A Novel Column Spacer with Concaved Top Surface for TFT LCD

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Abstract
A novel column spacer with concaved top surface has been made through conventional photolithography process. The mechanical characteristics of this spacer were also investigated by using load-unload cycle test. According to the experimental results, the deformation ratio of this new designed spacer is larger than that of conventional column spacers about two times in the lower loading stage. At the higher loading stage there is no obviously difference in deformation ratio between the new designed spacer and the conventional spacer.

1. Introduction
Recently, a technology for rapidly filling the liquid crystal, i.e. a One Drop Fill (ODF) technology of the liquid crystal, is developed by T. Ishihara et al. [1]. According to a manufacturing process of the ODF technology of the liquid crystal, the operation window (or liquid crystal margin) of the quantity of the dropped liquid crystal on the substrate depends on the elasticity of the spacer. When the number of the spacers is too many or the plastic deformation of the spacers is too small (e.g. elastic constant is too high), it can be observed that the relative quantity of the liquid crystal is too little so as to result in air bubbles [2]. In the model of an ideal elastomer, the spacer with higher deformation ratio (i.e. with a lower elastic constant) can acquire the larger liquid crystal margin. On the other hands in order to assure the proper operation of a liquid crystal display device, it is critical that the cell gap is maintained uniformly and precisely throughout the entire display. Any slight deviations in the cell gap will result in a noticeable and defective appearance in the display (so-called Mura defect). This can readily be seen in a conventional LCD display panel with a fingertip pressure on the surface [2]. A spacer with lower elastic constant will easy to result in a dark spot during fingertip test. In order to achieve a larger margin in ODF process and better resistance on fingertip simultaneously, much effort focused on the spacer material, size, and position has been done [3~5]. Although in S. Hiromasa et al. [4] a spacer with single concaved top surface has been proposed, the mechanical characteristics of the spacer has not been elucidated clearly yet. In this paper various kinds of the spacer with concaved top surface were successfully made by conventional patterning process without using a halftone mask and the mechanical properties of these spacers were also investigated.

2. Experimental Procedure
A schematic structure of conventional column spacer is shown in Fig. 1. A schematic structure of single concaved column space proposed by S. Hiromasa [4] is shown in Fig. 2. The design concept of the

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concaved spacers in this paper is shown in Fig. 3 for comparison. In figure 3 the new novel spacers with plurality of slits on the top surface were made by a proper mask aperture design without using a halftone mask. The schematic mask aperture design is illustrated in Fig. 4. By adjusting the dimension of aperture "b" marked in the figure 4, the novel column spacers with plurality of slits on the top surface could be acquired. The mask aperture "b" was also set to 15x150um in another mask to form a standard column spacer with a size of 15x150um as a reference base (without slits) for comparison. All of the spacer height (photo resist thickness) was made to 3.5um. The photo resist material of the novel spacers used here was negative type, same with that of current used. The mechanical characteristics of the spacers were evaluated through the load unload cycle test. The load unload test was carried out by using a dynamic ultra micro hardness test machine (DUH-201 SHIMAZU). The detail of the test method has been described in R. Harada et al. [6].

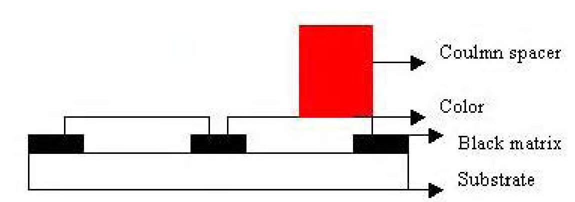

Figure 1 Schematic structure of conventional column spacer

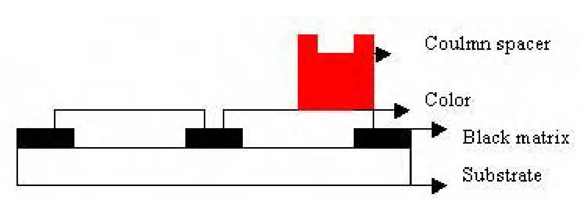

Figure 2 Schematic structure of single concaved column space proposed by S. Hiromasa [4].

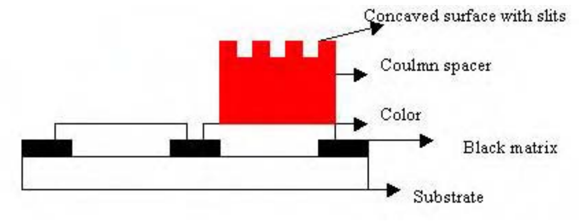

Figure 3 A Schematic structure of the new novel spacers with plurality of slits on the top surface

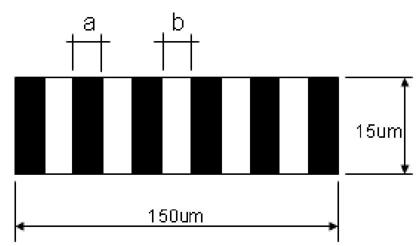

Figure 4 A schematic illustration for the design of mask aperture

3. Results and Discussion

3.1 SEM Observation

A typical SEM top view of this novel spacer is shown in Fig. 5. As can be seen in figure 5, a concaved top surface with a plurality of slits could be obviously identified. The designed novel spacer has been successfully prepared through conventional photolithography process.

