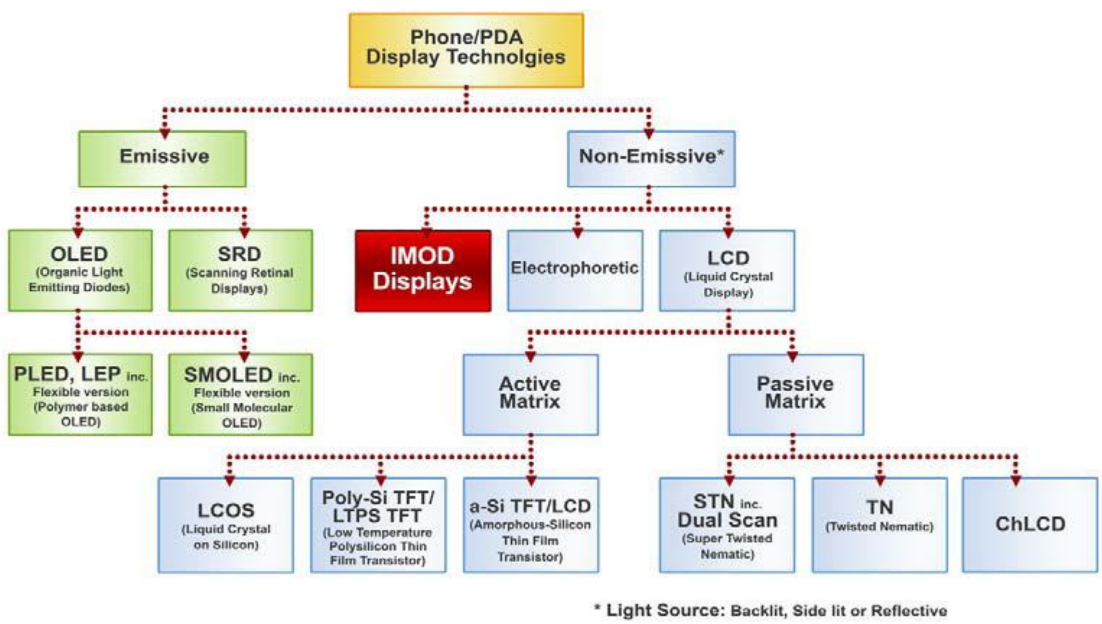

Fig 6: Mirasol Display’s Relative Position in the Display Technology Landscape

3. BASIC STRUCTURE OF IMOD PIXEL

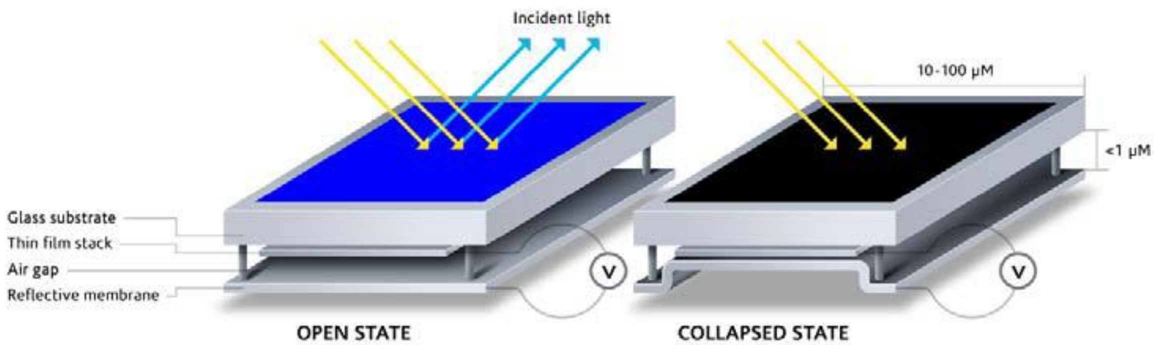

Fig 7: Basic Structure of an IMOD Pixel

Figure 7 illustrates the basic structure of an IMOD pixel. The pixel consists of a glass substrate which is coated with thin films. Beneath the glass is a reflective conductive membrane which is separated from the glass by a thin air gap. When a voltage is applied to the membrane and the thin films on the glass, the membrane experiences electrostatic attraction and is drawn towards the glass. This state is called the collapsed state and the pixel appears black as the light entering is shifted to the UV spectrum. The application of a lower voltage level returns the membrane to the original position, called the open state. In this state the pixel appears bright and colored. This color is generated by interference of light, a process which is much more efficient than using color filters. Figure 4 illustrates the superior efficiency of the mirasol display when compared to color filter-based reflective displays.

