Digital Micro Hinge (DMH) Based Display Pixels

Wallen Mphepö, Yi-Pai Huang, Per Rudquist, and Han-Ping D. Shieh

***Abstract*—Using concepts from thin-film optics we hereby present a different design for a potentially high performance display system. The system's pixel design is centered around the selective reflections and transmissions of well defined and constructed thin films on specific substrates. By computing the relevant parameters for specific thin films that can reflect and transmit only Red, Green and Blue light and marrying the result to an RGB LED backlight system a rather unique display system emerges which we termed the Digital Micro Hinge Display (DMH).**

***Index Terms*—Cubic zirconia, digital micro hinge, thin film, field sequential color (FSC).**

I. INTRODUCTION

THIN-FILM based pixels for display systems are not entirely new [1], [9]. One of the current most visible and most closely related to our design is the Mirasol technology from Qualcomm Inc. This technology has its fair share of pros and cons like any other. However it is some of the pros of solid-state thin-film [1], [2] pixels that motivated us to pursue the herein presented Digital Micro Hinge (DMH) display pixel mechanism.

II. BACKGROUND

A. The Basic Concept

In order to make a full color display it is necessary to have a pixel mechanism that exhibit primary colors or other colors that can be used in combination to produce a full color display. In our case we focused on determining a thin-film solution that can achieve simultaneous Red, Green, and Blue selective reflection [3], [4]. Based on the implied properties of thin film constructive and destructive interferences we hypothesize that using a high refractive index substrate coupled with a suitable lower refractive index thin film we can construct a simultaneous Red, Green, and Blue reflective structure. To proceed we posed the question: "Given a thickness of a film in a particular layer system, what visible wavelengths will constructively or destructively interfere upon reflection from the top and bottom surface of the film?" From which we proceeded to require that the resulting colors be Red, Green, and Blue. Therefore, the standard procedure would be as follows.

1) Knowing the film index and thickness will pin the $2\mathrm{tn}$ value. Hence

$$m\lambda_{\text{outside}} = 2\mathrm{tn}_{\text{film}} \tag{1}$$

gives either bright or dark interference pattern where m = order of interference, λ = the wavelength, t = thickness of film, n = refractive index of film

2) The visible range is from 400 to 700 nm in air. Thus plugging in 400 and 700 would give "endpoints" for m.
3) Noting that we could have bright or dark interference pattern i.e., m or $(m + 1/2)$, we will call just these two m^* and note that m^* could be integer or half-integer.
4) We then calculate the ends of the range as follows:

$$m^*_{\text{low}} = \frac{2\mathrm{tn}_{\text{film}}}{700}; \quad m^*_{\text{high}} = \frac{2\mathrm{tn}_{\text{film}}}{400}. \tag{2}$$

where m = order of interference, λ = the wavelength, t = thickness of film, and n = refractive index of film.

5) Next, we figure out which whole numbers are between those two end points, and which half-integers are between them as well.
6) Next, we plug back in to find the wavelengths (in two groups, whole integers, half-integers)
7) If the result is outside of 400–700-nm range, we recheck step 5 for possible errors.
8) Finally, we determine which group of wavelengths are brights and which are darks (based on surfaces).

Using the above basic thin-film optics computation, it can be easily shown that we need only search for an arbitrary film system with refractive index ∼1.5 and set its thickness to ∼1230 nm. This arbitrary thin-film system will produce a simultaneous RGB Reflector.

Using thin-film CAD simulation software [5] we can easily verify this by inputting film thickness of 1230 nm, refractive index 1.5 and substrate index of 2.14 and normal incidence.

Also using similar derivation we can also obtain Min/Max reflections of individual desired wavelengths with values of reflectance/transmittances in the conventional display panel level range or higher. Suppose we choose a new thin-film system, one comprised of Silver metal of thickness 1250 nm with refractive index of 0.18 coated onto a Cubic Zirconia substrate with refractive index of 2.14 as above. Then if white light is incident on this film system the graph in Fig. 1(a) will be observed in thin film CAD.

Now, if we increase the thickness of the silver thin film first to 1530 nm and then to 1810 nm while all the other parameters are fixed, the graphs shown in Fig. 1(b) and (c) will be observed.

As can be observed, the reflectance level of the 450-nm Blue wavelength keeps increasing with each increment of the silver

---

Manuscript received July 28, 2009; revised October 23, 2009. Current version published March 16, 2010. This work was supported by iMult Inc., Newark, DE.

W. Mphepö is with the National Chiao Tung University, Hsinchu, Taiwan 300, and also with Chalmers University of Technology, Goteberg, Sweden (e-mail: wallen.ge94@nctu.edu.tw).

Y.-P. Huang and H.-P. D. Shieh are with National Chiao Tung University Hsinchu, Taiwan 300 (e-mail: boundshuang@mail.nctu.edu.tw).

