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單一液晶空隙(cell gap)之半穿透半反射型液晶顯示器 研究成果報告(精簡版)

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Single-cell-gap Transflective TFT-LCD using Partial Switching

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ABSTRACT

In this paper, we propose a new design for achieving a single-cell-gap Transflective TFT-LCD. Narrow striped electrode is used in the reflective (R) region such that the electric fields generated there are dominated by fringing fields. This results in reduction in LC switching angle in the R region and hence much better matched R-V and T-V curves with optical efficiency of ≥ 90% at the same applied voltage.

INTRODUCTION

In recent years, Transflective TFT-LCDs (TR-LCDs) have become a very important display mode for small to medium sized portable electronic devices such as cellular phones, digital cameras & PDAs. The main advantage of TR-LCDs over conventional transmissive-type TFT-LCDs is that the former is capable of displaying legible images under any illumination conditions, i.e. suitable for both indoor and outdoor applications. Due to the optical-path difference between the transmitted (T) and reflected (R) lights, many of the TR-LCDs with high optical efficiency at present are based on the rather complicated "double-cell-gap" structure, which requires more demanding fabrication process control and hence often leads to lower production yields and higher manufacturing cost. Moreover, this structure also exhibits other undesirable properties such as unequal response time between T and R images, reduced aperture and very often limited viewing-angle characteristics. Thus, there have been active developments in proposing new designs for achieving a single-cell-gap TR-LCDs in recent years [1-5]. In this paper, we describe a new design for achieving a single-cell-gap TR-LCD that is based on the concept of "Partial-switching" [6].

STRUCTURE AND PRINCIPLES

The general structure and principle of this new design is shown in figure 1. As in a typical TR-LCD, it consists of a transmissive T region (or sub-pixel) and a separate reflective R region (or sub-pixel) as shown on the left and right hand sides of figure 1 respectively. In the T region, the VA-LC (Vertically-Aligned Liquid

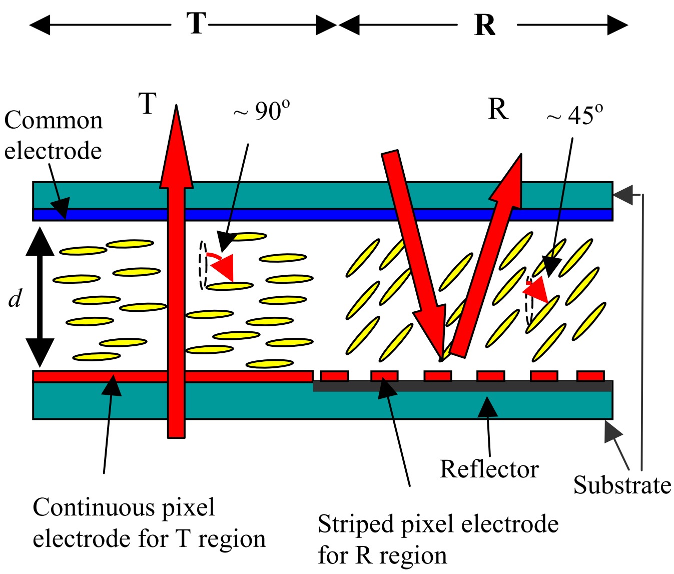

Fig.1: Principle and structure of the proposed single-cell-gap TR-LCD based on Partial Switching. The VA LC molecules in the R region are switched by a smaller angle (~ 45°) with the use of a narrow-striped pixel electrode. Cell gap d is the same for both T & R regions.

Crystal) molecules are switched by the vertical electric fields generated by the common electrode in the upper substrate and the pixel electrode in the lower substrate. In order to obtain a maximum transmission change, the LC layer's retardation Δn.d (product of LC birefringence Δn and cell gap thickness d) is usually set to be ~ λ/2 (a half-wave plate, λ = incident light wavelength) such that, when the molecules in the T region are switched by an angle of ~ 90° upon the applied electric fields, the transmission will be changed from minimum to maximum. In the R region, however, the reflected light has a double-path upon its reflection and hence experiences twice as much as retardation change (2 x Δn.d) as that for the T region, thus the voltage-dependent reflectance (R-V) curve would increase about twice as quickly as that of T-V curve. Without a modification in design, one cannot obtain both high T & R optical efficiency at the same applied voltage with a single cell gap structure.

