

SIMPLIFIED FIELD EFFECT TWISTED NEMATIC LIQUID CRYSTAL DISPLAY CONSTRUCTION.

The present invention relates to electro-optical devices and, more particularly, to those of the field effect, twisted nematic liquid crystal type having a simplified sandwich construction.

- 5 A liquid crystal display device of the field effect, twisted nematic type can be generally obtained by interposing a nematic liquid crystal compound or mixture having positive dielectric anisotropy between a spaced front and rear electrode
- 10 and associated liquid crystal alignment means. Typically, the display device is constructed using spaced glass substrates, the front substrate carrying one or more transparent electrode layers, e.g. tin oxide, patterned to define numerals, letters or other
- 15 display information and the rear substrate carrying one or more rear electrodes. In twisted nematic displays, the substrates have alignment means associated therewith at the interface with the liquid crystal to impart optical rotary power to the liquid crystal
- 20 by arranging its molecules initially in a helical pattern parallel to the substrates. This helical pattern is controlled or realigned by the application of a suitable electric field between the front and rear electrodes to vary the optical rotation through the
- 25 liquid crystal layer. By this variation in optical rotation and with the aid of crossed polarizer layers associated with the front and rear electrodes, the

twisted nematic liquid crystal display device
can be used to display information.

In the past, the alignment means associated
with the electrodes of the display have taken
5 several forms. One known means for imparting the
initial helical alignment to the liquid crystal
has been to rub the glass substrate in one
direction with a cloth or other material after the
electrode layers have been applied and then to
10 place the substrates in spaced apart relation
with the direction of rubbing on one substrate
being perpendicular to that on the other. Thin layers
or films of material such as polyimide resin have
also been applied to the substrates and rubbed to
15 impart alignment characteristics thereto as shown
in U.S. Patent 4,068,923. According to another
method, the substrates are rubbed as described above
and subsequently a layer of dichroic dye is applied
onto the rubbed surface and dried so that a film
20 having alignment as well as polarizing characteristics
is formed; e.g. see U.S. Patent 3,731,986. In
still another technique known as the slope evaporation
method, the substrates are placed at an inclined
orientation relative to a source of inorganic material
25 such as silicon oxide and a layer of material
is deposited on the substrates by vapour deposition
at a preselected orientation, the deposited layer
forming an alignment film.

Further, it is known that certain nematic
30 liquid crystal materials exhibit polarizing character-

istics on their own and that such a nematic material can be solidified on a substrate in the presence of an orienting field generated by rubbing, brushing, stretching or applying an electric or magnetic
5 field to form a solid, permanently oriented polarizer film, e.g. as described in U.S. Patent 2,400,877. However, commercial twisted nematic liquid crystal displays have used external sheets of polarizing material adjacent the exterior surfaces of the
10 substrates out of contact with the liquid crystal material.

These liquid crystal displays can be used in the reflective and/or transmissive mode. If the reflective mode is used, a reflector of, for example,
15 metallic foil is placed behind and adjacent the rear polarizer layer of the display. On the other hand, it is sometimes necessary to operate the display in both modes, for example, in digital watch displays having day and night time viewing capability and
20 to this end a so-called transflector is used in lieu of the reflector to not only reflect incident ambient light during day time operation but also to transmit light from a light source behind the display for night time viewing. The transflector typically
25 may comprise a translucent or frosted glass or plastics sheet and/or a thin metallic layer or deposit.

In the past, prior art workers have recognized the desirability of simplifying the structure of
30 twisted nematic liquid crystal displays to reduce the

number of components in the sandwich construction and thereby reduce the thickness and overall cost of the display. The present invention has as one of its important objects such a simplification in display construction.

In accordance with one aspect of the invention, there is provided a liquid crystal display device of the field effect, twisted nematic type, which comprises an untreated substrate and associated electrode layer having a treated polarizer layer thereon in contact with the liquid crystal, the polarizer layer being treated in situ on said substrate and electrode layer to impart a preselected artificial liquid crystal alignment-promoting orientation thereto so that said polarizer layer serves the dual function of polarizing and liquid crystal alignment means in the display. Many polarizer films or layers inherently exhibit the ability to promote alignment in the liquid crystal layer when brought into contact therewith with the liquid crystal alignment-promoting direction of the untreated layer corresponding generally to the polarizing axis thereof. By, however, treating such a polarizer layer in situ, the invention enables the liquid crystal to be artificially aligned.