Color versions of one or more figures are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/JDT.2009.2038175

(a)

Chart Min Wavelength 400 Chart Max Wavelength 700
Polarization 50 % of P Pol 50 % of S Pol
Angle of Incidence 0 degrees
All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	450	13.181	%	0	13.181	%	0

Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1250
Substrate	2.14	

Changing one layer New Me

(b)

Chart Min Wavelength 400 Chart Max Wavelength 700
Polarization 50 % of P Pol 50 % of S Pol
Angle of Incidence 0 degrees
All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	450	87.169	%	0	87.169	%	0

Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1530
Substrate	2.14	

Changing one layer New Merit

(c)

Chart Min Wavelength 400 Chart Max Wavelength 700
Polarization 50 % of P Pol 50 % of S Pol
Angle of Incidence 0 degrees
All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	450	93.975	%	0	93.975	%	0

Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1810
Substrate	2.14	

Changing one layer New Merit

Fig. 1. Graph of %Reflectance versus Wavelength showing with: (a) film thickness at 1250 nm and normal incidence angle there is a minimum reflectance at 450-nm Blue wavelength, of which the value of this reflectance is 13%; (b) film thickness at 1530 nm and normal incidence angle (which is the thickness used for green pixel minimum reflectance) there is a ∼87% reflectance at 450-nm Blue wavelength; and (c) film thickness at 1810 nm and normal incidence angle (which is the thickness used for red pixel minimum reflectance) there is a ∼94% reflectance at 450-nm Blue wavelength.

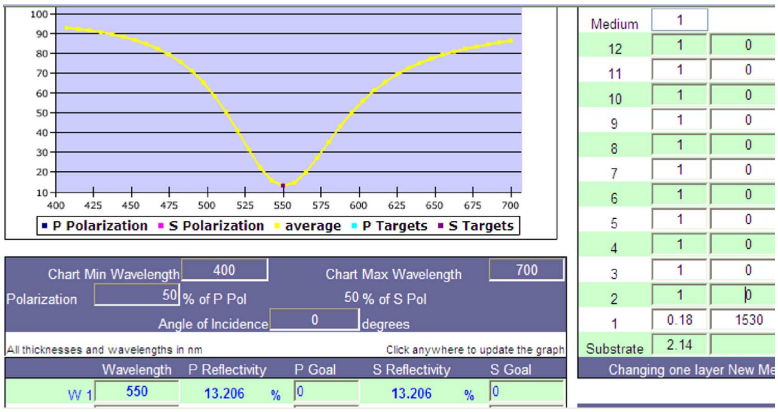
thin-film thickness from 13% to over 90% reflectance. Thus we can obtain intermediate reflectance levels by using intermediate thicknesses that give rise to reflectances between these two extremes.

Thus obviously we can modulate the transmittance of a wavelength by varying the thickness of the thin film. Similarly this can be done for Green wavelength 550 nm and Red wavelength 660 nm as well.

B. Thin-Film Thickness & Peak Transmitted Wavelength Filtering Effect

The relationship between film thickness and the peak transmitted wavelength is given by

$$t = \frac{\lambda}{2n\mathrm{Cos}\beta}. \tag{3}$$



Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1530
Substrate	2.14	

Changing one layer New Me

Chart Min Wavelength 400 Chart Max Wavelength 700

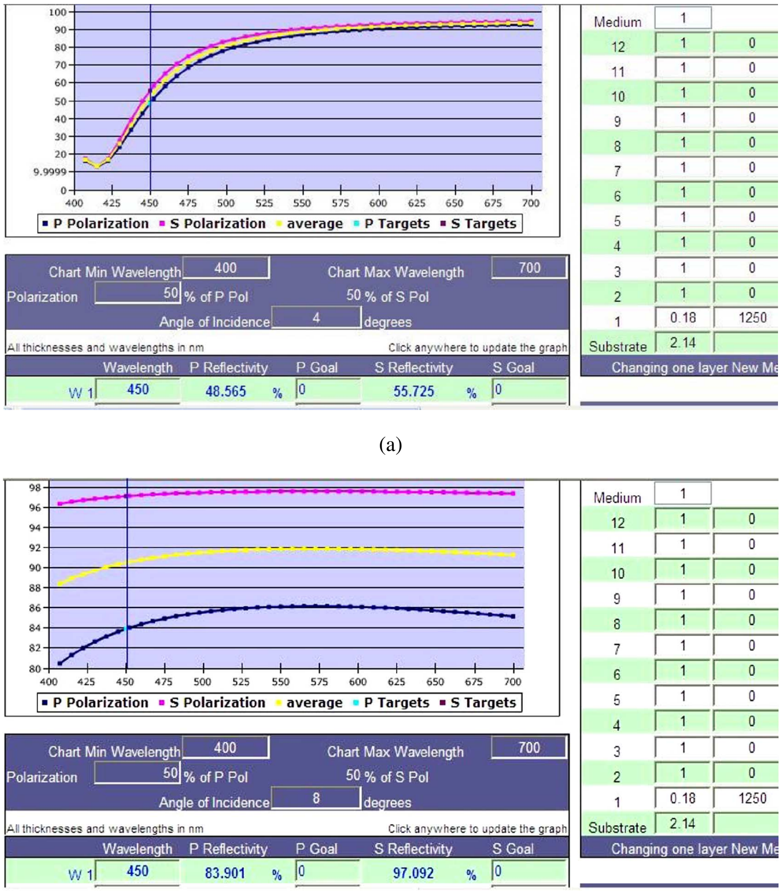
Polarization 50 % of P Pol 50 % of S Pol

Angle of Incidence 0 degrees

All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	550	13.206	%	0	13.206	%	0

Fig. 2. Shows the graph of %Reflectance versus Wavelength showing that with film thickness at 1530 nm and normal incidence angle there is a minimum reflectance at 550 nm Green wavelength of $\sim 13\%$ and also that transmittance profile is nearly symmetrical.



Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1250
Substrate	2.14	

Changing one layer New Me

Chart Min Wavelength 400 Chart Max Wavelength 700

Polarization 50 % of P Pol 50 % of S Pol

Angle of Incidence 4 degrees

All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	450	48.565	%	0	55.725	%	0

(a)

Medium	1	
12	1	0
11	1	0
10	1	0
9	1	0
8	1	0
7	1	0
6	1	0
5	1	0
4	1	0
3	1	0
2	1	0
1	0.18	1250
Substrate	2.14	

Changing one layer New Me

Chart Min Wavelength 400 Chart Max Wavelength 700

Polarization 50 % of P Pol 50 % of S Pol

Angle of Incidence 8 degrees

All thicknesses and wavelengths in nm Click anywhere to update the graph

	Wavelength	P Reflectivity		P Goal	S Reflectivity		S Goal
W 1	450	83.901	%	0	97.092	%	0

(b)

Fig. 3. Shows the graph of %Reflectance versus Wavelength showing that with film thickness fixed at 1250 nm but incidence angle changed to (a) 4 degrees there is a mean $\sim 53\%$ reflectance at 450 nm Blue wavelength and (b) 8 degrees there is a mean $\sim 93\%$ reflectance at 450 nm Blue wavelength.

where $\mathrm{t} = \text{film thickness; lambda} = \text{peak transmitted wavelength; n} = \text{refractive index of thin film;}$ beta is the angle of refraction in the thin film.

For normal incidence the incidence angle alpha is equal to zero degrees and, beta is also equal to zero.

However, if the angle of incidence is not zero then the mean peak transmitted wavelength is given by

$$\lambda_{\text{new}} = \lambda_0 \sqrt{1 - \frac{\mathrm{Sin}^2\alpha}{n^2}}. \tag{4}$$

where lambda new is the new mean peak transmitted wavelength, lambda zero is the mean peak transmitted wavelength at normal incidence angle, alpha is the angle of incidence off normal and n the refractive index of the thin film. Changing angle of incidence alpha does change the angle beta. This change is less than that of alpha, however for the sake of being conservative and also since our angle ranges are small, we can assume that beta is approximately equal to alpha.

Thus we can compute the new corresponding film thickness t' that would give rise to the new mean transmitted wavelength as follows:

$$t' = \frac{\lambda_0\sqrt{1 - \frac{\mathrm{Sin}^2\alpha}{n^2}}}{2n\mathrm{Cos}\beta_{\mathrm{new}}}. \tag{5}$$

From the physics of thin-film filters, we know that in order to design a thin-film filter for a given wavelength then the thin-film thickness has to be at half wavelength of the desired peak transmitted wavelength or any multiples of the half wavelength. From this we can then deduce that another effective film thickness that gives rise to the new mean transmitted wavelength but at normal incidence is given by $2t'$ since that is a multiple of t'.

Visually this is clearer as can be seen from the near symmetry which is more obvious in the graph below in Fig. 2 shown for a wavelength that lies in the middle of our range.

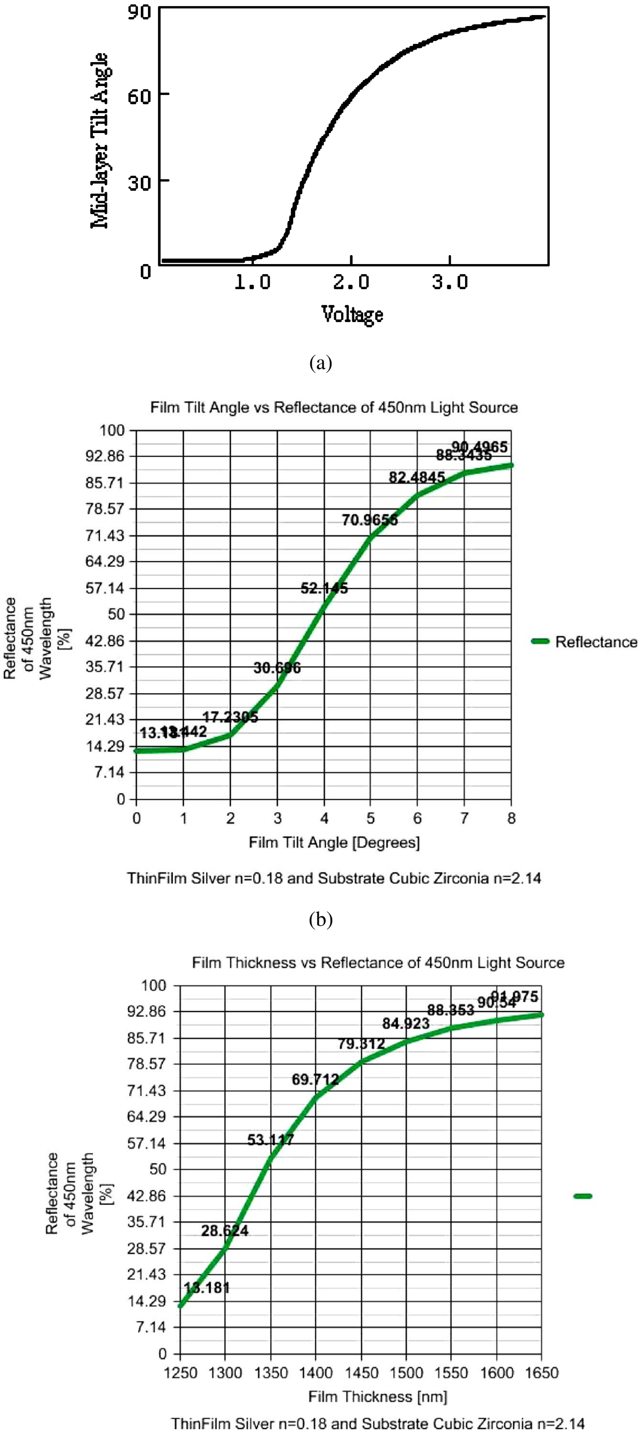
From this information, we can thus use a similar derivation to also obtain Min/Max reflections of individual desired wavelengths. This time it is obvious that by varying the incident light's angle we can also vary the level of reflectance of a particular desired wavelength. Using the same thin-film system as above but with Silver metal film of thickness 1250 nm, if white light is incident on this film system at normal angle it will be observed that the graph will look as in Fig. 1(a).

