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(54) ELECTROCHROMIC DISPLAY ADAPTED FOR MULTIPLEXING

(71) We, TIMEX CORPORATION, a corporation organized under the Laws of the State of Delaware, United States of America, of Waterbury, Connecticut 06720, United States of America, 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:—

10 This invention relates to electrochromic displays and more particularly to electrochromic displays adapted for multiplexing of electrode-segments and counter-electrodes.

15 If a layer of an electrochromic material is disposed between, on or over at least one of a pair of electrodes and/or forms a part thereof, across which a potential is applied, the light reflective and transmitting characteristics of the material may change. If the electrodes and the electrochromic film are provided on a surface of a transparent glass plate, the light transmitting ability of the combination can be varied by the application of an electric field across the electrochromic material, turning it darker for example, decreasing its light transmitting ability over the area of the electrodes energized.

In recent years a great deal of interest has been shown in the provision of electrochromic displays having, for example, a digital readout.

20 Typically, the prior art electrochromic displays consist of a cell having patterns each formed by a plurality of electrode-segments which are coated with an electrochromic material, said electrode-segments each being separately connected for separate energization thereof, a single common electrode associated with a plurality of indicia, and a single electrolyte layer associated with said plurality of indicia and the common electrode. However, these prior art electrochromic displays have many drawbacks such as requiring a large number of electrical connections to the display and the inability to multiplex because of cross-talk, i.e., leakage current, which may cause unwanted activation of other electrode-

segments.

As is known to those skilled in the art of producing electrodes and leads, each input point to electrical apparatus, such as an electrochromic display, is a potential trouble point and thus the elimination of input points is an elimination of potential trouble points, and accordingly, it is most desirable to provide electric apparatus, such as an electrochromic displays with a minimum of electrical input points.

Accordingly, it is an object of the present invention to provide an electrochromic display adapted for multiplexing of electrode-segments with reduced lead or electrical connections to/from and on the electrochromic display.

According to the invention there is provided an electrochromic display device comprising in layered form a first transparent substrate with at least a first and second electrode pattern formed thereon with each electrode pattern comprising at least one selectively energizable electrode-segment and an electrochromic layer on each said electrode-segment; a second substrate with at least a first and second isolated and selectively energizable counter-electrode, said first counter-electrode being associated with said first pattern and said second counter-electrode being associated with said second pattern, a first layer of electrolyte material between said first pattern and associated first counter-electrode, and a second layer of electrolyte material between said second pattern and associated second counter-electrode.

Preferably the electrode-segments are transparent and each electrode pattern includes a plurality of electrode-segments selectively energisable to form digits with each corresponding transparent electrode-segment in each digit-pattern being interconnected on the first transparent substrate to form groups of commonly energizable segments with each group having a single or common electrical connection to/from the display.

Some preferred embodiments of the present

invention will now be described in more detail, reference being made to the accompanying drawings, wherein:—

Figure 1 is an exploded perspective view of an electrochromic display incorporating the present invention;

Figure 2 is an enlarged cross-sectional view taken through an assembled display of the type shown in Figure 1 and along the line I—I therein;

Figure 3 is an enlarged cross-sectional view of another embodiment of the present invention; and

Figure 4 is an exploded perspective view, partially cutaway, of a third embodiment of the present invention.

Referring now to Figure 1 of the drawings, the electrochromic display device is shown as a sandwich-like construction comprising a first transparent substrate 10 and a second spaced substrate 11, which need not be transparent, and a plurality of separator-electrolyte layers 12, 13 and 14 between the substrates 10 and 11.

The lower substrate 11 is formed, for example, from an opaque ceramic or a transparent material such as "NESA" glass (the word "NESA" is a registered Trade Mark) and is coated with a reflective and/or light opaque finish on its outer surface. The inner surface is coated or overlaid in several areas with a suitable conductive layer to form separate and electrically isolated counter-electrodes 15, 16 and 17 each connected to a respective terminal 18, 19 and 20. The counter-electrodes 15, 16 and 17 are electrically insulated from each other due to the insulating qualities of the lower substrate 11 and the spacing between each counter-electrode.

