

PATENT SPECIFICATION

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(54) DISPLAY DEVICE

(71) We, INTERNATIONAL BUSINESS MACHINES CORPORATION, a Corporation organized and existing under the laws of the State of New York in the United States of America, of Armonk, New York 10504, 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:—

This invention relates to display devices.

Many different approaches to direct view display devices are known. One approach is to use a photochromic material in a display device to produce a direct view image. However, these devices are of relatively low optical sensitivity and require the use of thermal or in some cases visible radiation to erase the image and allow subsequent re-use.

The prior art also teaches the use of structural electrode arrays to produce electrochromic images in the form of characters and images. There is a one-to-one correspondence between the electrodes or activated electrode segment and the resulting image. This in general reduces the versatility of the device and also presents certain difficulties in addressing and driving the display.

Another approach is to use a device with a photoconductive material overlaying an electrochromic material. The optical image reduces the resistance of the photoconductive material in the exposed area so that the corresponding area of the electrochromic material is energized by a voltage across the cell. This configuration solves the electrode problem of electrochromic devices but requires a more complex structure due to the layered structure. The materials must be selected for compatibility with all the other materials. Furthermore, the exposure and application of the voltage must be simultaneous unless a persistent photoconductor is used.

Still another approach is described in our copending patent application 12974/76 (Serial No. 1522226). The direct view display device described in that application includes a pair of conductive electrodes in spaced relationship and a suitable recording medium occupying the space between the electrodes. The recording medium exhibits the properties of being photo-ionizable and capable of electro-chemically producing coloured species. The image is produced by exposing the medium to an optical pattern of activating radiation of an intensity suitable to produce a latent image of the pattern and then applying a low voltage of a first polarity across the electrodes to produce a very dense image corresponding to the pattern. The image can be erased by applying a low voltage of opposite polarity across the electrodes and the display device can then be re-used. These devices are suitable for many applications. In some instances, however, it is desirable to have a removable copy of the image. Another area of interest in devices of this type is to have improved resolution as well as to increase the lifetime of the device.

According to the invention a display device comprises first and second transparent parallel planar electrodes enclosing only first, second and third layers of material, and means for selectively applying a voltage between the electrodes to produce an electric field wherein the first and third layers enclose the second layer, the first layer is a film of solvent, the second layer is a normally light-transmitting recording medium which has the properties of being photoionizable and capable of electrochemically producing a coloured specie, and the third layer comprises a redox material.

The invention will further be explained, by way of example with reference to the drawing which is a cross-sectional view of a display device embodying the invention.

The visual image display device contains transparent electrodes 12 and 14

on substrates 16 and 18, respectively. The transparent electrodes 12 and 14 are typically NESA (Trade Mark materials, that is, SnO_2 , In_2O_3 and mixtures thereof or may be a thin layer of aluminium, gold, platinum or equivalent materials. In a preferred embodiment electrode 12 is aluminium and electrode 14 is SnO_2 . The substrates 16 and 18 are typically glass or a clear polymer although equivalent transparent materials may be used. In a preferred embodiment substrate 16 is Mylar (Trade Mark) film and substrate 18 is glass.

Positioned between electrodes 12 and 14 and adjacent to electrode 12 is barrier layer 20. The barrier layer 20 not only introduces the assymetry into the display cell 10 necessary for erasure, but also increases enhancement efficiency. The barrier layer 20 comprises a suitable matrix such as a polymer which contains an appropriate amount of a material that is readily oxidizable and reducible, but does not change its colour during the erase cycle.

Several techniques for forming the barrier layer 20 on the conductive electrode 12 are known and they include methods such as dip coating, spin coating and use of a doctor blade. The most uniform and reproducible coatings have been obtained by dip coating. Using a formulation consisting of: 41.2 g of 4% 8061 Elvamide (Trade Mark) nylon resin (a polyamide resin) in ethanol, 1.8 g H_2O and 0.2 g zinc nitrate, (with respect to total resin/solvent weight), barrier layers of 2μ thickness have been formed at a dip speed of 2 ft/min. The coated electrode is then heat cured at $65-70^\circ$ for 10 minutes to remove excess solvent. The resulting barrier layer 20 is optically transparent and free from bubbles and surface reticulation. The amount of redox substance in the completed barrier layer 20 can vary from about 1% to about 60% but the preferred amount is from about 20% to about 40% by weight. Other polymer and redox substances can be used such as a sulfonated polystyrene polymer and zinc chloride, lead nitrate and cadmium nitrate redox substances. Other similar known redox substances should be operable provided they are compatible in this device.