In order to reduce the single-path retardation change in the R region, we propose a new design such that it can switch the VA LC molecules in the R region "partially" (e.g. by ~ 45°) as shown in figure 1. The major modification required in this new design is that the pixel electrode in the R region now consists of narrow striped electrode which can generate mainly fringing fields instead of vertical fields. (Note: though not shown in figure 1, polarizers and quarter-wave films are required above and below the two substrates as usual for the VA-type TR-LCDs.)

Generation of fringing fields:

As mentioned above, the partial switching in R region is achieved through fringing fields which are generated using narrow striped electrode. This is shown in more detail in figure 2. As shown in figure 2, the striped electrode is characterized by i) the electrode width (L) and ii) the electrode gap (G) between two adjacent striped electrodes. In general, larger the value of L is, larger the value of G would be required in order to maintain a relatively large proportion of fringing fields in the R region. This is because, as shown in fig.2, the electric fields generated just "above" the striped electrodes tend to be stronger and more like vertical fields. The fringing fields that we desire (which tend to be oblique in direction and also weaker in strength compared to vertical electric fields) are generated mainly in the gap region G "between" two adjacent striped electrodes as shown in figure 2.

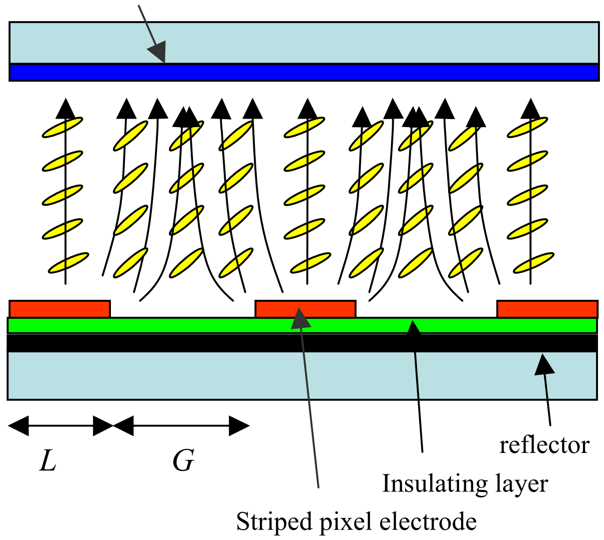

Fig. 2: Generation of fringing fields in the R region using narrow striped pixel electrode. The striped electrode is characterized by its width *L* and gap *G*.

RESULTS AND DISCUSSIONS

In this section, we demonstrate some of the optimized simulation results obtained through the commercially available 2D LCD simulation software "*2DimMos*" provided by *autronic-Melchers*, Germany. The LC parameters used are based on the Merck liquid crystal MLC 6608 with $\Delta n = 0.077$ and $\Delta\varepsilon = -3.7$. The cell gap d was chosen to be 6μm in these examples and the VA pretilt angle was set to be 85°. A lower VA pretilt angle (e.g. 85°) has been found to achieve better matching of the R-V and T-V curves compared to those with higher VA pretilt angle (e.g. 88°-89°). A reference for obtaining lower VA pretilt angle can be found in [7].

With the above initial conditions, figures 3 & 4 show the matched R-V and T-V curves for cases of L=1μm and L=3μm respectively. The required gap values G for matching the T-V curves in these two cases are 6μm and 8μm respectively. As shown in both figures, the R-V and T-V curves have become much better matched and with similar slopes (gamma curves) and high optical efficiency of ≥ 90% for both R and T at the same applied voltage of 3V. Figures 5 and 6 show the effects of the gap value G on the R-V curves with L=1μm and L=3μm respectively. As shown in figures 5 & 6, the R-V curves shift to the right (i.e. with a lower slope) as G value increases. At the same time, and is particularly obvious in case of L=3μm, the maximum value of R also decreases gradually as the G value increases. Moreover, as we compare the results obtained for L=1μm and L=3μm, we note that the potential maximum value of R at the optimized condition also becomes lower as L increases since higher and higher proportion of vertical fields are generated in the R region.

