Value Proposition of mirasol Displays

QUALCOMM MEMS TECHNOLOGIES, INC

mirasol
Displays by Qualcomm

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Introduction

Qualcomm's mirasol® displays are a technology breakthrough that deliver substantial performance benefits over competing display technologies. The reflective displays, based on interferometric modulation (IMOD) technology, offer a significant reduction in power consumption as compared to other display technologies, while extending device battery life and enabling new features. Moreover, these displays require no backlighting and can be viewed in bright sunlight and in a wide range of environments.

Inspired by the simplicity of natural iridescent colors, the mirasol display physically manipulates light using micron and sub-micron sized mechanical elements. These simple, elegant structures result in a display that is:

- Highly Reflective – provides consistent viewing quality in varied environments ranging from dim indoor lighting to the brightest outdoor sunlight
- Energy Efficient – dramatically reduces the energy consumption from the display resulting in increased usage time across every usage models
- Inspiringly Innovative – enables increasingly diverse industrial designs and applications while greatly enhancing the potential for carrier revenue.

This paper will consider current market trends that drive the convergence of multimedia applications onto the cellular phone and the demand this convergence places on the limited battery budget of the typical handset. Specifically, this discussion will center on the ever-increasing gap between the energy available and the energy demands of the handset. Similarly, this paper will consider the convergence driven market trend of expanding handset use in increasingly diverse viewing environments. Finally, this paper will address the solutions mirasol display technology offers to these trends. Namely, this paper will illustrate the energy savings mirasol displays provide, and their ability to enable utilization of the handset throughout the entire range of illumination conditions.

Operational Principles of the mirasol Display

As shown in the left-hand side of Figure 1, each pixel within a mirasol display is composed of micro-electro-mechanical-system (MEMS) elements. The display is built on a glass substrate, and each MEMS element functions as a resonant optical cavity that strongly reflects a specific portion of the visible spectrum. The related visual color that is created is directly proportional to the cavity's depth. Thin films deposited on the substrate comprise one wall of this cavity, and the other wall is a highly reflective flexible membrane. When electrostatic force is applied across the cavity, the membrane collapses against the substrate films, the cavity becomes very thin, and the resonant wavelength moves into the ultraviolet spectrum. Consequently, the viewer perceives a collapsed MEMS element as being black or "off." As shown in the right-hand side of Figure 1, color displays are made by composing a single pixel from MEMS elements of different thicknesses. Varying the cavity depth results in variations of resonant wavelengths which yield variations of color. This pixel construction utilizes no color filters, polarizers, or organic compounds. Such simplicity leads to high-energy efficiency, brightness, and environmental stability that are the hallmarks of the mirasol design.

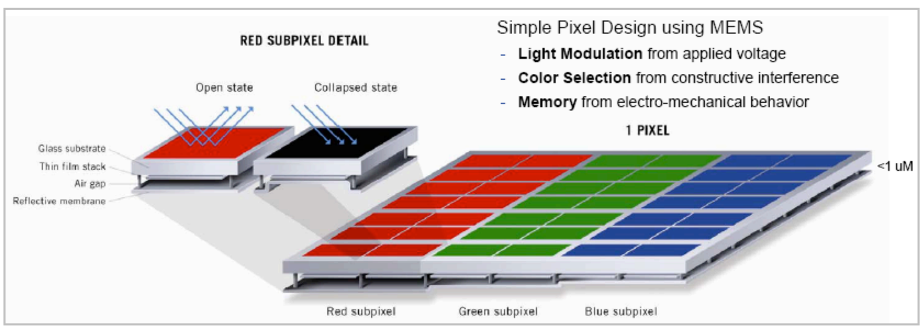

Figure 1: An overview of the mirasol pixel structure and operation

The Mobile Device Energy Gap

The mirasol display characteristics described above are key enabling capabilities for wireless devices and handsets in the coming years. Multimedia applications that require dramatically increased processing power and dramatically increased screen-watching time, for instance, are becoming increasingly prevalent in handsets. Increasing data usage, web browsing, and GPS applications all are contributing to this widening energy gap. Sound industrial design, solid feature integration, and a bigger battery alone will no longer suffice in providing energy consumption balance.

