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Effect of Geometry in Wire Grid Polarizers on Contrast Ratio of Display Panels

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ABSTRACT
In liquid crystal display (LCD) panels, there are two polarizing films and liquid crystal tunes the polarization of backlight. As large the size of the panel is, the polarizing film becomes expensive because of the fabrication cost of the film. Wire grid polarizers (WGPs), which consist of metal wires on a transparent substrate, could be the alternative for the large area LCD panels. In this study, we investigate the effect of the geometry of the wire grid polarizer on the contrast ratio, which is an important property in LCD device. We conduct a simulation with WGPs in different tip shapes and different design of protection dielectric layers and extract the data for obtaining contrast ratios. The contrast ratio of the WGPs with sloped edges is lower than that of WGPs with straight edges. In addition, dielectric layers should not fill the gap between the metal lines to ensure high contrast ratio.
Keywords *- wire grid polarizers, liquid crystal display, tip shape, dielectric layer, metal wire*.

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I. INTRODUCTION

Polarizers are essential in liquid crystal displays (LCDs) because the transmission of light emitted from backlight can be modulated by tuning polarization. Although polymer based polarizing film has been commercialized, new technology should be pursued because the requirement of low cost solutions in large area polarizers is increased. Wire grid polarizers (WGPs), which are the array of metal line patterns on a transparent substrate, has been regarded as a candidate to replace the film as the fabrication methods have been developed. [1-9] Although there have been many reports on the fabrication methods [1-7] and the simulation results [8-9] on the polarizers themselves, the study on the contrast ratio from the WGPs is still necessary to be used for LCD panels. In this paper, we study the effect of geometry of WGPs on the expected contrast ratio of the LCD panels. We neglect the loss from the liquid crystal sandwiched by two polarizers and conduct optical simulation on the extreme cases. The shape of the WGPs and protecting layers placed on the WGPs affects the contrast ratio and we obtained the ideal design for higher optical performance in WGPs.

II. RESULTS & DISCUSSION

Contrast ratio (CR) is the most important performance indicator in LCD panel. Contrast ratio can be defined as the ratio of the luminance in white mode to that in black mode. In case of two-polarizer systems, the luminance of white mode can be

$$\text{Luminance in white mode} = TM1\times TM2 + TE1\times TE2 \quad (1)$$

where TM1 and TM2 are the transverse magnetic (TM) waves through polarizer 1 and 2, and TE1 and TE2 are the transverse electric (TE) waves through polarizer 1 and 2 as shown in Figure 1(a). The luminance in black mode can be determined as below.

$$\text{Luminance in black mode} = TM1\times TE2 + TM1\times TE2 \quad (2)$$

From the definition of luminance in white and black mode, we can describe the contrast ratio as below.

$$Contrast\ Ratio = \frac{white}{black} = \frac{TM1\times TM2 + TE1\times TE2}{TM1\times TE2 + TE1\times TM2} \quad (3)$$

We calculate the contrast ratio with a commercial optical simulation package (G-solver) with a various design of wire grid polarizers, such as height, tip shapes, protection dielectric materials and the structure dependence.

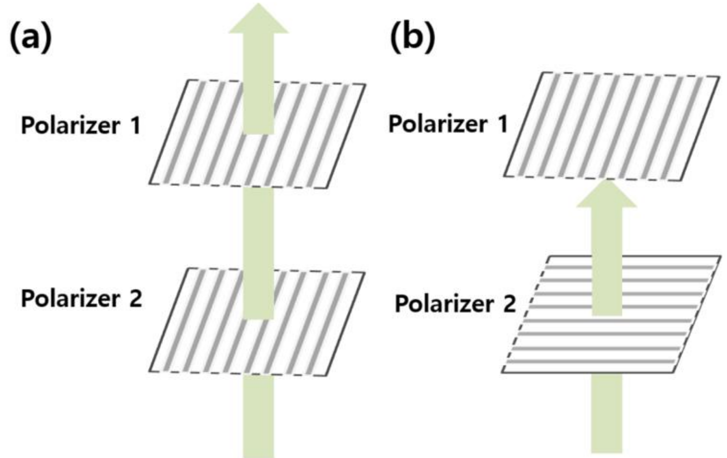

Figure 1. Schematic illustrations of (a) white mode and (b) black mode in two-polarizer system.

We design the wire grid polarizer as a repeated line array. We fix the period of the lines as 100 nm and the width as 50 nm, which is described previously. Instead, we alter the height of the metal lines from 50 nm to 300 nm to investigate the effect on transmittance and contrast ratio. As shown in Figure 2(a), the transmittances with different heights, which are estimated from the TM/2, show little effect on the design factor. On the other hand, the contrast ratio, which is defined as equation (3), has a trend of increasing as the height is dramatically increased (Figure 2(b).