Referring back to Fig. 1(a), the figure shows the graph of %Reflectance versus Wavelength showing that with film thickness at 1250 nm and normal incidence angle there is a ~13% reflectance at 450 nm Blue wavelength.

Now if the incident angle is changed from normal to 4 and then 8 degrees onto the same thin film, then the following graphs will be observed.

As can be observed the reflectance level of the 450 nm Blue wavelength keeps increasing with each 4 degrees increment of the incident angle onto the film system from about 13% to over 90%. Thus obviously we can modulate the transmittance of a desired wavelength by varying the tilt angle of the thin film. Similarly this can be done for Green wavelength 550 nm and Red wavelength 660 nm as well. So we will proceed by using 450 nm Blue wavelength as our example case since the same can be done for also Green and Red wavelengths.

Thus graphically it is clear there is a correlation between the effect of increasing the thickness of the thin film on the level of transmittance and the effect of increasing the tilt angle of the thin film on the level of the transmittance of the same wavelength. Apart from this, there is also a correlation between tilt angles and transmittances that correspond to Twisted Nematic Liquid crystal cells technology as well. The typical Twisted Nematic LCD cell's tilt angles and transmittance curve for comparison purposes are shown below.

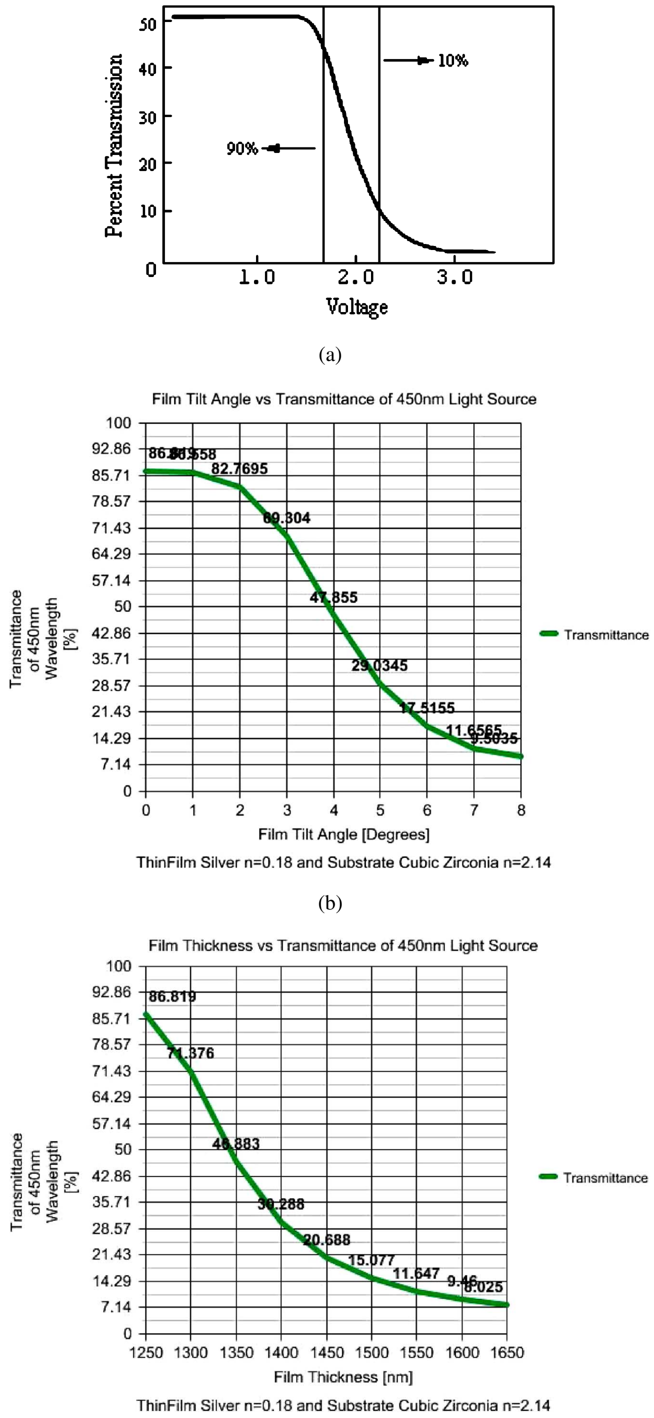


(a)

(b)

(c)

Fig. 4. (a) Mid layer Tilt Angle of Liquid Crystal Molecules versus Voltage for Twisted Nematic LCD cell. (b) Graph of %Reflectance versus Thin Film Tilt Angle showing that with film thickness fixed at 1250 nm and incidence angle gradually increasing there is a corresponding increase in reflectance of 450 nm Blue wavelength. (c) Graph of %Reflectance versus thin-film Thickness showing that with incidence angle fixed at normal and film thickness gradually increasing there is a corresponding increase in reflectance of 450 nm Blue wavelength.