As handset power is increasingly applied to multimedia applications, a form of 'energy crisis' occurs. The blue, red, green, and yellow sections in the center of the Figure 2 bar graphs represent respectively voice call, MP3, FM radio, and miscellaneous handset activities that are forecast to remain relatively constant through 2015. The cyan sections at the left side of the graph represent increasing use of multimedia functions. These functions are all dependent on the display and would require the backlight of an LCD display, for instance, to be continually illuminated. Powering this backlight reduces the energy remaining in the handset battery, and is reflected by the shrinking "standby" portions of the bar graphs.

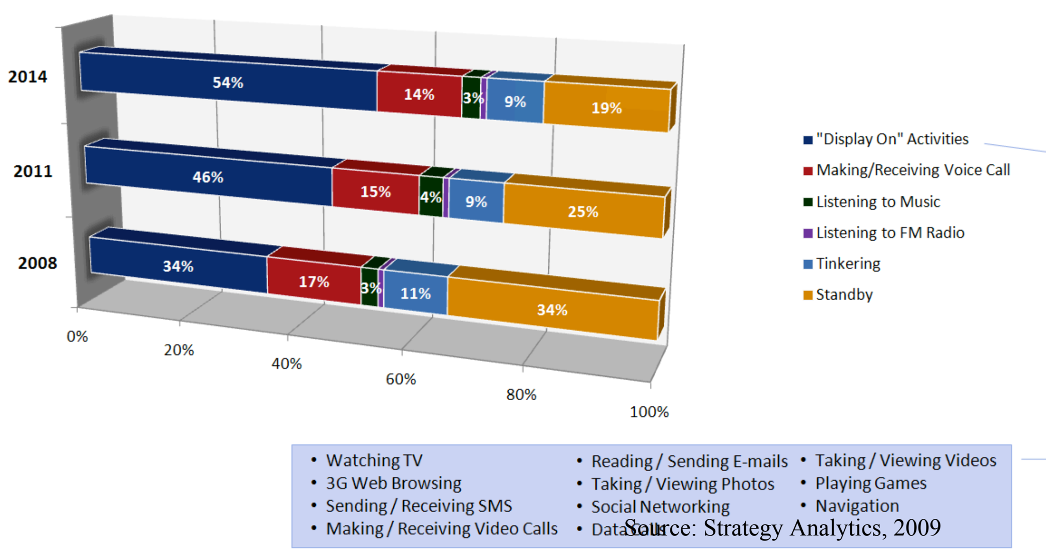

Figure 2: Energy budget trends driven by application shifts

This energy dilemma would be mitigated if battery capacity increases by a commensurate amount between now and 2015, but that will not likely be the case as there is a growing energy gap between greatly increasing energy demand and moderately increasing battery capacity (Figure 3). Motorola's former CTO, Padmasree Warrior, stressed in 2006 that developing components, software, and applications that consume less power "will be just as important as improving battery life technology" over the coming years. Qualcomm's mirasol display will be a key component applied to the solution of this energy dilemma.

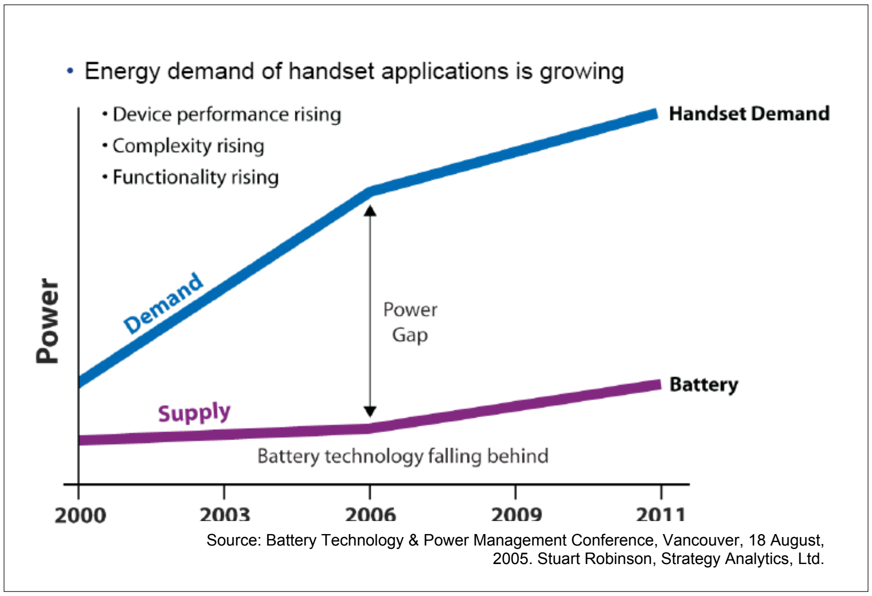

Figure 3: The "energy gap" not closed by improved battery capacity must be closed with components boasting improved efficiency

