

PATENT SPECIFICATION

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(54) ELECTRONIC WRISTWATCH

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company 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 electronic wristwatches.

According to the present invention there is provided an electronic wristwatch comprising oscillating means for producing a standard time signal, divider means for producing from the standard time signal a timing signal, transforming means for producing driving signals from the timing signal and a display device arranged to be driven by the driving signals to display a time indication, the display device comprising a pair of spaced apart electrode means between which there is disposed a display material, the display material being such as to undergo a reversible oxidation-reduction reaction and a colour change when a voltage is supplied to the electrode means.

The display material may be inorganic. Thus the display material may be any one or more of molybdenum trioxide, tungsten dioxide, niobium oxide and titanium dioxide.

The display material may be dyestuff. Thus the dyestuff may be a viologen dyestuff.

In one embodiment the display material is such as to display a plurality of colours, the colour displayed being dependent upon the level of voltage applied to the electrodes.

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

Figure 1 is a plan view of a display device of an electronic wristwatch according to the present invention;

Figure 2 is a cross-section of the display device of Figure 1;

Figure 3, consisting of Figures 3a, 3b and 3c, illustrates an electronic wristwatch according to the present invention; and

Figure 4 is a circuit diagram of part of the circuitry of the electronic wristwatch of Figure 3.

For many years wristwatches have taken the form of precision instruments. Conventional mechanical wristwatches are driven by a main spring, use a hair-spring and a balance wheel as a time standard, and display a time indication by means of hands driven by the main spring through a gear train. As electronic techniques have developed, electronic wristwatches are being produced. In electronic wristwatches, a battery is used as the source of driving power instead of a main spring and a tuning fork is used as a time standard instead of a hair-spring and balance wheel. Furthermore, in recent years electronic wristwatches which will keep time to a remarkably high degree and using a quartz crystal oscillator as a time standard have been produced.

However, these electronic wristwatches, whilst having internal electronic components, indicate the time by means of hands as in conventional mechanical wristwatches. Display devices which consist of light-emitting diodes or liquid crystal elements and which are driven electrically have been proposed for electronic wristwatches and some of these display devices indicate the time in digital form. Electronic wristwatches of this kind can be thought of being "solid state" because they have no mechanical parts. However, solid state electronic

wristwatches have drawbacks: display devices consisting of liquid crystal elements are unreliable and tend to lack clarity and display devices consisting of light-emitting diodes tend to have an unacceptably high power consumption.

It is known that some dyestuffs change colour reversibly when undergoing an oxidation-reduction reaction. These dyestuffs may be of the oxidation type or the reduction type. In some cases, the oxidation type of dyestuffs present a dark colour, and the reduction type of dyestuffs present a light colour or are colourless. On the other hand in some cases, the oxidation type of dyestuffs present a light colour or are colourless and the reduction type of dyestuffs are coloured. Moreover, some organic dyestuffs show a marked difference in solubility between the oxidation type and the reduction type.

Whether a dyestuff is of the oxidation type or of the reduction type is determined by the difference between the oxidation-reduction potential of the dyestuffs and the applied potential. Accordingly, whether the dyestuff is of the oxidation type or of the reduction type can be determined by disposing the dyestuff between parallel electrodes and applying a voltage thereto.

In one embodiment of a display device of an electronic wristwatch according to the present invention a dyestuff of the reduction type, which is light coloured or colourless, is used as a display material and is disposed between transparent electrodes shaped to display a pattern, for example, numerals and/or characters. When a voltage is applied to the electrodes, the dyestuff changes to the oxidation type and becomes dark coloured. By this means a display is produced by the display device.

As mentioned above the solubility of some dyestuffs is greatly reduced when they change from the oxidation type to the reduction type or vice versa. In another embodiment of a display device of an electronic wristwatch according to the present invention such a dyestuff is used as a display material and is disposed between parallel electrodes and a voltage applied thereto. Thus the display material will change from the oxidation type to the reduction type or vice versa and be deposited on the electrodes and in this manner a display is produced.

