

PATENT SPECIFICATION (11)

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- (21) Application No. 9062/73 (22) Filed 23 Feb. 1973 (19)
 (31) Convention Application No. 27162/72 (32) Filed 17 March 1972 in
 (33) Japan (JA)
 (44) Complete Specification published 12 Feb. 1975
 (51) INT. CL.² G02F 1/13
 (52) Index at acceptance
 H4F 23E 25P2



(54) LIQUID CRYSTAL DISPLAY DEVICE

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese body corporate, of 3—4, 4-chome, Ginza, Cho-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.

According to one aspect of the present invention there is provided a liquid crystal display device comprising: two transparent plate members having electrode means on opposed surfaces thereof; nematic liquid crystal material with positive dielectric anisotropy between said plate members and in contact with the electrode means, the electrode means being such that the direction of alignment of the molecules of liquid crystal material is rotated through 90° between the electrode means; polarizing means in contact with each plate member;; and diffuse reflector means in contact with one of the polarizing means.

The diffuse reflector means may comprise a diffusing translucent member having a coating of reflective material thereon. The reflective material may be silver, aluminium or platinum. The translucent member may be of glass. Alternatively, the diffuse reflector means may comprise a metal member having a surface with a satin finish. The metal member may be silver, aluminium or platinum.

Alternatively, in a modified device the diffuse reflector means may comprise a reflector on said one polarizing means the latter being translucent.

Preferably the polarizing means are arranged with their planes of polarization at right angles to one another.

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

Figure 1 shows the principle of a liquid crystal display device according to the present invention; and

Figure 2 is a section of a liquid crystal

display according to the present invention.

The study of liquid crystal materials over the years has shown them to have the liquidity of a fluid and the optical anisotropy of a crystal. It has been discovered that liquid crystal materials can change their physical character and optical properties upon the application thereto of various forms of energy, such as an electric field, a magnetic field, etc.

One application of liquid crystal materials is in display devices since liquid crystal materials have a low energy consumption. Much work, therefore, has been done in the field of display devices employing liquid crystal material. In one conventional display device, a nematic crystal material which has negative dielectric anisotropy is used.

Liquid crystal materials are divided into three classes according to the arrangement of the molecules thereof, namely smectic, cholesteric and nematic. Furthermore, nematic liquid crystal materials are divided into two sub-classes, namely, those with positive dielectric anisotropy and those with negative dielectric anisotropy.

Nematic liquid crystal material with positive dielectric anisotropy has the property that the polarization and dipole moment of the molecules is in the longitudinal direction of the molecules. On the other hand nematic crystal material with negative dielectric anisotropy has the property that the dipole moment is at right angles to the longitudinal direction of the molecules. Typical examples of nematic liquid crystal material with positive dielectric anisotropy are: *p*-alkoxybenzylidene-*p*¹-aminobenzonitrile, *p*-acyloxybenzylidene-*p*¹-aminobenzonitrile, *p*-cyanobenzylidene-*p*¹-alkylaniline, *p*-cyanobenzylidene-*p*¹-alkoxyaniline.

It is well known that a display device may be formed by sandwiching nematic liquid crystal material between two electrodes. If the opposed surfaces of the electrodes are rubbed with gauze or cotton, for example, it is believed that the molecules of the very small quantity of water on the electrodes are aligned in the direction of rubbing. The

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molecules of the liquid crystal material in contact with these aligned water molecules also becomes aligned in a parallel direction. Thus if nematic liquid crystal material is enclosed between two electrodes whose opposed surfaces have been rubbed with gauze or cotton, for example, in mutually perpendicular directions, the molecules of the liquid crystal material arrange themselves in such a way that the direction of their alignment is rotated through 90° between the electrodes. Consequently, the nematic crystal material possesses an optical activity such that the plane of polarization of light is rotated by 90° as it passes through the nematic liquid crystal material. Accordingly, in a display device in which the nematic liquid crystal material and the electrodes are placed between two polarizing filters whose planes of polarization are at right angles, incident light will be transmitted through the display device. On the other hand, if the planes of polarization of the filters are parallel to one another light will not be transmitted through the display device but will be absorbed.

If an electric field, however, is applied between the electrodes, and if the nematic liquid crystal material has a positive dielectric anisotropy, then the molecules of the latter will be aligned at right angles to the direction of rubbing and so the optical activity will be destroyed.

