Title: LC cell bulging after hot press process

Abstract: A study of LC cell bulging after hot press process is presented. Using the method of observing the cell gap uniformity through a fluorescent light, the mechanism of buldge formation in LC cell is ascertained. Further, several approaches to alleviate the bulge problem are tested to be effective by experiments.

Keywords: cell gap, spacer, bulge, fluorescent light

Symposium Topic: Display manufacturing / Liquid Crystal and other non-emissive displays.

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Technical Summary

1. <u>Background and objectives</u>

Liquid crystal cell gap is an important parameter for various kinds of liquid crystal display modes. To obtain a uniform and desired cell gap is critical in the fabrication of LCD. Bulge of LC cell is a frequently encountered problem after hot press process. This problem seriously deteriorates the uniformity of cell gap. It becomes intolerable especially when display area is near the peripheral sealant, such as LCOS etc. In this paper, a study of the bulge problem is presented. We shall show that the bulge problem of LC cell originates from the elastic deformation of spacers, rather than from the shrinkage of the sealant during temperature change or curing process. Based on this mechanism, several approaches to alleviate the bulge problem are studied experimentally. Experimental results show these approaches are effective, which further confirm the correctness of the proposed mechanism.

This study uses the normal fluorescent light to observe the cell gap uniformity. Comparing with using cell gap measurement instrument, the approach using fluorescent light is proved to be more intuitive and effective in the observing cell gap uniformity. Unlike sunlight or incandescence light, the line spectrum of fluorescent light is very narrow, indicating a longer coherence length, In fact, it is much longer than a normal LCD cell gap. This makes it possible to observe the cell gap uniformity through interference patterns formed by reflected beams from the two LC/glass interfaces. One can judge the cell gap uniformity by observing the number and density of the interference lines.

Though cell gap control can be well done nowadays, however, technologies related to cell gap control, such as the topic in this paper, are not amply discussed in literature.

2. <u>Experiment Results</u>

Fig. 1 shows the bulge problem of LC cell after hot press process. The spacers distributed in this LC cell are polymer spacer with diameter of 6 μm. The size of the whole substrate is 150mm square. The hot press condition is 0.65 kg/cm^2, 150℃. This picture was taken under fluorescent lamp with black background. To improve the clarity of the interference lines, the contrast of the picture has been adjusted.

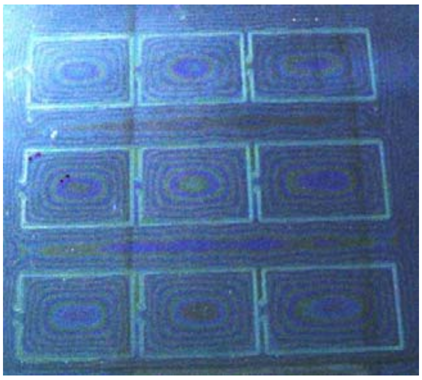


Fig. 1. LC cell without spacer mixed in sealant.

The interference lines clearly show that the cell is severely bulged. There are about 4 blue color interference lines from the sealant to cell center. Assuming the wavelength of blue color is 0.45 μm, according to the principle of interference, we can roughly estimate that the cell gap difference between cell center and peripheral sealant is about $4 \times 0.45/2 = 0.9$ μm. Using cell gap measurement instrument, we measured that the cell gap at the filling mouth is about 5.5 μm. From the distribution of interference lines shown in Fig. 1, we can ascertain that the cell gap at the filling mouth is equal to the cell gap at peripheral sealant. So it can be ascertained that the cell gap at peripheral sealant is smaller than the spacer size (space diameter is 6 μm).

Based on these facts, we can hypothesize the mechanism of the formation of LC cell bulge. Fig. 2 depicts the mechanism.

