Viewing angle improvement of TN mode by HD layer inside LC cell and a compensation film

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Abstract

Holographic diffuser(HD) layer was demonstrated to be located inside LC cell for a transmissive LCD of TFT-array on Color Filter structure. Master pattern of this layer was generated by holographic method and this pattern was replicated by the stamping of the master pattern on UV resin. Combined with a compensation film, TN-mode LCD with this layer showed improved viewing angle characteristics, especially along the up-down direction.

1. Objective and background

For wide-viewing angle application, TN with discotic-compensation film is widely used for medium size LCD while IPS or VA mode is generally used for large size application. The former has limited viewing angle problem while the latter have low light efficiency problem. Currently needs for brighter LCD are increasing, especially for LCD-TV application. So LCD satisfying wide-viewing angle and good light efficiency is a goal to reach.

In early nineties, a configuration using collimated backlight and light-direction changing layer was reported.[1] In that structure, light direction changing film is attached to the upper polarizer. To prevent image blurring due to parallax and to get good viewing angle characteristics, collimation of backlight was required to be as small as 10 degrees.

However, such a highly collimated backlight unit is very difficult to make. To solve this problem of backlight, we suggest locating Holographic Diffuser layer inside LC cell. (Figure 1) In this paper, we describe the process of making HD layer inside LC cell, the structure of LC panel and measurement of optical characteristics.

2. Result

2.1 HD layer located inside LC cell

We suggest a new structure in which diffusing layer is located between LC layer and glass substrate. As the distance between LC layer and diffusing layer is negligible compared to pixel size, clear image is observed. Polarization should be conserved through diffusing layer to maintain the black state of LCD. Also backscattering of outside light by diffusing layer should be minimized to prevent the reflection of outside image. For such reasons, holographic method was selected to make original diffusing pattern.[2,3] Other merits of Holographic Diffuser pattern are good light efficiency due to negligible backscattering, controllable scattering angles and nearly perfect replication of patterned layer.

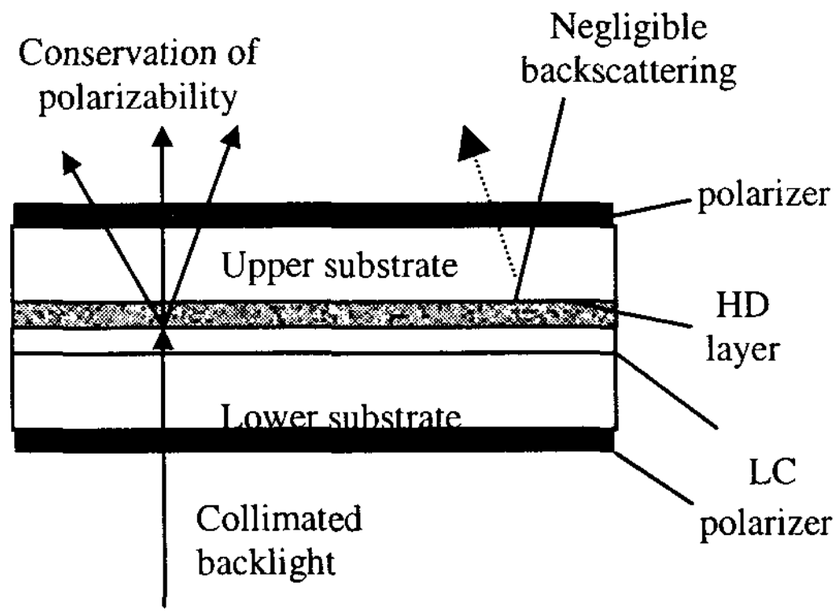

Figure 1 A schematic configuration of LC panel with HD(hologram diffuser) layer inside LC cell

2.2 Generation of master HD pattern

Photo-reactive resin was coated on the glass. This PR plate was placed behind the ground glass and is exposed to He-Cd laser. To remove strong dependency on diffraction direction and wavelength, laser beam was randomly scattered by ground glass and interference of these scattered light resulted in almost random distribution of light intensity at PR plate. (Figure 2) As a result, developed PR plate showed characteristics of achromatic diffuser.