Energy Metrics

Energy metrics are a key component in understanding a product's expected usefulness to consumers. Currently, there are two commonly published energy metrics for cell phones: Talk Time and Standby Time. These metrics are relics of the non-convergent handset era and are measured under non-display-watching conditions (these devices are no longer used only for talking). A specific handset with a power hungry display will, for example, yield the same Talk and Standby Times as an otherwise identical handset with a low power display technology. The false implication being that usage time is the same with the two very different handsets. It is important to consider alternative ways by which energy consumption can be measured. One way would be to use a new set of metrics more appropriate to multimedia activity.

These new metrics are based on the concept of residual energy. A phone's residual energy is defined to be the amount of energy remaining in its battery after a typical day's use (after using the phone in a typical manner, how many minutes of use are left for the multimedia applications). The right-most segments in the Figure 2 bar graphs can be thought of as representing a residual energy metric for one particular usage model. Expressing residual energy in an easy to understand form – minutes of video that can be viewed using end-of-day residual energy is essential. More video minutes mean that the phone has been more efficient during the day. Fewer video minutes mean that the phone has been more energy hungry.

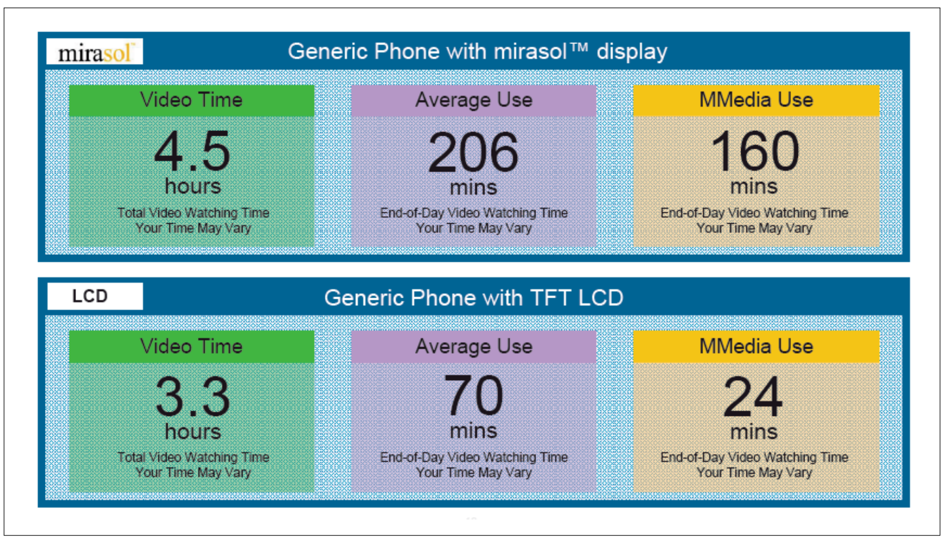

Figure 4: Comparative Residual Energy Metrics for LCD and mirasol equipped phones

The center column of Figure 4 shows results that might be expected for an average user. After one day's worth of normal usage, the phone equipped with the mirasol display will have enough energy to watch 206 minutes of video, more than enough for a theatrical movie. The LCD-equipped phone will have enough energy remaining to watch 70 video minutes of video. An almost three time's usage advantage is provided by the mirasol display-equipped phone. The right-most column of Figure 4 provides a metric appropriate to a heavy multimedia user. Not surprisingly, the phone featuring the mirasol display has a six times residual video advantage over the LCD residual energy metric. This represents a clear and valuable advantage enabled by the mirasol display.

The left column of Figure 4 presents a Video Time metric analogous to Talk Time and Standby Time. It's simply the total amount of video viewing time available from a fully charged battery.

Energy-Based Advantages

The implications of the energy savings outlined above are especially compelling when the display is singled out by application energy usage. Figure 5 displays energy consumption for four user activities: SMS, Web browsing, GPS, and video playback. In each case the energy consumed is divided into two portions. One is the display-related energy consumption, and the other is non-display-related energy consumption. Non-display-related energy consumption is assumed to be the same for both phones. Therefore, the difference is driven only by display-related factors. Across the four activities, the mirasol display yields energy advantages of between six to ten times that of the LCD. For applications with less demanding information refresh rates, power consumption of the mirasol display module can slip below 1mW.

