Investigation of Dark Spots Occurred in Plastic LCDs.

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Abstract

Plastic LCDs have remarkable advantages as compared to glass LCDs, but there still exist reliability issue.

Regarding the reliability issue of plastic LCDs, we investigated the phenomena of dark spots that often occurred in plastic LCDs.

It was recognized that dark spots are mainly caused by air bubbles that are induced from outside of LCD panel due to cell volume change with external stress and incomplete encapsulation. We have found that cell gap uniformity, spacer density and size and film deformation are important factors influencing dark spot behavior.

In this paper, we discuss the phenomena and origin of dark spots in plastic LCDs

1.Introduction

Plastic LCDs have marked advantages in comparison with common glass LCDs: thinner, lighter, non-breakable and conformable features. Therefore, plastic LCDs have been much studied recently. Currently, plastic STN-LCDs are commercialized as a first product, but it is expected that market will not be rapidly expanded because of low production yield due to reliability problem.

In general, plastic LCDs are easily deformed and distorted by thermal and mechanical stress, the deformation of which result in air bubble injection into LC cell. The air bubbles appear as dark spots[1~3].

The dark spot issue has been a well-known problem in plastic LCDs, but there has not been a report where dark spot was deeply analyzed. We often experienced the occurrence of dark spot during the plastic LCD panel fabrication process. The figure 1 shows a typical example for that.

It is thought that air bubbles are induced from outside of LCD panel due to cell volume change with thermal and mechanical stress in case of incomplete encapsulation.

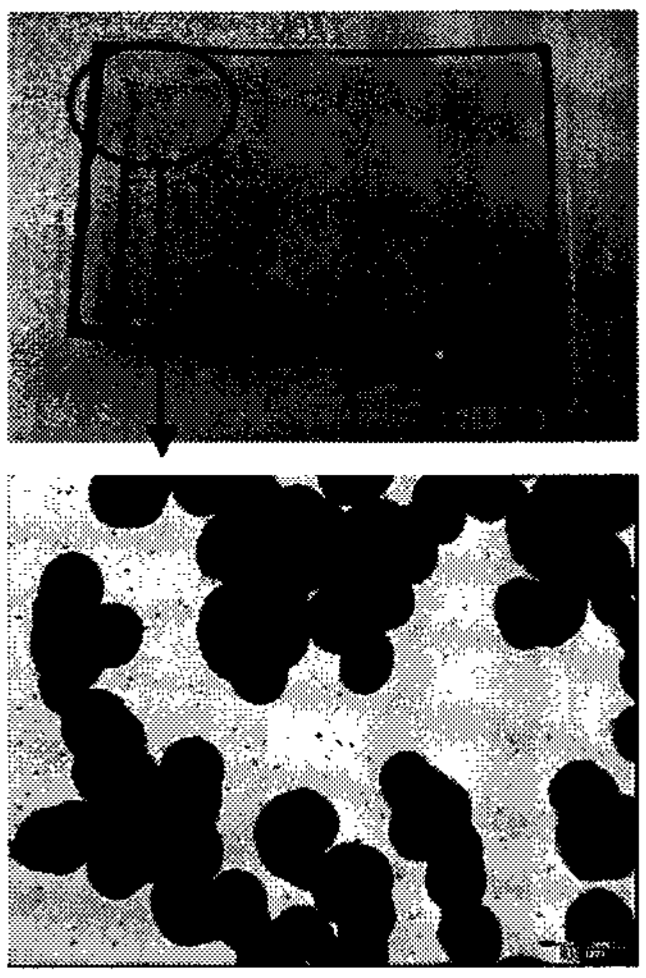


Figure 1. An example of dark spot generated due to mechanical stress

In order to avoid air bubble occurrence in plastic LCDs, it is necessary to reduce the rate of volume change due to external stress. We supposed that the parameters related to the rate of volume change due to external stress were cell gap, end seal pressure, substrate annealing treatment and spacer distribution.

In this paper, we investigated in detail the parameter dependence on dark spots occurrence.