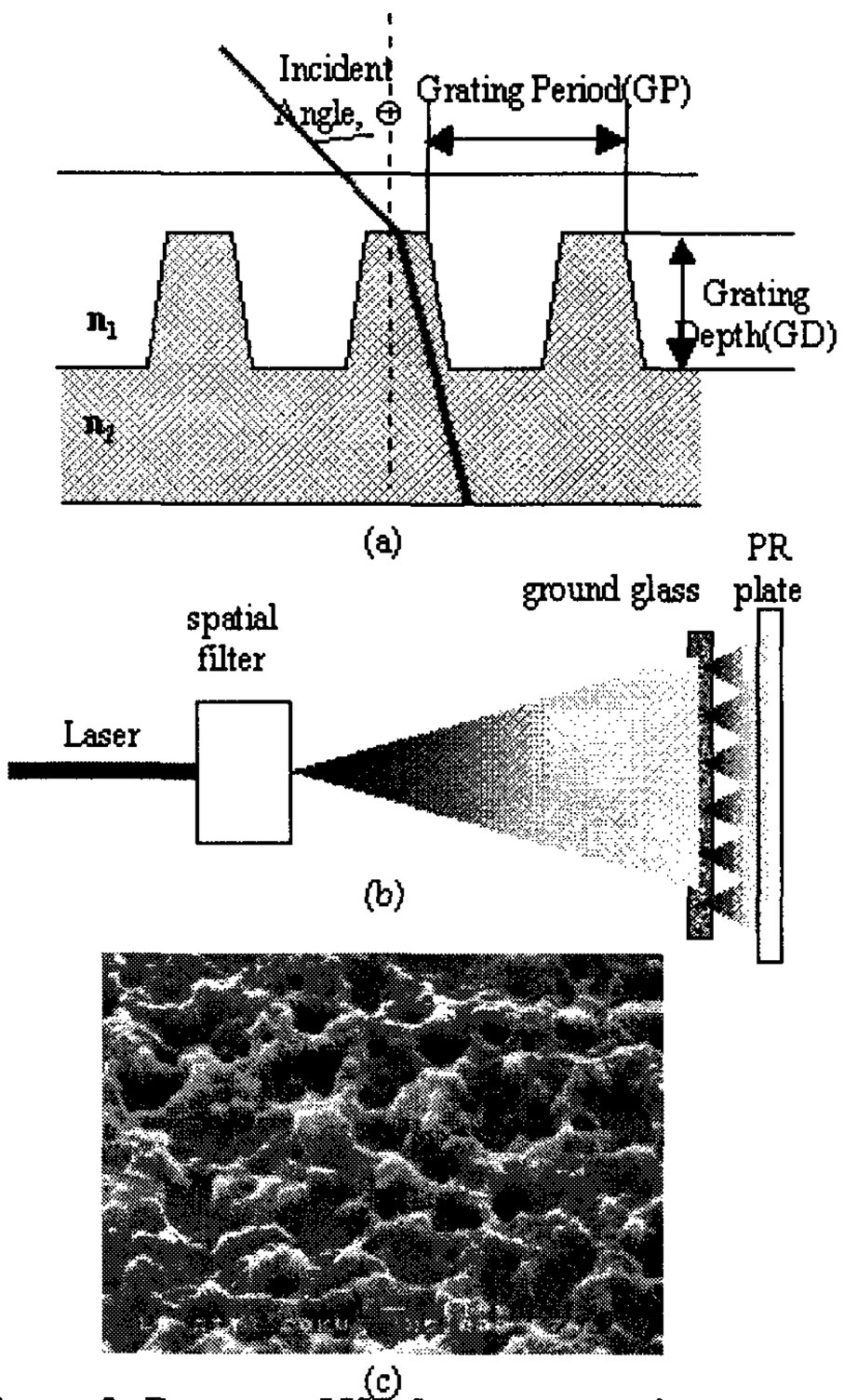

Figure 2 Process of HD layer generation (a) Determination of grating period and depth by diffraction simulation, (b) Master pattern generation by laser to PR resin through ground glass, (c) Photo of resultant random pattern

Two important parameters to determine the intensity distribution of diffraction are depth and period of the grating. For periodic grating between two layers, these parameters were calculated to be 1.1 and 1.2 μm when 0^{th} order diffraction is minimum.(Fig 2(a)) Photography of Figure 2 (c) shows that average depth and period of the random pattern are similar sizes. Metallic stamp of the equivalent pattern is replicated from this patterned PR plate by electroplating method and this stamp is used as master stamp.

