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A Thin Film Process to Improve Off Axis Viewing of Liquid Crystal Displays

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A well known technique to obtain homogeneous alignment of nematic liquid crystals with positive dielectric anisotropy for use in twisted nematic displays is to deposit a silicon monoxide film onto the aligning substrate surface at an oblique angle between 3–6°. This range of deposition angles provides excellent normal contrast ratio but is poor when viewed off axis. This paper describes an alternative approach utilizing a double SiO deposition that improves off axis viewing. The first SiO layer (350 Å) was deposited at 6°. The second layer (20–50 Å) was deposited at 30°. The second layer seems to have a smoothing effect on the 6° structure, as substantiated by TEM studies, thus lowering the tilt angle.

INTRODUCTION

A well-known technique to obtain homogeneous alignment of nematic liquid crystals with positive dielectric anisotropy for use in twisted nematic displays is to deposit a thin film onto the aligning substrate surface at an oblique angle. This was first reported by Janning.[1] Janning's work reported the angle of incidence of the aligning layer to be 5° to the vertical. Dixon[2] reported similar results showing how the contrast ratio decreased from 25 at 5° as the angle of incidence increased. Guyon[3] later showed the tilt angle dependence on the deposition angle in three different ranges. The tilt angle is defined as the angle the long axis of the liquid crystal molecule (director axis) makes with the substrate or aligning surface. In the first range, the angle of incidence was between 45–90° and no preferred orientation of the liquid crystal molecules was obtained. In the second range, 10–45°, the liquid crystal molecules align parallel to the substrate plate with the director axis perpendicular to the plane of incidence of the beam. In the third range, 0–10°, the director axis is in the plane of incidence of the beam with a tilt angle between 20° and 30°.

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Later, Odawara[4] reported a range between 15–18° where the liquid crystal molecules lie in the substrate plane with their director axes perpendicular to the plane of incidence of the beam. The advantage of this range was that an acceptable contrast ratio could be obtained with a low tilt angle.

Meyerhofer[5] has reported tilt angles ranging from 0° to 6° by depositing a very thin (less than 5 Å) layer of SiO at 6° over the 30° deposition. Before depositing the second layer, the plate is rotated 90° in the system.

Johnson[6] has also reported low tilt angles by depositing a 5° *deposition, rotating the plate* 90°, and then depositing a 30° deposition of comparable thickness. The thickness of each layer ranged from 50 Å to 500 Å.

This work covers an investigation of some of the above aligning techniques. It also presents an alternative approach to the alignment layer problem similar to that of Meyerhofer's and Johnson's, but with a number of distinct differences.

EXPERIMENTAL AND TESTING PROCEDURES

The substrate material used was soda lime (2 square inch) glass precoated with 200 Å indium-tin-oxide. Test cells were constructed using a circular electrode configuration, Figure 1, utilizing conventional photolithographic techniques.

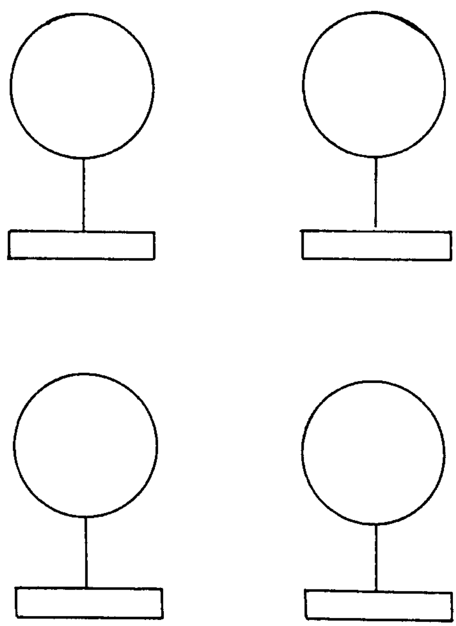

FIGURE 1 Circular electrode configuration used for testing liquid crystal displays.

The silicon monoxide was evaporated with an electron gun at a base pressure of 1×10^{-6} torr. The evaporation system used was equipped with a cryoshroud and titanium sublimator, substrate heaters, ionization gauge, deposition controller, and a multihearth electron gun. Since the substrates were not directly above the source but around an imaginary cylinder (8″ diameter) concentric about the source, a correction factor of 12° was introduced for all deposition angles. The controller, once programmed, completed the deposition by controlling the power to the electron gun utilizing a quartz crystal monitor. The deposition was terminated automatically by the monitor when the required thickness was reached. For the double SiO deposition, after the first deposition was completed the system was opened to the atmosphere, the angle of the plates was changed from 6° to 30°. The second deposition was then completed in the same manner as the first.