The display constructed of IMOD pixels in Figure 7 will be bichrome—that is, it can display any two colors. Full-color versions of IMOD displays, as shown in Figure 8, will be brought to market after the initial bichrome displays. They will use the same operating principle as bichrome displays, but will consist of grids of red, green and blue color subpixels that together can produce full color using spatial dithering. Spatial dithering divides a given subpixel into many smaller addressable elements, and drives the individual elements separately in order to obtain gray levels

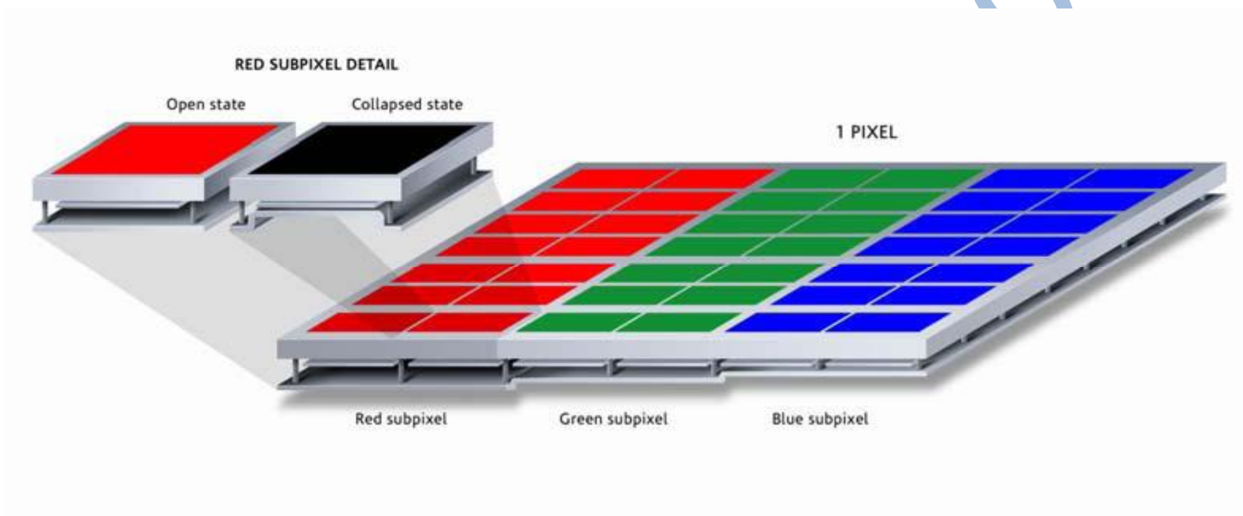

Fig 8: mirasol Display Colour Pixel Structure

The low power advantage of the mirasol display is due to the mechanical structure of the IMOD pixel.

A mirasol display can be manufactured on current FPD manufacturing lines. In fact, it actually can use a subset of LCD manufacturing due to its simpler structure. The IMOD element of a mirasol display provides functionalities that would require three separate elements in a LCD, Each of which require multiple processing steps. First, the modulation is accomplished via the Movable membrane rather than the liquid crystal. Second, the colour is generated using the air Gap rather than colour filters.