In another aspect, the invention provides a liquid crystal display device of the field effect, twisted nematic type, comprising:

- (a) an intermediate layer of liquid crystal material;
- (b) untreated front and rear substrates and associated electrode layers positioned on opposite sides of the liquid crystal layer, each said substrate and

associated electrode layer having a treated polarizer layer thereon in contact with said sides of the liquid crystal layer, each polarizer layer being treated in situ on its respective substrate and electrode layer to impart a pre-selected artificial liquid crystal alignment-promoting orientation thereto so that each serves the dual function of polarizing and liquid crystal alignment means in the display.

This arrangement might be used in the situation where the liquid crystal alignment directions of the front and rear polarizer layers are to be oriented at other than 90° with respect to one another to preferentially form the liquid crystal helix in one direction and thereby minimize certain undesired optical effects.

The rear substrate may include a reflective metallic electrode layer with said treated polarizer alignment layer on the inside surface thereof in contact with the liquid crystal layer of the display. Preferably, the reflective electrode member comprises metallic foil and the polarizer-alignment layer is bonded or deposited on the metallic foil.

A preferred polarizer-alignment layer or film comprises cyanoethylated polyvinyl alcohol or cyanoethylated polyvinyl butyrate each of which has a very high dielectric constant.

These and other details of the present invention will be more fully understood by reference to the following detailed description taken with the accompany-

ing drawings in which :-

Figure 1 is a cross-sectional view of a typical prior art twisted nematic liquid crystal display device;

5 Figure 2 is a cross-sectional view of a liquid crystal display device which is one embodiment of the invention, and

Figures 3 to 5 are views similar to Figure 2 showing further respective embodiments of the invention.

10 A typical prior art twisted nematic liquid crystal display device is illustrated in Figure 1 and includes front and rear glass or other transparent substrate 2 and 4 having conductive electrodes 6a and b and 8, of, for example, tin oxide thereon. Typically,
15 the front electrode is segmented in a particular pattern such as numerals, letters or other symbols to display information while the rear electrode may be provided in the form of unsegmented layer 8 as shown. With this type of unsegmented rear electrode, it is necessary
20 that the lead lines (not shown) connecting the front electrode segments to a voltage source be masked with suitable insulation to prevent unwanted optical activation of the liquid crystal layer or formed with a sufficiently narrow width that any optical effect
25 produced in the liquid crystal is not visible to the unaided eye of viewer A. On the other hand, the rear electrode may be patterned similarly to the front electrode with the front and rear segments being aligned to avoid any overlap of lead lines with the electrodes
30 and thereby prevent unwanted activation of the liquid

crystal layer. Vapour-deposited or otherwise applied onto the electrodes 6 and 8 are thin alignment layers 12 and 14, for example, .05 micron silicon oxide films vacuum deposited at a preselected angle. Spacing of the front and rear substrates a prescribed distance apart and sealing of the liquid crystal layer therebetween is achieved by epoxy or glass frit spacers 16 and 18 disposed around the periphery of the substrates. Polarizer layers 20 and 22 are positioned on the outside surfaces of substrates 2 and 4, respectively, with their polarizing axes oriented at 90° with respect to one another in well known fashion. Typical polarizer films heretofore used comprise 2 mil layers of polyvinyl alcohol bonded to a butyrate protective layer. Finally, a reflector 24 such as aluminum foil is disposed behind the rear substrate 4 and polarizer layer 22 to reflect incident ambient light. As used herein, "reflector" is intended to include also transflectors which were described hereinabove with respect to displays having both day and night time viewability. Of course, electrodes 6 and 8 are connected to suitable and well known electrical circuitry (not shown) to generate an electric field across the liquid crystal layer 10 to selectively alter its optical rotary power.