2.3 HD Replication Process on the substrate

To make HD layer directly on the glass substrate, UV resin of high refractive index (R.I.) 1.64 is coated on the substrate. This UV resin is hardened by UV radiation while it is pressed by master stamp. UV radiation is focused on small area where stamp is contacting UV resin. (Figure 3)

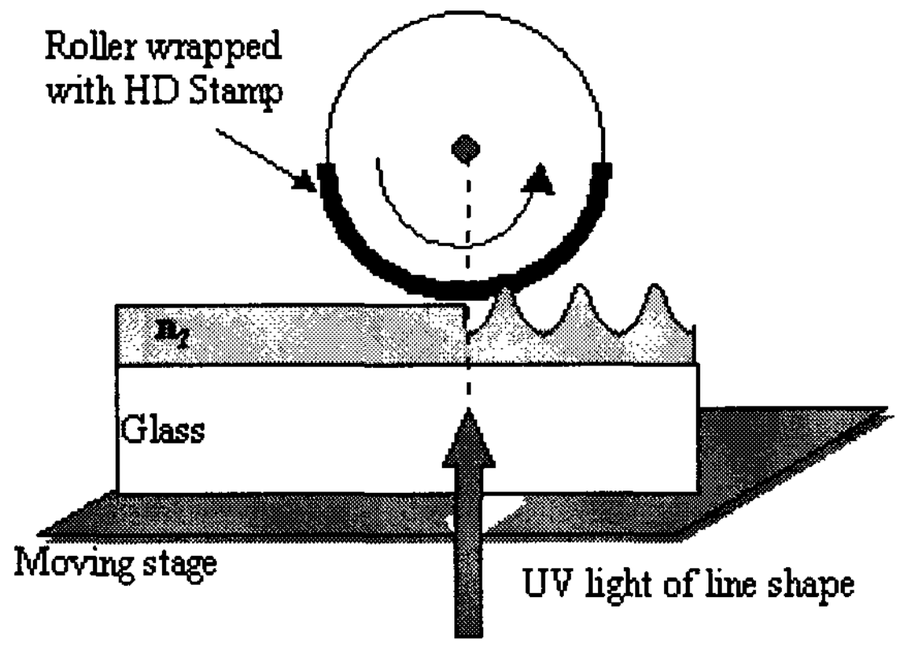

Fig3 Replication of HD patterns on upper substrate

On this patterned layer, transparent layer of low R.I. 1.34 is coated and thermally cured. Refractive index difference of two adjoined layers is 0.3. The other function of low refractive index layer is flattening the surface as roughness of ~1μm cannot be ignored compared with the cell gap of LC.

2.4 TFT-LCD panel structure

To simplify the integration process and focus on optical characteristics of HD layer, a structure is selected in which TFT and C/F is on the lower substrate and HD structure is located on the upper substrate.[4] On the upper substrate, UV resin of High R.I, flattening layer of low R.I, ITO and alignment layer are added, successively.(Fig. 4) Also, effective structure and compatability between HD layer and C/F layer is under consideration.