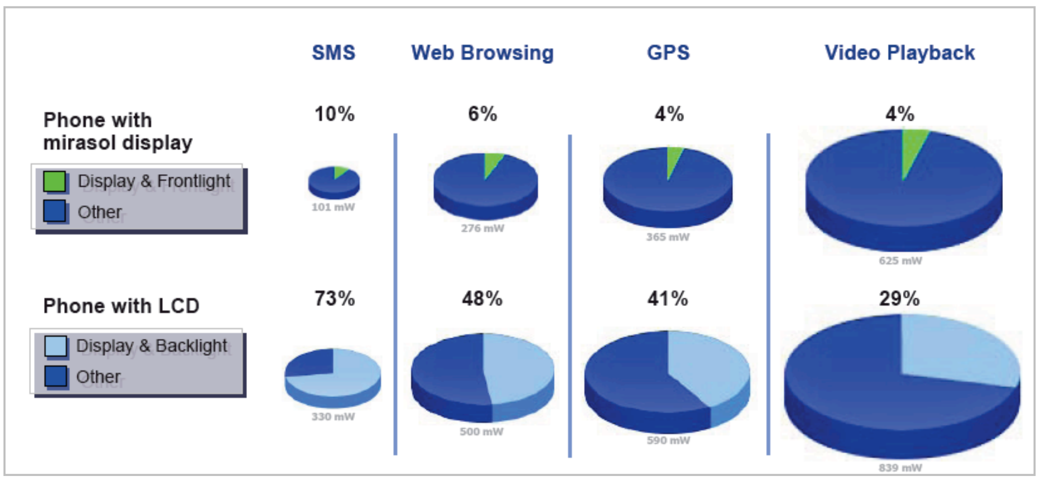

Figure 5: Relative energy consumption for several handset activities

This mirasol display advantage closes the "energy gap" discussed above, while also enabling new opportunities across the entire wireless handset value chain. Figure 6 illustrates opportunities afforded each value chain participant. Industrial design options and cost reductions accrue to handset manufacturers. The application and feature space expands for product managers – including the availability of previously unachievable applications. The increase in available revenue time (ART) means higher ARPU for carriers and operators. Users gain the use of valuable new features while being greatly freed from worries of dead batteries and the nuisance of over-frequent phone recharging.

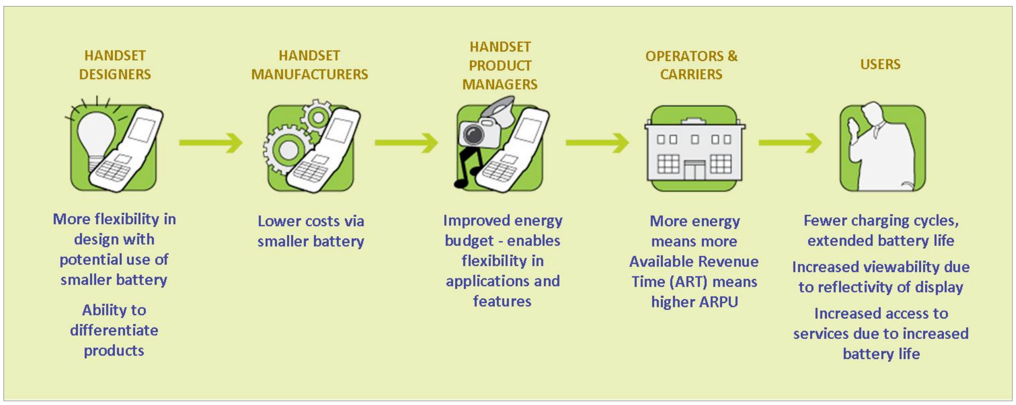

Figure 6: Enabling the wireless value chain.

Sunlight Viewability – The Ultimate Measure of a Display

The mirasol display's remarkable abilities to conserve energy, enable new applications, provide freedom to industrial designers, and enhance revenue streams compliment the display's fundamental ability to be viewed in direct sunlight, indeed to be consistently viewed in almost any environment, without degradation of contrast ratio or color depth.

Emissive displays generate their own illumination, yet the available light output consistently obscures in the face of modest room lighting and is significantly degraded in bright office lighting. Worse, emissive displays become washed out in diffuse sunlight, and are often overpowered in direct sunlight. Consequently, the viewing quality of emissive displays deteriorates to the same extent that the display light emission is washed out.