4. WORKING PRINCIPLE

A pixel in an IMOD based display consists of one or more sub pixels that are actually individual microscopic interferometric cavities similar in operation to Fabry-Pérot interferometers (etalons), and the scales in butterfly wings. While a simple etalon consists of two half-silvered mirrors, an IMOD comprises a reflective membrane which can move in relation to a semitransparent thin film stack. With an air gap defined within this cavity, the IMOD behaves like an optically resonant structure whose reflected colour is determined by the size of the air gap. Application of a voltage to the IMOD creates electrostatic forces which bring the membrane into contact with the thin film stack. When this happens the behavior of the IMOD changes to that of an induced absorber. The consequence is that almost all incident light is absorbed and no colours are reflected. It is this binary operation that is the basis for the IMOD's application in reflective flat panel displays. Since the display utilizes light from ambient sources, the display's brightness increases in sunlight. In contrast, a back lit LCD display suffers from incident light.

In RGB display, a single RGB pixel is built from several sub pixels, because the brightness of a monochromatic pixel is not adjusted. A monochromatic array of sub pixels represents different brightness levels for each color, and for each pixel, there are three such arrays red, green and blue.

4.2 Mirasol display consume the low power

Phone with mirasol	SMS	Web browsing	GPS	Video playback
Display & front light	10%	6%	4%	4%
other	90%	94%	96%	96%
Phone with LCD				
Display & back light	73%	48%	41%	21%
other	27%	52%	59%	79%

4.4 Importance of reliable viewing quality

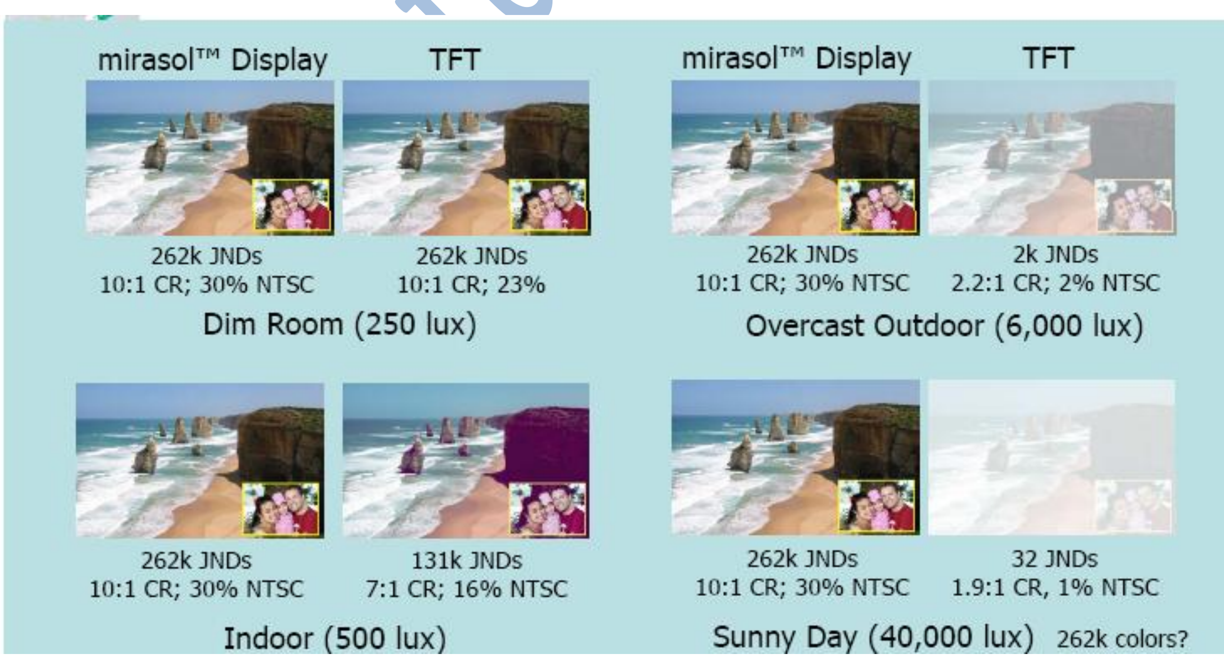

Fig 9 : Image quality of mirasol vs. TFT

5. COMPARISONS OF IMOD WITH OTHER DISPLAYS

5.1 IMOD Technology vs. LCD

A mirasol display's relative simplicity, low power usage and outdoor viewing characteristics make it a compelling replacement for LCDs. In the initial stages the mirasol display will compete primarily with monochromatic (MSTN) and color super twisted nematic (CSTN) displays, used in portable devices.

