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(54) ELECTRIC TIMEPIECES

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a corporation of Japan, 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 electric timepieces and more specifically to electric timepieces of the kind in which time is displayed by a plurality of controllable display devices in which display is effected by nematic or cholesteric materials in the liquid crystal phase. For the sake of brevity such devices will be referred to hereinafter and in the claims as "nematic or cholesteric liquid crystal display devices". The main object of the invention is to provide improved electric timepieces of this kind providing simple clear and satisfactory displays.

As is well known there are many crystal materials in the liquid crystal phase which have the property of causing scattering of light when a voltage is applied thereacross. Some nematic or cholesteric crystals have this property. Nematic crystals in the liquid crystal phase are particularly sensitive to the influence of an electric field which causes the molecules thereof to be disturbed and in consequence the light to be dispersed thereby. Only low electrical power is required to make use of this light scattering power and accordingly nematic or cholesteric liquid crystal devices are very advantageous for displaying time in electrical wrist watches and other small "self-contained" timepieces, for in such timepieces the achievement of low power consumption is of paramount importance since the source of operating electric power is a D.C. battery which has to be accommodated in the timepiece.

The present invention seeks to provide improved timepieces of the kind referred to which shall be relatively simple and economical to manufacture but which shall nevertheless provide a clear time display which is satisfactory and pleasing to the user.

According to this invention the display devices of an electric timepiece comprising a display arrangement having a plurality of controllable nematic or cholesteric liquid crystal time display devices as herein defined, an electric time-keeping apparatus arranged to control the time display given by said plurality of devices and means for connecting a battery to provide D.C. operating electric power to said apparatus include digital display devices for displaying the hours and minutes of time as variable numerical characters and display means for displaying predetermined periods of time shorter than one minute in a different manner.

Preferably said display means comprise a controllable set of sector shaped devices arranged adjacent one another to provide a circular display made up of adjacent sectors. The circular display may be made up of six sectors.

In one embodiment of the invention said time-keeping apparatus includes a time-standard master oscillator or vibrator, means for deriving from the output thereof a plurality of different frequencies in fixed predetermined different frequency relationships with the frequency of said output and means controlled by said plurality of frequencies for controlling the plurality of display devices to display time.

Electrical display devices employing crystal material in the liquid crystal phase most usually comprise a cell containing liquid crystal between a pair of Nesa electrodes ("Nesa" is a registered trade mark) of the conventional tin oxide material. When voltage is applied between the electrodes of the cell, however, electrolysis of water contained in the cell takes place. In practice there is water present in the cell either from moisture in the and and/or water which is not removed from the liquid crystal material during manufacture and/or from some other cause. Electrolysis of this water breaks it down into hydrogen and gas bubbles occur. The gas adversely affects the liquid crystal material and, moreover, the released hydrogen reduces

[Price 25p]

the Nesa film constituting the electrodes producing a black metallic film which is exfoliated from the substrate (usually glass) by which it is carried. As will be readily appreciated, electrolysis with its consequent release of gas bubbles of hydrogen and oxygen is particularly bad when D.C. is applied across the electrodes and, with D.C. operation, deterioration of a display device as so far described above may be rapid. The rate of deterioration in use may, however, be considerably reduced if, as is known, at least one of the electrodes has at least the surface thereof in contact with the crystal material made of a material which acts as a catalyst with respect to the combination of hydrogen and oxygen into water. Suitable electrode surface materials for this purpose are transition metals or alloys thereof or oxides of said metals or alloys, examples being palladium, platinum, nickel, iridium, rhodium, cobalt, iron, osmium, ruthenium, or an alloy thereof or a compound, e.g. an oxide, of such metal or alloy. The compound may be an oxide. If one of the electrodes is in the form of thin foil carried upon a transparent carrier substrate e.g. of glass, the selected electrode material (i.e. the palladium, platinum, iridium, rhodium, osmium or ruthenium, or alloy thereof, of compound of such metal or alloy) may be constituted by a deposit thereof which has been evaporated onto the said glass or other substrate with an intermediate layer provided therebetween for improving the adherence between the electrode material and the substrate, the intermediate layer being constituted by an evaporated deposit on the substrate of a highly adherent metal such as nickel, aluminium, copper, manganese, chromium, iron, titanium, or tantalum. Because a display device will have a long useful life, even when operated by D.C., if, as is known, at least one of its electrodes has the surface in contact with the crystal material made of a material which acts as a catalyst with respect to the combination of hydrogen and oxygen into water, electrodes so made are preferably employed in the time display devices used in carrying out this invention.

The invention is illustrated in and further explained in connection with the accompanying drawings.

In the drawings, Figures 1, 2 and 3, which do not show embodiments of this invention but are provided for preliminary explanatory purposes only, are simplified cross-sectional views showing three forms of display cell known per se, while Figures 4, 5 and 6 illustrate the present invention.