The inner surface or underside of the upper substrate 10 has formed thereon a conductive pattern of transparent electrode segments. The conductive electrode-segments are arranged to form, for example, a plurality of seven-segment pattern arrays 21, 22 and 23 of which the segments A to G can be selectively actuated via conductive leads 24 to 30 respectively to form a plurality of digits or other optical patterns. Each electrode-segment of each indicia/digit pattern 21, 22 and 23 is electrically connected to the corresponding and similarly designated electrode-segment in each of the other patterns 21, 22 and 23 via conductor leads 24 to 30 and to display terminals A' to G'. For example, conductor lead 24 is electrically connected to segment A and conductor lead 29 is electrically connected to segment E in each of the patterns 21, 22 and 23.

The upper substrate 10 may be of transparent glass or plastics with the transparent electrode-segments A to G and the conductor leads 24 to 30 formed thereon of a clear or transparent, conductive material such as tin oxide.

Coated on the transparent electrode-segments

A to G of each pattern 21, 22, 23 is a layer of electrochromic material A'' to F'', respectively. The electrochromic layers A'' to F'' are applied by suitable masking techniques to cover, for example, a smaller area than the electrodes so as to give good edge definition.

There are many suitable electrochromic materials available, c.f. for example U.S. Patent No. 2,319,765, which change their colour according to the particular state of oxidation. Therefore, since suitable materials are well known to those skilled in the art, no further discussion of these materials will be provided herein.

The two substrates 10 and 11 are assembled in a sandwich-like structure in which the electrode patterns 21, 22, 23 and the counter electrodes 15, 16, 17 respectively are in face-to-face arrangement in the cell cavity.

The separator-electrolyte layer 12, 13, 14 provided between each electrode pattern and its corresponding or associated counter-electrode may be a substantially solid layer as described in our copending Patent Applications Nos. 37664/75, (Serial No. 1494955) 18503/76 and 18504/76 (Serial Nos. 1512333 and 1533639) and the disclosures of these copending applications are incorporated herein by reference.

Briefly, each solid electrolyte forms a separator-electrolyte layer between the two substrates on the order of 25 microns in thickness. The solid electrolyte utilized in the embodiment is a selectively permeable and insoluble cationic ion exchange resin. Before or after assembly, the separator-electrolyte should be chemically wet by dipping in water or in very dilute acid such as dilute sulphuric acid.

It should be recognised, however, that the electrolyte layer can take any form, for example, a solid membrane layer such as a perfluorosulphonic acid polymer membrane or an insolubilized polystyrene sulphonic acid polymer membrane or finely powdered cation ion exchange resin in the hydrogen ion form or a liquid or gel so long as the display can be prepared with substantially electronically and ionically isolated and separated conducting sandwich-like indicia areas. Therefore, the phrase "layer of electrolyte material" is used hereafter to define a discrete island or area of electrolyte material which is associated with a display electrode pattern or part thereof. The separate and isolated sandwich-like areas provide a multiplexing capability to the display, and substantially cross-talk, i.e. unwanted current flow — ionic or electronic — between separate electrode patterns and thereby provide improved clarity of the display images, whether indicia or digits.

As is known in the art, current flow in one direction through the electrolyte will cause the electrochromic material to darken, while current flow in the opposite direction will cause it to "erase" or become transparent. This is in

contrast to displays which operate through application of an electric field such as field effect and dynamic scattering liquid crystal display.

Thus, in accordance with the invention an electrochromic display arrangement is provided which is capable of being matrix energized for actuating electrode patterns to display, for example, time information. The electrode patterns are actuated by the application of a potential coincidentally across one or more of the electrode-segments A to G, via the conductor leads 24 to 30, and the counter-electrode associated with the pattern/electrode-segment by applying the potential to the proper display terminal A' to G' and to the proper counter electrode 15 and/or 16 and/or 17. For example, each electrode-segment F in each pattern 21, 22 and 23 is shown as being selectively energized, as a group of electrode-segments, via a multiple switch contact and voltage source arrangement 52 and counter-electrode 18 is being selectively energized via a similar switch and voltage source arrangement 53 to cause electrode-segment F in pattern 21 to be actuated.

In Figure 2 of the drawings a display such as in Figure 1 is shown in cross-section assembled. The substrates 10 and 11 are bound to one another by an adhesive 31 such as epoxy which serves to hold the assembly together and to seal the inner layers around the periphery of the sandwich-like structure between the substrate 10 and 11.

