

Development of Ch-LC microencapsulated flexible displays with reduced driving voltage and much simplified manufacturing process

Seung-Gon Kang^{1,3}, Hyo-Taek Jang¹, You-Jin Lee², and Jae-Hoon Kim^{1,2}

¹Department of Electronics and Computer Engineering, Hanyang University, Seoul 133-791, Korea

²Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea

³Image Lab Corp., R&D Center, Room 909, Woolim Lion's Valley, 311-3, Sangdaewon-Dong, Joongwon-Gu, Sungnam-Si, Gyeonggi-Do, 462-120, Korea

¹jhoon@hanyang.ac.kr

ABSTRACT

We developed a novel Ch-LC microencapsulated flexible display with the characteristics of the reduced driving voltage and much simplified manufacturing process. The driving voltage of Ch-LC microencapsulated displays was drastically reduced by adopting the following two principal ways: 1) lowering the anchoring energy between liquid crystals and shell polymers, 2) optimizing the size of LC microcapsules and thickness of LC microcapsule-coated layer. And the fabrication processes was greatly simplified by taking advantage of both coating method using a bar coater and direct printing of opposite electrode using a screen print.

1. INTRODUCTION

There have been a number of investigations on the manufacture of reflection-type flexible displays using cholesteric liquid crystals. Generally, they can be classified into two categories like polymer-dispersed Ch-LCs (PDCLCs) [1] and polymer-stabilized Ch-LCs (PSCLCs) [2, 3]. Although both types have similar nature of confining liquid crystal molecules in a polymeric binder or network in the order of micrometer to sub micrometer size, these complex microconfined liquid crystals are somewhat different in the detailed geometry and surface-induced ordering. While the liquid crystal molecules in PDCLCs are usually confined in spherical droplets dispersed in the matrix, those of PSCLCs are submerged in the cross-linked network of polymer matrix. Due to these differences in the geometry, the surface-induced ordering of LC molecules in PDCLCs are readily configurable to

bipolar, radial, and axial symmetries, whereas those of PSCLCs do not exhibit such configurations induced by the interfacial interaction between LCs and surrounding polymers. Furthermore, PDCLCs are divided into three sub categories like emulsion-type, encapsulation-type, and phase separation-type. With thorough comparison on the cons and pros of every flexible display manufacturing methods using Ch-LCs mentioned above, we have finally selected a microencapsulation one since it has the following distinct features: 1) good compatibility with roll-to-roll process, 2) applicability to e-paper due to both good outdoor visibility and low power consumption, and 3) color capability.

In order to fulfill the development of flexible displays using Ch-LC microencapsulation with reduced driving voltage and much simplified manufacturing process, we invented a novel microencapsulation technology optimized for Ch-LCs, a simple coacervation [4] and membrane emulsification [5], and adopted a coating method of Ch-LC microcapsules using a bar coater. In this paper, the results of Ch-LC microencapsulation and EO performances of Ch-LC microencapsulated flexible displays will be reported.

2. EXPERIMENTAL

Fig. 1 shows the microscopic images of Ch-LC microcapsules fabricated with a simple coacervation and membrane emulsification, where (a), (b) and (c) are red, green, blue Ch-LC microcapsules respectively. As can be seen from the figure, the size distribution of each Ch-LC microcapsule is very narrow, exhibiting quite good

size uniformity. In order to fabricate the LC microcapsules with a narrow size distribution, we have developed a novel microencapsulation method, a simple coacervation using PVA polymer and membrane emulsification method. The overall size distribution of R, G, B Ch-LC microcapsules is $8.0 \pm 2.0 \text{ } \mu\text{m}$, even though there are some slight differences with respect to the R, G, B Ch-LCs.

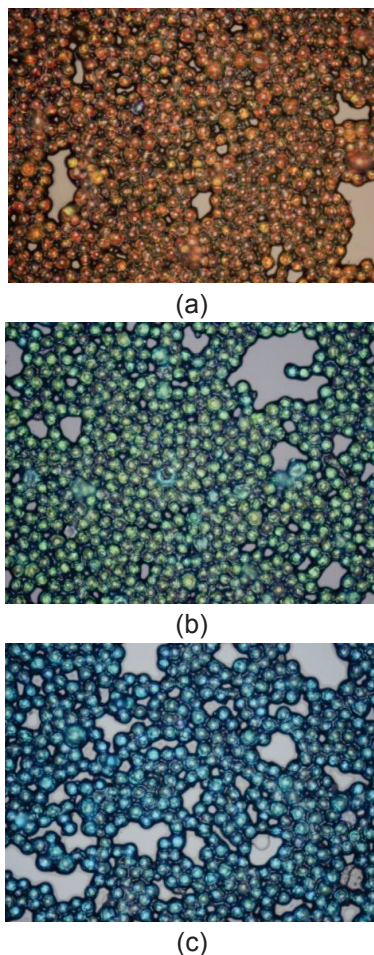


Figure 1. Microscopic images of Ch-LC microcapsules fabricated with a simple coacervation and membrane emulsification, (a), (b) and (c) are red, green, blue Ch-LC microcapsules, respectively.