The cell shown in Figure 1 comprises two glass plates 1, 3 which are spaced from and are parallel to each other and which, at their surfaces facing each other, are provided with transparent conductive film electrodes 2 which are spaced apart

by insulating spacer members 5. A nematic or cholesteric crystal in the liquid crystal phase is retained between the electrodes 2, and the insulating spacer members 5. The electrodes 2 are connected by lead wires in an electrical circuit which is shown as incorporating a battery 6, an ammeter 7 and a switch 8. When the switch 8 is closed, a voltage is applied to the electrodes 2 with the result that the crystal material 4 causes scattering of the light. One or both of the electrodes 2 is made of a catalytic substance which causes hydrogen and oxygen to combine to form water, e.g. a transition metal such as palladium, platinum, nickel, iridium, rhodium, cobalt, iron, osmium or ruthenium, or an oxide thereof.

In Figure 2 the display device comprises a transparent electrode 1 and an electrode 9 constituted by a metallic catalytic substance such as a transition metal which can act as a catalyst, to cause H_2 and O_2 to combine to form water. The surface of the electrode 1 facing the electrode 9 is provided with a transparent conductive film 2, the latter being spaced from the electrode 9 by insulating spacing member 5. Crystal material 4 in the liquid crystal phase is retained between the electrode 9, film 2 and insulating spacing members 5. The electrode 9 and the film 2 of the electrode 1 are connected in an electrical circuit comprising a battery 6 and a switch 8. When the switch 8 is closed, the direct current from the battery 6 causes the crystal material 4 to scatter light. Direct current operation may continue for a considerable time without degeneration of the device.

In Figure 3 the display device comprises two parallel glass plates 1, (shown broken away) each of which is provided at its internal surface with a film electrode 2 at least one of which is transparent. The electrode 2 is formed of a catalytic substance such as palladium, platinum, iridium, rhodium, osmium, ruthenium, or a compound thereof such as an oxide. The electrodes 2 are spaced apart by insulating spacing means (not shown), and interposed between the electrodes 2 is a crystal material 4 in the liquid crystal phase which has the property of scattering the light when voltage is applied between the electrodes 2 which are connected in a circuit including a direct current electrical source such as a battery 6. The electrodes 2 are formed on a glass surface and one may be either formed of black body material or be provided with a polished surface. By using for one electrode a black oxide or other black compound, or, alternatively, by polishing it to a mirror surface, a clearer vision of the liquid crystal display is obtainable.

Referring to Figure 4, which shows diagrammatically a timepiece in accordance with this invention, the said timepiece has, as its time-keeping standard, a master oscillator 25

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the output from which is fed to a frequency divider 26 followed by a decimal counter 27. The frequency of the master oscillator and the division ratio of the divider 26 and the counter 27 are such that the said counter provides a signal every 10 seconds. These signals are fed to a divide-by-six counter 28.

The divide-by-six counter output is delivered to a decoder 32 to control a six-sector second display D, each sector representing 10 seconds (see Figure 6 which shows the sector display more fully). The control is effected through a driving control circuit 36 receiving inputs from 32 and point 56 (54 is an AND gate) and a switching control circuit 55. The arrangement is such that a fresh sector is switched in every 10 seconds.

A divide-by ten counter 29 counts minutes up to 10 and is fed with a minute signal input. An output corresponding to the count therein is used to determine the display given by a digital (numeric) minute display device 44 via a decoder 33 and a switching control circuit 38. The digital display device 44 is of a known type and may, as shown in Figure 5, comprise seven selectable segments switchable (by 38) to display any numeral.

In similar manner a 10 minute input signal fed to a divide-by six counter 30 operates a 10 minute digital display device 43 similar to the device 44, via a decoder 30 and switching control circuit 39.

31 is a divide-by twelve counter, which receives an hour signal input and operates, via a decoder 35 and switching control circuit 40 two digital display devices 42 and 41 of which 42 displays hours and 41 the tens figure of the hours.

A switch 52 is provided for resetting each frequency divider into its initial condition. Switches 49, 50 and 51 are for setting the minutes, tens of minutes, and hours displayed by the digital display devices to the required numbers. These switches may be used, accordingly, when it is required to set the digital display of the watch to the correct time. Since the displayed time-setting means form no part of this invention and may be as known per se they need not be described in detail herein. However, as will be apparent from Figure 4, operation of the switches 49 to 51 inclusive step up the counts in the counters 29 to 31, so that, by actuating switches 49, 50 and 51 the counters 29, 30 or 31 receive, via gates 48, signals which produce the result of stepping up the minute, tens of minutes and hours, respectively, displayed while switch 52, which also operates on the counter 31, has the effect, when operated, of stepping up the tens figure of the hours display. As will also be seen from Figure 4 the position of each of the switches 49 to 52 determines whether the potential at its output terminal is V_H or earth potential. The counter elec-

trode of the non-digital sector display device is referenced 47 and those of the digital display devices 41 to 44 are all referenced 46. These counter electrodes are at a potential V_L so that the potential between the selected segment electrode or electrodes of any of the digital display device and the counter electrode of that device will be either V_O or V_O' as given by:—

$$V_O = V_H - V_L \quad (1) \quad 75$$

$$V_O' = V_E - V_L \quad (2) \quad 75$$

where V_E is earth potential.

