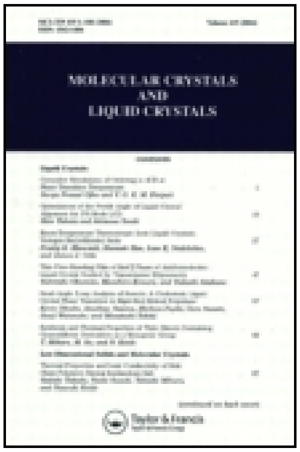

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UNIFORMLY ALIGNED FERROELECTRIC LIQUID CRYSTAL CELL APPLIED TO A LIGHT VALVE

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Abstract A ferroelectric liquid crystal light valve (FLCLV) for laser pulse recording is studied. We have fabricated a FLCLV that is equipped with a SiO obliquely evaporated film as a liquid crystal alignment layer and a metal-insulator-semiconductor (MIS) photodiode as a photoconductive layer. When the cell gap is about 3um, the liquid crystal alignment shows scale like defects. When the cell gap is reduced to 2um, that scale like defects disappear. High resolution capability of 50 lp/mm is obtained using diode laser, the power of which is merely 20pJ, in this cell.

INTRODUCTION

Today's high information oriented society demands display devices, such as a monitor for engineering workstation, to have faster response, higher resolution and larger display area. Liquid crystal light valve (LCLV) is one of the display devices, developed to fulfill this demand [1,2].

Until now, heat mode LCLV have been investigated [3,4]. But in this device, a writing time is too long to attain the real time writing. Whereas, the photon mode LCLV utilizing the ferroelectric liquid crystal (FLC) is a very promising candidate for fulfilling the demand mentioned above, because FLC possesses a very fast response time and also a memory effect. Application of FLC to LCLV in the photon mode, i.e., FLCLV, has been the interests of many researchers [5,6].

FLCLV has a structure that basically holds the FLC mixture between two transparent electrodes and a photoconductive layer is attached to one of the transparent electrodes. When application of voltage across the cell and a laser beam addressing are done synchronously, only the FLC area irradiated by laser changes it's state to one of the two states and the switched state is memorized even when the voltage application goes on without irradiation. Although the switching time is in the order of several tens of microseconds, irradiation of laser beam for each pixel requires only tens of nanoseconds. So the laser beam addressed FLC realizes a very high resolution display with fast response time.

Despite this attractive feature of FLCLV, some technical problems to be solved remain, one of which is the alignment of FLC.

The FLC cell, when rubbed polyimide is employed as an alignment layer, suffers from typical liquid crystal alignment defect which is sometimes called the zig-zag defect. The dimension of this defect is comparable to or bigger than the laser addressed picture element spot, resulting in the deterioration of the picture.

Combination of the SiO oblique evaporation film as an alignment layer and application of strong electric field has been tried on the FLC cell. The resulting cell shows excellent bistability without any zig-zag defect, establishing a very high resolution LCLV with the aid of a photoconductive layer.

This report describes the cell structure with FLC aligned by an obliquely evaporated SiO film and it's LCLV performance by optical addressing.

EXPERIMENTAL

The alignment layer was formed via the following two steps. First, SiO was evaporated from the angle normal to the ITO glass plate. Then, the plate was rotated by 85 degrees about the axis perpendicular to the evaporation flux direction. The thickness of the obliquely evaporated SiO film was 250A measured in the direction normal to the plate. For the cell fabrication, antiparallel scheme about the evaporation direction was employed. FLC mixture (CS-1014:CHISSO CORPORATION) was filled into the cell by the capillary method.

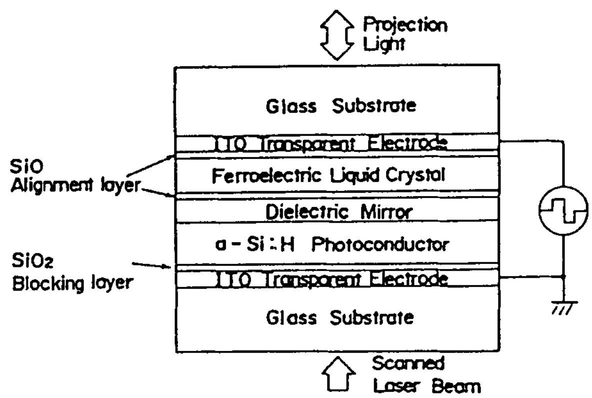


Figure 1. Structure of FLCLV

The cell structure of FLCLV is shown in figure 1. Hydrogenated amorphous silicone, the photoconductive layer, was doped with boron and nitrogen [a-Si:H(:B:N)] [7]. With an additional insulating layer between ITO and the photoconductive layer, MIS photodiode was formed [8,9].

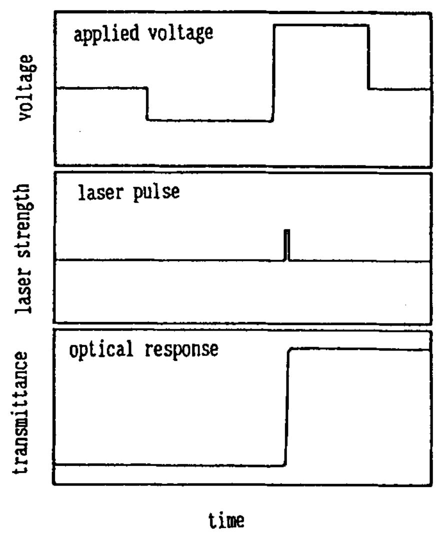
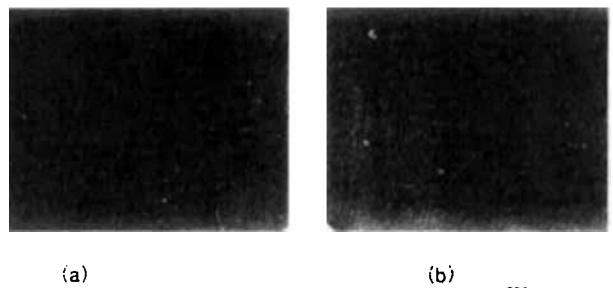


Figure 2. Writing sequence viewing one pixel

To prevent the glass substrate from warping which was caused by the thermal stress during the a-Si layer formation, i.e. to minimize the deviation of the actual cell gap from the designed one, the glass substrate that had 5mm thickness was adopted.