The thickness of the silicon monoxide aligning layer during the deposition was monitored with a quartz crystal monitor. The as deposited thickness was measured with an interferometer. Because of the different positions and angles of the monitor and glass slides with respect to the source and the sensitivity factors (density and geometry) that were programmed into the monitor controller, the thickness readings on the monitor were much higher than the measured values. This was done to obtain optimum rate sensitivity. A calibration curve was then established with measured thickness as a function of the monitor reading. Since the practical lower limit of the interferometer used was approximately 150 Å, a linear dependence of the monitor thickness and actual film thickness was assumed to determine the thickness of thinner films.

In this study the aligning material was deposited onto the front and back plates at the same orientation relative to the source. A ninety degree twist was obtained by a ninety degree rotation of the back plate during assembly. All contrast ratio measurements were made in the transmissive mode, Figure 2. The off axis contrast ratio measurements were made by rotating the display, as shown in Figure 2. A polar plot would give the contrast ratio as a function of all viewing angles. This rotation, however, simulates the rotation of a display in a wrist watch.[7] The lamp intensity for the contrast ratio measurement was set between 1200–1500 cd/m^2 as measured by the photometer through the display and polarizers. The polarization efficiency was 0.96. The tilt angle measurement technique used in this study was a magneto-capacitive method.[8] The average tilt angle can be determined utilizing this technique by comparing the capacitance of the display with the field on with the capacitance of the display with the field off. The field strength used was five kilogauss.

The films were studied with a transmission electron miscroscope. A two step relication technique[9] was used to prepare the films for the transmission electron microscope.

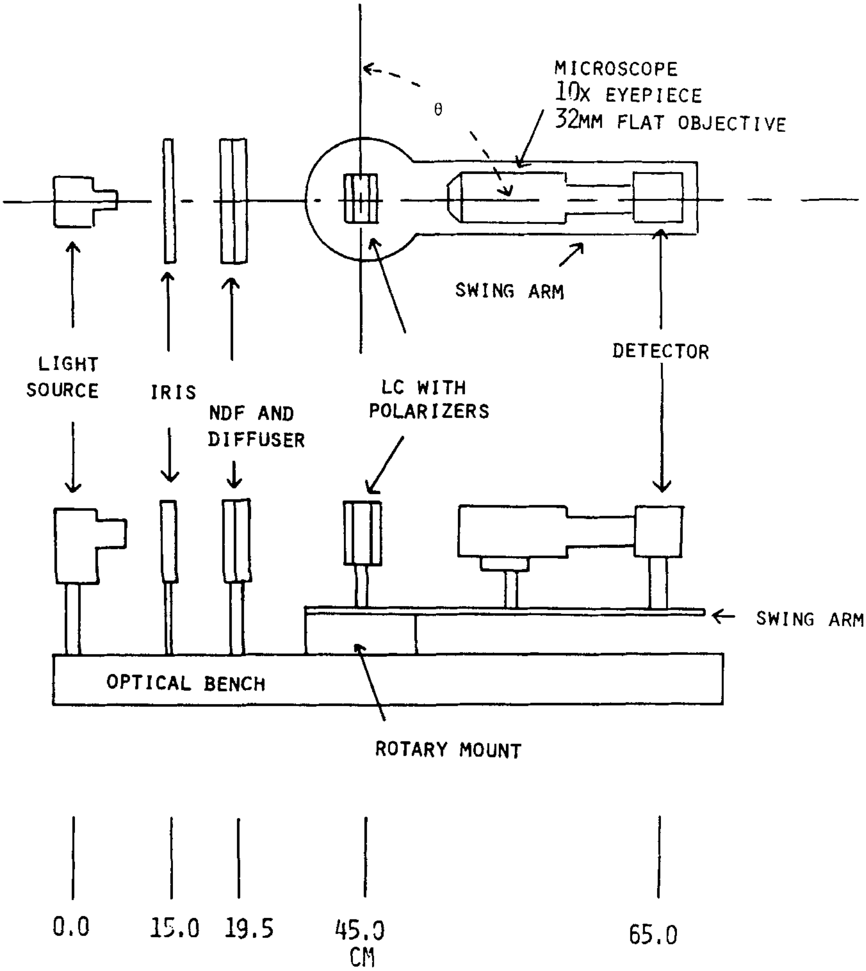

FIGURE 2 Optical set-up for measuring contrast ratio.

