

Nov. 23, 1965

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 IMAGE FORMATION AND DISPLAY UTILIZING A THERMOTROPICALLY
 COLOR REVERSIBLE MATERIAL
 Filed Oct. 24, 1962

3,219,993

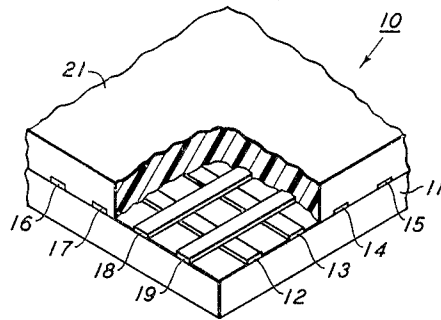


FIG. 1

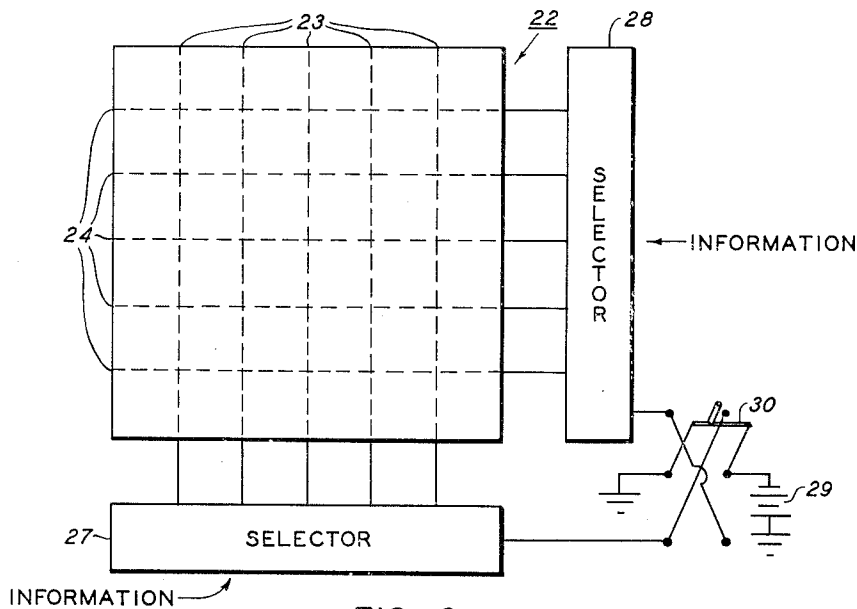


FIG. 2

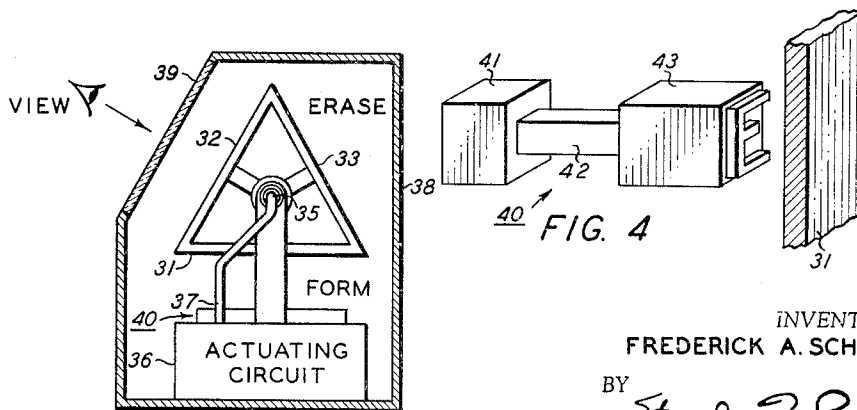


FIG. 3

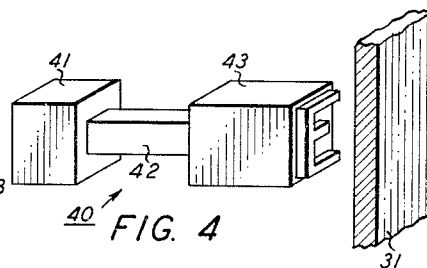


FIG. 4

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IMAGE FORMATION AND DISPLAY UTILIZING A THERMOTROPICALLY COLOR REVERSIBLE MATERIAL

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Filed Oct. 24, 1962, Ser. No. 232,799
7 Claims. (Cl. 340—324)

This invention relates to the temporary storage of information and more specifically, to the temporary storage of information on a thermotropically reversible medium.

