The effect of pretilt angle on viewing angle in In-Plane switching mode LCD

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Abstract

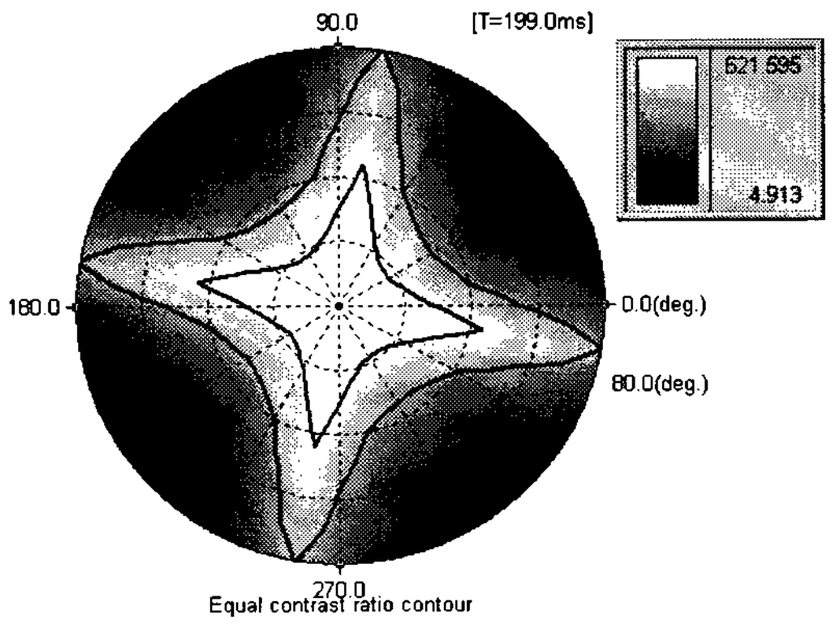
The effect of pretilt angle on viewing characteristics of an IPS cell is discussed. We calculated optical viewing angle in the IPS cell as function of pretilt angle from 0.5° to 4°, so that we could confirm that low pretilt angle was profitable for wider viewing property. In order to verify the calculation, we made an IPS cell with very low pretilt angle by the alignment method using ion beam exposure. In the experiment, we confirmed that wider viewing characteristics can be achieved if lower pretilt angle was applied in IPS mode. And Ion beam alignment method was useful for low pretilt creation.

1. Introduction

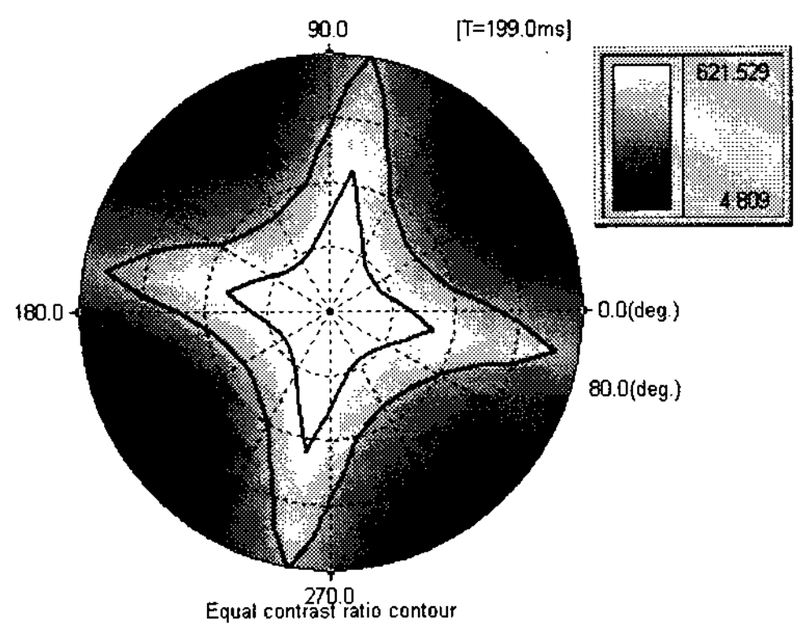
One of the most important requirements in the LCD might be a wide viewing angle. The most general method for the improvement of viewing-angle property is optical compensation with compensate film , which presents the retardation from variating to the oblique direction. , However this method has a demerit that it is very hard to achieve the perfect compensation effect. On the contrary, the IPS (In-plane switching) mode can exhibit wide viewing angle characteristics without compensation. Therefore, The LC mode which requires wide viewing characteristics has been focused on IPS mode. The conventional rubbing method limits the viewing angle improvement of IPS mode. The rubbing method leaves the debris by the cloth during the rubbing process. Rubbing may also give rise to an electrostatic discharge that can influence the electronic circuitry just below the surface of the rubbed polyimide thin film. The pretilt angle generated by the rubbing process is higher than 1°. In order to solve these problems, a non-contact alignment method would be highly desirable for future generations display for large, high-resolution. Recently a ion beam method for LC alignment was reported by IBM[4,5] and research activities for this alignment method are in process by several research institutes for more wide application in LCDs. In order to optimize display performance, it is necessary to control the pretilt angle which is suitable for each mode of LCDs. One of potential methods to control the pretilt angle can be the ion beam alignment technique. The change of ion beam parameters varies the pretilt angle of LC. In suitable ion beam condition, low pretilt angle is created. In this paper, we report on viewing angle characteristics depend on the pretilt angle in IPS LC cell.