In both display devices described above, the display is maintained even after the voltage has been removed from the electrodes. The voltage required for these display devices is relatively small because the oxidation-reduction potentials of most dyestuffs are two volts or less and the driving current required is extremely small since it is only necessary to donate or accept the number of electrons involved in the reduction-oxidation reaction. Further, since the dyestuffs change from being colourless or of a light colour to a dark colour, the display produced by these display devices has a relatively high degree of contrast. Moreover, the display is maintained until a voltage in the reverse direction is applied, and thus the display devices are persistent. Display devices of these types are well suited for use in electronic wristwatches which are driven by a power source of limited capacity such as, for example, a battery.

Inorganic materials, for example, molybdenum trioxide, tungsten dioxide, niobium oxide and titanium dioxide may be used as display materials in display devices according to the present invention. These inorganic materials are completely colourless or white in colour when of the oxidation type but when they are changed to the reduction type they present a blue or black colour.

An oxidation-reduction reaction essential involves donation or acceptance of electrons. When one of these inorganic display materials is disposed between transparent electrodes and DC voltage is applied to the electrodes, the display material adjacent the negative electrode, i.e. the electrode at which a reduction reaction occurs, becomes coloured. Thus, if the negative electrode is disposed towards an observer, the colour change on application of a voltage will be visible and a clear display will be obtained.

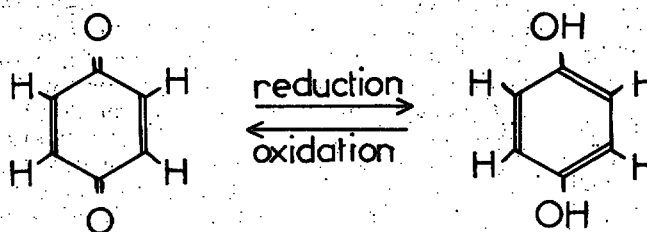
Molybdenum trioxide, tungsten dioxide, niobium oxide and titanium dioxide may be used on their own or in combination as a display material of a display device of an electronic wristwatch according to the present invention. Thus a mixture of titanium dioxide and molybdenum trioxide or a mixture of titanium dioxide and tungsten dioxide may be used as a display material. The greater the degree of reduction of the display material, the darker the colour obtained. The degree of reduction is determined by the applied voltage which also determines the speed of the reduction reaction. It is thought that this results from the number of colour centers caused by the lack of oxygen.

The display of a display device of an electronic wristwatch according to the present invention is extinguished by applying a reverse voltage to the display material or by

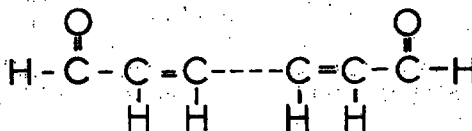
heating the display material, both of which cause an oxidation reaction. Even if the display material undergoes excessive oxidation at the time of extinguishing the display, no specific problems occur. Since the display material is used in the form of a powder or a thin film, the characteristics of the display device are dependent upon various factors such as the condition of the powder or thin film and the form of the electrolyte and electrode material by means of which the voltage is applied to the display material.

The display material of a display device according to the present invention may be hydroquinone (1,4 dihydroxybenzene) which may be used by reducing p-quinone (1,4 benzoquinone).