First brought to light in 1968, LCD technology has rapidly gained a foothold in the display market. Continuous improvements to the chemical mixtures and display-drive electronics, as well as optical films, have overcome the initial problems of the STN-based displays, namely low contrast and low resolution. While scientists continue to work on reducing the power requirements and improving the sunlight readability of the STN and TFT type LCDs, limitations inherent in the technology are making it difficult to achieve meaningful improvements.

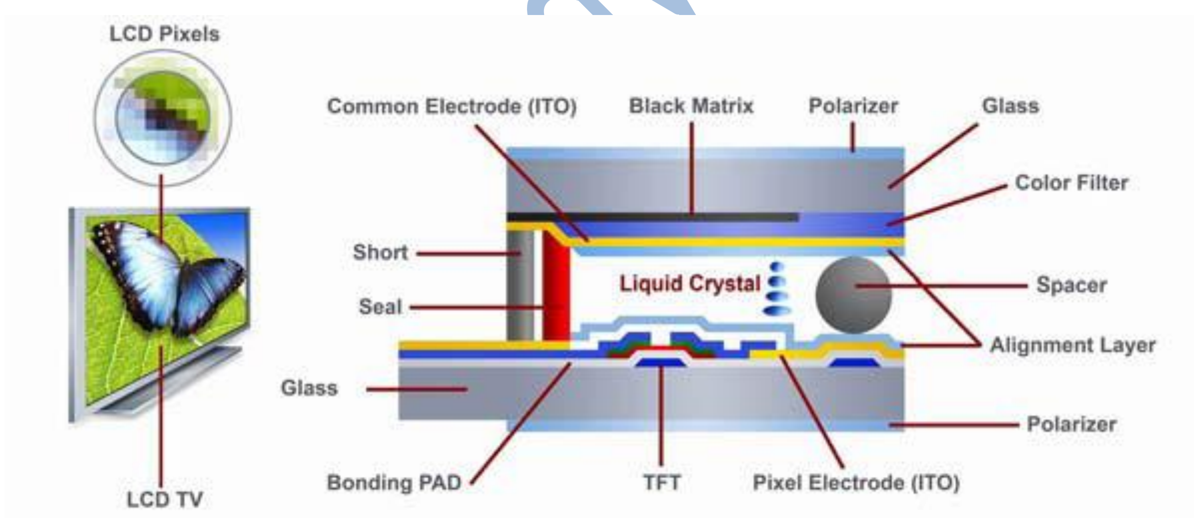

Fig 10: Structure of an LCD pixel

Figure 10 shows the complexity of an LCD. Note the extensive use of optical films such as polarizer's and color filters, as well as the thin film transistor element which itself requires several process steps to fabricate. Since LCDs work with polarized light, the necessity of using a polarizer limits the amount of light that is reflected or transmitted from the display at least 50%

of light is discarded by the polarizer. The additional layers, such as the color filter, reduce light even further a typical LCD will only transmit six percent of the light it has the potential to use.

Consequently, today's LCDs require brighter backlights in order to be readable, whether in total darkness or in the bright sunlight. These brighter backlights lead to greater power consumption. Since a mirasol display operates as a reflective display, powered illumination is only needed when incident light falls below a level that would make reading a newspaper difficult. Currently, backlighting for LCDs is the single biggest power draw in portable displays. This is especially true in bright environments where the backlight has to be switched to the brightest mode. The fact that mirasol displays do not require extra illumination in these environments gives them a big power-consumption advantage. If supplemental lighting is required, in a dark room for example, mirasol displays would still require only one half to one third the power needed by an LCD display.

