A Study of Digital Paper with Guest-Host type Liquid Crystal Medium

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Abstract

"Digital Paper" was recently proposed as a new medium that offers the advantages of both softcopy and hardcopy. This study examines the possibility of surface electric charge driving a liquid crystal medium using an ion projection head for realizing Digital Paper.

A guest-host type liquid crystal sheet medium was prepared. An ion projection head with charge dot density of 300 dpi was used for surface charge formation.

It was confirmed that white images could be repeatedly formed on a black background by ion projection followed by image erasure to the black background by heating. It is demonstrated that this sheet medium has ideal characteristics; it reproduces the viewing angle and flexibility of paper. This method is thus promising as a candidate for realizing Digital Paper.

Introduction

Visual Display Terminals such as CRTs, LC (Liquid Crystal) Displays, and Plasma Displays are very popular and often used in daily life. These softcopy devices have important advantages in terms of digital information handling and rewritability, but they are handicapped in terms of awkward physical form and poor support when reading large volumes of material. Hardcopy is still recommended if we want to read a lot or want to carry the information around. The concept of Digital Paper[1] was recently proposed as an ideal medium that combines the advantages of softcopy and hardcopy. Various methods have been proposed as candidate technologies for Digital Paper. This study examines the possibility of driving a liquid crystal medium by using an ion projection head that establishes surface electric charge[2,3] as one way of realizing Digital Paper.

Liquid Crystal Sheet

We prepared a guest-host type liquid crystal medium combining dichroic dye held in Smectic A LC droplets in polymer binder.[4,5] Changing the array direction of the liquid crystal molecules controls the light transmission of the medium by controlling the electric field across the medium; the light absorption characteristics of the dichroic dye varies with its molecular direction, which follows that of the liquid crystal molecules. The substrate of the medium sheet is a PET film (188µm thick) with evaporated ITO electrodes. The 6µm thick guest-host type liquid crystal layer was formed on the base PET film. The protecting layer is a 2µm thick layer of UV curable type resin. We prepared, in total, 4 types of medium: two types of LC materials (A and B) and two ratios of LC to polymer binder (40/60 and 50/50 by volume). The size of each test sheet was 200mm×300mm.

Experimental Method

We tested surface electric charge driving of the LC sheet using the apparatus illustrated in Fig.1. The test sheet medium on the stage receives controlled ion flow from the ion projection head[6,7] set above the stage. The stage speeds examined were 1.0 and 2.5mm/sec. Negative corona ions were projected from the head to form surface electric charge patterns on the sheet. The density of the surface charge dot images was 300 dpi since the ion projection head resolution was 300 dpi. The surface electric potential of the medium was measured just after the imaging process by using a surface potential meter in order to confirm the surface electric potential needed to form images on the sheet.

We measured the optical density of image and non-image areas by using an optical densitometer and calculated the contrast ratios.

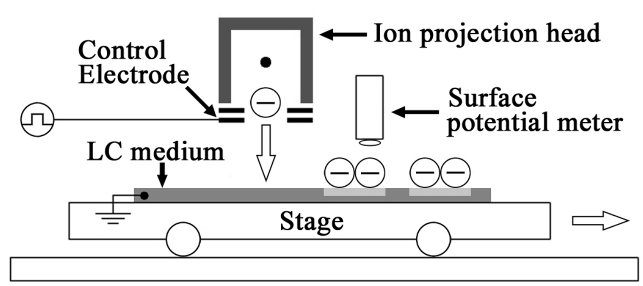

Figure 1. Illustration of imaging process.

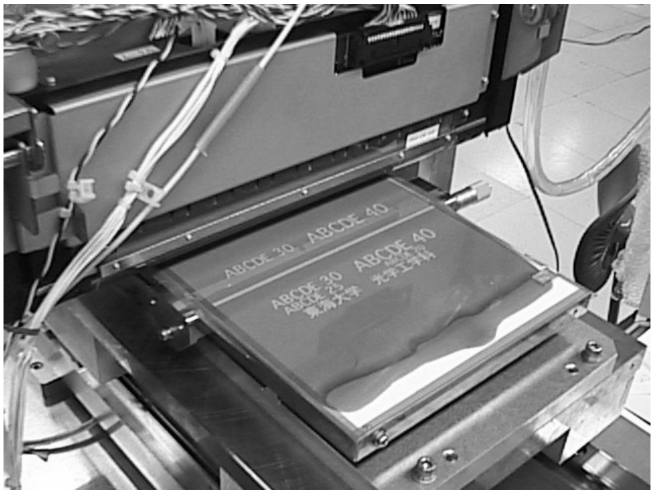

Figure 2. Experimental apparatus for image formation.