2. Experimental

We carried out experiments by use of various materials. The substrate was 120㎛ thickness polyethersulfone (PES) film with ITO (Indium Thin Oxide). A sealant was dispensed on one substrate, while spacers with size of 3.5㎛ and 5㎛ were sprayed onto the other substrate. Liquid crystals were injected into the cells and then polarizers were adhered to the cells to complete panels.

The thermal stress to plastic LC cells was induced by change of ambient temperature of the cells as follows: three cycles of sequential thermal stress at 70℃ for 30 min, RT for 15min and -15℃ for 30min respectively. The mechanical stress was induced by strong detachment of polarizer.

In case of that the parameters were not optimized relevant to cell volume change rate, we observed that dark spots occurred in many cells.

3. Results and discussion

The parameter dependence of dark spots occurrence are described one by one below. The pressure to LC cells in end seal process was set to be proportional to spacer density so that the force applied to unit spacer was the same.

3.1. The cell gap dependence of dark spot

The plastic film cell volume was changed by thermal stress. Figure 2. shows how dark spots were proceeding with time for different spacer sizes after thermal stress was applied to LC cells.

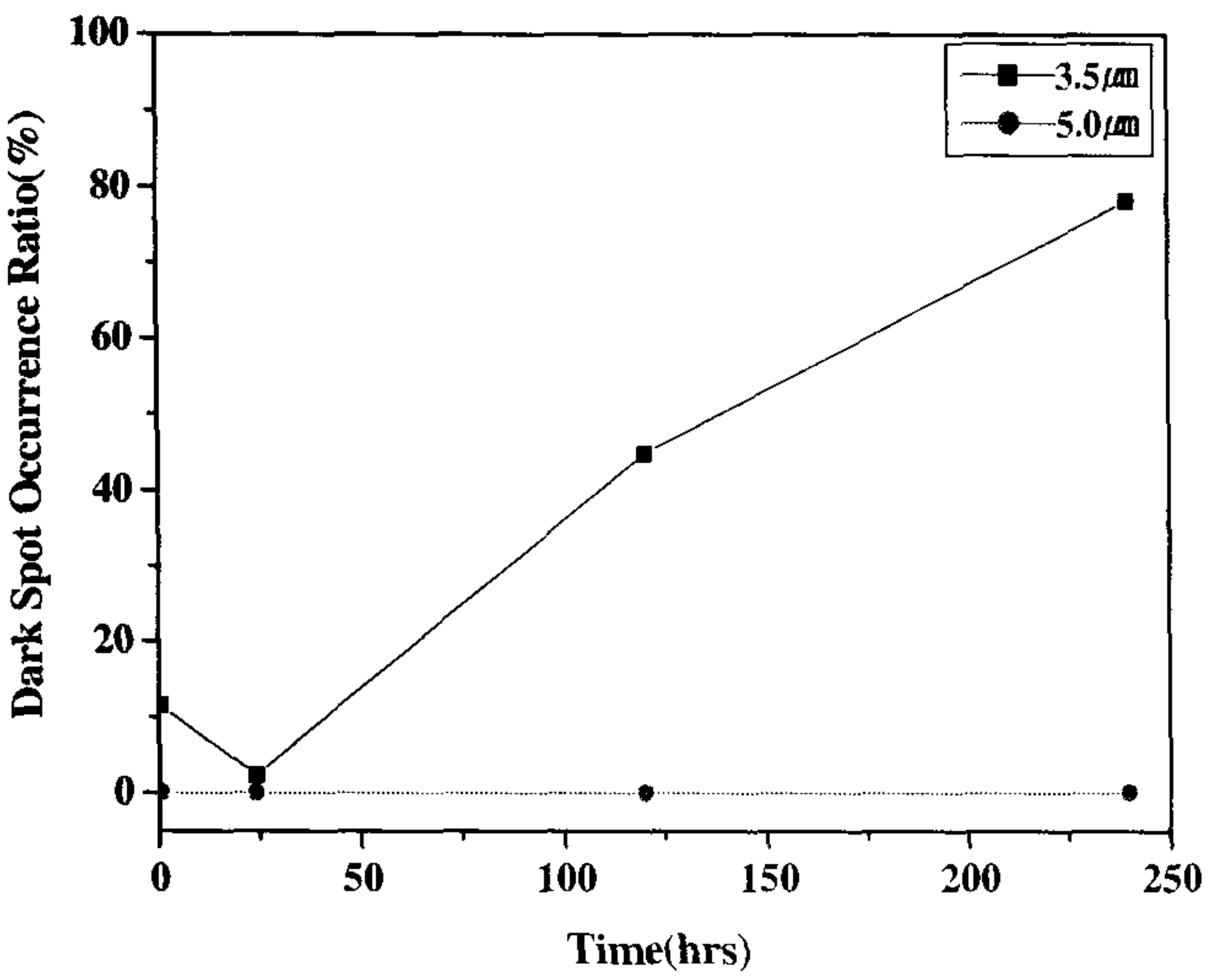


Figure 2. The spacer size dependence on dark spot

Dark spots appeared in case of 3.5㎛ cell gap, but not in case of 5.0㎛ cell gap. In case of 3.5㎛ cell gap, dark spots slowly decreased for 25 hours at room temperature. It is inferred that the volume change of 3.5㎛ cell decreased for some time after the thermal stress and dark spots disappeared gradually.

Dark spots in 3.5㎛ cell increased with time after 25 hours. It means that volume change due to deformation of LC cells increased after 25 hours. We think that the deformation LC cells were induced by the deformations of polarizers and substrate.

The volume change in 5.0㎛ cells might be the same as that in 3.5㎛ cells. The reason why dark spots in 5.0㎛ cells did not occur even for the same volume change as that in 3.5㎛ cells is understood by the difference of volume change between two cells.

These results imply that in order to avoid dark spot occurrence in plastic LCDs, cell gap should be chosen large enough for small volume change rate.

3. 2. Spacer density dependence of dark spot

In this experiment, we investigated dark spot occurrence behavior with variance of spacer density in plastic LC cells.

Figure 3. shows how dark spots were proceeding with time for different spacer density after thermal stress was applied to LC cells.