Given how difficult it is to view a typical transmissive LCD in a sunlit environment, LCD developers have been working diligently on reflective LCDs. Today, there are a number of portable devices using transflective LCDs. The transflective display was invented to improve the performance of the transmissive LCD outdoors, where bright ambient light quickly overpowered the LCD backlight, making the display hard to read. It was also configured to address the shortcomings of a purely reflective LCD in a dark environment. The transflective display employs a reflector that lets some light through from a backlight. Using such an element, the display can be used in the dark where the backlight provides illumination through the partly transmissive reflecting element. In the bright outdoors, the backlight can be switched off to conserve power and the mirrored portion of the reflector allows the LCD to be viewed by making use of the ambient light. Theoretically, the transflective display appears to fix the shortcomings of the purely reflective and transmissive displays. But in reality, this approach is a compromise and offers a rather poor viewing experience.

Qualcomm's mirasol displays are considerably less complex than LCDs. As described in the previous part, the IMOD element in a mirasol display is bistable and the display can therefore maintain a given image without the need for continuous power. Bistability also leads to a significant amount of power savings when compared to an LCD, which has to be continuously driven as many as 60 times a second in order to prevent the display from losing the image. In addition to the power savings, the mirasol display provides a better viewing experience when compared to the LCD.

A human's visual perception is strongly related to two elements luminance and contrast. Luminance is simply the amount of light reaching the eye. This could include light being emitted or reflected by the display. Contrast is the ratio of the luminance of the bright pixel in a display to the dark pixel. If no light is being emitted from a display, one will not see an image and the contrast ratio will be one. Similarly, if the display is reflecting a lot of light in both the bright and dark state, the contrast ratio will again be poor and the image will again be unreadable.

The problem with LCD displays in bright environments is that the amount of light being transmitted is about the same as the ambient light around it. At the same time, the bright ambient light overpowers the dark pixels, making them appear brighter and reducing the contrast ratio to close to one, thereby making the display unreadable. But in the case of a mirasol display, its pixel is reflective and will reflect all the ambient light when driven to the bright state and in the dark state is able to significantly reduce the reflected light. This provides a contrast ratio very similar to an easily readable black-and-white newspaper—an 8:1 ratio with 60% reflectivity. A mirasol display typically exhibits a contrast ratio of 10:1 with reflectivity on the order of 50%. So while LCDs experience significant viewability issues, a mirasol display's reflectivity provides an optimum viewing experience for the user.

An additional benefit of the mirasol display is switching speed. If the displayed image is rapidly changing, it is important that the display pixel changes its state from black to white or vice versa on the order of a few milliseconds or faster. If the pixel takes any longer, the human eye will perceive the switch as an effect typically referred to as motion blur. An IMOD pixel in a mirasol display is able to change its state in roughly 10 microseconds, as compared to a STN display pixel which takes roughly 10 milliseconds. The IMOD pixel is approximately 1000 times faster. This translates directly to an improved, sharper-looking image. Qualcomm believes that demand for video applications on portable devices will increase significantly over the next few years. Fast display-response times will be critical for optimum viewability. IMOD technology found in mirasol displays is expected to handle 15 frames per second in the early products and 30 frames per second in the later versions.

Portable devices are subject to environmental extremes that can affect LCDs, which usually operate in the 10 to 30 degree Celsius range and which are limited by changes in viscosity of the liquid-crystal material. Here again, a mirasol display's simplicity gives it an advantage, because it can operate in extremes from minus 30 to plus 70 degrees Celsius. Another advantage mirasol displays have over LCDs are that mirasol displays are impervious to UV exposure. Additional advantages of mirasol displays compared to current LCD displays include a wider, more symmetric viewing angle, faster video response and a larger operational temperature range.

5.2 IMOD Technology vs. OLED

Since IMOD components in mirasol displays can be built on a subset of FPD fab lines, the mirasol display's manufacturing costs are expected to ramp quickly downward as volume increases. OLEDs, on the other hand, require completely new fab facilities.

Perhaps the mirasol display's greatest advantage over OLEDs, especially in the battery powered, small-screen arena is that in order to be visible, the OLED must be powered continuously. OLEDs, then, typically consume around 200mW, compared to 10s of microwatts for mirasol displays without supplemental lighting (display in hold state showing static image).