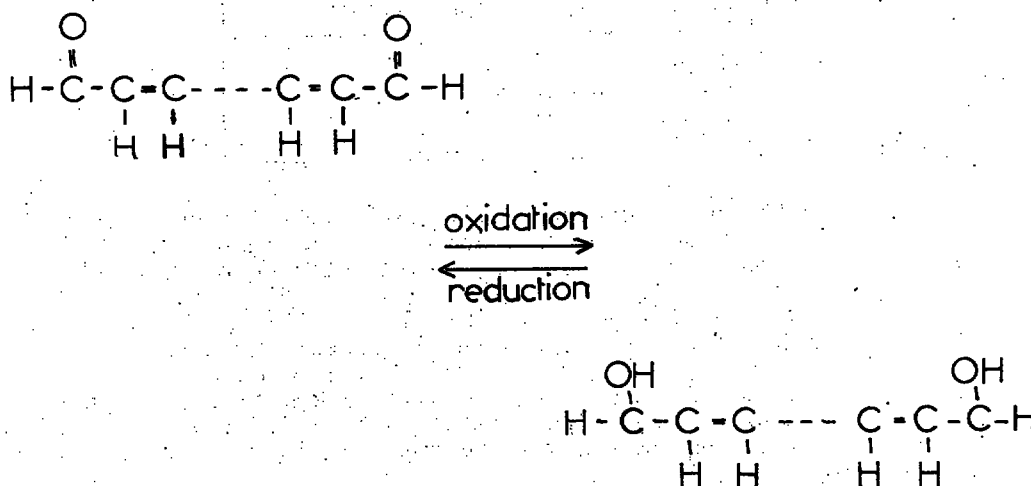
The reaction is as follows:—



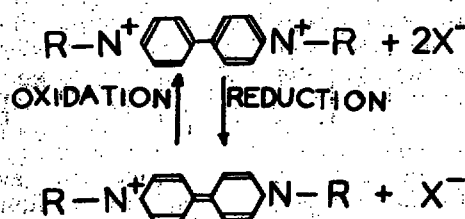
Alternatively, the display material for a display device according to the present invention may be:



and undergo the following reaction:



The display material for a display device according to the present invention may be a viologen dyestuff. A viologen dyestuff is a 4,4 dipyridylium compound which undergoes the following reaction:



where X is a halogen atom and R is an organic radical such as alkyl, alkoxy, acyl, acyloxy, alkyl carbonate etc.

Since the oxidation-reduction potential of a viologen dyestuff is between -300 and 450 millivolts, it is possible to drive a display device of an electronic wristwatch according to the present invention incorporating the viologen dyestuff using a relatively low voltage. The oxidation type of viologen dyestuff will dissolve in water or alcohol, but the reduction type is difficult to dissolve and will deposit on the negative electrode and by this means a display can be formed.

The display material for the display device of an electronic wristwatch according to the present invention may be anthracene.

The colour of the display produced by a display device of an electronic wristwatch according to the present invention, where the display materials are dyestuff, can be selected by mixing various types of dyestuff and suitably choosing the voltage applied thereto. For example, in the case of a display device of an electronic wristwatch according to the present invention which display device displays four digits, i.e. produces an hours indication and a minutes indication, the hours indication can be displayed with a blue colour and the minutes indication with a bluish purple colour. The same display device could be arranged so that the hours indication and the minutes indication are displayed with a blue colour and the date indication and a seconds indication are displayed with a bluish purple colour merely by changing the voltage applied to the display device.

The display material of a display device of an electronic wristwatch according to the present invention may comprise of a display material of the oxidation type which is dark in colour and a display material of the reduction type which is dark in colour so that the display material is deposited on both electrodes when a display is produced.

The following table gives the oxidation-reduction potentials of various display materials for use in display devices of electronic wristwatches according to the present invention.

methylviologen	-0.446 volts
benzylviologen	-0.363
2,6 dibromophenol	0.217

The construction of one embodiment of a display device of an electronic wristwatch according to the present invention is shown in Figures 1 and 2. A transparent electrode 301' is formed on a glass base plate 301 which faces an observer.

A transparent electrode is formed on the whole inner surface of a rear glass plate 302. A spacer 303 is enclosed between the glass plate 301 and the glass plate 302 to maintain them spaced apart. A display material, together with an electrolyte, are sealed in the space 304 between the glass plates 301, 302. The transparent electrode on the glass plate 302 may have a similar shape to the transparent electrode 301', especially if the display device is to produce a multicolour display.

Figure 3 shows one embodiment of an electronic wristwatch according to the present invention, Figure 3a being a plan view from above of the watch movement and Figure 3b being a plan view from beneath of the watch movement. Figure 3c is a perspective view of the wristwatch as a whole. On an upper surface of a printed circuit base plate 501, there is a display cell 502 according to the present invention. On the lower surface of the base plate 501 there is disposed integrated circuitry 503, a quartz crystal oscillator 504, a battery 505 and a trimmer capacitor 506.

Figure 4 shows one embodiment of a circuit for use in an electronic wristwatch according to the present invention. The operation of this circuit will be described assuming that a time indication is displayed in hours and minutes. An oscillator (not shown) for example a quartz crystal oscillator produces a standard time signal of relatively high frequency. A divider circuit (not shown) produces from the standard time signal a one-minute signal 701 having a frequency of 1/60Hz which is applied to the input of a divide-by-ten counter/decoder circuit