(a)

(b)

(c)

Fig. 5. (a) Voltage versus Transmittance of a Twisted Nematic Liquid Crystal LCD, of particular importance to note is that maximum transmittance is only 50% due to the polarizers. Whereas our proposed system ranges from $\sim 13\%$ to $\sim 86\%$ which is a wider gray level range by a factor of 1.46. (b) Graph of %Transmittance versus thin-film Tilt Angle showing that with film thickness fixed at 1250 nm and incidence angle gradually increasing there is a corresponding decrease in transmittance of 450 nm Blue wavelength. (c) Graph of %Transmittance versus thin-film Thickness showing that with incidence angle fixed at normal and film thickness gradually increasing there is a corresponding decrease in transmittance of 450 nm Blue wavelength.

The one-to-one mapping between the tilt induced transmittance level versus thin-film thickness induced transmittance level is obvious but what is not is that the average correlation between them is 90% for the monochromatic RGB light. However, since LEDs usually have a band of wavelengths, this increases the overlap and raises the correlation between them to slightly over 95%. Thus a thickness induced transmittance level is statistically identical to the tilt induced transmittance level. Hence changing one parameter is directly related to changing the other and within our range, with 95% correlation. Therefore we can justifiably substitute a variation of one parameter for the other in terms of modulating transmittance without loss of generality on the display level macro scale.

However, the LED bands cannot be too broad, as tilting the thin films under broadband LEDs light source would merely shift the peak of transmittance to a visibly different wavelength

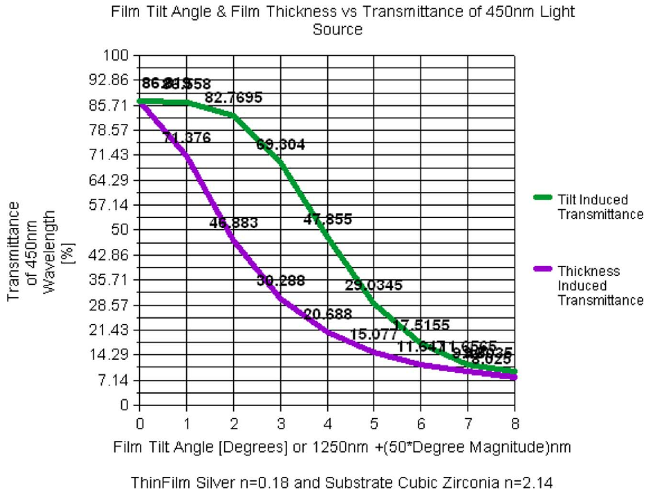


Fig. 6. Combined graph of %Transmittance versus thin-film Thickness & Tilt Angle showing that with one of the parameters fixed and the other parameter gradually increased there is a corresponding decrease in transmittance of 450 nm Blue wavelength.

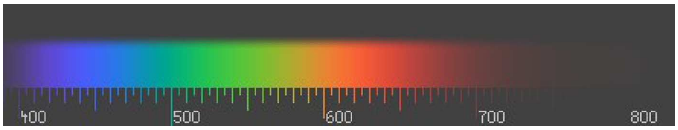


Fig. 7. Shows a standard reference plot of the visible color spectrum and the corresponding wavelengths in nanometers for a convenient comparison to the wavelength ranges in this paper.

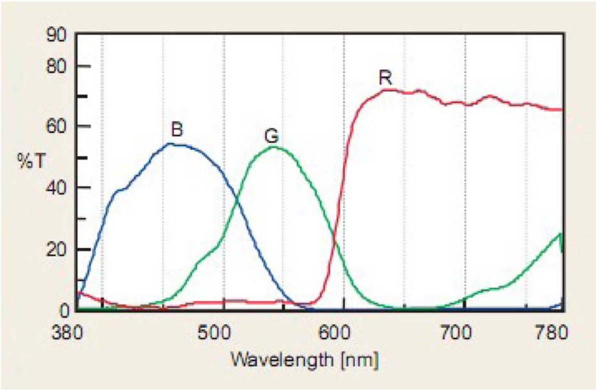
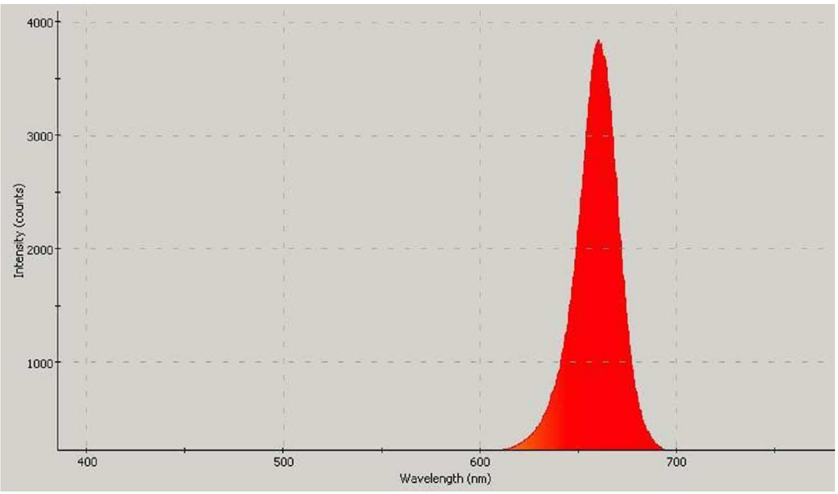
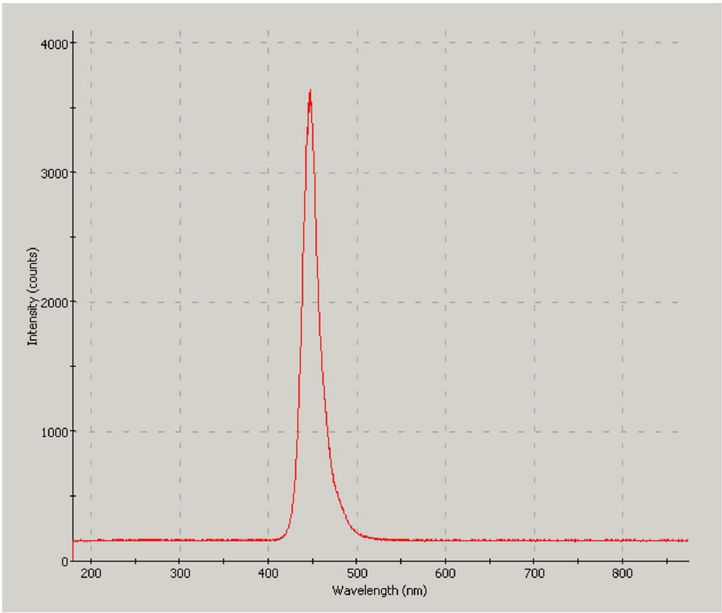


