

PATENT SPECIFICATION

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(54) LIQUID CRYSTAL DISPLAY DEVICE

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese body corporate, of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to liquid crystal display devices and in particular, although not so restricted, to liquid crystal display devices for wristwatches.

According to one aspect of the present invention there is provided a liquid crystal display device comprising a nematic liquid crystal material sandwiched between two transparent plate members, opposed surfaces of which have electrode means thereon, each of the opposed surfaces of the plate members being treated so that molecules of liquid crystal material in contact therewith are aligned in a given direction, the plate members being substantially square or rectangular in plan and said given directions being at an angle to one another and to the sides of the plate members.

At least one of the given directions may be parallel to a diagonal of the plate members.

Said given directions are preferably at or substantially at right angles to one another.

The nematic liquid crystal material may have positive dielectric anisotropy.

According to a further aspect of the present invention there is provided a wrist watch having a liquid crystal display device as recited above.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figures 1a and 1b show, in plan, two embodiments of a conventional liquid crystal display device;

Figures 2a and 2b show, in plan, two embodiments of a liquid crystal display

device according to the present invention; and

Figure 3 is a perspective view of a liquid crystal display device according to the present invention.

In the drawings like parts have been designated by the same reference numerals.

Nematic liquid crystal material has a structure in which the molecules are aligned parallel to one another. If a nematic liquid crystal material is inserted between two plate members, this structure is greatly influenced by the nature of the opposed surfaces of the plate members in contact therewith. When each of the opposed surfaces of the plate members is rubbed in a given direction with, for example, compressed cotton, the molecules of the nematic liquid crystal material in contact therewith are aligned with the given direction. If the two plate members are arranged so that their given directions of rubbing are at an angle to one another, the orientation of the molecules of the nematic liquid crystal material continuously changes between the plate members, the molecules in contact with each plate member being in alignment with the given direction of rubbing thereof. Thus, in effect, the nematic liquid crystal material has a spiral structure in a direction perpendicular to the planes of the plate members.

A nematic liquid crystal material having such a spiral structure is optically active, the direction of the plane of polarization of polarized light passing through the nematic liquid crystal material being rotated by an angle equal to the angle between the given directions of rubbing of the plate members. Thus, when the given directions of rubbing of the two plate members are at right angles to one another, the plane of polarization of polarized light passing through the nematic liquid crystal material will be rotated through 90°.

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If the nematic liquid crystal material has positive dielectric anisotropy, when a voltage is applied thereacross by means of transparent electrodes provided on the opposed surfaces of the plate members, the molecules of the nematic liquid crystal material become aligned with the electric field and the spiral structure disappears, that is to say the liquid crystal material becomes optically inactive. If the liquid crystal display device described above is positioned between two polarizers which have their planes of polarization at right angles to one another, this optical inactivity can be seen when a voltage is applied between the electrodes; thus the display will be dark in the region of electrodes with a light background.

The degree of alignment of the molecules of the nematic liquid crystal material with the electric field is dependent upon the applied voltage which is usually about 6 volts AC. However, with a voltage of this magnitude the molecules of the nematic liquid crystal material in between the plate members are not perfectly aligned with the electric field. To obtain perfect alignment of the molecules of the nematic liquid crystal material with the electric field, an applied voltage of about 15 volts AC is required. Thus when only about 6 volts is applied across the electrodes, the nematic liquid crystal material does not become totally optically inactive. Consequently, the optical effect is different according to the direction of observation of the liquid crystal display device and there is, in fact, one direction in which the optical inactivity when an electric field is applied to the electrodes cannot be observed.

Referring now to Figures 1a and 1b of the drawings there is shown two conventional liquid crystal display devices of the type discussed above. The two plate members are indicated by the reference numerals 1, 2 and the respective given directions of rubbing are indicated by the reference numerals 3, 4 respectively. The polarizers and the electrodes are not shown in Figures 1a and 1b.

An arrow indicates the direction 5 in which optical inactivity cannot be observed when an electric field is applied to the nematic liquid crystal material, this direction 5 being defined by the given direction 4 of rubbing of the plate member 2 and the direction opposite to the given direction 3 of rubbing of the plate member 1. It has been found that the direction 5 is the same irrespective of whether the spiral structure of the nematic liquid crystal material is dextrorotatory or levorotatory. An arrow indicates the direction 6, opposite to the direction 5, in which the optical inactivity is observed very clearly.

As shown in Figures 1a and 1b, the given

direction 3, 4 of rubbing of the plate members 1, 2 are substantially parallel to the sides of the plate members. Thus the direction 5 is either from the top right upper side of the liquid crystal display device to the bottom left lower side or from the top right lower side of the liquid crystal display device to the bottom left upper side, depending upon the given directions of rubbing. The directions "top" and "bottom" refer to the directions in the plane of the drawings whereas the directions "upper" and "lower" refer to the directions at right angles to the plane of the drawings.

Referring to Figures 2a and 2b there is shown part of a liquid crystal display device according to the present invention; like parts in Figures 2a and 2b and in Figures 1a and 1b have been designated by the same reference numerals. Again, the polarizers and the electrodes are not shown in Figures 2a and 2b. The given directions 3, 4 of rubbing are arranged so that they are at an angle to the sides of the plate members 1, 2 which are substantially rectangular in plan although they may be substantially square in plan. Thus the observer looks at the display in the direction 6 in which the optical activity appears clearly, the direction 5 being from the top central lower side of the liquid crystal display device to the bottom central upper side or from the top central upper side of the liquid crystal display device to the bottom central lower side. Thus in the case where the plate members are rectangular (as shown) or square in plan the given directions 3, 4 of rubbing are at an angle to the sides of the plate members and parallel to at least one of the diagonals. In the case where the display is elongate the directions 3, 4 of rubbing are at an angle to the length direction of the display.