A second barrier layer 22 is positioned between barrier layer 20 and electrode 14 and adjacent barrier layer 20. The second barrier layer 22 is a solid material which is normally a substantially light transmitting medium in the visible spectrum having the properties of being both photo-ionizable and capable of electrochemically producing a coloured specie.

The layer 22 contains a resin, an active material and, in some cases, an activator. An activator is not needed with certain active materials, for example, the spiropyran. An activator is also not

necessary when a copy is desired as will be hereinafter fully described.

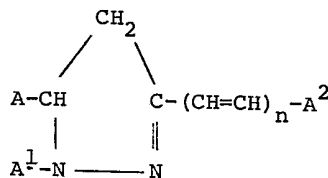
Resins suitable for use in layer 22 must be clear or transparent and have marginal solubility in layer 24 hereinafter fully described. Among resins which may be used are polyvinyl butyral, polycarbonate, polyamide, polyacrylates, polymethacrylates, polyvinylcarbazole.

Active materials contemplated for use in layer 22 of this invention can be selected from any of a number of active materials which demonstrate the properties of being both photoionizable and capable of electrochemically producing coloured species. The active materials that can be used at the present time fall within one of three groups or classes of chemical compounds. These groups are the triaryl or diaryl styryl pyrazolines, spiropyran and redox polymeric materials.

The preferred concentration of the active materials is 2 to 20 wt %. The concentration can be higher or lower than the preferred range based on desired visual contrast considerations.

The triaryl and diaryl styryl pyrazolines are the most effective active materials. Specific compounds of this group which are effective are 1 - phenyl 3 - p - diethylaminostyryl - 5 - p - diethylamino - phenyl - 2 - pyrazoline (hereinafter referred to as DEASP), 1 - p - anisyl - 3 - p - diethylaminostyryl - 5 - p - diethylaminophenyl - 2 - pyrazoline (hereinafter referred to as M-DEASP), and 1 - phenyl - 3 - p - piperidino - phenyl - 5 - (2 - thienyl) - 2 - pyrazoline.

Other pyrazoline compounds having the structure shown below which demonstrate the properties of being both photoionizable and capable of electrochemically producing chemical species are included.



wherein n is zero or one, and A , A^1 and A^2 are each aryl radicals.

In this formula when $n=1$ the materials may be classified chemically as diaryl styryl pyrazolines. It is preferred that one or more of the aryl groups be substituted, most preferably with groups known in the art to be electron donating groups. The most preferred substituent groups are methoxy, ethoxy, dimethyl amino, diethyl amino and the like. It is not preferred to substitute the aryl groups with electron withdrawing groups such as nitro and cyano.

Activators when used in layer 22 may be polyhalogenated alkanes such as carbon tetrachloride, carbon tetrabromide, iodoform and bromoform, and other polyhalogenated compounds such as 2,2,2 - tribromethanol and dichloroacetone. The concentration of the activator used, depends upon the active material and resins used. The activator concentration may be 5 to 50 wt %.

The layer 22 may be formed by preparing a solution containing the resin, active material and activator when desired in a suitable solvent such as chloroform. The solution is then sprayed or spun onto the layer 21 and dried to form a coating or layer with the desired thickness. The preferred thickness is of the order of 10 microns although the thickness may vary from 7 to 100 microns.

A solvent film 24 is positioned between layer 22 and electrode 14. Suitable solvents for use in the film 24 are halogenated hydrocarbon solvents and other non-aqueous solvents such as acetonitrile and tetrahydrofuran which only marginally dissolve the resin used. Preferred solvents for use with the polyvinylbutyral resins are chloroform, 1,2 dichloroethane, dichloromethane and mixtures thereof. The film 24, in copy embodiments also contains an activator. The thickness of the film 24 is that which is sufficient to make uniform electrical contact between layer 22 and electrode 14.

The display cell 10 can be transparent under ambient light. However, when a region of a cell is exposed by light distribution as shown in the drawing to the light of the wavelength to which the active material in layer 22 is sensitive with an energy density of about 25 to 500 microjoules per centimeter squared, a latent image is produced in the irradiated region.