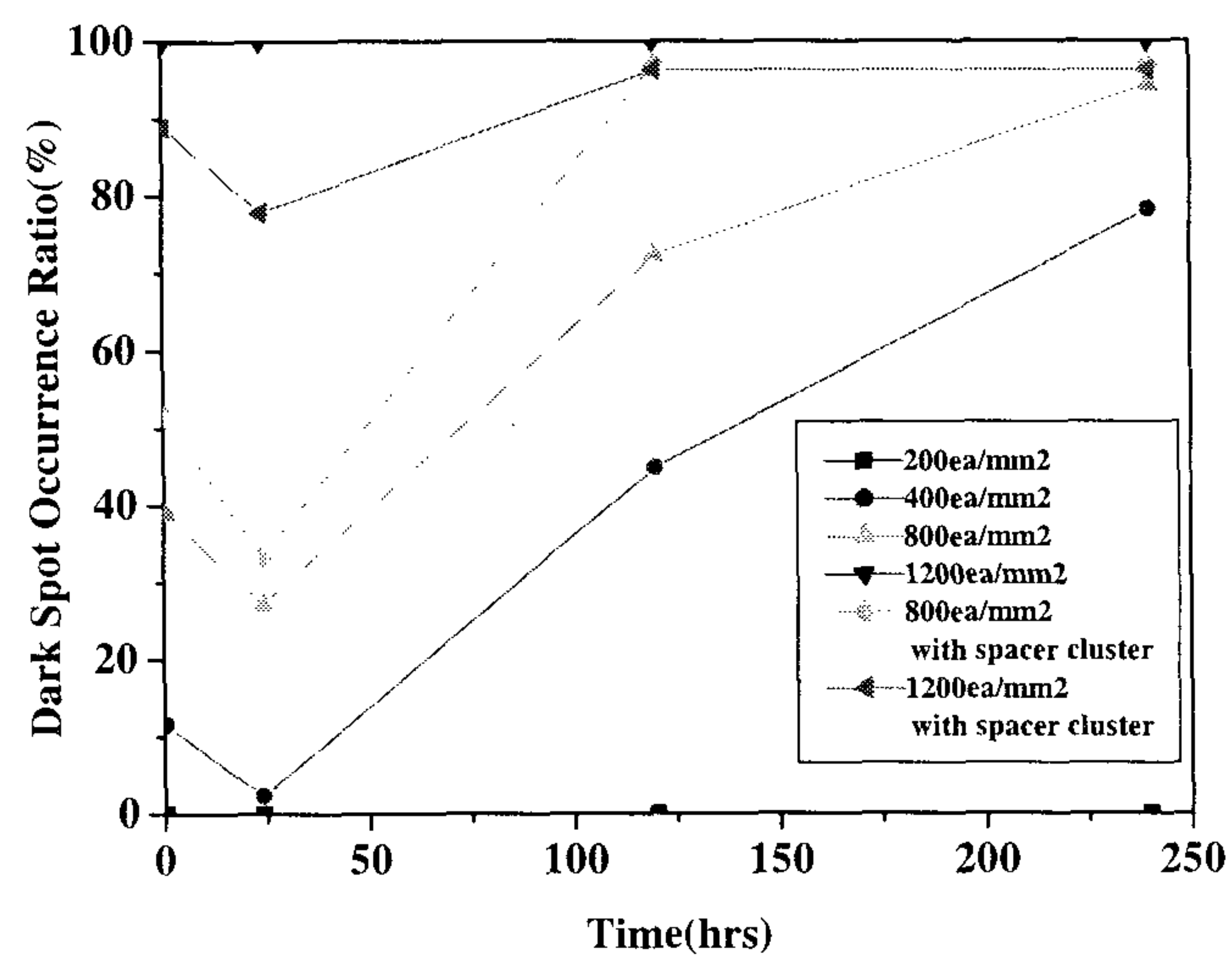


Figure 3. The dependence of spacer density for dark spot(spacer size: 3.5㎛).

As shown in Figure 3, dark spots increased as spacer density increased in the cells. Also, dark spots easily occurred in the cells with spacer clusters, which were often formed in non-uniform spray process of spacers.

Figure 4 shows dark spots appeared in LC cells with different spacer densities. As shown in Figure 4, dark spots occurred in the cells with spacer densities of 400ea/mm^2, 800ea/mm^2 and 1200ea/mm^2, but did not occur in case of 200ea/mm^2.