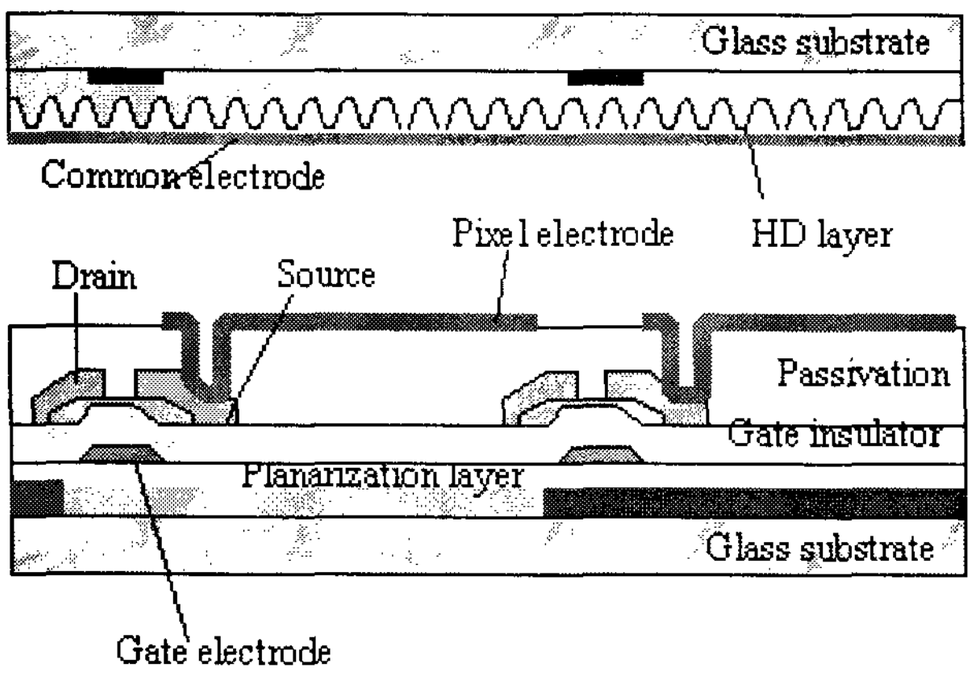

Figure 4 LC panel structure where upper substrate consist of HD layer and and lower substrate consists of TFT on C/F

Table 1 summarize the necessary characteristics and related factors to place HD layers inside LC cell.

Characteristics	Related factor
Hardness	Maintainance of cell gap
Resistance to chemicals	Solvent, PR and etchant
Thermal stability	PI, ITO,.. process temp.
Adhesion to other layers	sealant break
Thermal expansion matching	ripple & stress between layer

Table 1: Necessary characteristics of material inside LC cell

2.5 Optical characteristics

14.1" XGA TFT-LCD of TN mode sample was made and various optical characteristics were measured.

Figure 5 shows the microscopic photography of LCD pixels, where picture of repeating vertical black and white lines is displayed. Figure 5(a) of suggested structure shows the clear pixel image. However in case of LCP where diffuser is placed outside the substrate, brightness difference between white and black lines decreased. (Figure 5(b))

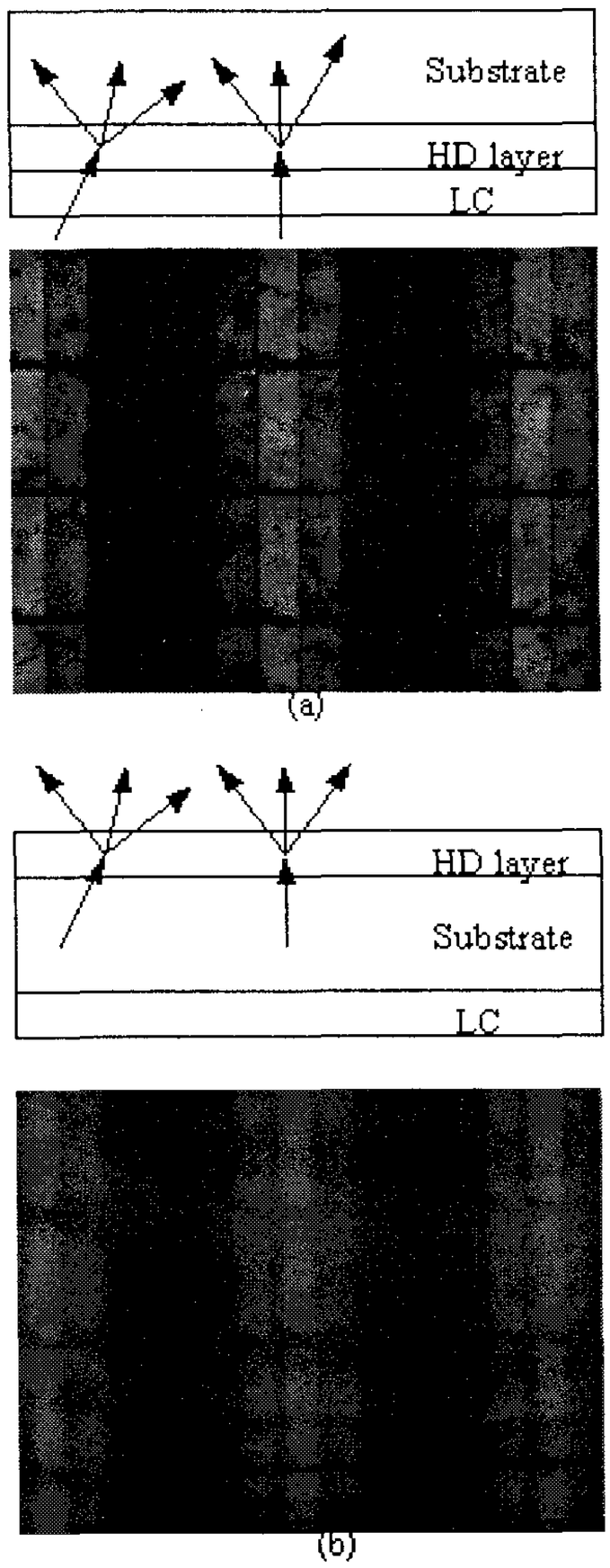

Figure 5 Position of HD layer and photograph of LCD pixels where diffusing layer is located (a) inside LC cell and (b) outside substrate.