OLEDs offer several advantages over LCDs. However, the technology has not gained a major foothold for several reasons. The cons will be discussed on the next page while the pros will be reviewed here. The basic OLED cell structure is comprised of a stack of thin organic layers that are sandwiched between a transparent anode and a metallic cathode. When a current passes between the cathode and anode, the organic compounds emit light the obvious advantage is that OLEDs are like tiny light bulbs, so they don't need a backlight or any other external light source. They're less than one-third the bulk of a typical color LCD and about half the thickness of most black-and-white LCDs. The viewing angle is also wider, about 160 degrees. OLEDs also switch faster than LCD elements, producing a smoother animation. Once initial investments in new facilities are recouped, OLEDs can potentially compete at an equal or lower cost than incumbent LCDs.

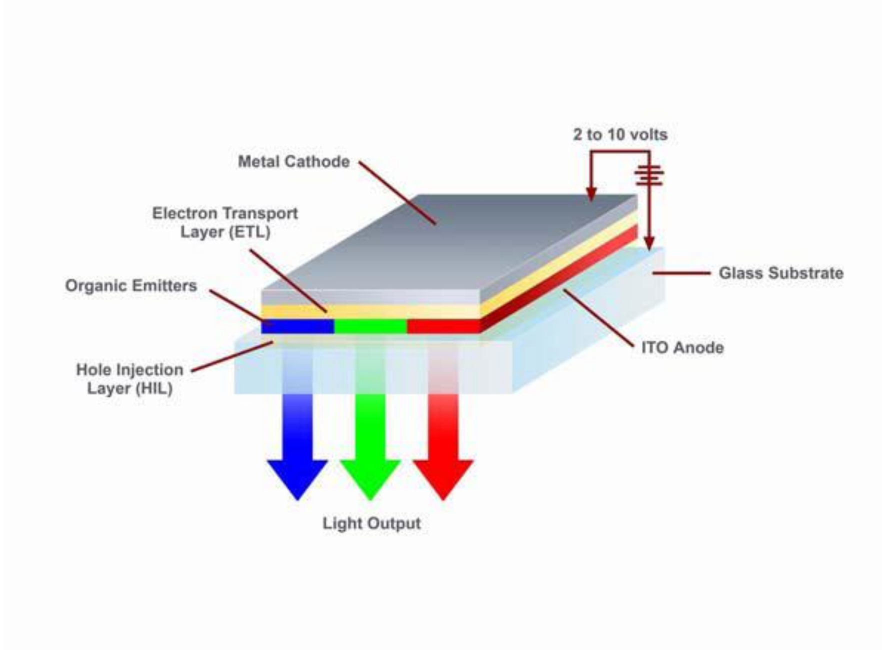

Fig 11: Structure of an OLED Pixel

Despite these advantages, OLEDs have experienced slow acceptance in the industry for a Variety of reasons. First, they have a relatively short lifespan and as power/brightness is increased the life is reduced dramatically. This is especially true for the blues, which lose their color balance over time. Low manufacturing yields have also been a problem, keeping the cost of production relatively high. As OLEDs are susceptible to water and oxygen contamination, during manufacturing they need to be encapsulated and sealed against the elements adding significant cost and complexity. In addition, only low resolution OLED displays can use passive matrix backplanes and higher resolutions require active matrices, which need to be highly conductive since OLEDs are current driven. Typically, low temperature poly silicon (LTPS) backplanes are used which adds cost and complexity. These conductors are also highly reflective requiring the OLED designers to add a circular polarizer on the front of the display reducing the efficiency of the display and increasing the cost. Finally, as is the case with all emissive displays, OLED displays have poor readability in environments such as the bright outdoors.