Image enhancement comprises a conversion of the latent image into a high density and high contrast visible image, and the enhancement is achieved by the momentary application of a potential between the electrodes which results in the subsequent production of coloured species in those areas that have been exposed to light. In the embodiment shown in the drawing, the enhancement is accomplished by the application of potential of about 2 to 20 volts from voltage source 28 by switch 30 to the device so that the colouration in the same region is intensified. The intensification is proportional to the applied voltage and the duration of its application.

The image is formed on the surface of the second barrier layer which comes in contact with the film of solvent. It has been observed that the second barrier layer can be removed from the device with the image intact. As a result a copy is formed. The

copy can be subsequently returned to the device and erased when there is the necessary contact with the film of solvent and the potential is applied in the reverse direction. In a practical embodiment the second barrier layer is comprised by a tape which can be moved past the electrodes so that a succession of images can be formed thereon.

Example 1

The device was formed by providing a first barrier layer on a 7 mil aluminized Mylar. This barrier layer was formed by coating at a speed of 2 f.p.m. (feet per minute) a solution containing 41.2 g 4% polyamide (Elvanide (Trade Mark) 8061 made by Dupont) in ethanol, 1.8 g water and 0.2 g zinc nitrate. The thickness was 2.5 microns. This barrier layer was air cured to remove the solvent. A second barrier layer was formed by coating at a speed of 8 f.p.m. a solution containing 10g 5% polyvinyl butyral (Butvar (Trade Mark) B73 made by Monsanto) in 10 g chloroform, 2 g carbon tetrachloride and 1.0 g M-DEASP. The thickness was 10 microns. A film of 1, 2, dichloroethane was placed between the second barrier and a tin oxide coated glass substrate to form the device. The second barrier layer was exposed to ultraviolet light to produce a latent image. A potential of about +5 volts was applied to the tin oxide electrode to enhance the image. The second barrier layer was removed from the device and the image remained intact. The second barrier layer was then put back into its proper position in contact with the 1, 2, dichloroethane, the potential was reversed and the image was erased.

Example 2

The same device as in Example 1 except a film of dichlorobutane was used instead of 1, 2, dichloroethane. Similar results were obtained.

Example 3

The same device as in Example 1 except a film of 1, 1, 1 trichloroethane was used instead of 1, 2 dichloroethane. Similar results were obtained.

Examples 4—7

The same device as in Example 1 except the polyvinyl butyral in the second barrier layer was replaced by one of the following resins:

polyamide (Milvex (Trade Mark) 4000)
styrl-n-butyl methacrylate
poly-n-vinyl carbazole
polyacrylate (Acryloid C-10LV)
Similar results were obtained.

Example 8

The same device as in Example 1 except the second barrier layer has been modified. The activator carbon tetrachloride is not present. A separate coating or film of 2.5% nitrocellulose polymer dissolved in tetrahydrofuran was applied at 5 f.p.m. The nitrocellulose film served as the activator as well as being resistant to solvent attack.

Example 9

The same device as in Example 8 except the solvent film consisted of a mixture of 10 cc 1, 2 dichloroethane, 0.1 g carbon tetrabromide and .02 g 2, 4 - bis[2 - hydroxy - 4 - diethylamino phenyl] - 1,3 - cyclo butadiene diylum - 1, 3 - diolate. The device was exposed to a photoflood light through a Wratten (Trade Mark) #29 filter to give an image that was enhanced by the application of a potential of +5 volts. Since the Wratten #29 filter transmits wavelengths longer than 6000 Å, sensitization was achieved with this device.

WHAT WE CLAIM IS:—

1. A display device comprising first and second transparent parallel planar electrodes enclosing only first, second and third layers of material, and means for selectively applying a voltage between the electrodes to produce an electric field wherein the first and third layers enclose the second layer, the first layer is a film of

solvent, the second layer is a normally light-transmitting recording medium which has the properties of being photoionizable and capable of electrochemically producing a coloured specie, and the third layer comprises a redox material.

2. A device as described in claim 1 wherein said film of solvent is a chlorinated solvent.

3. A device as described in claim 2 wherein said film of solvent is taken from the group consisting of 1,2 - dichloroethane, dichlorobutane, and 1,1,1 - trichloroethane.

4. A device as claimed in any preceding claim, wherein the second layer comprises a resin containing a triaryl or diaryl styryl pyrazoline.

5. A device as described in claim 4 wherein said resin is taken from the group consisting of

polyvinyl butyral
polycarbonate
polyamide
polyacrylates
polymethacrylates
polyvinylcarbazole.

6. A display device constructed and arranged to operate substantially as described with reference to the drawing.

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