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[73]	Assignee	General Time Corporation Stamford, Conn.				
[54]	MOVING INDICATOR ELECTROCHEMICAL DISPLAY 2 Claims, 6 Drawing Figs.					
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[51]	Int. Cl.....	G04c 17/00, C23b 5/26				
[50]	Field of Search.....	340/373, 378 R, 379, 366 R; 58/23 R, 50 R, 126 R; 23/230 LC; 204/23, 45 R, 46, 15, 18 R; 350/267, 269, 160				
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ABSTRACT: A moving indicator electrochemical display which may be used for a linear, or for a circular display device such as a clockface. A plurality of conductive electrodes are provided on an insulating substrate in a regular pattern and covered with a shallow layer of electrolyte containing ions of a visible electrodepositable material. Electrical circuitry is provided which applies a potential between a pair of adjacent electrodes making one an anode and one a cathode, the potential being sufficient to cause plating of the visible electrodepositable material on the cathode to produce a visible indicator. Switching means cause the potential to shift between successive electrode pairs giving the appearance of a moving indicator device.

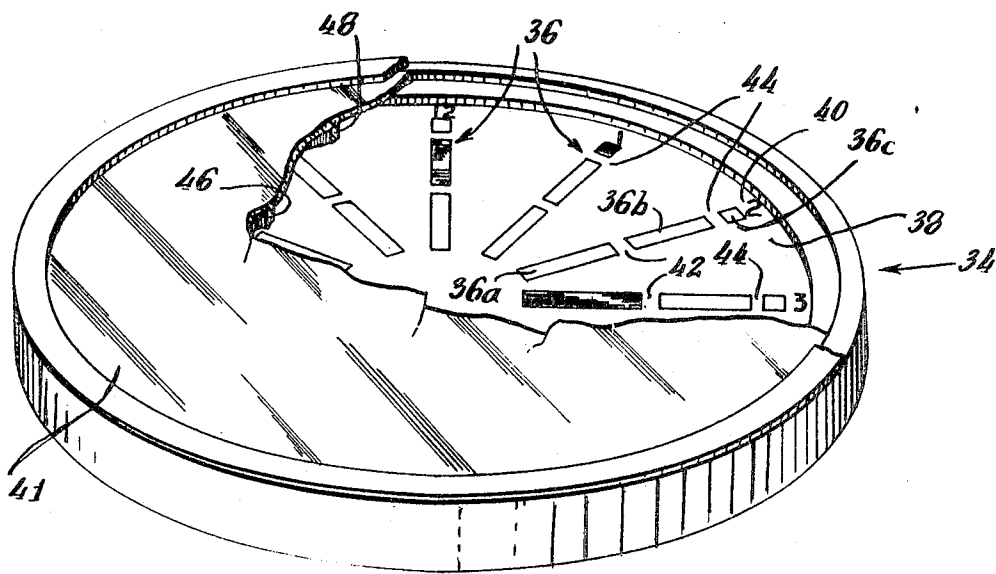


Fig. 1

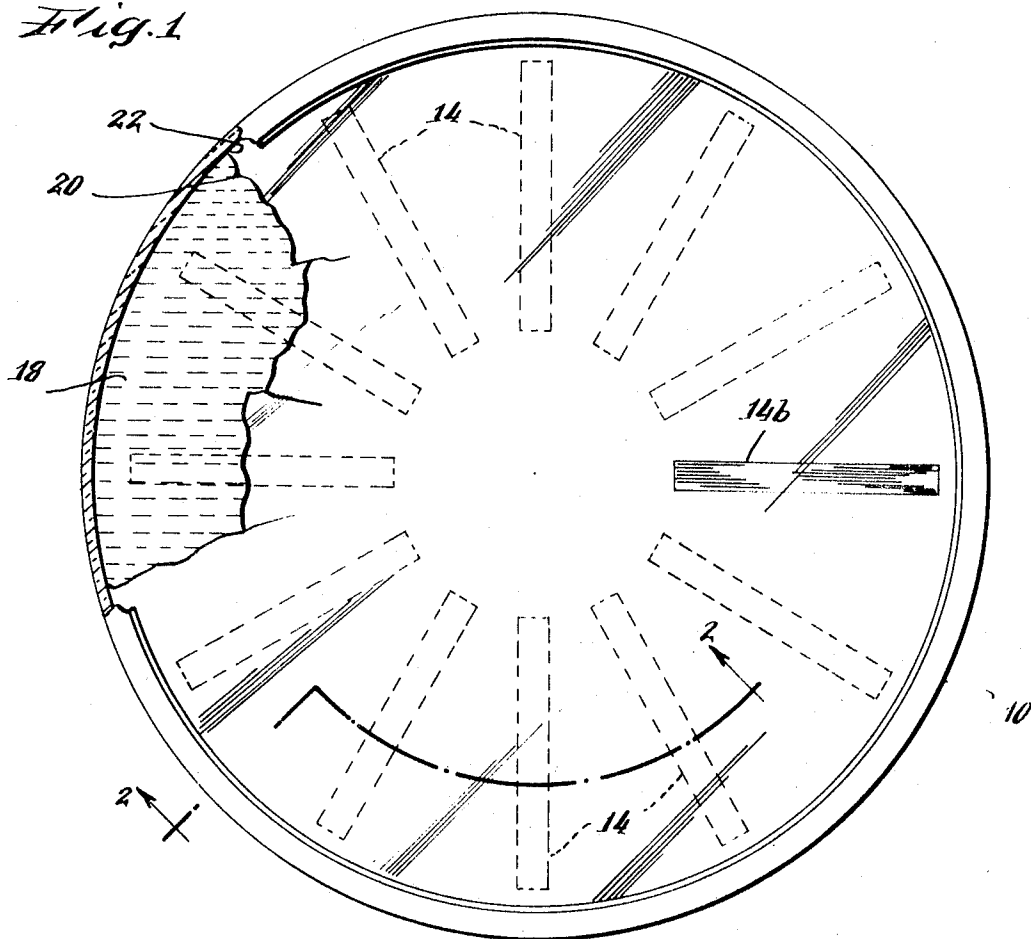
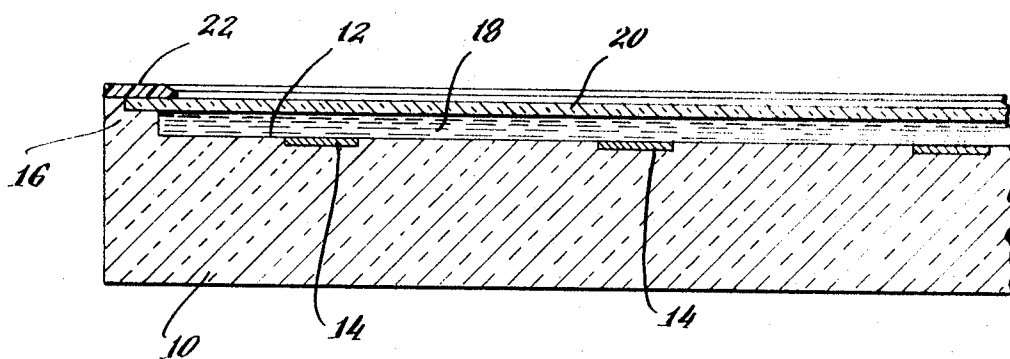


Fig. 2



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Fig. 3.

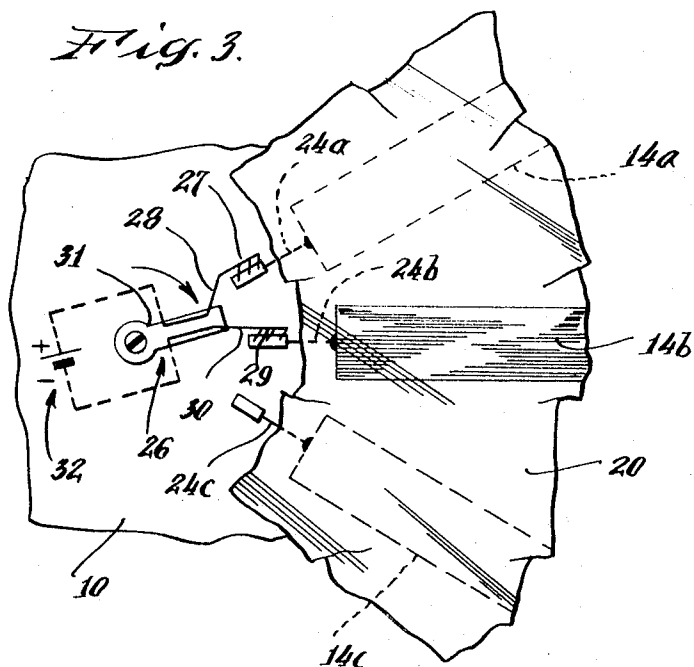


Fig. 4.