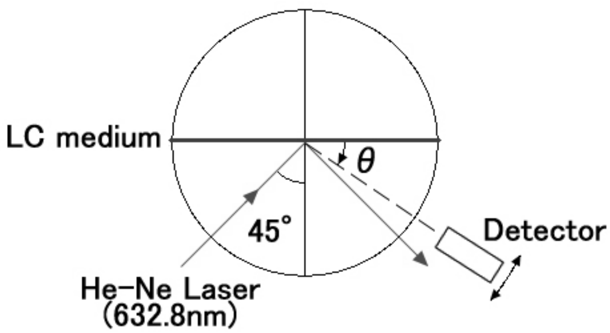

Figure 3.Measurement of reflection characteristic: cross section view (θ: 0 ~ 90 degrees).

Figure 4. Typical image formed on liquid crystal medium by ion projection (LC type-B, Composition ratio-50/50).

The reflection characteristics of the images formed on the medium (see Fig.3) were measured at angles ranging from 0 to 90 degrees to the medium's front surface using light from a 45 degree angled He-Ne laser (632.8nm). The reflection characteristics of plain copier paper were also measured in the same way for reference.

Experimental Results

A typical image, white characters on a black background, formed on the liquid crystal medium by ion projection is shown in Fig.4. The overview of the medium shown in Fig.5 demonstrates its flexibility; it can be curled up like paper.

Figure 6 shows the measured relation between optical density of the medium and surface potential for LC type-B. The optical density of the sheet is almost linear to the surface potential from 160 v to 320 v.

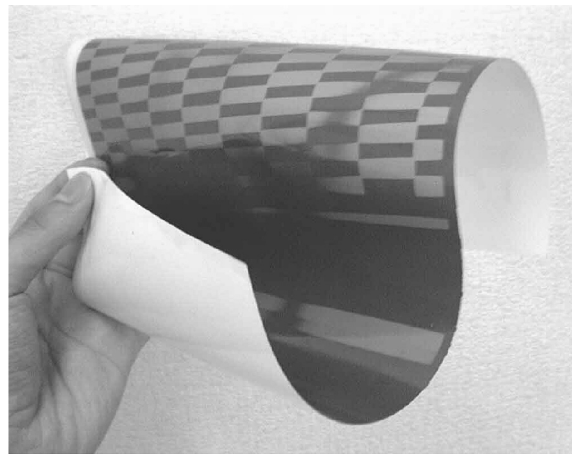

Figure 5. Overview of guest-host type liquid crystal sheet medium (LC type-B, Composition ratio-50/50).

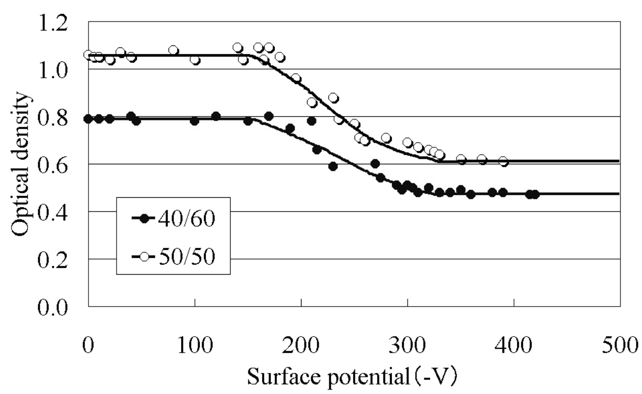

Figure 6. Measured relation between surface potential and optical density (LC type-B).

The optical densities and contrast ratios measured for the 4 test media are shown in Table 1. The optical density of each medium saturates at surface potentials from 310 v to 350 v. The measured optical densities increase as the ratio of liquid crystal to polymer binder increases. This is because the dichroic dye quantity increases with the liquid crystal quantity.