Figure 2 (wherein like numerals represent like features) illustrates one embodiment of the invention characterised by the placement of polarizer layer 30 on electrode segments 6a and 6b in contact with the liquid crystal layer 10 so that the layer not only

functions as polarizing means in the display but also as liquid crystal alignment means by virtue of its own inherent ability to promote preferential molecular alignment in the liquid crystal when brought into
5 contact therewith with the liquid crystal alignment-promoting direction of the polarizer layer 30 corresponding to its polarizing axis. Although not wishing to be bound by theory, it is believed that the polarizer layer exhibits liquid crystal alignment
10 capabilities as a result of its inherently oriented molecular structure which through Van der Waals forces influences the liquid crystal molecules adjacent thereto.

Polarizer films exhibiting the inherent ability
15 to also function as liquid crystal alignment means in the untreated condition in the display are available commercially, for example, under the designation XA Transfer Film from Marks Polarized Corp. This polarizer film comprises a 4-8 micron layer of iodine-
20 treated, oriented polyvinyl butyrate and can be purchased in large sheet form and then cut to size to fit over the front substrate and electrode segments thereon, the film being bonded thereto by various means such as thermal bonding. However, to optimize the
25 structure and performance of the display, in accordance with the present invention, the polarizer layer is treated in situ to artificially alter its liquid crystal alignment-direction or axis, by rubbing or otherwise. A polarizer film made from XA Transfer Film

with a thickness of 4 microns has been utilized on the front substrate and electrode segments as illustrated in Figure 2 and, in conjunction with a SiO₂ alignment layer and standard outside polarizer on the rear substrate, produced excellent twisted nematic (helical) orientation in the liquid crystal layer and excellent overall display appearance. Operating voltage was about 6 volts. The thickness of the polarizer layer is an important consideration in the invention as a means of reducing the required operating voltage and assuring acceptable switching speed. To this end, the polarizer film is used in preferred thicknesses of less than 6 microns, preferably less than 4 microns.

Another preferred polarizer-alignment film or layer useful in the invention is cyanoethylated polyvinyl alcohol or cyanoethylated polyvinyl butyrate as a result of its very high dielectric constant, e.g. a dielectric constant on the order of 25-30 at 10 micron thickness as opposed to

about 8 for uncianoethylated polyvinyl alcohol or butyrate at the same thickness. With cyanoethylated polyvinyl alcohol or butyrate, the voltage drop across the polarizer layers would thus be significantly less and the necessary driving voltage for the display would not be much different from that for a display with exterior polarizers. The cyanoethylated forms of polyvinyl alcohol or butyrate are available from Poly Sciences Corporation.

Of course, rather than being used as a preformed, precut film, the polarizer-alignment layer 30 may be formed in situ on the untreated substrate 2 and electrode segments 6a and b. For example, one technique which might be employed is to directionally dip-coat the untreated substrate-electrode segments in liquid dichroic material so that the as-applied coating incorporates the molecular orientation necessary for the polarizing as well as liquid crystal alignment functions and retains the orientation after solidification. The dip-coated layer would function as a polarizer-alignment layer 30 after solidification and further treatment in situ by rubbing etc.

Fig. 3 illustrates another embodiment of the invention wherein like numerals represent like features. In this figure, the structure of the display is considerably simplified by utilizing, in addition to the preformed polarizer-alignment film 30 on the front substrate 2, a preformed polarizer alignment film

32 on the rear substrate 4 and electrode 8. Of course, the polarizer-alignment films 30 and 32 could also be formed in situ on each substrate by the directional dip-coating technique already discussed. It is apparent from a comparison of Figures 1 and 3 that the structure of the display has been simplified by reducing the number of layers in the display sandwich from ten in Figure 1 to only eight in Figure 3.

In the event that the liquid crystal alignment axes of the front and rear polarizer layers 30 and 32 of Figure 3 are to be oriented at other than 90° , for example 88° , with respect to one another to preferentially orient the liquid crystal helix in one direction so as to minimize reverse tilt effects, it is convenient to simply apply the aforementioned polarizer layers to the substrate with their polarizing axes in crossed (90°) relation and then to rub or otherwise treat their surfaces to artificially alter their liquid crystal alignment directions at the preselected non-orthogonal angle, e.g. 88° . This mechanical

treatment of the polarizer layers after application to the substrate and independent of their polarizing axes is an advantageous and novel means for optimizing the structure and performance of the display. The polarizer layers may be of the preformed type bonded to the substrate or of the formed-in-place type, e.g. directionally dip-coated substrates, or a combination thereof.