Figure 1 shows the principle of a liquid display device according to the present invention. A nematic liquid crystal material 3 with positive dielectric anisotropy is placed between two transparent electrodes 1, 2. The opposing surfaces of the electrodes are treated, for example, by rubbing, so that the direction of alignment of the molecules of the liquid crystal material is rotated through 90° between the electrodes. A polarizing filter 4 and a polarizing filter 5 is disposed adjacent each electrode the planes of polarization of the filters being at right angles to one another. Leads from the electrodes 1, 2 are connected to a power source 6, a switch 7 being provided in the circuit.

A liquid crystal display device constructed as above will have an optical activity such that light will have its plane of polarization rotated through 90° as it passes through the liquid crystal material. Thus when the switch 7 is open, incident light 8 will pass through the liquid crystal display device. However, when the switch 7 is closed, incident light will not pass through the liquid crystal display device because the molecules of the liquid crystal material are re-orientated on the application of an applied electric field, and the optical activity of the liquid crystal material is destroyed so that it becomes optically isotropic. If the filters 4, 5 are arranged with their planes of polarization par-

allel to one another, incident light will pass through the liquid crystal display device when the switch 7 is closed but not when it is open.

To reduce the amount of incident light absorbed by the filters 4, 5 a diffuse reflector (not shown) is provided on the surface of the filter 5. In this manner, the liquid crystal display device can be used in an environment in which the light conditions are poor. The diffuse reflector may, for example, be a frosted or translucent glass plate coated with a highly reflective metal such as silver, aluminium or platinum. The metal may be vapour deposited or plated onto the glass plate. Alternatively the diffuse reflector may be a silver sheet with a satin finish, an aluminium sheet, an opaque plastics sheet coated with silver, aluminium or platinum, etc. The satin finish may be produced by anodising in the case of aluminium, or by alumite treatment or by chromet treatment.

In the case where at least one of the filters is translucent, a mirror reflector can be utilized in place of the diffuse reflector.

One embodiment of a liquid crystal display device according to the present invention is shown, in section, in Figure 2. A display cell comprises two transparent plates 11, 12 provided with transparent conductive films 13, 14 respectively. A nematic liquid crystal material 16 with positive dielectric anisotropy is enclosed between the films. The films are treated, for example, by rubbing so that the direction of alignment of the molecules of the nematic crystal material is rotated through 90° between the films. A polarizing filter 9 and a polarizing filter 10 are disposed on the transparent plates 11, 12 respectively. The polarizing filter 10 is provided with a diffuse reflector 15 which may be of the construction described in connection with Figure 1. Leads from the films 13, 14 are connected to a power source 18, a switch 17 being provided in the circuit. When the switch 17 is open, the liquid crystal material is optically active so that the plane of polarization of light passing there-through is rotated through 90° . When the switch 17 is closed this optical activity is destroyed as explained above.

The liquid crystal display device described above has the advantage that, due to the provision of the diffuse reflector, the display, which is apt to be dark on account of the light absorbed by the polarizing filters, is bright and contrast is good.

A liquid crystal display device according to the present invention may be used, for example, in a wrist watch, a clock, a compact electronic desk-top calculator, etc.

Coloured glass or other material may be used for the diffuse reflector if it is desired that the display of the liquid crystal display device is coloured.

WHAT WE CLAIM IS:—

1. A liquid crystal display device comprising: two transparent plate members having electrode means on opposed surfaces thereof; nematic liquid crystal material with positive dielectric anisotropy between said plate members and in contact with the electrode means, the electrode means being such that the direction of alignment of the molecules of liquid crystal material is rotated through 90° between the electrode means; polarizing means in contact with each plate member; and diffuse reflector means in contact with one of the polarizing means.
2. A device as claimed in claim 1 in which the diffuse reflector means comprises a diffusing translucent member having a coating of reflective material thereon.
3. A device as claimed in claim 2 in which the reflective material is silver, aluminium or platinum.
4. A device as claimed in claim 2 or 3 in which the translucent member is made of glass.
5. A device as claimed in claim 1 in

which the diffuse reflector means comprises a metal member having a surface with a satin finish.

6. A device as claimed in claim 5 in which the metal member is silver, aluminium or platinum.

7. A modification of the device as claimed in claim 1 in which the diffuse reflector means comprises a reflector on said one polarizing means the other being translucent.

8. A device as claimed in any preceding claim in which the polarizing means are arranged with their planes of polarization at right angles to one another.

9. A liquid crystal display device substantially as herein described with reference to and as shown in Figure 2 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1975
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY
from which copies may be obtained.