Fig. 8. Shows a standard plot of the Transmittance profiles of the RGB color filters in conventional liquid crystal displays.



(a)



(b)

Fig. 9. (a) Spectrograph of a narrow band Red LED from: (a) Radio Shack, Radio Shack Part # 276-0008 Rectangular Red LED [7]. (b) KingBright, Kingbright Part# L7113NBC [7]. These graphs clearly show that their transmittance wavelength range is narrower than that of the conventional LCD blue filter in Fig. 8.

color instead of modulating the gray level of the primary color. Please see Fig. 7 for the ranges.

Thus narrow band LEDs need to be utilized for this application. For comparison's sake a standard graph for a typical conventional LCD filters' transmittance profiles is shown below, Fig. 8.

The next logical question then becomes will LEDs with narrow enough bands comparable to current LCD color purity and output, see Fig. 8, be available on the market in the near or not too distant future. The answer is no—they are already on the market and have been for several years already [7]. Please see example LEDs from Radio Shack and Kingbright in Fig. 9(a) and 9(b).

As can be observed, the profile [7] in Fig. 9(a) is approximately all red and modulating it, while it would shift the wavelength to less than 20 nm FWHM, the wavelengths are all in the red range. Thus the effect of modulating it is clearly that of modulating red gray level on a macro display level scale.

Similarly for this Blue LED in Fig. 9(b) as can be observed, the profile is approximately all Blue and modulating it while it would shift the wavelength, to less than 20 nm FWHM, the wavelengths are all in the Blue range [7]. Thus the effect is clearly that of modulating blue gray level on macro display level scale as opposed to a shifting to a totally different primary color as would be the case in broadband type LED. Moreover, ultra narrow band interference filters suitable for our proposed pixel type are continuously being drastically improved [8], [9].

III. APPLYING THE OBSERVATIONS

It is observed from the above that all the three colors minimum and maximum reflections are within the same angular range of 0–8 deg. Therefore, attaching appropriate Color Filters

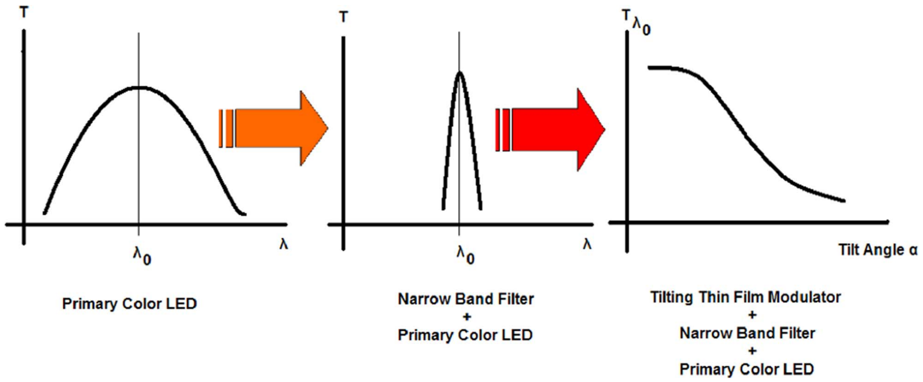
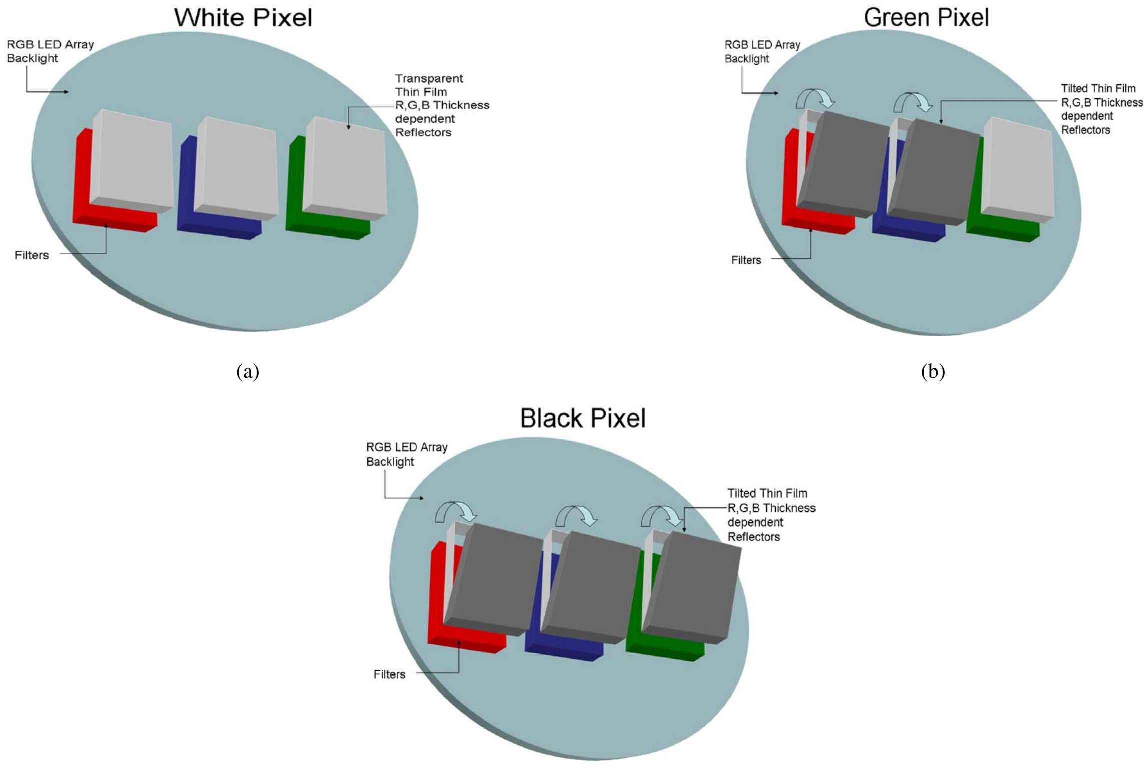