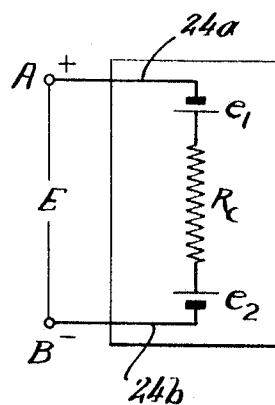


Fig. 6.

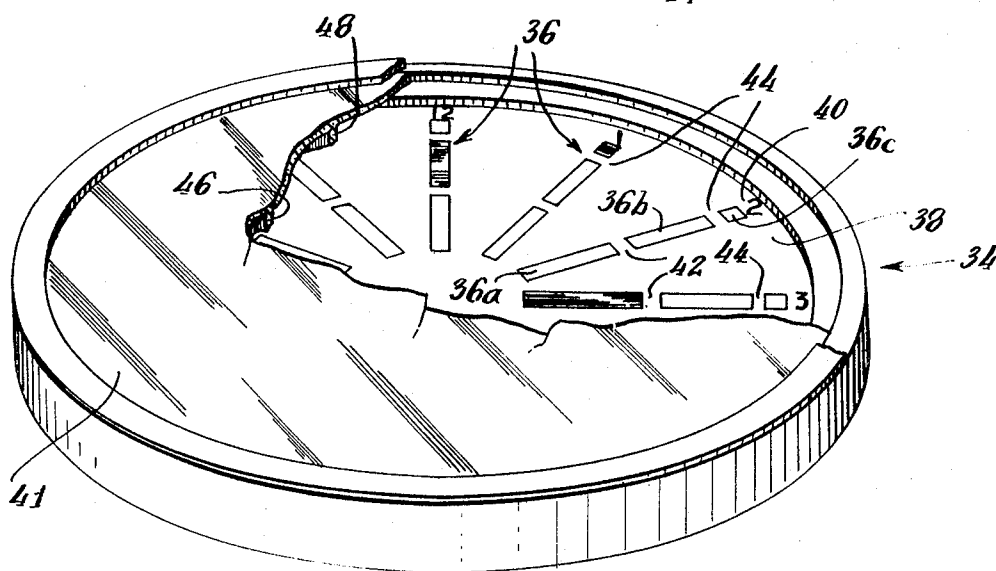
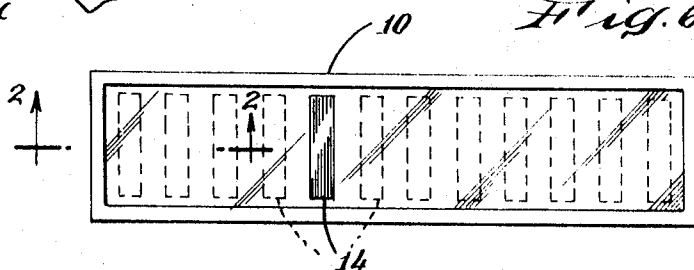


Fig. 5.

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MOVING INDICATOR ELECTROCHEMICAL DISPLAY

BACKGROUND OF THE INVENTION

Numerous so-called solid-state display devices have been devised in recent years for use as high-speed computer readouts, instrumentation dials, clockfaces and the like. These solid-state devices are attractive from the standpoints of small size, relatively low power requirements, and the elimination of moving parts which make for ease of manufacture and efficient and economical operation.

The prior art devices have relied on a variety of solid state phenomena for their operation; for example electroluminescence, thermoluminescence, thermochromic reactions, molecular alignment such as is disclosed in my copending application Ser. No. 718,823 filed Apr. 4, 1968, now Pat. No. 3,524,726 and ionization of gas as disclosed in copending application Ser. No. 705,793 filed Feb. 15, 1968, now U.S. Pat. No. 3,500,121. Many of the prior art devices, however, suffer disadvantages which make them impractical for particular applications. Some have relatively large power requirements making them impractical for use, for example, in battery powered devices. Others are temperature-sensitive. Still others have been limited by their nature to static displays and cannot be used for a continuous readout of information, for example, as on a dial face instrument.

Accordingly, representative objects of the present invention are to provide an electrochemical display device which can be used in a moving indicator display, which is operable under low power, and which is simply constructed and efficient and economical in operation.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

SUMMARY OF THE INVENTION

The present invention relates to a moving hand electrochemical display device in which a thin but visible film of electrodeposited material is shifted from electrode to electrode in the display to produce one or more moving hand indicators.