5 702. Each time a pulse of the one-minute signal is received by the counter/decoder circuit 702 the latter produces appropriate ones of outputs A to G which are applied to segment electrodes 707 of a display cell 704 which displays the units of minutes of the time indication. The counter/decoder circuit 702 also produces an output signal having a frequency of 1/600Hz which is applied to a divide-by-six counter/decoder circuit 703. Each time the counter/decoder circuit 703 receives a pulse, the latter produces appropriate ones of outputs A to G which are applied to respective segment electrodes of a display cell which displays the tens of minutes of the time indication. The counter/decoder circuit 703 produces an output signal having a frequency of 1/3,600Hz for driving the hours indicating part of the wristwatch which is not shown in Figure 4. 10

Whether or not the display cell 704 produces a display depends upon the voltage potential between the segment electrodes 707, to which is applied a potential of $+\frac{V}{2}$ or $-\frac{V}{2}$, and a common electrode 706. Accordingly, if a potential of $+\frac{V}{2}$ is applied to the common electrode 706 and a potential of $-\frac{V}{2}$ is applied to the electrodes 707, the voltage potential between the electrodes 707 and the common electrode 706 will be $+V$ which is such as to cause a change in the display. On the other hand, if a potential of $-\frac{V}{2}$ is applied to the electrodes 707, the voltage potential between the electrodes 707 and the common electrode 706 will be 0 which is such that the display will be maintained in its current state. 15 20

Since this display cell is persistent and although a certain current must be applied to cause the display to be produced, it is unnecessary for current flow to maintain the display once it has been produced. Similarly, in the case of extinguishing the display it is sufficient merely to cause a given current to flow in the reverse direction. Although the numerals displayed by operation of the timepiece circuitry of Figure 4 change on application of pulses of the one-minute signal 701, the period when a segment is caused to produce a display and when the display is extinguished are different for each segment. 25

If the display cell is controlled so that every segment thereof only receives current at the time when a display is to be produced or when a display is to be extinguished, not only will power consumption be reduced, but also the deterioration of the display cell will be prevented. To this end a switching circuit 705 and a switch control circuit 708 are provided. 30

The pulse widths of the outputs of monostable multivibrators 709, 710 are so chosen as to correspond to the time required to produce a display or to extinguish a display and are triggered by the one-minute signal 701. In the switch control circuit 708 the outputs from the monostable multivibrators are selected by the outputs A to G from the counter/decoder circuit 707 through AND gates 711, 712. Simultaneously an output signal is produced from an OR gate 714 when the AND gates 711, 712 are in receipt of control signals from a flip-flop circuit 713 for memorizing whether a display is to be produced by a segment or is to be extinguished. This output signal is applied to the switching circuit 705 corresponding to the same segment so that the corresponding output from the counter/decoder circuit 702 is permitted or prevented from passing thereto. 35 40

The output from the multivibrators 709, 710 cannot be used directly to control the display of the hours indication. Therefore, AND gates 715, 716 and a flip-flop circuit 717 receive the outputs from the multivibrators and are triggered by the output signal of the preceding counter/decoder circuit. The gates 715, 716 are closed by a gate output of a given pulse width from the AND gate 716 applied to the flip-flop circuit 717. Thus a pulse of the same period and the same width as the output signal from the preceding counter/decoder is obtained. 45 50

The solid state electronic wristwatch according to the present invention and described above is reliable and produces a colourful display with a minimum power consumption.



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WHAT WE CLAIM IS:—

1. An electronic wristwatch, comprising oscillating means for producing a standard time signal, divider means for producing from the standard time signal a timing signal, transforming means for producing driving signals from the timing signal and a display device arranged to be driven by the driving signals to display a time indication, the display device comprising a pair of spaced apart electrode means between which there is disposed a display material, the display material being such as to undergo a reversible oxidation-reduction reaction and a colour change when a voltage is supplied to the electrode means.
2. An electronic wristwatch as claimed in claim 1 in which the display material is inorganic.
3. An electronic wristwatch as claimed in claim 2 in which the display material is any one or more of molybdenum trioxide, tungsten dioxide, niobium and titanium dioxide.
4. An electronic wristwatch as claimed in claim 1 in which the display material is a dyestuff.
5. An electronic wristwatch as claimed in claim 4 in which the dyestuff is a viologen dyestuff.
6. An electronic wristwatch as claimed in any preceding claim in which the display material is such as to display a plurality of colours, the colour displayed being dependent upon the level of voltage applied to the electrodes.
7. An electronic wristwatch substantially as herein described with reference to and as shown in the accompanying drawings.

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