Fig. 10. Forming, narrowing and modulating of the proposed pixel color wavelength in terms of %transmittance T, desired primary color wavelength lambda zero and tilt angle of thin-film alpha as the light passes from the narrow band LED, through the narrow band filter and then the gray level modulating thin film.



(a) (b)

(c)

Fig. 11. (a) Shows the thin films oriented at normal incidence angles in such a way that they produce maximum transmittances of all three primary colors resulting in white pixel. Film thicknesses for $\mathrm{Blue} = 1250$ nm, $\mathrm{Green} = 1530$ nm and $\mathrm{Red} = 1810$ nm. (b) Shows the thin films oriented in such a way that Blue and Red are blocked (oriented at 8 degrees tilt) and Green at maximum transmittances (normal incidence angle) resulting in Green pixel. Similarly the other primary colors can also be obtained by blocking the other two. Film thicknesses for $\mathrm{Blue} = 1250$ nm, $\mathrm{Green} = 1530$ nm and $\mathrm{Red} = 1810$ nm. (c) Shows the thin films oriented (8 degrees tilt angle) in such a way that they produce minimum transmittances of all three primary colors resulting in Black pixel. Film thicknesses for $\mathrm{Blue} = 1250$ nm, $\mathrm{Green} = 1530$ nm and $\mathrm{Red} = 1810$ nm.

and LED backlighting will produce an easy to conceptualize flat panel display with pixels functioning as illustrated in Figs. 10, and 11(a)-(c), whereby changing the film thickness or tilt angle changes the transmission level hence result in the gray level. Different combinations of angular tilted films [10] or thin-film thicknesses then give rise to different perceived display colors.

IV. Experiment and Results

Using small cubic zirconia substrates $\mathrm{n} = 2.14$ coated with Silver thin film of refractive index 0.18, color filters placed behind the substrates and RGB LED light source at normal incidence the experiment was repeated for each primary color to try and get the best possible minimum transmittance and maximum transmittance. Almost immediately the alignment issue became apparent when we tried to manually vary the tilt angles. This thus rendered obtaining smooth varying gray levels impossible in this experiment. Therefore ultimately out of several photographs obtained from the experiments even the best bright and dark states captured on camera for each color were not extremely impressive. However, they do clearly show that the concept is feasible.

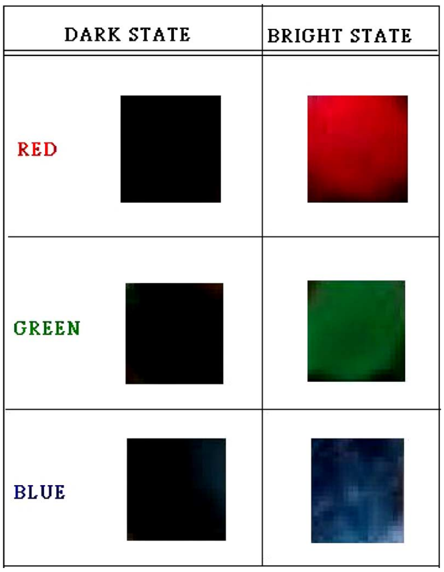


Fig. 12. Zoomed-in photographs of the central parts of the Digital Micro Hinge pixels showing the dark states, film tilted at 8 deg, and bright states films at normal incidence, for each of the primary colors. Film thicknesses for $\mathrm{Blue} = 1250$ nm, $\mathrm{Green} = 1530$ nm and $\mathrm{Red} = 1810$ nm.

