LARGE AREA MICRO-ENCAPSULATED REFLECTIVE GUEST-HOST LCDS AND THEIR APPLICATIONS

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Abstract

We have developed large area micro-encapsulated reflective monochrome guest-host LCDs. Easy fabrication process based on screen-printing has realized A5-size LCD, with good uniformity and high image quality, suitable for electronic book applications.

Introduction

We have been developing micro-encapsulated guest-host liquid crystals (LCs) [1)~3)] to realize tri-layered reflective displays[4)], which is the most promising structure for reflective color LCDs. Micro-encapsulated LCs offer the advantages of easy printing by various methods and solidification after heating. These advantages apply to even single-layer LC cell structures.

Our objective is to develop a new LC cell structure using monochrome guest-host micro-encapsulated LCs. Screen-printing of the micro-capsules on large area substrates and adhesion of thinner counter film substrate are the main fabrication processes.

We have developed thin and light A5-size LC panels. These features are the most suitable for portable applications such as electronic books (e-books).

Micro-encapsulated LC

Principle of coloring

Our developed microcapsules include guest-host LCs which consist of host LCs and guest dichroic dyes solved in the LCs. The absorbance of dichroic dyes depends on their direction. Host LC motion by electric field changes the directions of the dyes in each capsule. As a result, the absorbance can be controlled electrically.

Fabrication Process

Micro-encapsulated LCs were fabricated using a film emulsification method. Mixtures consisting of nematic LCs, dichroic dyes, monomers, cross-linking materials and initiators, were extruded through micro-pores into water. The emulsion was heated to polymerize the very thin shells of capsules. The ratio of LCs was about 90wt.%. Figure 1 shows the fabricated micro-encapsulated LCs dispersed in water. The diameter is about 10 microns.

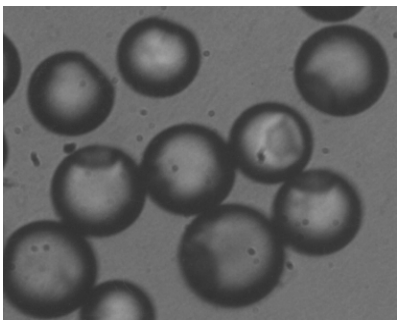

Figure 1 Photograph of dispersed micro-encapsulated LCs.

To reduce the optical scattering which is mainly caused by the mismatch of refractive index between the neighboring capsules, lower refractive anisotropic LCs (Δn~0.07) were used.

Results

Cell structure and fabrication process

Figure 2 shows the schematic view of the newly developed micro-encapsulated LC cell.

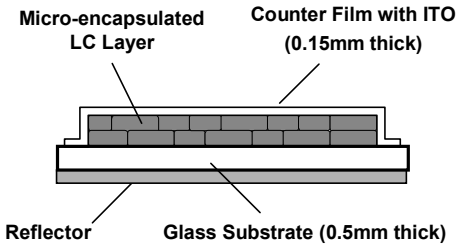

Figure 2 Schematic view of LC cell structure.

Micro-encapsulated LC was screen-printed on a thin substrate. After heating evaporated the dispersion media, the LC layer became solid-like. Therefore, thin film substrate with ITO electrode could be attached to LC layers by pressing. Finally the periphery of the counter film was sealed. Figure 3 shows the fabrication processes.

The thickness of LC layer is about 8 microns. Figure 4 shows the top view of the screen-printed micro-encapsulated LC layer. The shape of each capsule changes flatly. It shows that the layer is filled up with capsules uniformly with no dead-space.

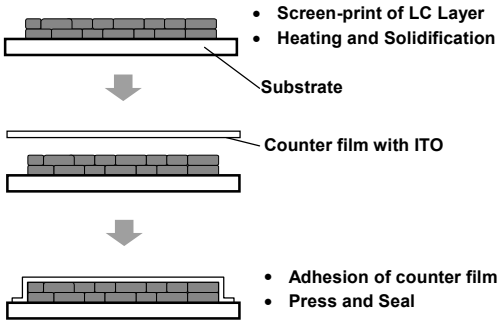

Figure 3 Fabrication process of new LC cell structure.