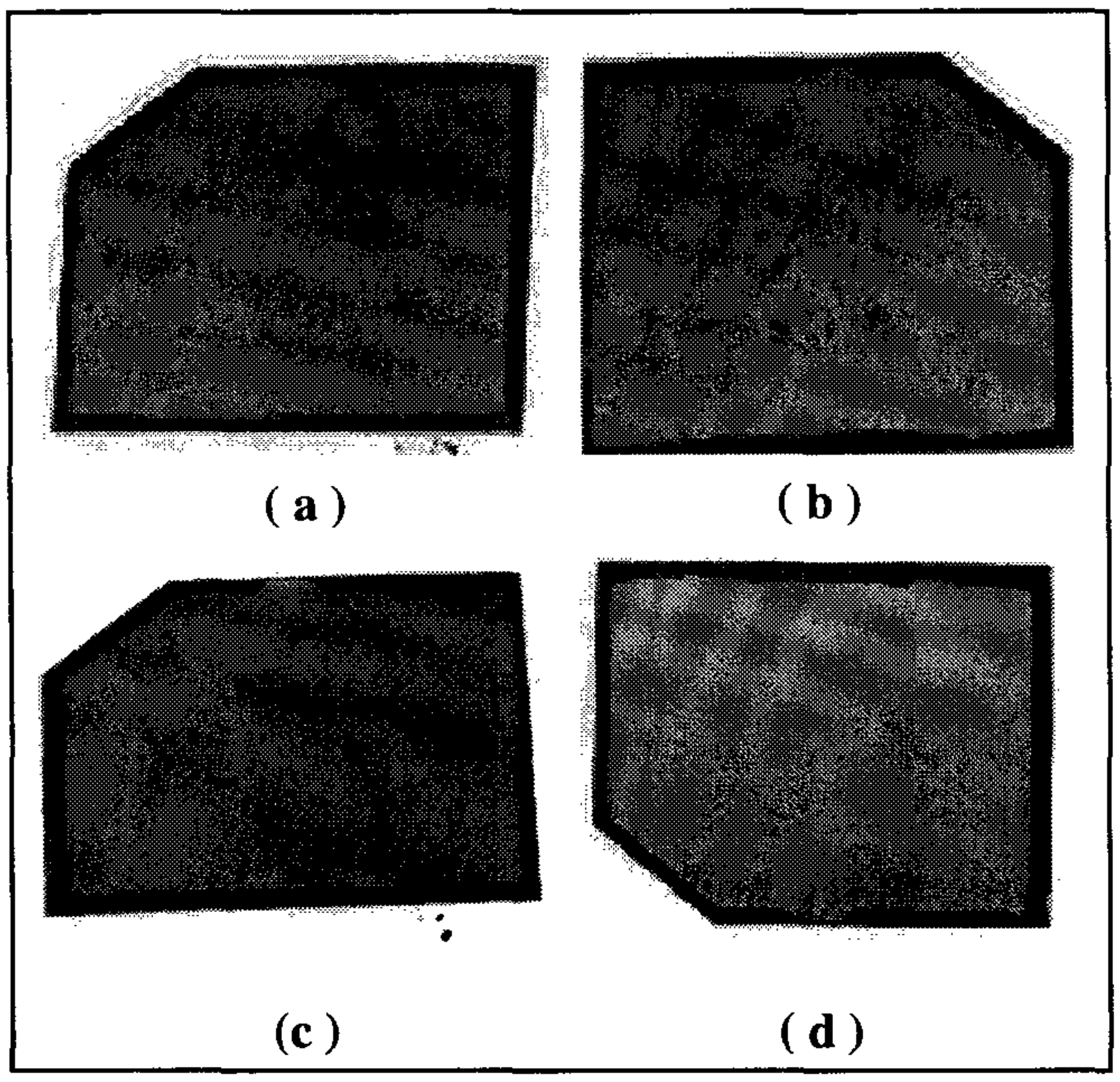


Figure 4. Plastic LC cells with and without dark spot dependent on spacer density; (a) 1200ea/mm^2 (b) 800ea/mm^2 (c) 400ea/mm^2 (d) 200ea/mm^2

In order to make uniform cell gap in the plastic cells, the pressure to LC cells in end seal process should be proportional to spacer density. Therefore, the pressure to LC cells is higher in high spacer density cells than in low spacer density cells.

The reason why dark spots occurred as many as high spacer density cells can be understood by volume expansion degree after end-seal process. After end-seal process, cells naturally expand due to the relaxation of spacers from pressed state. The expansion of cells influence dark spot occurrence.

As the results, low spacer density in LC cells is preferred to prevent dark spots in plastic LCDs. If spacer density is however too low, it is difficult to uniform cell gap. Therefore, we should fined optimum spacer density for preventing dark spots and cell gap uniformity.

In addition, regular distribution of spacer for spacer cluster free is important to prevent dark spots. The electro-static charge generation should be controlled during spacer spray process in plastic LCDs because spacer clusters are easily formed in presence of electro-static charge in LC cells.

3. 3. Substrate annealing dependence of dark spot

It is necessary to control the thermal expansion of plastic substrate by thermal stress to reduce dark spots occurrence. In order to reduce the thermal expansion degree of plastic substrates we treated annealing of the substrates.