If the display devices have a threshold voltage of the V_{TH} and the voltage required for a continuous display is V_{ON} , the n the values of V_O and V_O' are so chosen that:

$$V_O > V_{ON}$$

$$V_O' < V_{TH}$$

$$V_{ON} > V_{TH}$$

subtracting (1) from (2) gives

$$V_O - V_O' = V_H - V_E$$

so that

$$V_O > V_H - V_E$$

Figure 5 shows one of the digital display devices in more detail (for example the minute display device 44) together with the switches SW_1 to SW_7 which are actuated by and form part of the switching control device (38 in the case of the device 44) which effect selection among the seven segments of said display device. When any of the switches is in one position the segment to which it is connected receives the potential V_H . In the other switch position the segment is at potential V_E i.e. is earthed. With the switches in the positions shown in Figure 5 the numeral 7 is displayed, as indicated by the shading.

Figure 6 shows, in manner similar to that adopted for Figure 5, the non-digital display device which, in this example has six sectors S_1 to S_6 . The switches in the switch control device 55 are also shown in Figure 6. With the switches in the positions shown in Figure 6 the two sectors S_1 to S_2 are receiving the potential V_H and therefore display 20 seconds. This is indicated by the shading. Of course by using a different number of sectors different intervals of time, less than one minute, can be displayed non-digitally.

For reasons already explained herein the electrodes in the display devices employed preferably have at least their surfaces in contact with the liquid crystal material made of a material which acts as a catalyst with res-

5 pect to the combination of oxygen and hydro-
gen into water and the known general manu-
facturing methods used in the known display
devices hereinbefore described with reference
to Figures 1 to 3 may be applied, in manner
which will be obvious, to the display devices
used in carrying out this invention.

WHAT WE CLAIM IS:—

- 10 1. An electric timepiece comprising a dis-
play arrangement having a plurality of con-
trollable nematic or cholesteric liquid
crystal time display devices, as herein
defined, an electric time-keeping appar-
atus arranged to control the time display
15 given by said plurality of devices and means
for connecting a battery to provide D.C.
operating electric power to said apparatus and
devices wherein said plurality of display de-
vices include digital display devices for dis-
20 playing the hours and minutes of time as
variable numerical characters and display
means for displaying pre-determined periods
of time shorter than one minute in a different
manner.
- 25 2. A timepiece as claimed in claim 1 where-
in said display means comprise a controllable

set of sector shaped devices arranged adja-
cent one another to provide a circular display
made up of adjacent sectors.

30 3. A timepiece as claimed in claim 2 where-
in the circular display is made up of six
sectors.

35 4. A timepiece as claimed in any of the
preceding claims wherein said time-keeping
apparatus includes a time-standard master
oscillator or vibrator, means for deriving from
the output thereof a plurality of different fre-
quencies in fixed pre-determined different fre-
quency relationships with the frequency of
said output and means controlled by said plur-
40 ality of frequencies for controlling the plur-
ality of display devices to display time.

45 5. A timepiece as claimed in any of the
preceding claims and substantially as herein
described with reference to the accompanying
drawings.

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5 pect to the combination of oxygen and hydrogen into water and the known general manufacturing methods used in the known display devices hereinbefore described with reference to Figures 1 to 3 may be applied, in manner which will be obvious, to the display devices used in carrying out this invention.

WHAT WE CLAIM IS:—

- 10 1. An electric timepiece comprising a display arrangement having a plurality of controllable nematic or cholesteric liquid crystal time display devices, as herein defined, an electric time-keeping apparatus arranged to control the time display
15 given by said plurality of devices and means for connecting a battery to provide D.C. operating electric power to said apparatus and devices wherein said plurality of display devices include digital display devices for displaying the hours and minutes of time as
20 variable numerical characters and display means for displaying pre-determined periods of time shorter than one minute in a different manner.
25 2. A timepiece as claimed in claim 1 wherein said display means comprise a controllable

set of sector shaped devices arranged adjacent one another to provide a circular display made up of adjacent sectors.

30 3. A timepiece as claimed in claim 2 wherein the circular display is made up of six sectors.

4. A timepiece as claimed in any of the preceding claims wherein said time-keeping apparatus includes a time-standard master
35 oscillator or vibrator, means for deriving from the output thereof a plurality of different frequencies in fixed pre-determined different frequency relationships with the frequency of said output and means controlled by said plurality of frequencies for controlling the plurality of display devices to display time.
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5. A timepiece as claimed in any of the preceding claims and substantially as herein described with reference to the accompanying
45 drawings.

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