The three sandwich-like structures 32, 33 and 34 correspond to electrode patterns 21, 22 and 23 respectively in cross-section along lines I-I. Each sandwich-like structure, as hereinbefore stated, comprises a first substrate 10, an electrode-segment pattern 35, 36, 37, a layer of electrochromic material 38, 39, 40 on each electrode-segment, a separator-electrolyte layer 41, 42, 43, and a counter-electrode 44, 45, 46 each being associated with an electrode pattern 21, 22, 23 respectively, and a second substrate 11. The sandwich-like structures 32, 33 and 34 are spaced apart to provide substantially electrical and ionic isolated and separated sandwich like conducting areas.

The display shown in cross-sectional view in Figure 3 is similar to the display shown in Figures 1 and 2 with the difference being that a transparent or opaque and insulating material 47 is provided between the digit conducting areas. This is particularly desirable if a liquid electrolyte is employed.

The display shown in Figure 4 is generally similar to the display shown in Figures 1, 2 and 3 with the difference being that separate and isolated pools or islands 48, 49 and 50 of a liquid or gel electrolyte are provided for each pattern of electrode-segments. The pools of liquid or gel electrolyte are contained by side walls 51 and the sandwich structure of the

substrates 10, 11. The side walls 51 can be formed from any suitable material such as a transparent or opaque epoxy or gasket-like material.

It is not necessary to the functioning of the display according to the invention that a single electrochromic layer be applied. For example, the counter-electrode can be coated with the same or substantially the same electrochromic material as is utilized on the electrode-segments.

While the invention has been described with respect to three preferred embodiments, it should be apparent to those skilled in the art that such modifications may be made thereto as fall within the scope of the appended claims, for example using other methods or means of providing isolated and separated patterns and counter-electrode conducting areas or islands.

WHAT WE CLAIM IS:-

1. An electrochromic display device comprising in layered form a first transparent substrate with at least a first and second electrode pattern formed thereon with each electrode pattern comprising at least one selectively energizable electrode-segment and an electrochromic layer on each said electrode-segment, a second substrate with at least a first and second isolated and selectively energizable counter-electrode, said first counter-electrode being associated with said first pattern and said second counter-electrode being associated with said second pattern, a first layer of electrolyte material between said first pattern and associated first counter-electrode, and a second layer of electrolyte material between said second pattern and associated second counter-electrode.
2. An electrochromic display device as claimed in Claim 1, wherein each electrode pattern includes a plurality of electrode-segments selectively energizable to form digits.
3. An electrochromic display device as claimed in Claim 2, wherein each digit-pattern is comprised of seven electrode-segments and each corresponding electrode-segment in each said digit-pattern is electrically interconnected to form seven selectively energizable groups of electrode-segments with each group containing only one electrode-segment in each of the digit patterns.
4. An electrochromic display device as claimed in any one of Claims 1 to 3, wherein the counter-electrodes are isolated by forming each electrode pattern, the associated counter-electrode and the associated layer of electrolyte into separate sandwich-like structures spaced apart between the two substrates.
5. An electrochromic display device as claimed in any one of Claims 1 to 4, wherein the electrolyte material is a perfluorosulphonic acid polymer membrane.
6. An electrochromic display device as claimed in any one of Claims 1 to 4, wherein



contrast to displays which operate through application of an electric field such as field effect and dynamic scattering liquid crystal display.

5 Thus, in accordance with the invention an electrochromic display arrangement is provided which is capable of being matrix energized for actuating electrode patterns to display, for example, time information. The
10 electrode patterns are actuated by the application of a potential coincidentally across one or more of the electrode-segments A to G, via the conductor leads 24 to 30, and the counter-electrode associated with the
15 pattern/electrode-segment by applying the potential to the proper display terminal A' to G' and to the proper counter electrode 15 and/or 16 and/or 17. For example, each electrode-segment F in each pattern 21, 22
20 and 23 is shown as being selectively energized, as a group of electrode-segments, via a multiple switch contact and voltage source arrangement 52 and counter-electrode 18 is being selectively energized via a similar switch
25 and voltage source arrangement 53 to cause electrode-segment F in pattern 21 to be actuated.

In Figure 2 of the drawings a display such as in Figure 1 is shown in cross-section
30 assembled. The substrates 10 and 11 are bound to one another by an adhesive 31 such as epoxy which serves to hold the assembly together and to seal the inner layers around the periphery of the sandwich-like structure between the sub-
35 strate 10 and 11.