RESULTS AND DISCUSSION

The tilt angle as a function of deposition angle for an aligning layer of silicon monoxide is shown in Figure 3. Low tilt angles were found at the high deposition angles. Tilt angles below 15° were measured at deposition angles between 14–18°. In most cases the tilt angle ranged from 3–9° in this transition region (14–18°). This compared well with results reported by Odawara in this region.

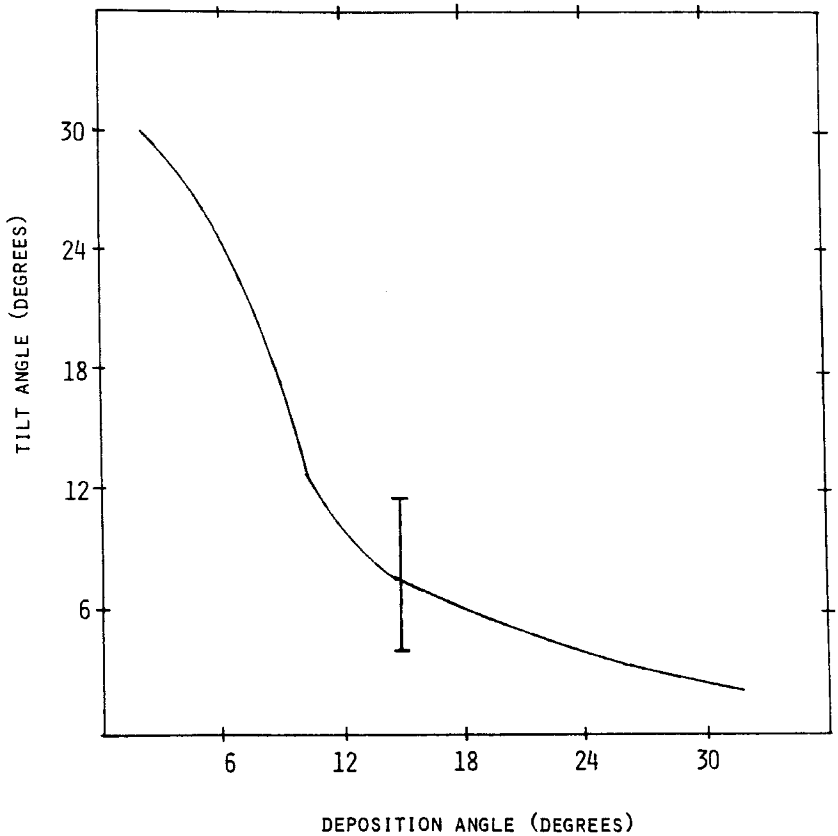

FIGURE 3 Tilt angle as a function of deposition angle for an aligning layer of silicon monoxide. (Error bar applies to 14–18° deposition angles).

The off axis contrast ratio for silicon monoxide is observed to vary with deposition angles as shown in Figure 4. The thickness of the displays used for all contrast ratio measurements ranged from 10–12 μm. Deposition angles of 6°, 15° and 27° were used with measure tilt angles of 24°, 8° and 3° respectively. The lower tilt angles show significant improvement at the higher viewing angles, but poor normal contrast ratio. A comparison of the off axis contrast ratio as a function of viewing angle for a 6° cell and a double SiO deposition cell is shown in Figure 5. For the double SiO deposition, Figure 6, thickness of the first deposition was 350 Å and the second deposition was 30 Å. A significant improvement was found in off axis viewing with the double SiO deposition.