The sequence of bias voltage application and laser pulse irradiation are shown in figure 2. The pulse voltage of 16V and the pulse width of 350us are the typical writing condition for this experiment.

RESULTS AND DISCUSSION



See Color Plate II.

Figure 3. Alignment of liquid crystal Cell gap (a) 2um (b) 3um

The liquid crystal alignment under two different conditions are shown in figure 3. As can be seen in this figure, the cell gap of 2um results in an almost perfect alignment without any defect, whereas cell gap of 3um produces scale like defects over the whole display area and these defects become the source of deterioration in the display performance. It has been revealed that the cell gap plays an essential role in obtaining good alignment of FLC in the case of SiO oblique evaporation layer usage with having an a-Si layer beneath the SiO layer, as has been widely believed.

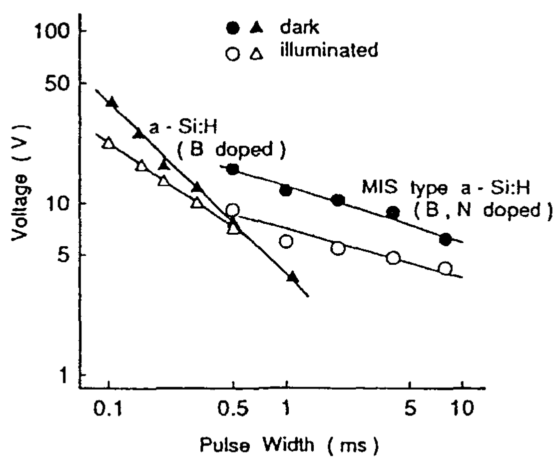


Figure 4. Critical pulse area of FLCLV

Figure 4 shows margin for bias voltage in laser pulse writing. In general, FLC has a threshold which is defined by the multiple of pulse width and pulse height of bias voltage. So, when we plot the minimum pulse height which switches from one state to another for each pulse width, we can draw a line on the bias voltage vs. pulse width figure. The line means that below this line the cell does not switch and above the line the cell does switch. The threshold line is sometimes called critical pulse area. The upper two lines in figure 4 correspond to the cases that the photosensitive layer is fully illuminated by a halogen lamp, and the lower two lines correspond to the cases that the cell is in the total darkness. So the area between the upper and the lower lines provides voltage margin where the laser writing on FLCLV is possible. The two lines by triangles represent the case that the laser writing is performed on FLCLV with photosensitive layer which does not include the MIS structure, whereas the two lines by circles represent the case that FLCLV has the photosensitive layer with MIS structure. It is clearly seen that FLCLV with photosensitive layer including MIS structure has far wider writable margin. The result shows that high impedance provided by the MIS structure contributes to the obtained wide writable margin of bias voltage.

Figure 5 shows the relation between the power of laser writing pulse and the resulting spot diameter. In this experiment, the laser spot was as small as 10um in diameter. As the laser power was increased from zero, it starts to write a pixel at certain power level. And when the laser power was in excess, the written spot starts to expand and became larger than the writing laser spot. The laser power of 20pJ resulted in the written spot size as being 10um, the same size as the writing laser spot size.

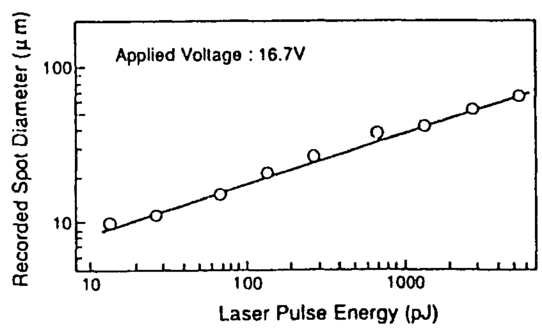


Figure 5. Recorded spot diameter versus irradiated energy

Figure 6 shows a photo of display image that has been written by the laser pulse recording [2]. The performance of the display is summarized in table 1. A resolution of 50 lp/mm has been achieved, as can be seen in the photograph.

CONCLUSION

A ferroelectric liquid crystal light valve equipped with SiO obliquely

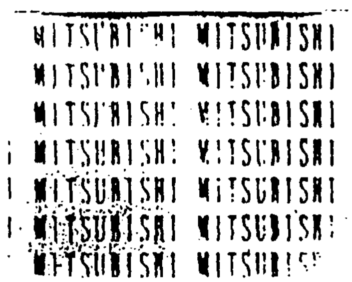


Figure 6. Magnified display image
Laser pulse recording

Table 1. Performance of the display

Resolution	1500×1600 pixels
Writing Speed	0.5 sec/frame
Screen Size	30" diagonal
Brightness	1000 cd/m²
Contrast Ratio	24 (green light)

evaporated film as an alignment layer and MIS photodiode as a photosensitive layer has been proposed. By the utilization of the SiO obliquely evaporated film as the alignment layer, very uniform alignment without any defect which otherwise deteriorates the display image has been achieved. Introduction of the MIS photodiode as the photosensitive layer in the LCLV resulted in the wide margin of the bias voltage. We have achieved the resolution as high as 50 lp/mm with the pixel size as small as 10um.

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