Figure 7 shows the 2D reflectance profile across the R region for the case with striped electrode design L=1μm and G=6μm. (Note: the striped electrode and the reflector are both located on the upper substrate in the simulation model since the ambient light is incident from the bottom in the 2DimMos simulation software) As shown in fig. 7, the reflectance increases as the applied V increases and reaches its maximum at 3V. The reflectance also shows peaks and valleys across the cell at the intermediate voltage levels. Referring to figure 2, the peaks correspond to the regions above the centre of each striped electrode segment where vertical electric field is dominated and valleys correspond to the regions between striped electrode segments where fringing field is dominated. Moreover, as shown in fig.7, the LC molecules in the bulk are indeed switched partially by ~ 45° to achieve the maximum reflectance R at 3V.

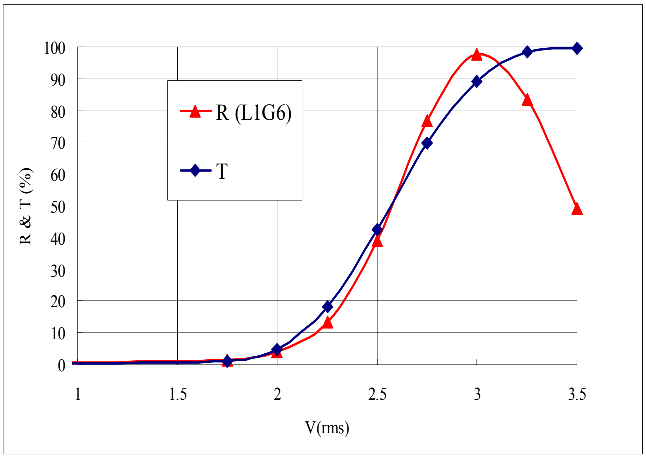

Fig.3: Matched R-V and T-V curves of a single-cell-gap TR-LCD with <u>*L*=1μm and *G* =6μm</u> in the R region. The cell gap *d* in both T and R regions is 6μm. The LC parameters are based on MLC 6608 with Δn=0.077 and Δε=-3.7. High optical efficiency of ≥ ~ 90% is obtained for T and R simultaneously at 3V.

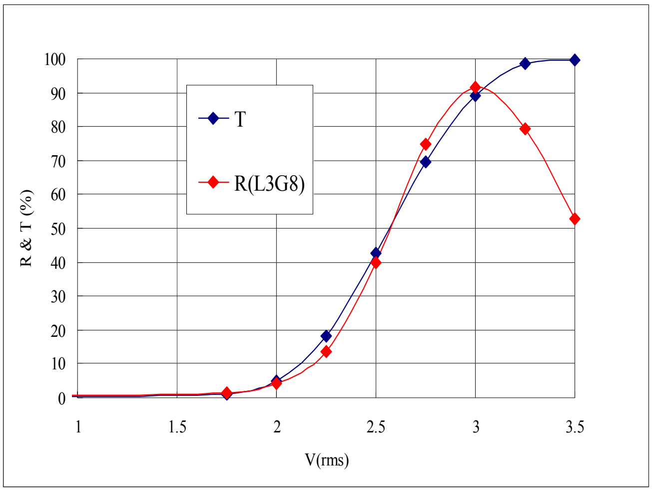

Fig. 4: Matched R-V and T-V curves of a single-cell-gap TR-LCD with <u>*L*=3μm and *G* =8μm</u> in the R region. The cell gap d in both T and R regions is 6μm. The LC parameters are based on MLC 6608 with Δn=0.077 and Δε=-3.7. High optical efficiency of ~ 90% is obtained for T and R simultaneously at 3V.

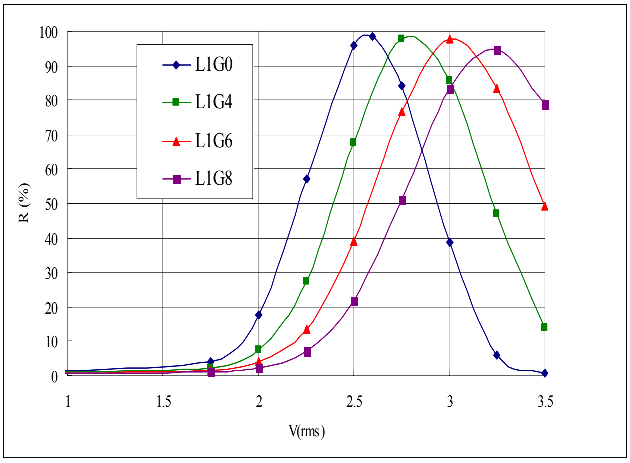

Fig. 5: Effect of increasing the value of G on R-V curves in the case of <u>*L*=1μm.</u> As G increases, the R-V curve shifts to the right with a decreasing slope. R-V curve with L=1μm and G=6μm (L1G6) is found to match T-V curve quite well as was shown in fig. 3.