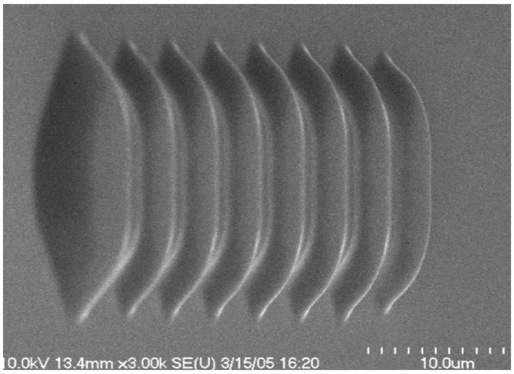

Figure 5 A typical SEM top view of this novel spacer

3.2 Mechanical characteristics

The deformation amount and deformation ratio of the various kinds of concaved top surface with plurality of slits under a lower loading stage (here used 30mN) are listed in Table1. It should be noted that the type 1 to 9 were the experimental spacers and the type 10 was the conventional spacer without any slit on the top surface. As can be seen in the Table 1, the deformation ratio of type 7 was about 8.57%, which is larger than that of the type 10 (3.26%) about two times.

Table 1 Deformation amount and deformation ratio of the various kinds of concaved top surface with plurality of slits under a lower loading stage (here used 30mN).

No	30mN	
	deformation (um)	deformation ratio %
1	0.180	5.14%
2	0.183	5.23%
3	0.199	5.69%
4	0.192	5.49%
5	0.168	4.80%
6	0.218	6.23%
7	0.300	8.57%
8	0.157	4.49%
9	0.219	6.26%
10	0.114	3.26%

The deformation ratio is defined as the deformation amount divided by the original spacer thickness (here is set to 3.5um). The load-unload cycle test results of the experimental spacers and the conventional spacers are shown in the Fig. 6. The applied force was set to a range from 0 to 35mN for evaluating the mechanical properties at low loading stage.

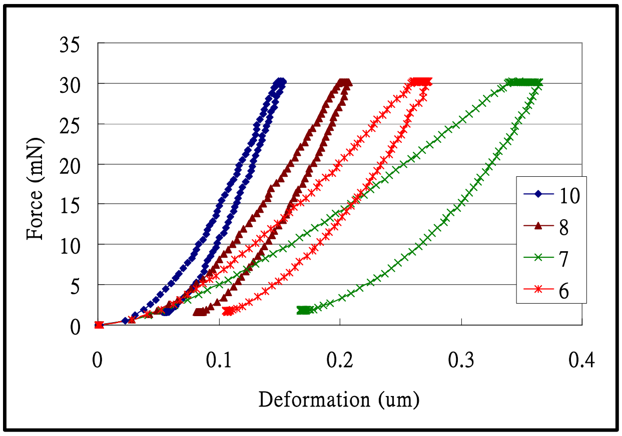

Figure 6 The load-unload cycle test results of the experimental spacers and the conventional spacers

It could be seen in figure 6 the deformation amount for the concaved spacers is much larger than that of conventional one. In view of the ODF process, the liquid crystal margin increases with the increase of deformation ratio of spacers. By comparing the curves of figure 6 a wider margin could be obtained by using the experiment spacer of type 7 because of its lower elastic constant. By using the novel spacer a larger deformation ratio can be acquired, thus a wider margin can also be obtained. The load-unload test curves of concaved top surface with plurality of slits and conventional spacer under the higher loading stage (here used 150mN) are shown in Fig. 7.

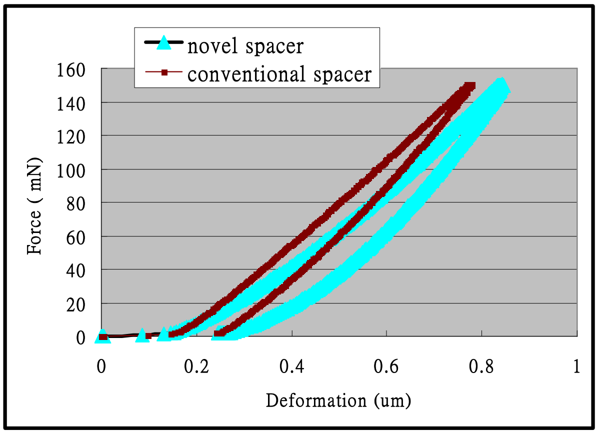

Figure 7 The load-unload test curves of concaved top surface with plurality of slits and conventional spacer under a higher loading stage (here used 150mN)

It should be explained that in order to simulate the condition of fingertip the applied force was set to a range form 0 to 150mN, which should be higher than that of the vacuum pressure during cell manufacture process. It could be found in figure 7 there is no significant difference between the novel spacer and the conventional spacer at the higher loading stage. Thus it could be expected that the cell gap deviation of the panel using novel spacer is almost same with the panel using conventional spacer during fingertip test, i.e. the resistance of mura defect resulted from fingertip stress could be considered as the same level between the novel spacer and conventional one. It is believed that by using this novel design, a panel with satisfied liquid crystal margin and better cell gap stability could be achieved.

4. Conclusions

A spacer with concaved top surface has been successfully made through conventional photolithography process. Based on the experiment results, the deformation ratio of this new designed spacer is larger than that of conventional column spacer about two times in the lower loading stage. At the higher loading stage there is no obviously difference in deformation ratio between the new designed spacer and the conventional spacer. By using this novel design, a panel with a satisfied liquid crystal margin and better cell gap stability can be achieved.

5. Acknowledgements

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De-Jiun Lee received his M.S. degree from bioengineering department of TATUNG University of Taiwan in 1998 and joined Chunghwa Picture Tubes (CPT) in 2004 as a R&D engineer of TV design division of TFT business unit of CPT.

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