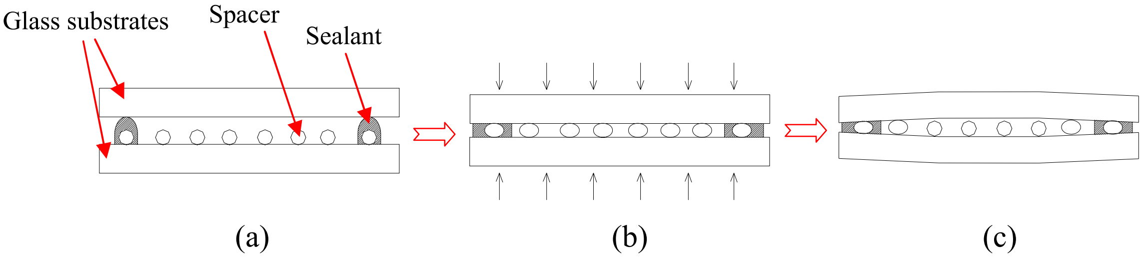


Fig. 2. (a) Before hot press; (b) During hot press; (c) After hot press.

Fig. 2(a) shows the assembled cell before hot press. Because spacers are uniformly dispensed on the whole substrate in the spacer dispensing process, there must be spacers in sealant as well. Fig. 2(b) depicts the situation during hot press process. During hot press process, the spacers are deformed into ellipsoid due to the external pressure. After hot press is completed, the external pressure exerted on substrates release, the spacers distributed in cell center resume their former shape, but the spacers distributed in sealant are prevented to resume to their original shape for the reason that the sealant which had become rigid during hot press process, they are kept in a compressed state. As a result, the cell gap at sealant position is smaller than spacer diameter, and the cell gap is larger than spacer diameter in cell center, which is depicted in Fig. 2(c).

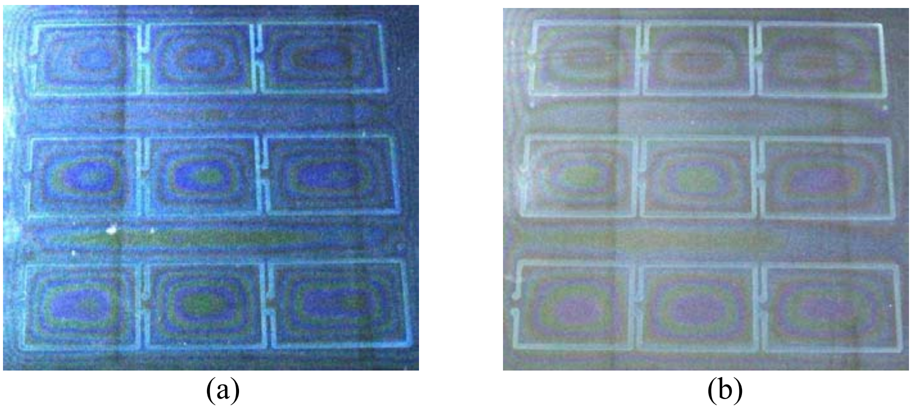
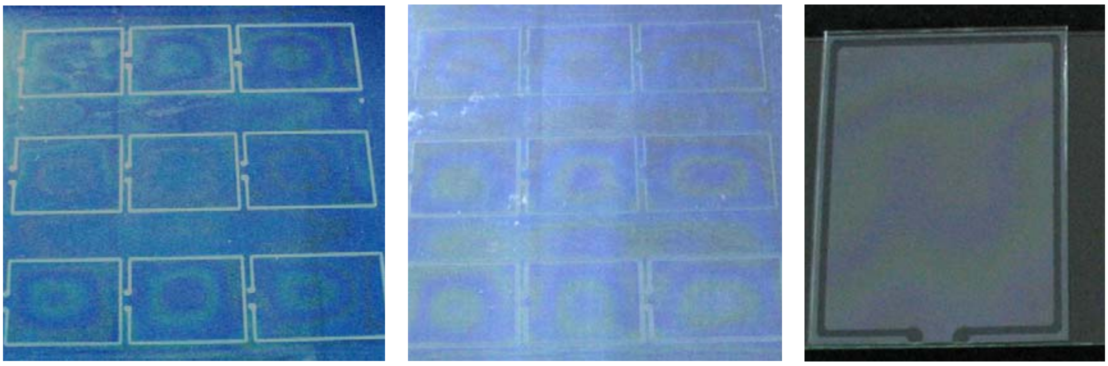


Fig. 3(a) LC cell with 2.5% 6 μm polymer spacer mixed in sealant curing at 150℃; (b) LC cell with 2.5% 6 μm polymer spacer mixed in sealant curing at 100℃.