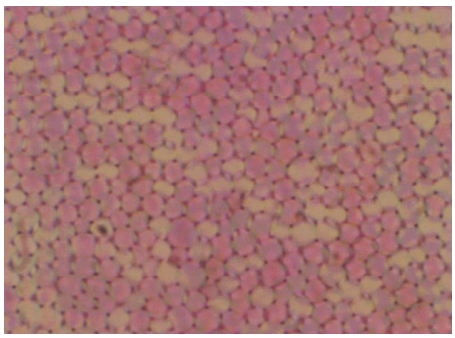

Figure 4 Photograph of screen-printed micro-encapsulated LC.

Our newly developed structure consists of a glass substrate and a thin film, whereas the conventional LC cell structure consists of two glass substrates. Therefore, the weight and thickness can be about half those of the conventional structure. As micro-encapsulated LCs can be printed on other materials besides glass substrate, flexible LC cell structure can be realized using two flexible film substrates.

Pressure sensitivity

In this cell structure, micro-encapsulated LC layer must withstand the pressure by itself because there are no spacers. We estimated the pressure sensitivity that would degrade the LC performance. Figure 5 shows the measurement method.[5)] Pressure is applied with a cylinder whose diameter is 8mm.

After release of the pressure, the LC cell was driven to white state and the difference of reflectance between the pressed points and their surroundings was measured. Figure 6 shows the ratio of reflectance change. The stronger the pressure is, the greater is the ratio. It was found that the change of reflectance disappeared after a few hours. This change and recovery are thought to be caused by the deformation of microcapsules because the inner LC alignments strongly depend on the shape of the capsules.

It is considered that this LC cell structure can withstand the pressures to which it would be subject in actual use.

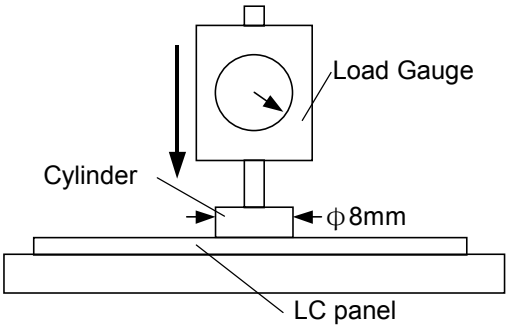

Figure 5 Schematic view of pressure test.

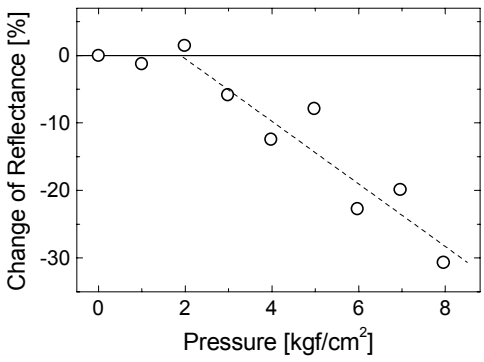

Figure 6 Ratio of reflectance change by pressure.

Display performance

Some anthraquinone dichroic dyes, which have high dichroic ratio of about 10, are mixed to realize black color. Anthraquinone dyes are highly reliable compared to azo dyes. Figure 7 shows a spectrum of micro-encapsulated LC with mixed black dyes. Broad absorbance over the entire visible wavelength is realized.