As the distance between HD layer and LC cell is only a few micrometers, collimation degree of backlight does not affect the clearness of pixel image. So, if viewing angle of LCD is increased, acceptable collimation range of backlight can be enlarged without the deterioration of image sharpness.

To decrease the light leakage of LC panel at black state, C-plate type is selected to be placed between the lower substrate and lower polarizer.

Main weakness of film-compensated TN mode is gray inversion along the Up-Down direction. Gray-inversion characteristics of sample were measured for following conditions.

i) Backlight distribution was varied by inserting 1~2 prism sheets. When two prism sheets is used, FWHM (full width half maximum) of backlight distribution is about 50 degree

ii) C-plates of various retardation value were added.

Sample of zero compensation shows no noticeable improvement. The best condition is measured to be the case of 226 nm C-plate and backlight of two prism sheets. Gray inversion was not observed to appear for the range of 60/60 degree along the Up-down as well as Left-Right direction. (Figure 6) This result also accords with the fact that c-plate of retardation 226 nm is best compensating condition when retardation of polarizers is considered. It can be concluded that requirement of collimated backlight diminishes when internal HD layer and a compensation film is used at the same time.

Main problem of current structure is decrease of Contrast Ratio. At the current status, conservation ratio of polarizability through HD layer is not 100%. Light leakage from slanted direction also affects the normal CR. We think that CR can be improved by optimizing the backlight distribution and conservation of polarizability of HD layer.

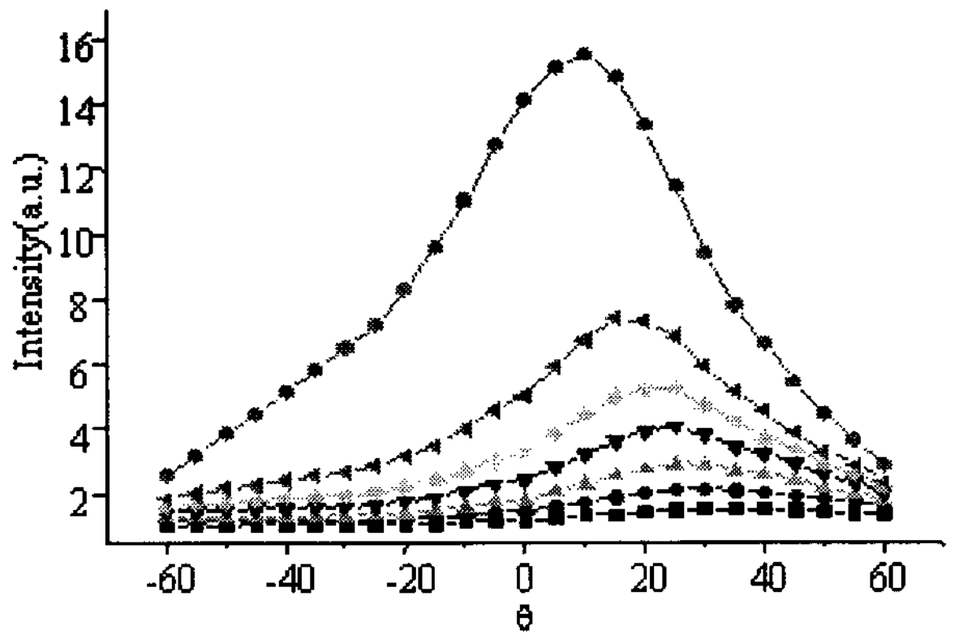

Figure 6 Gray level characteristics of sample panel along the Up-Down direction of TN mode panel. C-plate of 226 nm and backlight of two prism sheet was used.

3. Impact

We demonstrated to place an optical component inside LC cell. The technology can be used to make other optical components and it will be helpful in making thinner and lighter displays in the end. We observed improvement of gray-inversion along the vertical direction of TN mode, also.

4. Acknowledgements

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5. References

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