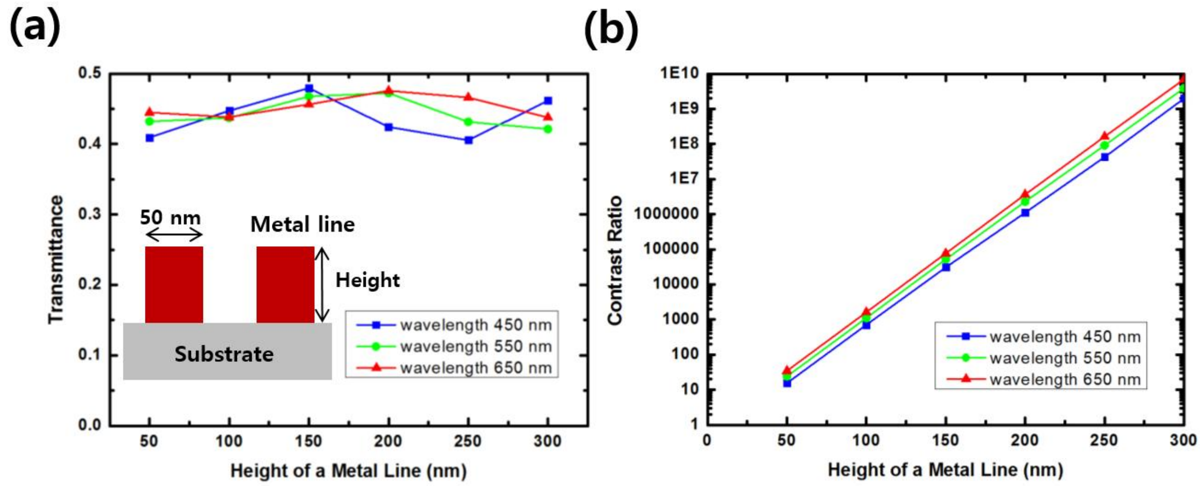

Figure 2. Grapes of (a) transmittance and (b) contrast ratio in different pattern heights.

As the contrast ratio differs with respect to the design parameters, we calculate the contrast ratio of wire grid polarizers with different tip shapes. After conventional semiconductor processing, such as dry etching following photolithography, the edge of the rectangular shape can be removed. Figure 3 shows the effect of tip shapes in WGPs on the contrast ratio. We fix the width of WGPs to 50 nm again and estimate the contrast ratio with different distance from the rectangular edge. For example, when the distance is zero, the tip shape is rectangular. On the other hand, the tip becomes triangle when the distance is the half of the width (25 nm). As shown in the graph, the contrast ratio decreases rapidly when the tip shape is changed from the rectangular shape. From the simulation result, we can obtain the optimized condition of the rectangular WGPs. Then, we conduct the optical simulation considering dielectric materials as protection layers. Without the protecting layer on WGPs, metal lines with high aspect ratio can be broken when external force is applied. We assume two different WGP structures. First one is the structure of dielectric layer in the same thickness (150 nm) with the metal lines is just place on the metal line array (Figure 4(a). Second, we investigate the case of filling dielectric materials in the gap of the metal lines as shown in Figure 4(b).

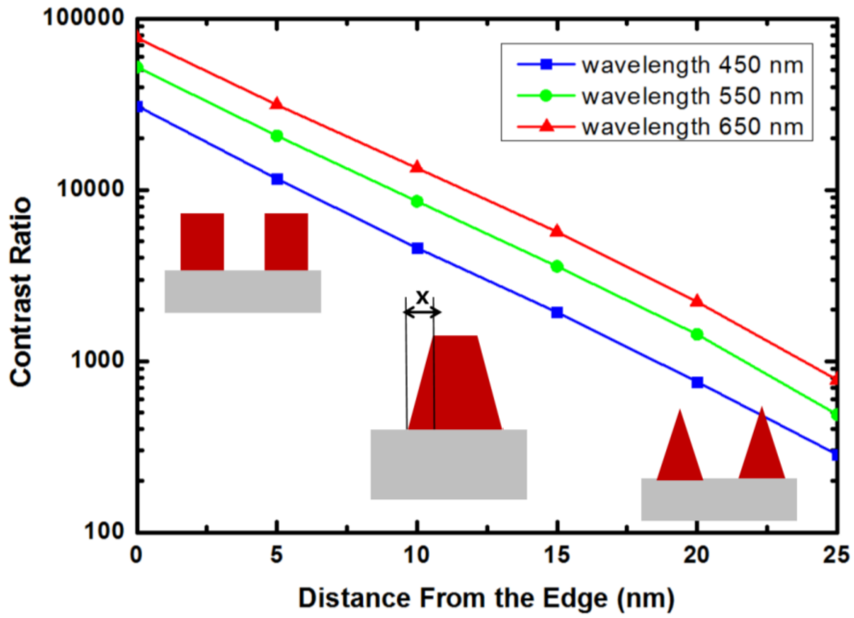

Figure 3. Graphs of (a) TM deviation and (b) ER deviation from the average when the width deviation is 10 %.