5.3 IMOD Technology vs. EPD

Electrophoretic (EPD) displays use the concept of electrophoresis, which is the movement of an electrically charged object under the influence of an electric field, in order to display information. The charged object is typically a tiny ball the diameter of a human hair. It is typically black on one side and white on the other, or it can be tiny apsules filled with charged white particles suspended in coloured oil. The application of an electric field changes the orientation of these objects, thereby making the display pixel appear black or white when viewed with reflected light. This technology has been successfully implemented by several companies and displays using this technology offer a comparable level of readability, wide viewing angle and bistability as an IMOD-based display. However, these displays are currently not capable of offering full colour at a high level of reflectivity. In order to display colour it is necessary to use colour filters, which results in a major drop in display brightness and readability. Switching speeds are also much slower than those of an IMOD element used in mirasol displays. A transition from black to white requires a state change in which a physical object has to move through a viscous fluid. Because of this naturally slow process, an electrophoretic display is typically very slow to update (on the order of 500 milliseconds or slower), making it unsuitable for video applications.

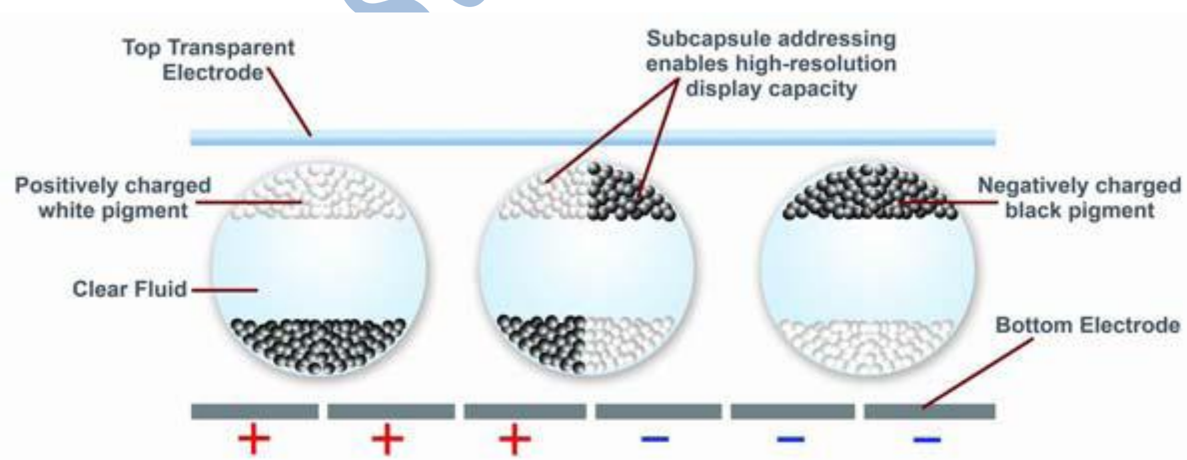

Fig 12: Inner Structure of an Electrophoretic Display

5.4 IMOD Technology vs. ChLCD

Cholesteric LCDs (ChLCDs) are based on a type of liquid-crystal which has a very tightly wound spiral structure, with a pitch on the order of the wavelength of light. This material has the unique ability to reflect light of certain wavelengths (depending on the pitch) and as a result appear colored. When an electric field is applied to the material, it can be switched into a state where the spiral structure is broken and, as a result, the material appears translucent. If a display similar to a reflective STN display is constructed using this material, the rear substrate does not need to be reflective. In fact, it can be tinted black so that when the material appears translucent, the viewer actually sees a black pixel. Displays constructed as such have the ability to produce a bichrome image. In order to produce full-color displays, these displays are usually stacked one on top of the other, with each display producing red, green or blue.