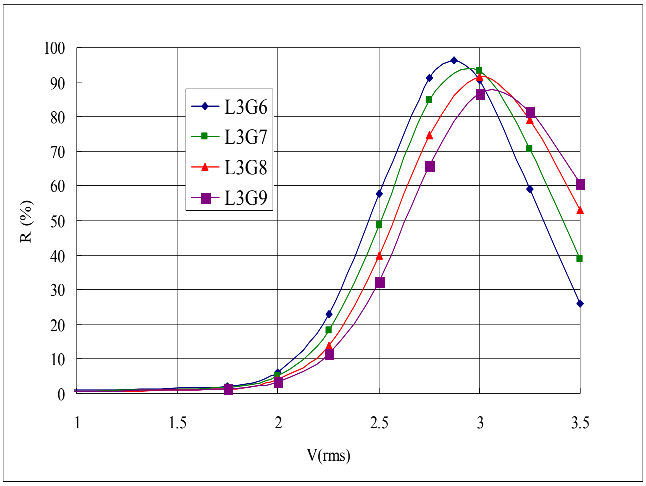

Fig. 6: Effect of increasing the value of G on R-V curves in the case of <u>*L*= 3μm.</u> As G increases, the R-V curve shifts to the right with a decreasing slope and a reduction in the maximum value of R. R-V curve with L=3μm and G=8μm (L3G8) is found to match T-V curve quite well as was shown in fig. 4.

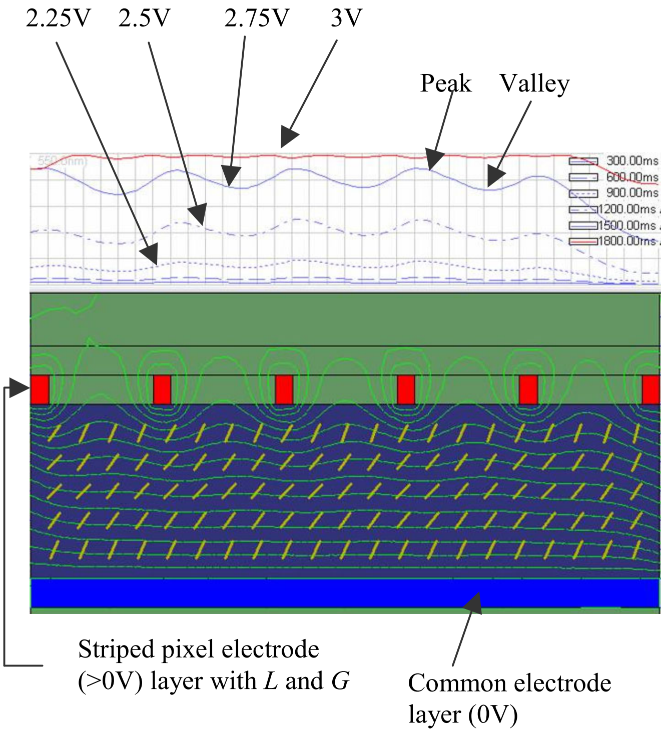

Fig. 7: A 2D reflectance profile across the R region with L=1μm and G=6μm. The reflectance increases as applied voltage increases. The Peaks and Valleys correspond to the regions which are dominated by vertical and fringing fields respectively. The LC molecules in the bulk are indeed rotated "partially" to ~ 45^{o} direction by the fringing fields to achieve the maximum reflectance R =~100% at 3V.