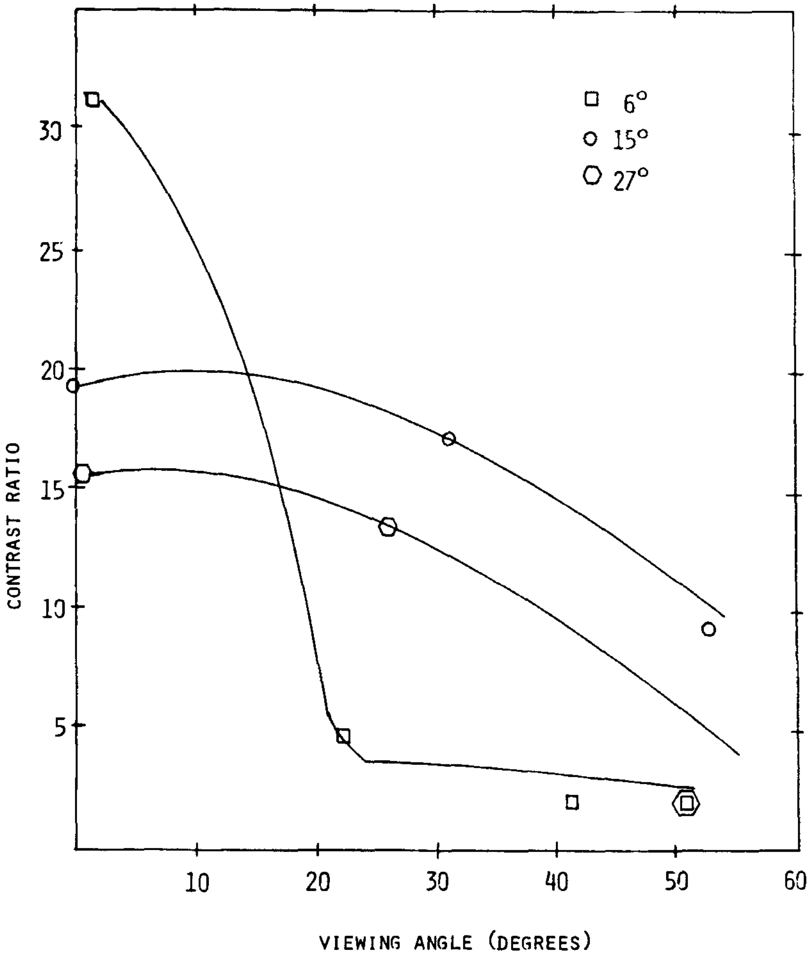

FIGURE 4 Off axis contrast ratio for deposition angles of 6°, 15°, and 27° or measured tilt angles of 24°, 8° and 3° respectively.

Both the tilt angle and the contrast ratio show a similar dependence on thickness of the second silicon monoxide deposition as shown in Figure 7. For a 15 Å deposit, the tilt angle is 11°. The tilt angle then remains relatively constant for thicknesses ranging from 20 to 60 Å. At 60 Å, however, the tilt angle starts to rapidly decrease. At 75 Å, tilt angles of 3–6° were measured. The contrast ratio rapidly drops at thicknesses greater than 60 Å. The results can be compared to the double deposition technique reported by Meyerhofer. The technique itself, however, is just the opposite. His first deposition was at