V. CONCLUSION AND FUTURE WORK

The basic concept of a digital micro-hinge pixel has been presented. The theory is almost related to the Mirasol technology from Qualcomm Inc. [6] except Mirasol technology modulates light by controlling the different air gaps between thin-film stacks and reflective membranes for each primary color. Whereas in our system there is no air gap, the applied thin-film thickness can be the same for all primary colors even though they are designed to be different in this example case for easy conceptualization. Our thin films are also directly applied onto the substrate. Light modulation in our proposed design is achieved by changing the thickness of these thin films or by tilting the thin films, varying the incident angle, as if on a hinge - hence the name Digital Micro Hinge. Our future work will focus on thin films with higher gray level ranges and augmenting them with pre-filtered ultra narrow band, $\sim$2 nm passbands [8], RGB LEDs. Thus from the human visual system stand point the device is not a color tuning system but a more restricted gray level modulated array of pixels within the desired $\sim$2 nm color wavelength range [8]. It is worth noting that this range is not comparable to but better than most conventional liquid crystal displays primary color filter outputs. Please see Fig. 8 for comparison. Also in practice for enhanced dark state our backlight LEDs will also be turned off at predetermined optimal cut off transmittance level points, while for the alignment issue we are currently exploring suitable electronic alignment systems.

REFERENCES

[1] H. A. Macleod, *Thin-Film Optical Filters*, 3rd ed. Boca Raton, FL: CRC Press, 2001, ch. 2 & 8, IoP.

[2] R. A. M. Hikmet and H. Kemperman, “Electrically switchable mirrors and optical components made from liquid-crystal gels,” *Nature*, vol. 392, pp. 476–479, 1998.

[3] N. Y. Ha, Y. Ohtsuka, S. M. Jeong, S. Nishimura, G. Suzaki, Y. Takanishi, K. Ishikawa, and H. Takezoe, “Fabrication of a simultaneous red-green-blue reflector using single-pitched cholesteric liquid crystals,” *Nature Mater.*, vol. 7, pp. 43–47, 2008.

[4] L. D. Negro, M. Stolfi, Y. Yi, J. Michel, X. Duan, L. C. Kimerling, J. Leblanc, and J. Haavisto, “Photon band gap properties and omnidirectional reflectance in Si/SiO$_2$ Thue-Morse quasicrystals,” *Appl. Phys. Lett.*, vol. 84, pp. 5186–5188, 2004.

[5] Light Machinery Online Calculators-Thin Film CAD. [Online]. Available: http://www.lightmachinery.com/Thin-film-CAD841.htm Light Machinery Inc., Available

[6] How MEMS-Based IMOD Technology Works [Online]. Available: http://www.mirasoldisplays.com/mobile-display-imod-technology.php?p=2&techID=2 Qualcomm Inc., Available

[7] LED Museum Kingbright L7113NBC, Narrow Band 450 nm Blue [Online]. Available: http://ledmuseum.home.att.net/ledblu2.htm, http://ledmuseum.home.att.net/ledred.htm Available, Radio Shack # 276-0008 Rectangular Red LED, $1.79

[8] S. Cianci, J. B. Hawthorn, and J. O’Byrne, “Designing ultra narrow band interference filters,” in *Optical Fabrication, Metrology, and Material Advancements for Telescopes, Proceedings of the SPIE*, 2004, vol. 5494, pp. 520–528.

[9] H. Jorke and M. Fritz, “Stereo projection using interference filters,” in *Stereoscopic Displays and Virtual Reality Systems XIII, Proceedings of the SPIE*, Jan. 2006, vol. 6055, p. 8.

[10] P. H. Lissberger and W. L. Wilcock, “Properties of all-dielectric interference filters. II. Filters in parallel beams of light incident obliquely and in convergent beams,” *J. Opt. Soc. Am.*, vol. 49, pp. 126–130, Feb. 1959.

Wallen Mphepö received the International Baccalaureate Diploma from UWC Atlantic in Wales in 1995, the Bachelors degree with a double major in physics and mathematics from Colby College, Waterville, ME, in 1999, and the Masters degree in liquid crystals and display technologies from The Swedish Liquid Crystal Institute, Borlänge, Sweden, in 2005. He is currently working toward the Joint Double Ph.D. degrees in photonics and nanotechnology from National Chiao Tung University, Hsinchu, Taiwan, and Chalmers University of Technology, Goteberg, Sweden.

Yi-Pai Huang received the Ph.D. degree in photonics from National Chiao Tung University, Hsinchu, Taiwan. He is currently an Assistant Professor, in Department of Photonics/Display Institute, National Chiao Tung University, Hsinchu, Taiwan. Dr. Huang is the Secretary General of the Society of Information Display (SID), Taipei Chapter, Taiwan.

Per Rudquist , photograph and biography not available at time of publication.

Han-Ping D. Shieh (S’79–M’86–SM’91–F’8) received the B.S. degree from National Taiwan University in 1975 and the Ph.D. degree in electrical and computer engineering from Carnegie Mellon University, Pittsburgh, PA, in 1987.

He joined National Chiao Tung University (NCTU), Hsinchu, Taiwan, as a Professor at Institute of Opto-Electronic Engineering and Microelectronics and Information Research Center (MIRC) in 1992 after as a Research Staff Member at IBM T.J. Watson Research Center, Yorktown Heights, NY, since 1988. He is now the Dean, College of Electrical and Computer Engineering, NCTU, and AU Optronics Chair Professor. His current research interests are in display, optical MEMS, nano-optical components, and solar energy. He currently serves as a Director, SID (Society for Information Display), and has served as program chair, committee member, organized conferences in major data storage (ISOM, MORIS, Intermag, ODS, APDSC) and display (SID, IDRC, ASID, FPD Expo, etc.). He has published more than 140 journal papers and has more 30 patents to his credit.

Dr. Shieh is an Associate Editor of IEEE/OSA JOURNAL OF DISPLAY TECHNOLOGY and *Journal of Society for Information Display*. He is the Fellow of the Optical Society of America (OSA) and Society for Information Display (SID).