After finishing the fabrication of LC microcapsules, they should be converted to a coating solution in order for them to be coated on a substrate. The coating solution of Ch-LC microcapsules is prepared by mixing the microcapsules with a binder with an appropriate ratio. In our case, we used PVP (Aldrich) as a binder since it shows the similar property of refractive index with the shell polymer, PVA, and has the good insulation characteristic as well.

Fig. 2 shows the overall construction of our prototype samples, consisting of three layers such as LC microcapsule, insulation, and opposite electrode. As for the printing process, first of all, the coating solution is coated on a flexible substrate of ITO PET using a conventional bar coater. Then the coated LC microcapsule layer is cured in an oven with a view to dry the remaining aqueous solvent all. Secondly, an insulation layer is coated over the LC microcapsule layer using an applicator, in order to prevent any possible short circuit between ITO and carbon black. Finally, the opposite electrode of carbon black is directly printed with a screen printer over the insulation layer. We chose the carbon black as the opposite electrode because it is well compatible with the printing process and has good light absorbing property, which is very important characteristic to get better contrast ratio in the cholesteric LCDs.

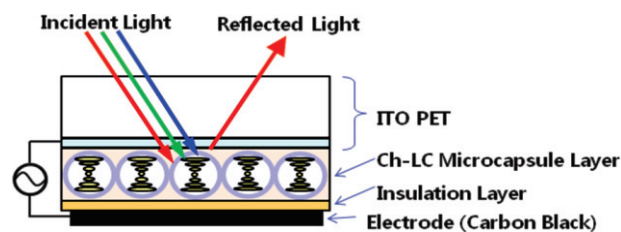


Figure 2. Construction of monochromatic Ch-LC microencapsulated flexible displays

3. RESULT

Fig. 3 shows the prototypes of our monochromatic flexible displays using R, G, B Ch-LC microcapsules, where (a), (b), and (c) are red, green, and blue Ch-LC flexible displays, respectively. As can be seen clearly from the photos, the segment-type flexible displays with adopting three different R, G, B colors of Ch-LC microcapsules exhibit their inherent reflection colors with better contrast ratio due to the advantage of direct printing of carbon black electrode over the Ch-LC microcapsule layer.

In order to achieve the reduced driving voltage in the Ch-LC microencapsulated flexible displays, we have tried our best to fabricate as uniform LC microcapsuled as possible taking advantage of both a simple coacervation and membrane emulsification method. The uniform size distribution of LC microcapsules in the microencapsulated displays plays a very crucial

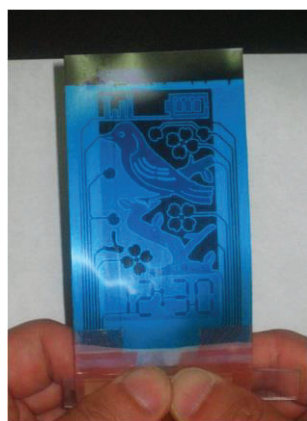
role in the EO performance of hysteresis-free and reproducibility. Due to these reasons, the narrower the size distribution of LC microcapsules is, the better the EO performances of LC microencapsulated displays are achieved. It can also contribute to the reduction of driving voltage in the Ch-LC microencapsulated displays.



(a)



(b)



(c)

Figure 3. Photos of three prototypes for segment-type Ch-LC microencapsulated flexible

displays: (a), (b), and (c) correspond to that of red, green, blue Ch-LC microcapsules, respectively

4. CONCLUSIONS

Through optimizing the size of Ch-LC microcapsules and the thickness of coated microcapsule layer, as well as introducing the surfactant in the fabrication of LC microcapsules which plays a role of reducing the surface tension between LC molecules and polymeric shells, we can drastically reduce the driving voltage of Ch-LC microencapsulated flexible displays from 70 V to about 40 V. Also we have simplified the overall manufacturing processes by adopting a bar coater for LC microcapsules and a screen print for opposite electrode. The resultant Ch-LC microencapsulated flexible displays with reduced driving voltage and much simplified manufacturing process can possibly be adapted to the applications of ESL (electronic shelf label), e-skin or a small size e-paper display.

REFERENCES

- [1] P. P. Crooker and D. K. Yang, "Polymer-dispersed chiral liquid crystal color display," *Appl. Phys. Lett.*, **57**, 2529 (1990).
- [2] H. S. Kitzerow, B. Liu, F. Wu, and P. P. Crooker, "Effect of chirality on liquid crystals in capillary tubes with parallel and perpendicular anchoring," *Phys. Rev. E* **54**, 568 (1996).
- [3] I. Dierking, L. L. Kosbar, A. C. Lowe, and G. A. Held, "Polymer network structure and electro-optic performance of polymer stabilized cholesteric textures - I. The influence of curing temperature," *Liq. Cryst.* **24**, 387 (1998).
- [4] N. Agnihotri, R. Mishra, C. Goda, and M. Arora. "Microencapsulation – A Novel Approach in Drug Delivery: A Review," *Indo Global J. Pharm. Sci.*, **2**(1), 1 (2012).
- [5] H. Yuyama, T. Watanabe, G. H. Ma, M. Nagai, and S. Omi, "Preparation and analysis of uniform emulsion droplets using SPG membrane emulsification technique," *Colloids and Surfaces*, **168**, 159 (2000).