The display comprises a substrate preferably formed of electrical insulating material such as glass or ceramic, or coated with such an electrical insulating material. The substrate is provided with a plurality of electrodes in the shape of indicator hands on the surface thereof. The electrodes are formed of an electrically conductive material and arranged in a regular pattern; for example, they may radiate from a common center as the spokes of a wheel or be arranged linearly in a parallel configuration. Preferably the electrodes and the substrate surface are treated to visually blend together and render the bare electrodes essentially invisible. A shallow layer of electrolyte containing ions of an electrodeposable material is provided over the electrodes and the entire assembly preferably sealed under a transparent cover plate.

The display is energized by suitable electrical circuitry which applies an electrical potential or voltage between adjacent electrodes, making one a strong anode and the other a cathode. The remaining electrodes are maintained weakly anodic as compared to the cathode to prevent extraneous plating. The potential is adjusted to a value which causes the electrodepositable material to plate out as a visible coating on the cathode. Preferably, the potential difference is applied as a relatively short pulse which plates out only as much material as is required for clear visibility. The electrical circuitry includes switching means for switching the potential difference to successive pairs of electrodes so that the previous cathode becomes an anode and the next successive electrode becomes the cathode. As a result of such switching, the material previously deposited on the old cathode redissolves into the electrolyte while a new coating is substantially simultaneously deposited on the new cathode. By continuing such switching between each successive pair of electrodes, the appearance of a moving indicator is obtained without any actual moving parts.

Preferably, an electrolytic solution is used having current and voltage requirements for plating which are sufficiently low to permit the use of battery power to drive the display.

The display as described above may be used as a circular or linear dial readout for a measuring instrument or the like. The circular configuration may similarly be used as a clockface. Preferably, when used as a clockface, each electrode is separated axially into discrete segments for hour, minutes and second indications.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a top plan view of a circular, moving indicator electrochemical display in accordance with the invention.

FIG. 2 is a partial sectional view taken along line 2-2 of FIG. 1 or line 2-2 of FIG. 6.

FIG. 3 is a partial top plan view of the display of FIG. 1 with a schematic of the circuitry used to drive the display.

FIG. 4 is a schematic of an equivalent circuit representing the electrochemical reaction between two electrodes in the display.

FIG. 5 is an isometric view partly in section of a clockface display in accordance with the invention.

FIG. 6 is a top plan view of a linear display in accordance with the invention.

Similar reference characters refer to similar parts throughout the several view of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, the display of the invention comprises a substrate 10 which is preferably formed of an electrical insulating material such as glass, ceramic, plastic or the like. Alternatively, substrate 10 may be coated with such an electrical insulating material. A plurality of electrodes 14 are provided on one surface 12 of substrate 10 to serve as the basis for the moving hand indicator. Electrodes 14 are typically arranged on substrate 10 in a regular pattern; they may radiate from a common center as shown for a circular dial or clockface, or be arranged linearly in a parallel configuration for a linear display as shown in FIG. 6.

As shown in FIG. 2, electrodes 14 are preferably recessed into surface 12 so that the electrode tops are flush therewith. In this way material is electrodeposited only on the upper visible surface thereof where it is needed. Electrodes 14 are preferably formed by thin or thick film techniques directly on surface 12 and from a nonreactive metal such as platinum or palladium. However, other metals and conductive nonmetals such as carbon may be used. Alternatively, electrodes 14 may comprise discrete strips of conductive material which are secured by adhesive or the like within the recesses in surface 12.

Electrodes 14 should blend with surface 12 of substrate 10, but should contrast in color with the material to be deposited thereon so that a readily visible display results only upon plating. The black color of carbon electrodes, for example, will blend readily with a flat black painted surface 12, but will contrast sharply with the color of most electrodeposited metals. However, where the electrodes are metallic, they may require further treatment to provide contrast. For example, platinum electrodes may be conveniently platinized to a deep black colored surface of platinum black for contrast.

Surface 12 of substrate 10 is preferably provided with a surrounding upstanding rim 16 (FIG. 1) so as to provide a receptacle area for liquid directly over electrodes 14. Into this area there is placed a shallow layer of electrolyte 18, typically about 0.2 millimeter to about 1 millimeter in depth over electrodes 14, containing ions of an electrodeposable material. The electrolyte used may be any one of numerous plating solutions commonly used for electroplating, the important con-

sideration being that the deposited material form a visible layer on the electrodes and be visible through the electrolytic solution. Typically, electrolyte 18 will comprise a solution of a soluble salt on one of the more readily platable metals such as, but not limited to, gold, platinum, silver, copper, nickel, chromium or zinc.