In this experiment, PES film substrates were annealed at 180℃ for 12 hours under the convection oven and we investigated dark spot occurrence in the LC cells fabricated with the substrates.

Figure 5 shows the results.

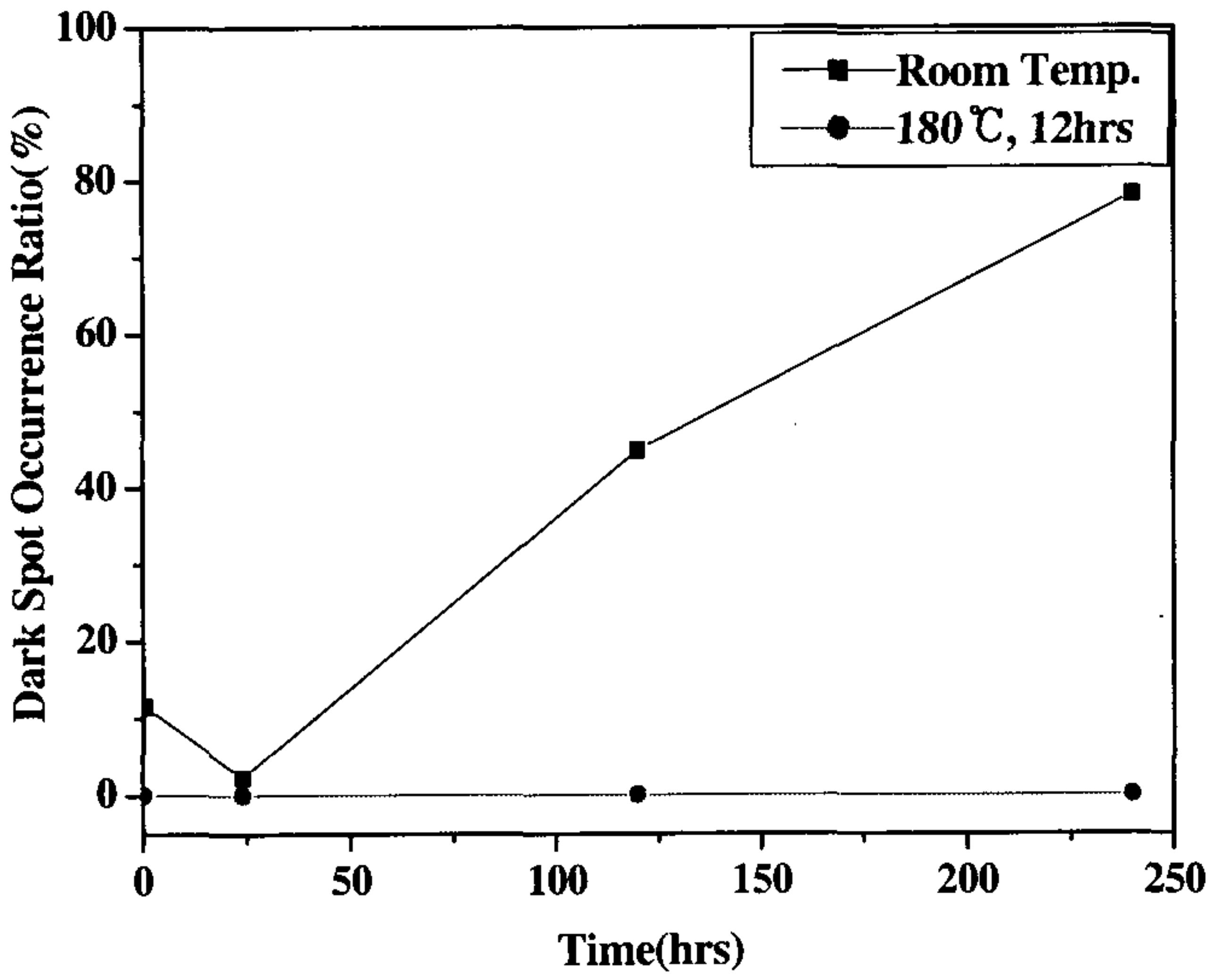


Figure 5 The dependence of annealing effect for dark spot.