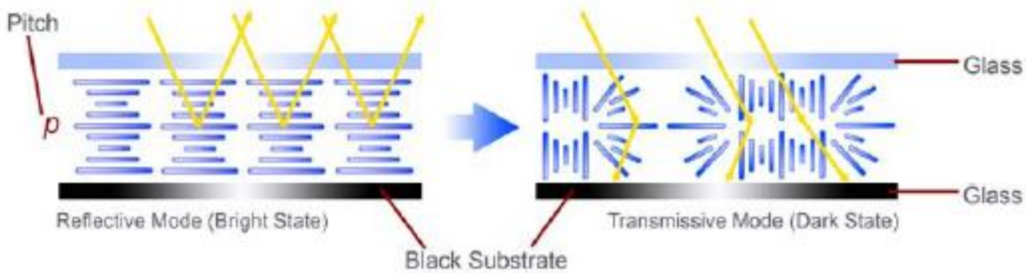

Fig 13: ChLCD Structure

ChLCD-based reflective displays are just as viewable and bistable as the mirasol display. However since producing color requires stacking, the modules are rather thick and the costs are higher. This stacking can also lead to image artifacts due to parallax error and dull looking colours—when light reaches the bottom layer, the quality of the display depends on the efficiency of the two displays on top of it. In order to reduce parallax, the substrates can be made thin, but this increases the module cost. Stacking also leads to alignment issues during manufacturing, because three individual displays must be aligned pixel to pixel. Display operation is also rather slow because the ChLCD has to break and build up the spiral structure when switching states. This limits the display's refresh rate and prevents video rate displays.

6. COMMERCIAL USES

IMOD displays are now available in the commercial marketplace. QMT's displays, using IMOD technology, are found in the Acoustic Research Stereo Bluetooth headset device, the Show care Monitoring system .In the mobile phone marketplace, Taiwanese manufacturers Inventec and Cal-Comp have announced phones with mirasol displays, and LG claims to be developing 'one or more' handsets using mirasol technology. These products all have only 2 color (black plus one other) "bi-chromic" displays. None are full color.

6.1 BENEFITS OF MIRASOL DISPLAY

- Significant Power Savings
- A Display for All Conditions
- True-to-Life Image Quality
- Robust Functionality Enhanced Durability
- Industry Compatibility
- Easy Integration Low Risk Adoption

7. MIRASOL IN FORTHCOMING DEVICES

Inventec Collaboration	mirasol	April 1, 2008 - *Inventec Sees Qualcomm's mirasol™ Displays in Future Smart Handheld Devices*
Cal-Comp Collaboration	mirasol	April 1, 2008 - *Qualcomm mirasol™ Displays Expand Global Footprint with Cal-Comp Deal*
Hisense Handset Model: C108	mirasol	Feb 11, 2008 - *Ultra Low Power Handset Featuring mirasol™ Display to Begin Shipping in 2008.*
Acoustic Research ARWH1 Bluetooth® Stereo Headset		Jan 07, 2008 - *mirasol™ Display Enters Commercial Marketplace via Airport Wireless.*
SHOW WCDMA Monitoring Device		Jan 07, 2008 - *Qualcomm to Supply mirasol™ Display to KTF for 2008 Release in Korean Markets.* - Contains QC's Mobile Station Modem™ MSM 6246™ baseband processor
Foxlink - GSM Concept Watch - Concept Bluetooth Stereo	mirasol	Jan 07, 2008– *Foxlink Selects mirasol™ Displays for Future Mobile Products*

8. ADVANTAGES AND APPLICATIONS

ADVANTAGES

- Industry compatibility
- speed
- Readability
- Less power consumption
- Consistent contrast quality
- Smoother animation
- Faster video response

APPLICATIONS

- MP3 player
- Cell phone secondary and main displays
- Portable Bluetooth accessories
- Handheld / wrist-worn GPS devices
- Industrial applications
- Gaming devices
- Digital TV and DVD players
- Medical imaging
- Automotive navigation
- Digital camera and camcorder screen

9. SUMMARY

Qualcomm's experience in the mobile phone industry, in addition to consumer research, has shown us that consumers will continue to demand and quickly adopt mobile products with an Always-On display, smooth video response, sunlight viewability and extended battery life. Qualcomm's mirasol display will not only replace existing technologies, it will transform the industry by changing user expectations and behavior. Its distinct advantages over LCDs, transmissive technologies and OLEDs emissive technologies, coupled with Qualcomm's commitment to be a major player in portable displays, makes the mirasol display a serious contender in the display space.

For manufacturers of displays and products that use them, mirasol displays present an Attractive, low-risk alternative to advanced LCD, OLED and EPD display technologies. Because mirasol displays conform to interconnect standards for most of today's small display applications, it can be designed efficiently into future products.

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