The top of the display is preferably sealed by a transparent cover plate 20 (FIG. 2) to protect against spillage and contamination, and permit use of the display in a vertical plane. Cover plate 20 may be of glass or plastic and is conveniently mounted in a ledge 22 formed in rim 16, and secured with adhesive or by clamping or the like.

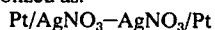
Silver nitrate makes a particularly attractive electrolyte for use in the display since electrodeposited silver is a bright, almost white colored metal which is quite visible on a dark electrode such as one of platinized platinum. Accordingly, the operation of the display will be described in conjunction with the use of silver nitrate electrolyte and platinized platinum electrodes. It will be understood, however, that the display may be operated in a similar manner with other combinations of electrolyte and electrode compositions, the principal differences being in the voltages necessary to effect plating.

Referring now to FIG. 3, there is shown a portion of the display face with a schematic of a simple circuit for energizing the display. An electrically conductive lead 24a, 24b, 24c, etc. is provided from a point on each electrode 14 to a point on substrate 10 where electrical contact may be conveniently made with a switching means 26. Leads 24 in the case of a circular display will normally extend from the converging ends of electrodes 14 toward the display center where switching means 26 may be conveniently located; however, the leads may extend from other points and in other directions. Alternatively, switching means 26 may directly contact electrodes 14. Leads 24 are preferably formed directly on substrate 10 by printed circuit or thin film techniques; they may however comprise discrete lengths of electrically conductive wire or foil.

Still referring to FIG. 3, switching means 26 may comprise a simple double pole stepping switch having one pole 28 connected to the positive side and the other pole 30 connected to the negative side of a direct current source 32 such as a battery. The contact ends of poles 28 and 30 are spaced to correspond to the spacing between adjacent leads 24. In this way contact is simultaneously made between poles 28 and 30 and two adjacent leads 24 when switch 26 is closed. Poles 28 and 30 may conveniently form part of a wiper arm 31 carrying brush contacts 27 and 29 which rotate about the center of the display in response to the output of a measuring instrument, or at a predetermined rate as with a clock mechanism. In a linear display the wiper arm will of course move linearly. Alternatively, switching may be accomplished electronically.

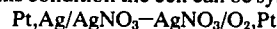
At the instant in time depicted in FIG. 3, positive pole 28 is in contact with lead 24a making electrode 14a an anode. Simultaneously, negative pole 30 contacts lead 24b making electrode 14b a cathode. The application of a sufficient voltage pulse from source 32 under these conditions will cause silver to plate out on electrode 14b (shaded portion) to produce a visible display indicator.

The voltage value necessary to cause visible plating can be determined from the electrochemical reactions taking place in the display. As shown in FIG. 3, platinum electrodes 14a and 14b in the surrounding silver nitrate electrolyte, and before application of any potential, comprises an electrolytic cell which can be symbolized as:



This electrolytic cell is represented by the equivalent circuit shown in FIG. 4 where e_1 and e_2 represent respectively the equal potentials of platinum electrodes 14a and 14b in silver nitrate electrolyte, and R_c is the electrical resistance of the electrolyte between electrodes 14a and 14b. When a predetermined voltage is applied between terminals A and B, a small current i_p can be made to flow through the cell and equilibrium is upset. Electrodes 14a and 14b then respectively become

polarized into an anode and cathode. This causes anode 14a to become saturated with a layer of oxygen atoms and cathode 14b to become covered with a layer of silver atoms. The voltage required to produce this result is called the precipitation voltage E_p . In this condition the cell can be symbolized as:



The potentials of the now dissimilar anode and cathode in silver nitrate become unequal and their algebraic difference is the polarization potential e_p , or:

$$e_p = |e_1| - |e_2|$$

This polarization potential e_p is always directed against the precipitation voltage E_p which created it. In addition to the polarization potential e_p , the electrolytic resistance R_c creates another potential directed against E_p which may be symbolized by $(i_p R_c)$. These two potentials counteract E_p to block further current flow and therefore prevent any visible plating.

Accordingly, referring back to FIG. 4, in order to get current to pass through the cell to plate out silver, E must be greater than the two potentials directed against it, or:

$$E > (e_p + i_p R_c)$$

Stated differently E must be greater than E_p .

The precipitation potential E_p for plating silver from a dilute solution of silver nitrate is about 0.8 volt. Visible plating can be effected by applying as little as 0.1 volt more, or 0.9 volt between electrodes 14a and 14b (FIG. 3). For the rapid switching needed in a display, however, it is preferable to apply a greater voltage, for example, of about 1.8 volts.