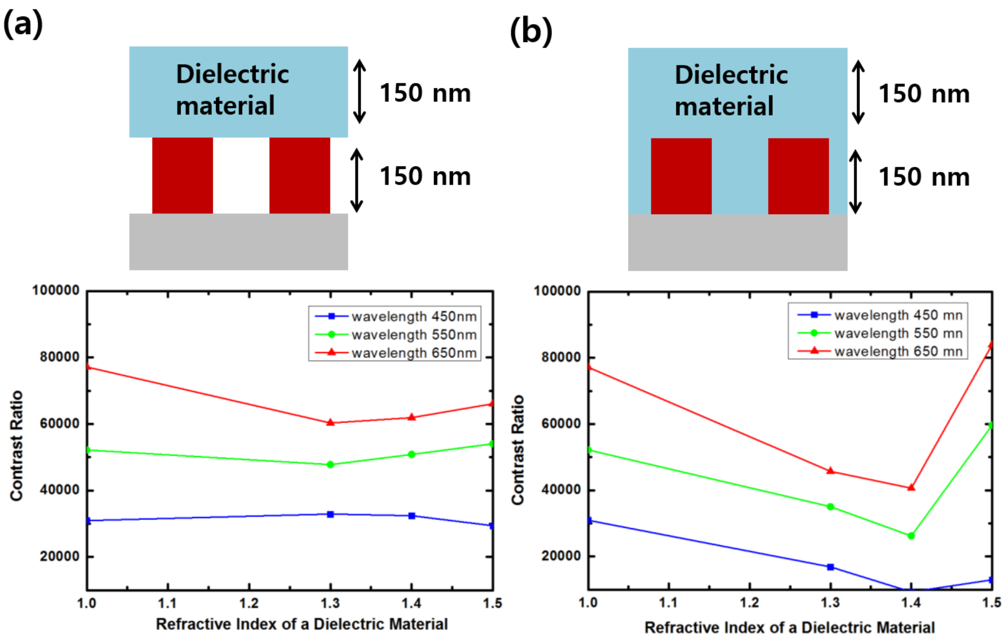

Figure 4. (a) A schematic illustration and a graph of the contrast ratio when a dielectric material is placed on the metal wires. (b) A schematic illustration and a graph of the contrast ratio when a dielectric material filled the gap between metal wires.

When the dielectric material is placed on the WGPs, the contrast ratio is about 5000 at 550 nm in wavelength. Also, the effect of contrast change on the refractive index is trivial. In case of filling dielectric materials, the contrast ratio change is bigger. When we deposit dielectric materials such as silicon dioxide or silicon nitride with a method of sputtering, the layer has the circular shape as shown in Figure 5. We calculate the contrast ratio with a different radius of the dielectric layer. For example, when the radius is smaller than 25 nm, the dielectric materials is on the metal lines. When the radius is greater than 25 nm on the other hand, the dielectric materials can fill the gap between the metal wires. As calculated in Figure 5, the effect of the dielectric layers is not critical, however, the contrast ratio in blue light is decreased rapidly when the dielectric layer contact together as shown in the lower right image of the graph.

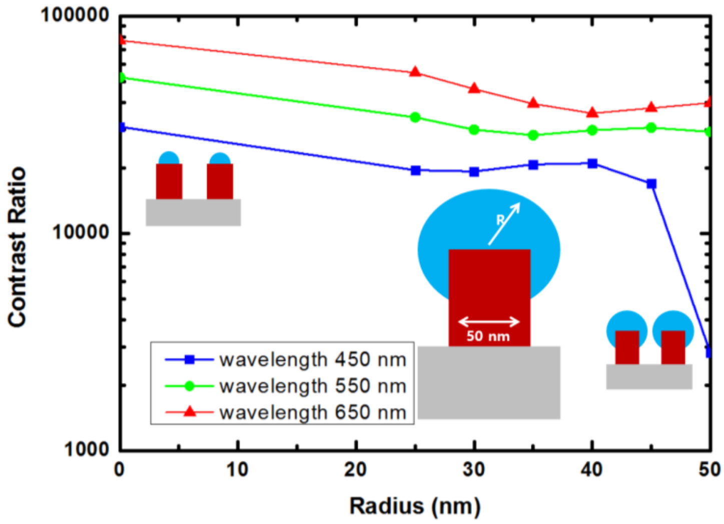

Figure 5. A graph showing the contrast ratio vs radius of circular dielectric layers.

III. CONCLUSION

In conclusion, we calculate and estimate the effect of the shape design on the contrast ratio, which is the most important spec in liquid crystal displays. The contrast ratio is changed by aspect ratio dramatically and the tip shape should keep rectangular line pattern. In addition, we consider the case of existing protecting dielectric materials. Dielectric materials can be hurdle to increase the contrast ratio; however, the effect is not too significant compared to aspect ratio.

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