It should be noted that in very dark environments all displays (including newsprint) will need supplemental lighting, and the mirasol display, because of its high reflectivity, utilizes a very low power front light in extremely dim conditions.

Figure 7 clearly illustrates the consistent viewing quality that would be available from a mirasol display versus the viewing quality expected from a TFTLCD. The results are qualitatively clear to the viewer, but they can be expressed quantitatively by the decreasing JND count indicated below the TFTLCD images and the constant JND count indicated below the mirasol display images.

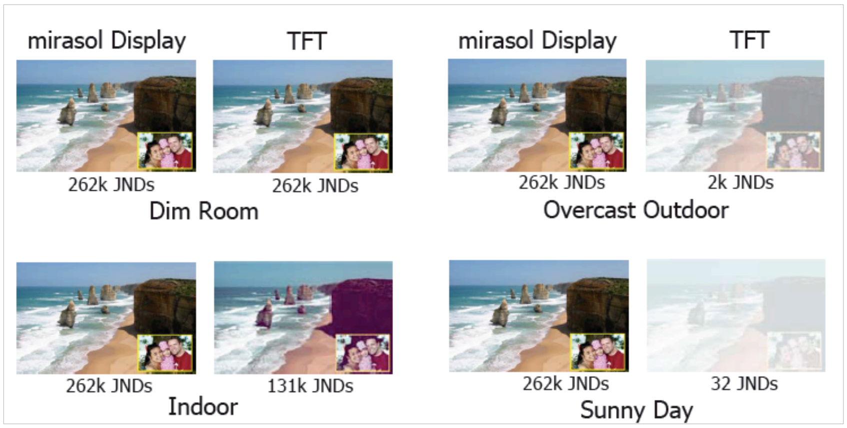

Figure 7: Consistent viewing quality of mirasol display (real world)

JND, or "just noticeable difference", is a recognized method of expressing the number of separately discernable image levels available to the viewer. One can associate the ability to discern small levels of difference in an image with perceiving the image as having high quality. Conversely, a decrease in JND count represents a decrease in the quality level of the viewed image. Figure 7 illustrates the mirasol display's ability to deliver consistent viewing quality across all levels of illumination.

Summary

The discussion above has illustrated the simple and elegant construction and operation of the mirasol display. The mirasol display is energy efficient, provides greatly extended battery life in handset usage models, and dramatically increases the features available to users, the design space available to developers, and the revenue streams available to operators. Bright, reflective iridescent colors are provided without the use of liquids, polarizers, organics, or semiconductor materials. The lack of these optical enhancers combines with the reflective nature of the display to offer consistent viewing quality across all environments, including bright sunlight.

Additionally, the consistent viewing quality facilitated by the inherent mirasol display design provides a significant advantage to consumers who desire to use their cellular phones anywhere, anytime, and under any viewing conditions. Indeed, the capability of reflective mirasol displays is such that current display metrics cannot adequately convey the value of the viewing experience, and the display industry and technical community are working to introduce to the marketplace new measurement metrics that will enable consumers to easily and appropriately evaluate display viewability.

For more information about mirasol displays, please visit www.mirasoldisplays.com.

Addendum

In late 2009, Qualcomm MEMS Technologies indicated its intention to enter the e-reader display market in the near future as a stepping-stone into larger industry proliferation. As a function of that intended market focus, it's relevant to offer a brief analysis of how the mirasol display value proposition will play specifically in an e-reader application.

The e-reader market is still relatively nascent, with almost every device characterized by use of EPD technology. The advent of the tablet computer in early 2010 also brought a new device into the e-reader realm with it's offering of e-reader applications. EPD technology has established itself as a seemingly ideal display technology for e-reader devices primarily due to its similarities to paper. It is reflective like paper, provides adequate contrast, and requires minimal power when used as a display with infrequent screen refreshes.

EPD does have some challenges in the e-reader market, however, especially with the advent of tablet computing devices. These devices feature e-reading applications and large, color, video-rate LCD displays. While these come with the same performance issues typical of LCD (inefficient battery management requiring frequent charging and poor to impossible outdoor viewing), the expectations of the e-reading consumer have started to shift to include color and video capabilities.

This expectation of paper-like qualities paired with color and video-rate capabilities makes mirasol displays the optimal choice for e-reader displays. For more information on how mirasol displays suit the e-reader device market perfectly, visit: www.mirasoldisplays.com/ereader .

www.mirasoldisplays.com

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