As shown in Figure 5, dark spots did not occur in the annealed cells. These results imply that substrate annealing treatment reduced thermal expansion of LC cells that resulted in reducing dark spots.

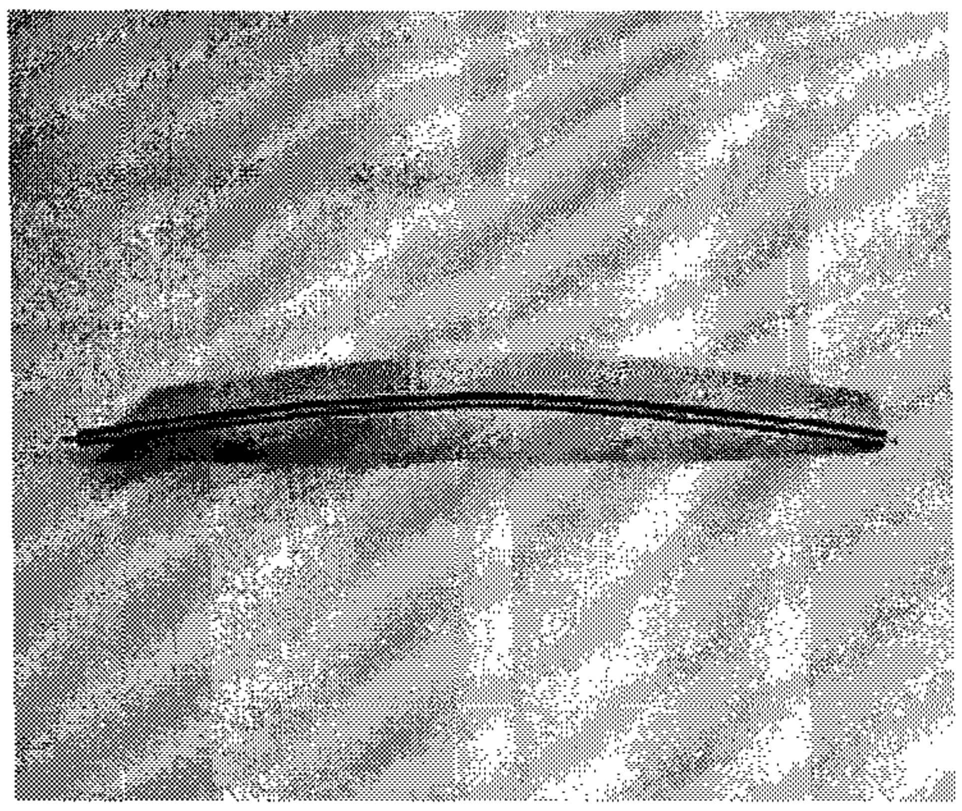
3.4. Polarizer dependence of dark spot

It is well known that commercially available polarizers have high thermal expansion property. The thermal expansion of the polarizers is a main factor related to the dark spot occurrence in plastic LCDs.