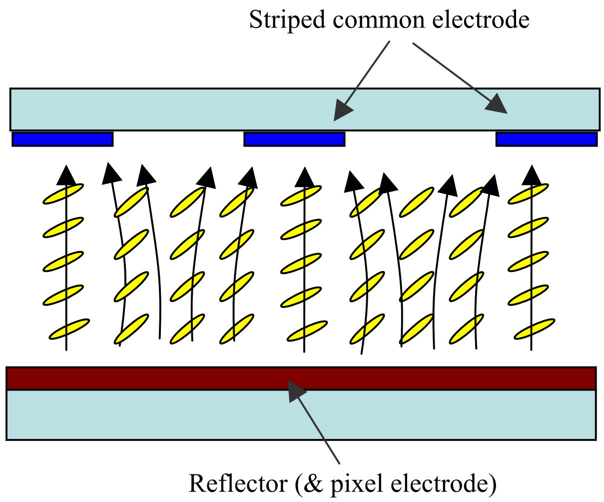

Fig.8: Alternative design with striped electrode on the upper substrate (i.e. striped electrode is now the common electrode instead of the pixel electrode)

Alternative design:

An alternative design for this Partial Switching scheme is to place the striped electrode on the upper substrate instead of on the lower substrate (i.e. the common electrode in R region now becomes the striped electrode) as shown in figure 8. The advantage of this alternative design is that the insulating layer on the reflector as shown in figure 2 may not then be necessary. Our preliminary simulation results indicate that this alternative design is also feasible and slightly different matching values of L and G may be required.

SUMMARY

In summary, we have demonstrated the principle of a new design for single-cell-gap Transflective TFT-LCD using Partial Switching. The design is based on the use of narrow striped electrode in the reflective region such that a strong proportion of fringing field is generated there. This results in the reduction of LC switching angle in the R region and leads to much better matched T-V and R-V curves. Our simulation results show that both high T & R optical efficiency of ≥ 90% can be obtained simultaneously at the same applied voltage. Our examples shown in this paper are based on VA LC mode with a pretilt angle of ~85^{o}.

ACKNOWLEDGEMENTS

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附件三

出席國際學術會議報告

報告人姓名	蔡永傑	服務機構 及職稱	臺大光電工程學研究所 Assistant Professor
會議 時間 地點	95 年 12 月 6-8 日 Otsu, Japan	本會核定 補助文號	
會議 名稱	（中文）國際顯示器研討會 （英文）International Display Conference (IDW"06), Otsu, Japan		
發表 論文 題目	（中文）1）單一液晶間隙之半穿透半反射型液晶顯示器 using Partial Switching, 2）廣視角單一液晶間隙之半穿透半反射型液晶顯示器 using PVA LC mode （英文）1) Single-cell-gap Transflective TFT-LCD using Partial Switching, 2) Wide-viewing-angle single-cell-gap Transflective TFT-LCD based on PVA LC mode		

報告內容應包括下列各項：

一、參加會議經過

Prof. Choi arrived in Otsu, Japan on Tue. 5th Dec. 2006. The conference started on Wed 6th Dec and ended on Fri. 8th Dec. Prof. Choi returned to Taiwan on Sat. 9th Dec.

二、與會心得

At this conference, many new and novel designs of TFT-LCDs were presented. In particular, many papers focus on emerging technologies for controlling (and varying) the liquid crystal display viewing angles. This is a very interesting topic and could form the next research topic in our Laboratory.

At this conference, I also presented two papers:

1) W. K Choi, R. C. Lee, C. C. Tasi & S. T. Wu, "Single-cell-gap Transflective TFT-LCD using Partial Switching," *International Display Workshops (IDW"06)*, Vol. 1, pp.169-172, Otsu, Japan, Dec. 2006
2) W. K. Choi, Y. H. Wu, M. L. Lee, K. H. Chen & Y.F. Luo, "Wide-viewing-angle single-cell-gap Transflective TFT-LCD based on PVA LC mode," *International Display Workshops (IDW"06)*, Vol. 1, pp.165-168, Otsu, Japan, Dec. 2006

Both papers were very well received with many questions and positive comments from the attendees. The first paper also won the "*Outstanding Poster Paper Award*"..

三、建議

This conference contains many good and outstanding papers. In particular, its focus on "liquid crystal science and technology" is very impressive and suitable for our Laboratory.

四、攜回資料名稱及內容

One set (3 books) of conference proceedings and 1 CD-ROM.

五、其他