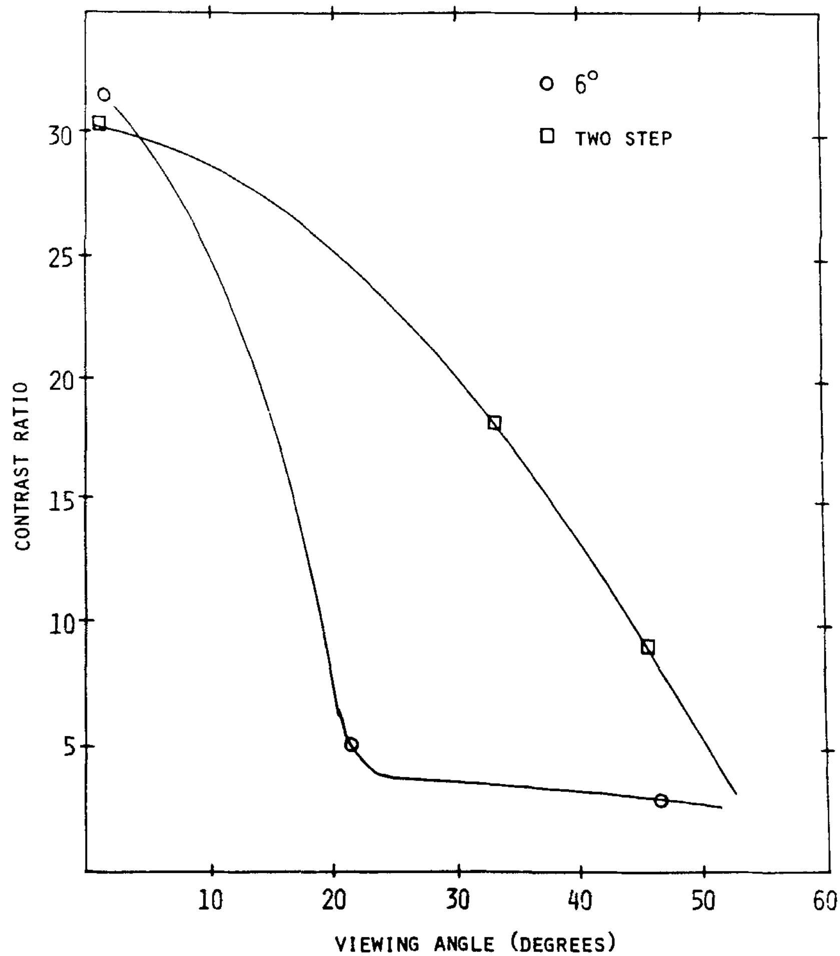

FIGURE 5 Off axis contrast ratio for a 6° deposition angle and a double SiO deposition.

30° and the second deposition was at 6° after a 90° plate rotation. Also, the thickness of the second deposition is about an order of magnitude lower in his case.

This technique is comparable to the one reported by Johnson. Two differences are the 90° plate rotation and the thickness control of the second deposition. Johnson also claims the 30° deposition is a synthesis of separate 5° and 30° depositions.

Figure 8 is a TEM micrograph of a replica of our double SiO deposition. A smoother structure was noted compared to a typical 6° deposition. The needle

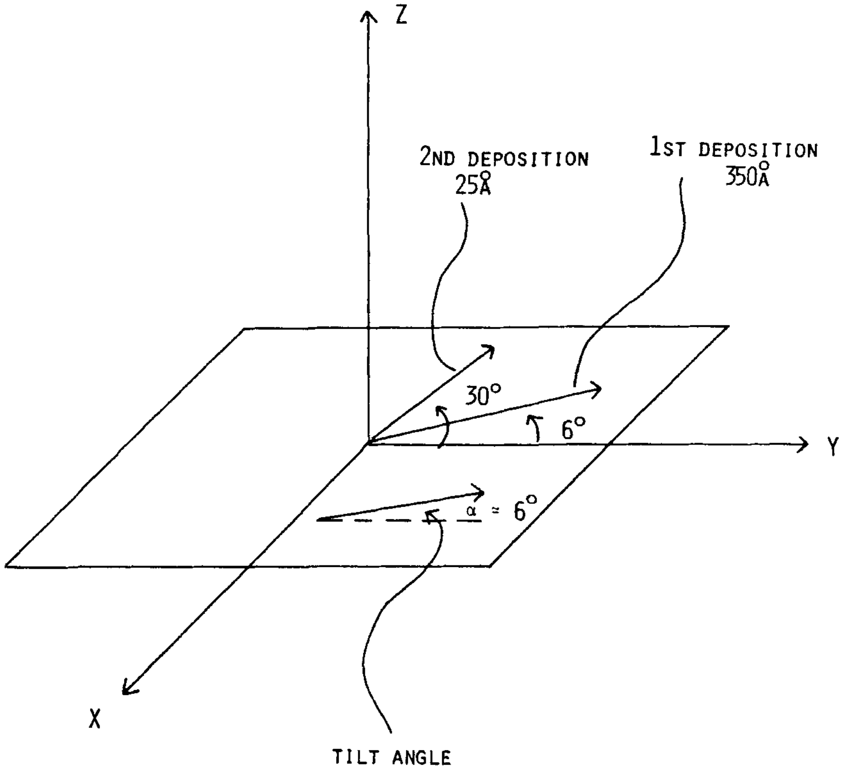

FIGURE 6 Plate rotation for double SiO deposition.

type structure found with 6° depositions was not present in the replicas of our double deposition approach. This structure allows the liquid crystal molecules to lie nearly parallel to the glass surface.

CONCLUSION

The tilt angle has been found to be an important parameter when evaluating the off axis contrast ratio of liquid crystal displays. The lower tilt angles result in better displays off axis but poorer at normal viewing angles. A good compromise for liquid crystal displays for wrist watch applications can be obtained with tilt angles between 8–11°. The best approach found to reproducibly obtain this compromise is a double SiO deposition. The first layer is deposited at 6° with a thickness of approximately 350 Å and the second layer is deposited at 30° with a thickness of 30 Å. This second deposition is a controlled method of slightly smoothing the 6° columnated structure, thus lowering the tilt angle.