The surface electric potential starts to decline just after ion projection. Typical measurements from the LC type-B medium (50/50), which offers the highest contrast ratio, showed that the surface electric potential decreased by 50 % after 40 minutes: this was measured when the original surface electric potential was 250 v. The image formed on this medium showed no change as the surface electric potential gradually decreased. It has been confirmed that the formed images show no change even 1 year after the image formation experiment, by which time the surface electric potential had already decreased to zero.

Measured reflection ratios between image areas and non-image areas are shown in Fig.7 (medium: LC type-B, composition ratio 50/50). The relative reflection ratio ranges from 2.0 to 3.0 over the practical viewing angle of 20 to 90 degrees, except for the mirror surface reflection condition at 45 degrees. These reflection characteristics are similar to those of coated paper and are expected to realize an ideal viewing system free from the viewing angle limitation common with popular LC media.

Table 1. Measured results on image density and contrast ratio.

Medium	LC material	A		B	
	Composition ratio (LC/polymer)	40/60	50/50	40/60	50/50
Surface Potential at density change (-V)	Start	210	250	160	170
	End	350	350	310	320
Final Optical density (O.D.)	Min	0.49	0.59	0.47	0.61
	Max	0.83	1.05	0.80	1.09
Contrast ratio	Log scale	1.69	1.78	1.70	1.79
	Linear scale	2.19	2.88	2.14	3.02

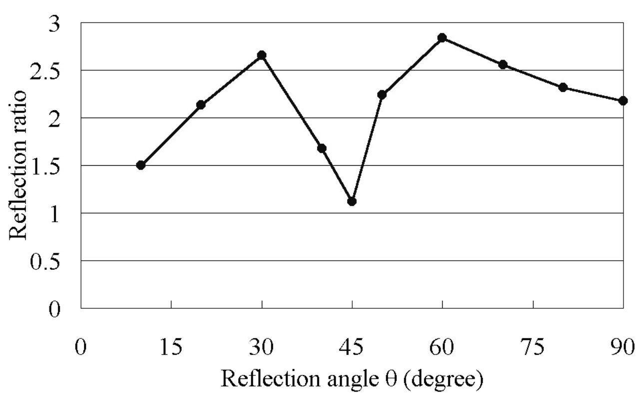

Figure 7. Viewing angle dependence of reflection ratio between the image area and the background (LC type-B, Composition ratio-50/50).

The erasure characteristics yielded by heating are shown in Fig.8 (medium: LC type-B, composition ratio 50/50). It is shown that the entire display area returned to its black state at about 60ºC. It was confirmed that the image formation process, ion projection followed by thermal erasure, could be repeated. This confirms the rewritability of this medium.

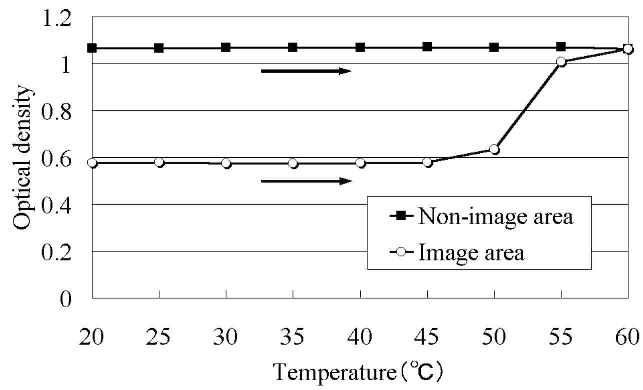

Figure 8. Erasure by heating (LC type-B, Composition ratio-50/50).

Summary

This study examined image formation on liquid crystal media by the ion projection driving method. Main results are shown as follows.

1) Image formation was well realized on a guest-host type liquid crystal sheet medium by using ion projection head.
2) The surface electric potential necessary for saturated image formation lies in the range 310 v to 350 v for the media used in this experiment. It was confirmed that there was no degradation in formed images even after the surface potential decreased to zero.
3) Ideal display characteristics can be achieved that are almost independent of viewing angle.

These results indicate that the sheet medium and imaging process demonstrated in this study form a promising approach to Digital Paper. Further study is needed on enhancing the contrast ratio, writing speed, resolution, and erasure system.

References

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Biography

Hirokazu Yoshikawa was born in 1976. He received his B.S. degree in 2000 from Tokai University. He is expected to receive his M.S. degree in Graduate School of Tokai University in 2002. He is now engaged in a study of Digital Paper Technology at Tokai University.