2. Experimental

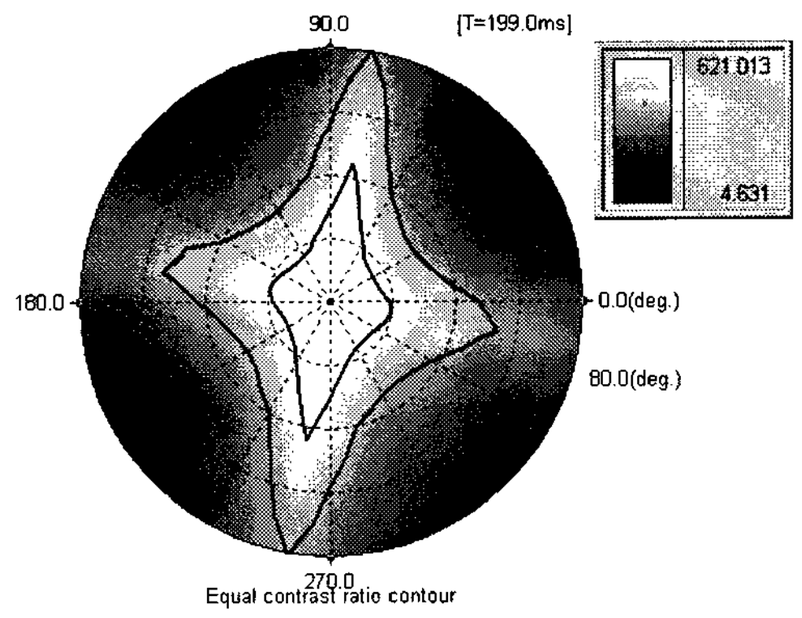
In general, the IPS mode would be designed with NB (Normally Black) mode because very good dark state could be obtained at voltage off state. With crossed polarizer, we need to set the LC directors to the same direction with transmission axis of the polarizer. This configuration allows good dark state irrespective of the retardation of the LC cell in the normal direction. In the case of the oblique incident light. we can predict that the retardation should be dependent on pretilt angle, so that it may cause the variation of their contrast and equ-contrast characteristics. To calculate the viewing angle performance, optical calculation has been performed by LCD-master shintech simulator. We assumed 2.36um cell gap. The interdigital electrode distance was 10 μm and the electrode width was 5 μm. The used LC material was ZLI-1557 of Merk. Figure1 shows calculated equ-contrast contours as a function of the pretilt angle. Applied pretilt angles in calculation are 0.5°, 2° and 4°, respectively. And each line shows equ-contrast contour of 400, 100 and 15 from center. From the figure, we confirmed that the lower pretilt angle liquid crystal has, the wider viewing angle-dependent-contrast ratio is . The relatively low contrast ratio line is insensitive to viewing angle. However, the highest contrast ratio line(400) shape is different for pretilt angle variation. From the Fig 2, we confirmed that the lower pretilt angle in the liquid crystal is needed for better viewing angle characteristics. When azimuthal angle of the viewing angle direction is fixed on the axis of the analyzer, The dark state of the cell aligned with high pretilt is not good as much as the case of the low pretilt. When the oblique incident light is perpendicular to optic axis of liquid crystal, the retardation at high pretilt aligned liquid crystal is larger than the one with low pretilt in liquid crystal layer. These viewing angle characteristics can be caused dark state. Difference of dark states is affected by the birefringence of the liquid crystal layer. Because retardation as inclined incident light is not zero. retardation at high pretilt aligned liquid crystal is larger than that of the case with low pretilt. As a result, it is necessary to generate low pretilt angle for wide viewing angle performance. In general, however, we cannot make very low pretilt angle by using conventional rubbing method. Pretilt angle of polyimides to align liquid crystal is higher than 1°. One of methods to be able to generate low pretilt angle and control the pretilt angle is ion beam alignment technique[3,4]. The ion beam alignment