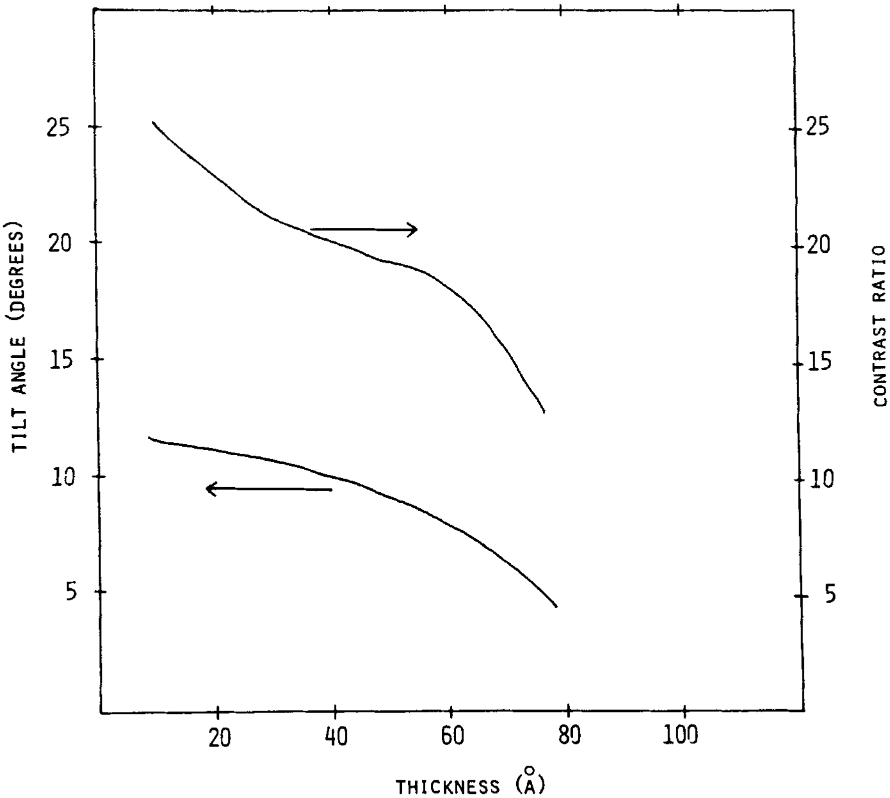

FIGURE 7 Contrast ratio and tilt angle as a function of thickness of second SiO deposition.

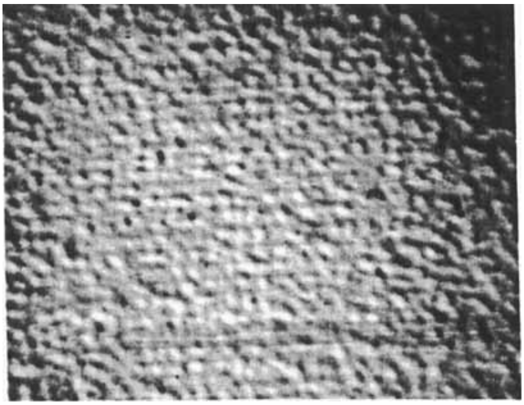

FIGURE 8 TEM micrograph at 20,000X of double SiO deposition.

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References

1. J. L. Janning, *Appl. Phys. Lett.*, **21**, 15 (1972).
2. G. D. Dixon, T. P. Brody, and W. A. Hester, *Appl. Phys. Lett.*, **24**, 47 (1974).
3. E. Guyon, P. Piranski, and M. Boix, *Lett. Appl. Eng. Science*, **1**, 19 (1973).
4. K. Odawara, T. Ishiboshi, and Kanazaki, *Liquid Crystal Display for Calculators*, Electron Tube Division, Hitachi, Ltd. (1975).
5. D. Meyerhofer, *Appl. Phys. Lett.*, **29**, 691 (1976).
6. M. R. Johnson, *Conference Record of 1976 Biennial Display Conference*, 49 (1976).
7. G. G. Barna, *Conference Record of 1976 Biennial Display Conference*, 29 (1976).
8. K. Toriyama and T. Ishibashi, *Nonemissive Electrooptic Displays*, Plenum, New York (1976).
9. Paulson, W. (private communications).