The precipitation potential E_p of a particular electrolyte and therefore the voltage necessary to cause plating can be reduced if desired by adding a more ionic, complex salt to the electrolyte to form a redox-system. For example, a complex salt mixture such as $\text{KAg}(\text{CN})_2 + \text{KI}$ may be added to silver nitrate electrolyte for this purpose. However, redox-systems are somewhat temperature dependent so that preferably E_p should not be reduced below about 0.1 volt. At lower values of E_p , temperature fluctuations may adversely affect plating and dissolution on the electrodes.

Still referring to FIG. 3, the deposited silver layer on electrode 14b can be shifted to electrode 14c by a clockwise rotation of poles 28 and 30 respectively into contact with leads 24b and 24c. This switch makes electrode 14b an anode and 14c a cathode. Under these conditions and with the proper voltage E , the silver on 14b quickly dissolves and substantially simultaneously a new deposit forms on electrode 14c. This procedure may then be continued in a clockwise direction to produce the effect of a clockwise moving indicator as the deposited layer appears to shift from electrode to electrode. To reverse the direction of movement, the polarity of each pole 28 and 30 is switched, that is pole 28 is made negative and pole 30 made positive, and the poles then moved in a counterclockwise direction. The same procedure is used for a linear display except that the clockwise-counterclockwise movements of poles 28 and 30 become linear movements, for example, to the right and left or up and down.

The display may be used conveniently as a clockface for a watch or larger clock, thus eliminating the need for actual moving hands. Referring to FIG. 5, the clockface 34 is constructed similarly to the display shown in FIGS. 1 and 2, and comprises a plurality of electrodes 36 on a substrate 38. Substrate 38 may also be provided with suitable indicia 40. Similarly to the previously discussed display, a receptacle area for electrolyte is provided on substrate 38 over electrodes 36, and the face may be sealed by a transparent glass or plastic cover plate 41.

Clockface 34, however, differs from a simple display in that each electrode 36 is preferably separated into three electrically insulated segments 36a, 36b and 36c, respectively for hour, minutes and seconds indications. Material electrodeposited on various combinations of hour, minutes and seconds segments serves to indicate the precise time, as for example, 3:00:05 as shown by the shaded segments in FIG. 5.

Preferably, the hour segments 36a and surrounding electrolyte are physically isolated from the minutes segments 36b

and their surrounding electrolyte, and both are physically isolated from the seconds segments 36c and their surrounding electrolyte. This is done to prevent undesirable cross-plating. Isolation may be effected by a pair of concentric cylindrical rings 46 and 48 preferably integrally formed on cover plate 41 (FIG. 5). Ring 46 covers the spaces 42 between hour segments 36a and minutes segments 36b, and ring 48 covers the spaces 44 between minutes segments 36b and seconds segments 36c. The rings should correspond in height to the depth of the electrolyte to properly isolate each group of segments.

Clockface 34 has been shown for simplicity having electrodes 36 at only the 12 hour positions; however, multiples of 12 electrodes will be used in a practical case for more precise timing and realistic indicator movement. Ideally, electrodes are placed at each minute interval between each hour so that there are a total of 60 segmented electrodes spaced at 6° intervals around substrate 38.

Clockface 34 may be actuated by an electromechanical system such as the wiper arm switching means 26 described with reference to FIG. 3. One wiper arm driven at a suitable rate will be provided for each of the hour, minutes and seconds groups of electrode segments. Alternatively, clockface 34 may be driven by an electronic control system of the type disclosed in previously discussed copending application Ser. No. 705,793 but suitably modified for use in an electrochemical display.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above

description or shown on the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A moving indicator electrochemical display system comprising, in combination:

A. a nonconductive substrate,

B. a plurality of electrically conductive electrodes spaced in a predetermined pattern on said substrate,

C. a layer of electrolyte covering said electrodes and containing ions of an electrodepositable material, and

D. energizing means for applying an electrical potential between adjacent electrodes to make one an anode and the other a cathode, said potential being sufficient to deposit a visible layer of said electrodepositable material on said cathode, and including switching means for sequentially switching said potential to successive electrode pairs whereby said deposited layer appears to transfer from electrode to electrode in the manner of a moving indicator.

2. A display system as defined in claim 1 wherein each said electrode is separated into a plurality of discrete segments and including energizing means for each group of corresponding segments.

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