(a) 0.5°



(b) 2°



(c) 4°

Fig.1 Equal contrast ratio contour as (a) pretilt angle 0.5° (b) pretilt angel 2° (c) pretilt angle 4° .The lines mean equal costrast ratio 400,100,15 from the inside

method is non-contact method which exposure ion beam on the polyimide surface with suitable energy, so that we can obtain very low and stable pretilt angle even below 0.5°. The cells for the experiment was prepared in the following manner. Indium-Tin-Oxide (ITO) coated on glass substrates was used for electrodes. The substrates were spin coated with SE-3046 used as polyimide, prebaked at 80 ℃ for 10 minutes and cured at 250 ℃ for two hours. Then polyimide layer was bombarded by a low energy argon ion beam and treated rubbing method. Figure.3 shows the schematic drawing of the ion beam system. As an ion source, a cold hollow cathode (CHC) type has used to yield ion beam. In order to collimate the ion beam, two perforated grids were used as electrofocusing lenses. CHC represents a separate cooled chamber that is supplied with a magnetic system and is connected with discharge chamber through an orifice hole. Argon gas feeding into ion source is being carried out through the only CHC. The discharge ignition in the cathode takes place at nominal values of discharge voltages and at nominal gas flow rates.A neutralizer filament on the outside of the ion source serves as a source of electrons necessary for compensation of ion beam spatial charge and reduces the repulsive force among ions.

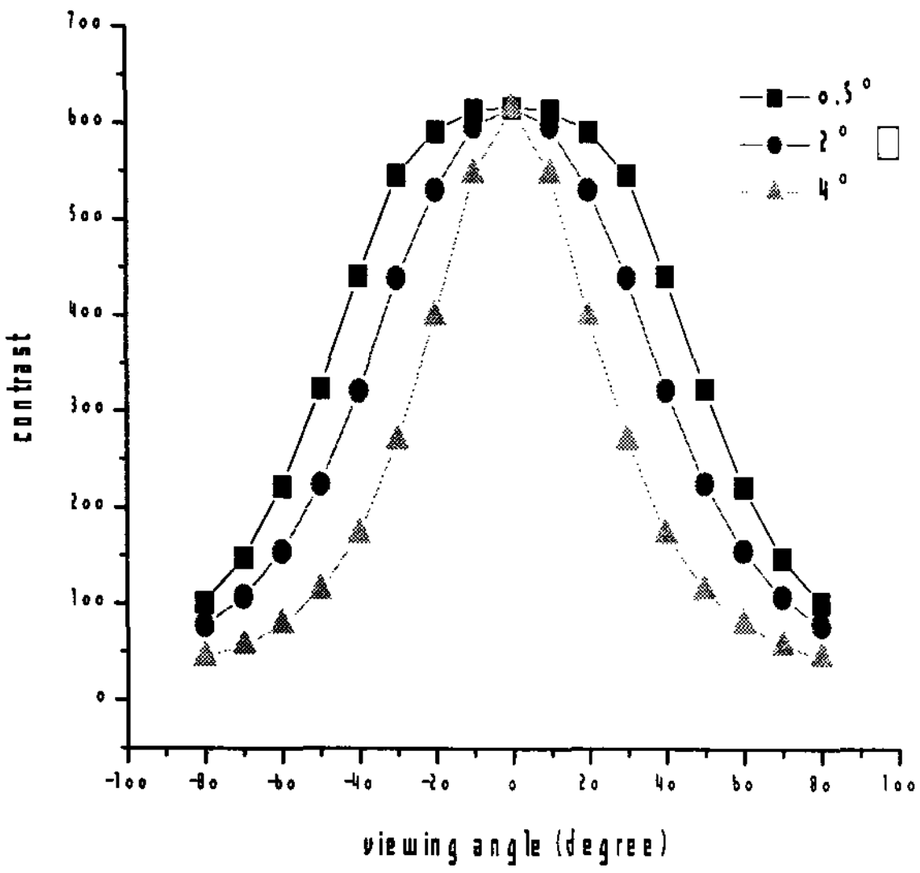


Fig.2 viewingangle-dependent-contrast ratio as pretilt angle variation

Parameters which influence the surface of polyimide may be the energy, exposure angle, exposure time and current density with respect to the ion beam. In our experiment, in suitable energy, exposure angle and exposure time, we could obtain pretilt angle even below 0.5°. Figure4 shows dark states fabricated by two methods. The pretilt angles of LC Cells fabricated by rubbed and ion beam-treated polyimides were different. As shown in table 1, Polyimide surfaces which bombarded ion beam create a pretilt angle of 0.5° in liquid crystals at the exposure angle of 30° and an exposure time of 20 s and ion beam energy of 250 eV , respectively. Rubbed polyimides create a pretilt angle of 4°. As illustrated in above, the dark state of the cell aligned with a pretilt angle of 4° is not as good as that with pretilt angle of 0.5°.