Figure 3 shows a liquid crystal display device according to the present invention sandwiched between polarizers 8, the nematic liquid crystal material being indicated by the reference numeral 7.

A liquid crystal display device according to the present invention is of particular use in wrist watches since it is possible to arrange for the direction 6 to be towards the observer in the normal position of observation and thus the display will be seen most clearly.

WHAT WE CLAIM IS:

1. A liquid crystal display device comprising a nematic liquid crystal material sandwiched between two transparent plate members, opposed surfaces of which have electrode means thereon, the opposed surfaces of the plate members being treated so that molecules of liquid crystal material in contact therewith are aligned in a given direction, the plate members being substantially square or rect-

If the nematic liquid crystal material has positive dielectric anisotropy, when a voltage is applied thereacross by means of transparent electrodes provided on the opposed surfaces of the plate members, the molecules of the nematic liquid crystal material become aligned with the electric field and the spiral structure disappears, that is to say the liquid crystal material becomes optically inactive. If the liquid crystal display device described above is positioned between two polarizers which have their planes of polarization at right angles to one another, this optical inactivity can be seen when a voltage is applied between the electrodes; thus the display will be dark in the region of electrodes with a light background.

The degree of alignment of the molecules of the nematic liquid crystal material with the electric field is dependent upon the applied voltage which is usually about 6 volts AC. However, with a voltage of this magnitude the molecules of the nematic liquid crystal material in between the plate members are not perfectly aligned with the electric field. To obtain perfect alignment of the molecules of the nematic liquid crystal material with the electric field, an applied voltage of about 15 volts AC is required. Thus when only about 6 volts is applied across the electrodes, the nematic liquid crystal material does not become totally optically inactive. Consequently, the optical effect is different according to the direction of observation of the liquid crystal display device and there is, in fact, one direction in which the optical inactivity when an electric field is applied to the electrodes cannot be observed.

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An arrow indicates the direction 5 in which optical inactivity cannot be observed when an electric field is applied to the nematic liquid crystal material, this direction 5 being defined by the given direction 4 of rubbing of the plate member 2 and the direction opposite to the given direction 3 of rubbing of the plate member 1. It has been found that the direction 5 is the same irrespective of whether the spiral structure of the nematic liquid crystal material is dextrorotatory or levorotatory. An arrow indicates the direction 6, opposite to the direction 5, in which the optical inactivity is observed very clearly.

As shown in Figures 1a and 1b, the given

direction 3, 4 of rubbing of the plate members 1, 2 are substantially parallel to the sides of the plate members. Thus the direction 5 is either from the top right upper side of the liquid crystal display device to the bottom left lower side or from the top right lower side of the liquid crystal display device to the bottom left upper side, depending upon the given directions of rubbing. The directions "top" and "bottom" refer to the directions in the plane of the drawings whereas the directions "upper" and "lower" refer to the directions at right angles to the plane of the drawings.

Referring to Figures 2a and 2b there is shown part of a liquid crystal display device according to the present invention; like parts in Figures 2a and 2b and in Figures 1a and 1b have been designated by the same reference numerals. Again, the polarizers and the electrodes are not shown in Figures 2a and 2b. The given directions 3, 4 of rubbing are arranged so that they are at an angle to the sides of the plate members 1, 2 which are substantially rectangular in plan although they may be substantially square in plan. Thus the observer looks at the display in the direction 6 in which the optical activity appears clearly, the direction 5 being from the top central lower side of the liquid crystal display device to the bottom central upper side or from the top central upper side of the liquid crystal display device to the bottom central lower side. Thus in the case where the plate members are rectangular (as shown) or square in plan the given directions 3, 4 of rubbing are at an angle to the sides of the plate members and parallel to at least one of the diagonals. In the case where the display is elongate the directions 3, 4 of rubbing are at an angle to the length direction of the display.

Figure 3 shows a liquid crystal display device according to the present invention sandwiched between polarizers 8, the nematic liquid crystal material being indicated by the reference numeral 7.

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WHAT WE CLAIM IS:

1. A liquid crystal display device comprising a nematic liquid crystal material sandwiched between two transparent plate members, opposed surfaces of which have electrode means thereon, each of the opposed surfaces of the plate members being treated so that molecules of liquid crystal material in contact therewith are aligned in a given direction, the plate members being substantially square or rect-



angular in plan and said given directions being at an angle to one another and to the sides of the plate members.

2. A display device as claimed in claim 5 1 in which at least one of the given directions is parallel to a diagonal of the plate members.

3. A display device as claimed in claim 10 1 or 2 in which said given directions are at or substantially at right angles to one another.

4. A display device as claimed in any preceding claim in which the nematic liquid crystal material has positive dielectric 15 anisotropy.

5. A liquid crystal display device substantially as herein described with reference to and as shown in Figures 2a, 2b and 3 of the accompanying drawings.

6. A wrist watch having a liquid crystal 20 display device as claimed in any preceding claim.

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