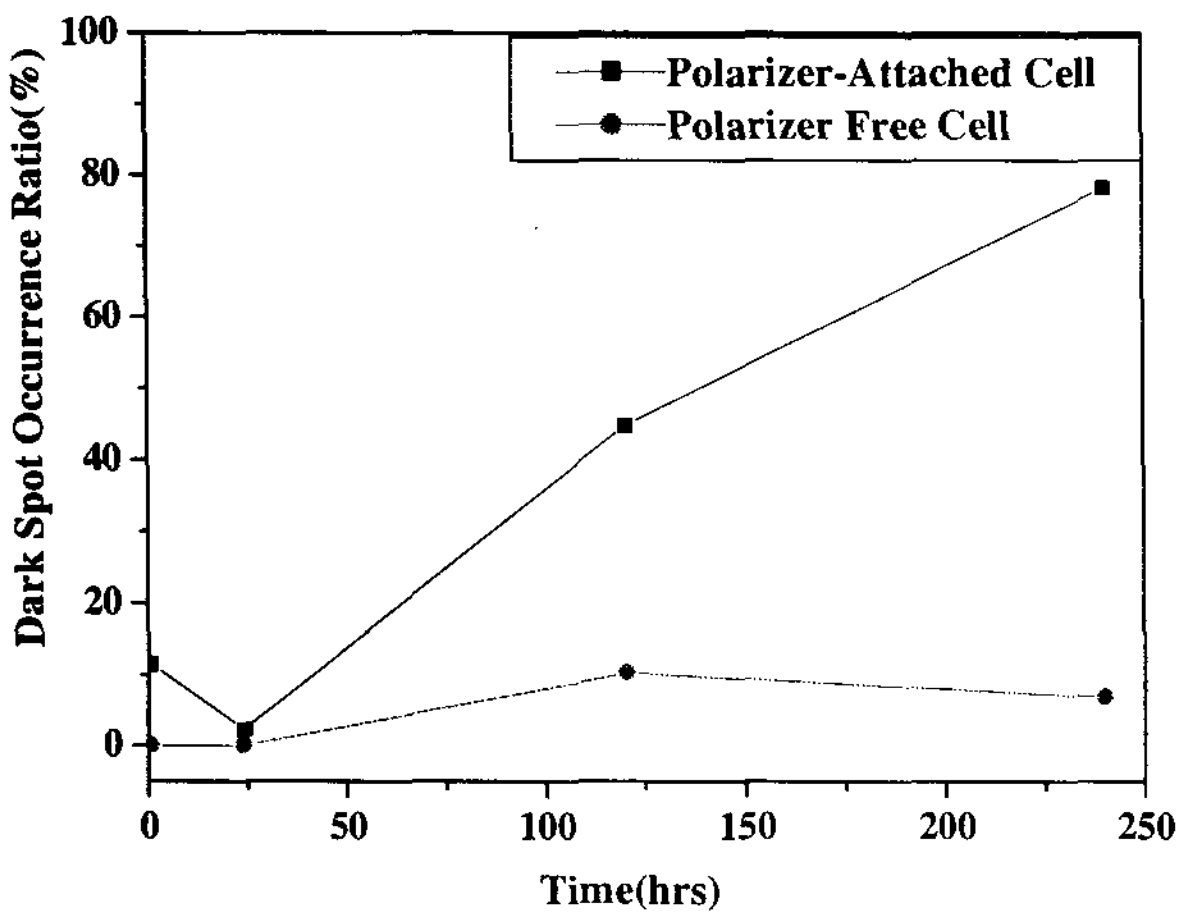
In this experiment, we investigated polarizer dependence of dark spots in the plastic LC cells. We made LC cells with and without polarizers.

Figure 6 (a) shows the deformation of LC cells with polarizers. Figure 6 (b) shows the dark spots occurrence in the LC cells depending on the presence polarizers. It is shown that the dark spots occurrence ratio was higher in polarizer-attached cells than in polarizer-free cells.

It is thought that the thermal deformation of polarizers influenced dark spot generation in plastic LCDs.



(a)



(b)

Figure 6. Dark spot occurrence depending on the presence of polarizers.

4. Conclusion

We investigated the phenomena and origin of dark spots in plastic LCDs with parameters such as cell gap, spacer density, substrate annealing treatment and polarizer.

We obtained the parameter dependence of dark spots as follow:

1) Dark spots occurred in LC cells with 3.5㎛ cell gap but not in LC cells with 5.0㎛ cell gap.

2) Dark spots occurrence ratio decreased as spacer density decreased in the range of 200ea/mm^2 to 800ea/mm^2.

3) The annealing treatment of plastic substrate is effective to reduced dark spots.

4) The deformation of polarizer is a main factor to generate dark spots.

5. Acknowledgements

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6. References

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