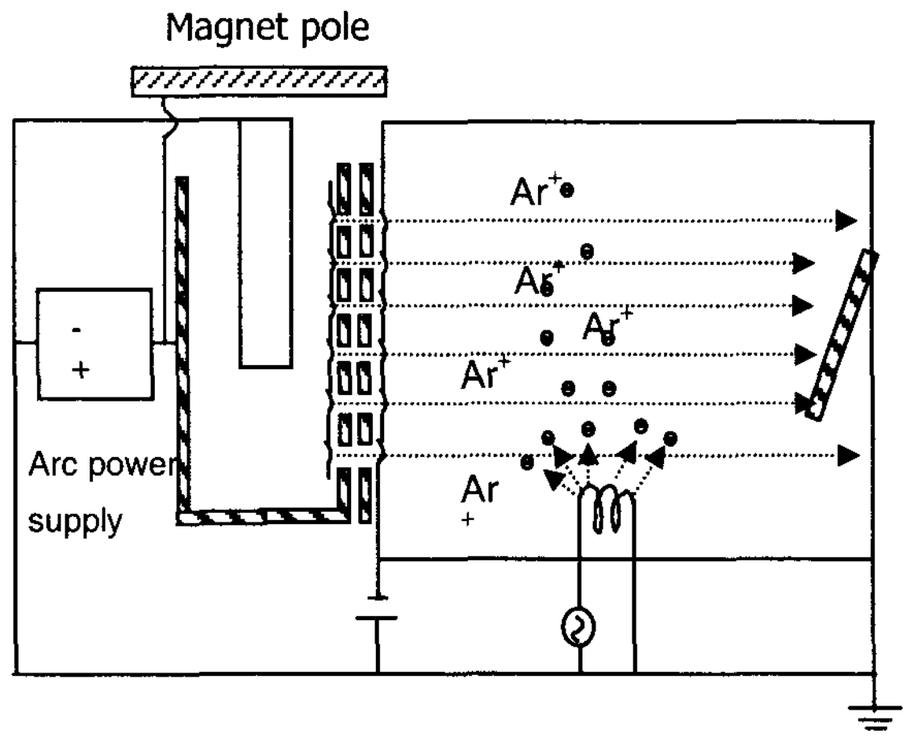


Fig. 3. Schematic drawing of the ion beam system

Ion beam energy	exposure angle	exposure time	current density
250 eV	30°	20s	100 uA/cm

Table.1 condition of ion beam soruce

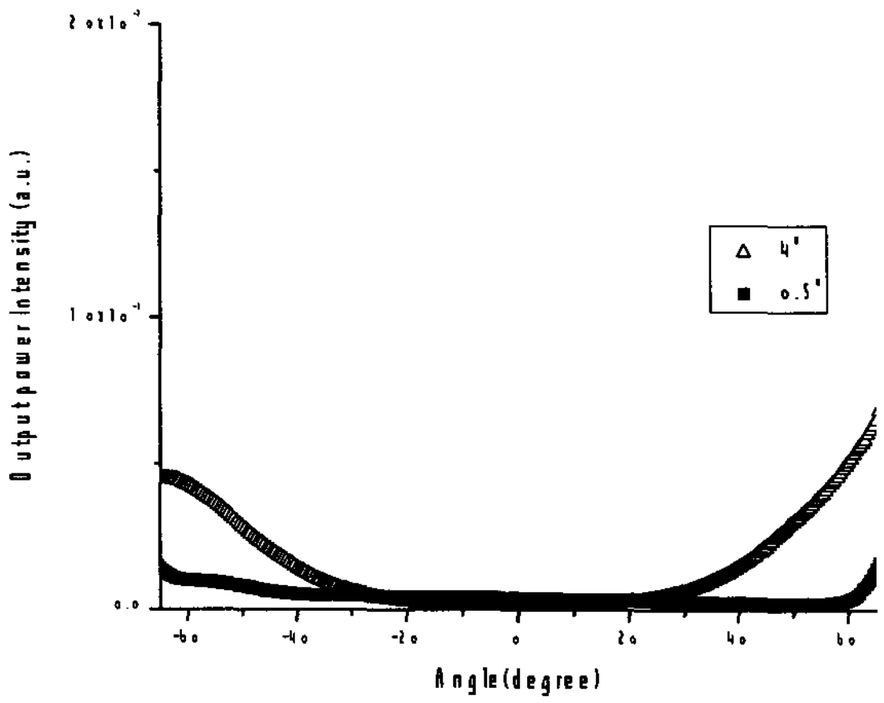


Fig.4 pretilt angle dependence of viewing angle at dark state

3. Conclusion

The viewing angle of an IPS cell was calculated as function of pretilt angle from 0.5° to 4°. We found that the viewing angle characteristic of the IPS cell which has low petilt angle is better than that of the IPS cell which has high pretilt angle. The low pretilt angle angle was achieved by exposing the ion-beam on the glass substrate.

4. Acknowledgment

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