Based on above assumption, we tried several approaches to alleviate the bulge problem. They are described as follows. (1) Increasing spacer density in sealant by mixing spacer into sealant. This will reduce the deformation of spacer at peripheral sealant due to external pressure. The experiment result is shown in Fig. 3(a), where the spacer mixed into sealant is the same type as the spacer distributed in cell center. The weight concentration is 2.5%. (It should be noted that all the spacers distributed in LC cell in following experiments is polymer material with diameter of 6 μm.) (2) As spacers become softer at high temperature, lower hot press temperature will reduce the deformation of spacers. After the external pressure is released, the cell can be put into oven to fully cure the sealant. In this approach, the temperature cannot be too low, or the sealant cannot lubricate well with substrate, and bubble will be generated between substrate and sealant. Here we reduce the temperature from the standard 150℃to 100℃. The experiment result is shown in Fig. 3(b), it can be seen that there is an improvement in uniformity comparing with Fig. 3(a). (3) If the sealant is mixed with the same size glass fiber spacer, in the same condition of hot press, the cell uniformity would be better than mixing with the same size polymer spacer. This is because the rigidity of glass material is much higher than polymer material. The experiment result is shown in Fig. 4(a). (4) The polymer spacers mixed in sealant is a slightly larger than those distributed in cell. We mixed 2.5% 6.4 μm polymer spacers into sealant. Fig. 4(b) shows the experiment result. (5) UV sealant can cure at room temperature, so the spacer in this case will be more rigid compared to hot press. Fig. 4(c) shows the LC cell using UV curing sealant. Though there is no spacer mixed in sealant. The uniformity of the cell gap is quite good.



(a) (b) (c)

Fig. 4(a) LC cell with 6 μm glass fiber mixed in sealant; (b) LC cell with 6.4 μm polymer spacer mixed in sealant; (c) LC cell using UV curing sealant.

3. Discussion

The above experimental results show that (3), (4) and (5) approaches can greatly improve the cell gap uniformity, while (1) and (2) approaches can also alleviate the bulge problem to some degree. All these approaches have value in practice of fabrication various kinds of LC cell. It is quite natural to think that reducing the external pressure during hot press process should also be an approach to alleviate the bulge problem. In fact, we have tried smaller pressure than 0.65 kg/cm^2, but it is found that too small pressure is not enough to flatten the substrates. As the glass substrates we used are for TN, so they are not as flat as those for STN.

It can be seen that the cell gap is still not perfect even utilizing the approaches of (3), (4) or (5). But in most cases, it is good enough. After filling liquid crystal, the cell gap uniformity will be further improved due to surface tension of liquid crystal [1]. Usually, for LCD mode having high requirements in uniformity and stability of cell gap, such as STN mode, an evenly distributed external force should be exerted on LC cell during end seal process. The absolute cell gap value will be affected by this force [2]. This process will further improve the uniformity and stability of cell gap.

4. Impact

To obtain a uniform and desired cell gap is critical in the fabrication of LCD. Bulge of LC cell is a frequently encountered problem after hot press process. This problem becomes intolerable, especially when the display area is near the sealant, such as LCOS etc. The study presented in this paper analyzed the mechanism of the formation of bulge. Several approaches are proved to be effective in alleviating the bulge problem experimentally. These approaches are practically useful in the fabrication of LC cell in manufacturing and research of LCD. Moreover, the fluorescent light were used in observing cell gap uniformity. This interesting method is proved to be intuitive and effective.

5. Reference

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