Figures 4 and 5 illustrate still other embodiments of the invention in which the structure of the field effect, twisted nematic display is simplified by combining the rear electrode, associated rear polarizer and liquid crystal alignment means, and reflector together in the form of a reflective metallic electrode member 36 having a transparent polarizer-alignment layer 32 on the inner surface adjacent and in contact with the liquid crystal layer of the display. More specifically, substrate 4 has adhered to its inner surface a reflective metallic rear electrode such as preferably metallic foil, e.g. aluminium foil, which in conjunction with the front electrode segments 6a and b are activated by a conventional voltage source to generate an electric field across the liquid crystal layer 10 for display purposes. Of course, the reflective electrode member 36 may be unsegmented

as shown in Figs. 4 and 5 with the lead lines insulated or it may be patterned complementary to the front electrode segments to avoid lead line overlap. The reflective electrode member 36 also serves to reflect any incident ambient light in the display and for this purpose may be adhered to a suitably etched inner surface on the substrate 4. Bonded or deposited atop the reflector-electrode member is polarizer-alignment layer 32 like those already referred to and described hereinabove. For example, the polarizer-alignment layer could be a preformed polarizer film or a polarizer layer deposited by directional dip-coating with its surface being mechanically treated to artificially alter the liquid crystal alignment direction. In Fig. 4, the front polarizer layer 20 is outside the display device in conventional prior art fashion whereas in Fig. 5 the front polarizer 30 is disposed on the inside of the display device and also functions as liquid crystal alignment means as described hereinabove.

It is apparent from a comparison of Figs. 1, 4 and 5 that the structure of the display has been simplified by reducing the number of layers in the sandwich construction from ten in Fig. 1 to eight in Fig. 4 and only seven in Fig. 5.

If desired, the reflective metallic rear electrode 36 can be made to function as a transflector by using a partially aluminized or silvered plastics layer. The rear electrode can be conveniently applied to the substrate by vacuum vapour disposition or

similar techniques. On the other hand, if the display is to operate only in the reflective mode, it may be possible to increase the thickness of the rear reflector-electrode member 36 and dispense with substrate 4 altogether, thereby further eliminating an additional layer from the sandwich construction.

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CLAIMS:

1. A liquid crystal display device of the field effect, twisted nematic type, which comprises an untreated substrate and associated electrode layer having a treated polarizer layer thereon in contact
5 with the liquid crystal, the polarizer layer being treated in situ on said substrate and electrode layer to impart a preselected artificial liquid crystal alignment-promoting orientation thereto so that said polarizer layer serves the dual function of polarizing
10 and liquid crystal alignment means in the display.
2. A display device according to Claim 1, wherein the polarizer layer is treated by rubbing.
3. A display device according to Claim 1, wherein the polarizer layer is treated to have a liquid crystal
15 alignment direction different from its polarizing axis.
4. A display device according to Claim 1, wherein the polarizer layer comprises cyanoethylated polyvinyl alcohol or cyanoethylated polyvinyl butyrate.
5. A liquid crystal display device of the field
20 effect, twisted nematic type, comprising:
 - a) an intermediate layer of liquid crystal material;
 - b) untreated front and rear substrates and associated electrode layers positioned on
25 opposite sides of the liquid crystal layer, each said substrate and associated electrode



- 5 layer having a treated polarizer layer thereon in contact with said sides of the liquid crystal layer, each polarizer layer being treated in situ on its respective substrate and electrode layer to impart a preselected artificial liquid crystal alignment-promoting orientation thereto so that each serves the dual function of polarizing and liquid crystal alignment means in the display.
- 10 6. A display device according to Claim 5, wherein the rear substrate includes a reflective electrode layer with said treated polarizer-alignment layer thereon in contact with the rear side of the liquid crystal layer.

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