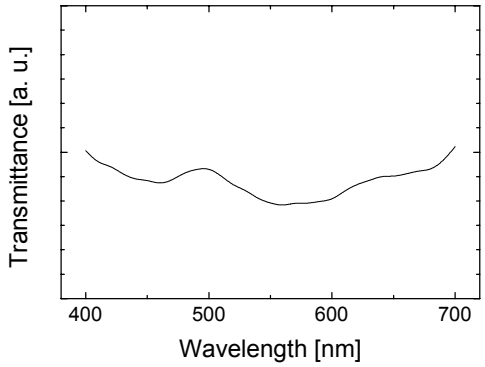

Figure 7 Spectrum of black/white micro-encapsulated LC.

Figure 8 shows the transmittance-applied voltage characteristics. This curve is not saturated even at high voltage. However, the dichroic ratio is more than 3.0 when applied voltage is over 20V.

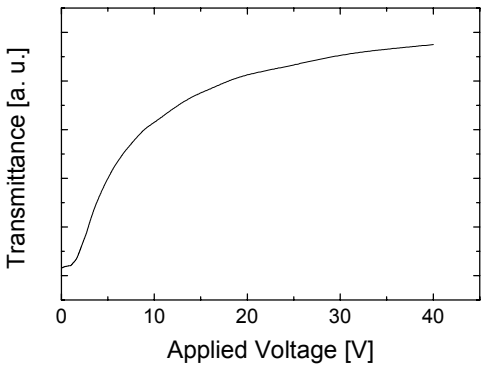

Figure 8 Transmittance-applied voltage characteristics.

As a result of recent developments, the surface roughness of printed micro-encapsulated LC layer has been reduced. The contact between the counter film and the LC layer has been improved. As a result, the driving voltage has been reduced by half.

The uniformity of reflectance in A5-size display area was measured. In the transparent state, the variation is less than ±6%. Good uniformity is realized.

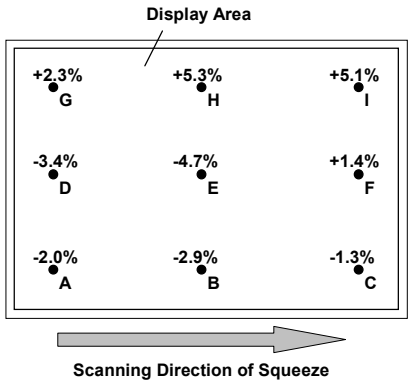

Figure 9 Reflectance variation of a display area.

Blur image was almost eliminated due to the effect of lower refractive anisotropy in LC and the control of the capsule diameter. It was found that micro-encapsulated LC can be applied even to high-definition displays.

Electronic book application

Figure 10 shows a mock-up of an electronic book (e-book) with A5-size black/white micro-encapsulated reflective LC displays which are segment type with fixed image. In an e-book, two display surfaces[6] and thinness are desirable. Our newly developed displays are suitable for e-books because of their thinness, light weight and high image quality.

Conclusion

We have developed large area reflective LCDs with micro-encapsulated LCs for the first time. Good black color was realized by highly reliable anthraquinone dichroic dyes. Easy fabrication processes which consist of LC ink printing and counter film substrate adhesion have realized thinner and lighter cell structure. As a result, we have realized high image quality reflective display with uniformity. Moreover, it has been confirmed that the display is tolerant of the pressures to which it would be subject in actual use.

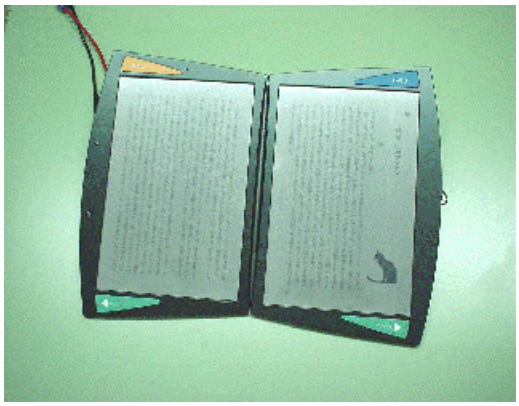

Figure 10 Electronic book mock-up with developed micro-encapsulated LC displays.

Acknowledgment

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