The three sandwich-like structures 32, 33 and 34 correspond to electrode patterns 21, 22 and 23 respectively in cross-section along lines I-I. Each sandwich-like structure, as herein-
40 before stated, comprises a first substrate 10, an electrode-segment pattern 35, 36, 37, a layer of electrochromic material 38, 39, 40 on each electrode-segment, a separator-electrolyte layer
45 41, 42, 43, and a counter-electrode 44, 45, 46 each being associated with an electrode pattern 21, 22, 23 respectively, and a second sub-
strate 11. The sandwich-like structures 32, 33 and 34 are spaced apart to provide substantially
50 electrical and ionic isolated and separated sandwich like conducting areas.

The display shown in cross-sectional view in Figure 3 is similar to the display shown in Figures 1 and 2 with the difference being that a
55 transparent or opaque and insulating material 47 is provided between the digit conducting areas. This is particularly desirable if a liquid electrolyte is employed.

The display shown in Figure 4 is generally similar to the display shown in Figures 1, 2
60 and 3 with the difference being that separate and isolated pools or islands 48, 49 and 50 of a liquid or gel electrolyte are provided for each pattern of electrode-segments. The pools of liquid or gel electrolyte are contained by side
65 walls 51 and the sandwich structure of the

substrates 10, 11. The side walls 51 can be formed from any suitable material such as a transparent or opaque epoxy or gasket-like material.

It is not necessary to the functioning of the display according to the invention that a single electrochromic layer be applied. For example, the counter-electrode can be coated with the same or substantially the same electrochromic material as is utilized
75 on the electrode-segments.

While the invention has been described with respect to three preferred embodiments, it should be apparent to those skilled in the art that such modifications may be made thereto as fall within the scope of the
80 appended claims, for example using other methods or means of providing isolated and separated patterns and counter-electrode conducting areas or islands.

WHAT WE CLAIM IS:-

1. An electrochromic display device comprising in layered form a first transparent substrate with at least a first and second electrode pattern formed thereon with each electrode pattern comprising at least one selectively energizable electrode-segment and an electrochromic layer on each said electrode-segment, a second substrate with at least a first and second isolated and selectively
90 energizable counter-electrode, said first counter-electrode being associated with said first pattern and said second counter-electrode being associated with said second pattern, a first layer of electrolyte material between said first pattern and associated first counter-electrode, and a second layer of electrolyte material between said second pattern and associated second counter-electrode.
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2. An electrochromic display device as claimed in Claim 1, wherein each electrode pattern includes a plurality of electrode-segments selectively energizable to form digits.
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3. An electrochromic display device as claimed in Claim 2, wherein each digit-pattern is comprised of seven electrode-segments and each corresponding electrode-segment in each said digit-pattern is electrically interconnected to form seven selectively energizable groups of electrode-segments with each group contain-
110 ing only one electrode-segment in each of the digit patterns.
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4. An electrochromic display device as claimed in any one of Claims 1 to 3, wherein the counter-electrodes are isolated by forming each electrode pattern, the associated counter-electrode and the associated layer of electrolyte into separate sandwich-like structures spaced apart between the two substrates.
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5. An electrochromic display device as claimed in any one of Claims 1 to 4, wherein the electrolyte material is a perfluorosulphonic acid polymer membrane.
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6. An electrochromic display device as claimed in any one of Claims 1 to 4, wherein
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the electrolyte material is finely powdered cationic ion exchange resin in the hydrogen ion form.

- 5 7. An electrochromic display as claimed in any one Claims 1 to 4, wherein the electrolyte material is an insolubilized polystyrene sulphonic acid polymer membrane.

- 10 8. An electrochromic display device adapted for multiplexing comprising in layered form a first transparent substrate having formed thereon at least two electrode patterns each pattern comprising at least a first and second electrode-segment with said first electrode-segments in each of said two patterns being electrically
15 interconnected to form a first selectively energizable group of electrode-segments and said second electrode-segments in each of said

two indicia being electrically interconnected to form a second selectively energizable group of electrode-segments, and a layer of electrochromic material on each said electrode-segment, a second substrate having a separate selectively energizable counter-electrode associated with each said pattern, and a separate layer of electrolyte material between each said pattern and the associated counter-electrode.

9. An electrochromic display device substantially as hereinbefore described with reference to the accompanying drawings.

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