There is a wide need today for reusable and erasable recording and display devices in many widely diverse fields. For example, such devices may be used as plotting boards, wall-hung display devices, printers, and the like, and may be adapted for both military and commercial use. Although the art of erasable recording has reached a very sophisticated state as it applies to magnetic recording, the erasable recording of directly visible images is still in its infancy. Therefore, in accordance with this invention there is described a recording and display member of unique construction and performance capability. In its preferred form the device utilizes a recording layer of a thermotropically, color-reversible material which exhibits a hysteresis effect in conjunction with a plurality of Peltier junctions or other devices capable of adding and subtracting heat from small sections of the recording layer or selected portions of it. In this way these sections are caused to change in color when they are brought up to a certain temperature and then may be caused to return to their original color when brought down below a significantly lower temperature. Since these color change temperatures, which in effect constitute a hysteresis loop, bracket ordinary room temperatures with some materials, any image formed on the recording layer may be preserved for display for considerable periods of time without any additional power being supplied to the system.

Accordingly, it is an object of this invention to provide a novel erasable recording medium.

It is a further object of this invention to provide an erasable recording medium capable of producing directly visible images.

It is also an object of this invention to provide a thermotropic recording medium having a reversible color hysteresis loop.

It is still further object of this invention to provide a novel method for the erasable recording of visible images.

Referring now to the drawings:

FIGURE 1 is a perspective, partially cut-away view of a fragmentary portion of the recording member of this invention.

FIGURE 2 is a plan view of a recording member according to this invention including a schematic of an exemplary actuating circuit.

FIGURE 3 is a partially section side view of a display system employing three of the erasable recording members of this invention.

FIGURE 4 is a partial side view of a modified apparatus according to this invention.

Referring now to FIGURE 1 of the drawings, there is illustrated a portion of a recording member 10 partially cut away for purposes of illustration. This recording member includes an insulating substrate 11 fabricated from a relatively strong rigid material, such as glass or Lucite. If it is desired to make the whole recording member flexible this supporting substrate may be fabricated of a more flexible material such as polyethylene, cellulose acetate, or the like, and, if the remaining sections of the recording member are sufficiently strong the sub-

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strate may be dispensed with entirely. Overlying the substrate 11 are a plurality of conductors 12, 13, 14, and 15 extending across the substrate in one direction in an array. In this embodiment of the invention these conductors are substantially parallel to each other so that no one of conductors 12-15 intersects any of the others. Another group of similar conductors 16, 17, 18, and 19, all of which are mutually nonintersecting, extend across the substrate in a second array substantially perpendicular to and intersecting the first array of conductors 12-15. It is essential that the materials utilized to fabricate the two conductor arrays be different and that these two different materials be selected so that the two when placed together form a good Peltier junction. As a matter of fact, the two arrays 12-15, and 16-19, need not necessarily be conductors in the restrictive sense of the term, the only requirement being that when placed together they form reversible thermoelectric junctions of the Peltier type. By laying these members down so that the two arrays are mutually intersecting a multiplicity of Peltier junctions are formed across the surface of the substrate, one Peltier junction being formed at each point of intersection. Many different materials have been shown to form good Peltier junctions. Materials presently undergoing investigation and which have demonstrated their feasibility for use in reversible thermoelectric generators or Peltier junctions include metals, alloys, semimetals, and semiconductors, especially of the highly doped variety. The overall conversion efficiency of these materials is generally described in terms of their "figure of merit." Many of the newly developed junction materials, generically described above, have figures of merit which exceed the classical junction material combinations such as copper and bismuth, or antimony and bismuth. The literature is replete with descriptions of these newly developed junction materials and whole texts have even been devoted to the subject, for example, see Thermoelectricity, Science and Engineering by Heikes and Ure, published in 1961 by Interscience Publishers; Thermoelectricity by C. Zener, published by Wiley in 1960; and, Semiconductor Thermal Elements and Thermoelectric Cooling, by Ioffe, published by Infosearch in 1957.

Peltier junctions of the type described have the unique property of thermal reversibility, that is to say, heat is given off by the junction when current is run through the junction in one direction while heat is extracted by the junction when current is run through it in the opposite direction. Thus, by merely reversing the direction of current through the junction it may be used either to heat or to cool the areas surrounding it.

Overlying the Peltier junctions formed by the intersecting arrays described above, is a recording layer 21 which reversibly changes in a visible way upon heating and cooling (thermotropic). Thus, record layer 21 may be made of a thermochromic material which changes color upon heating to one temperature and then changes back to its original color upon cooling to a lower temperature. For purposes of this specification and the appended claims, materials of this type which reversibly change in a visible manner either in color or transparency upon heating and cooling will be referred to as reversibly thermotropic. For example, an intimate mixture of 33.9% copper mercuric iodide and 60.1% silver mercuric iodide in a binder of Lucite 46 (a tradename for methylmethacrylate) was fabricated. At room temperature this film is a yellow-orange color but when heated to 70° C. the color changed to a crimson-red. This red color was retained on the film even after it was cooled down to room temperature but on further cooling to about 10° C. the film reverted to its original yellow-orange color. Upon reheating to room temperature the original yellow-

orange color is retained. In short, this material exhibits a temperature dependent color hysteresis effect. Other materials exhibiting this temperature-dependent color hysteresis effect may also be utilized so as to secure different color changes. For example, copper mercuric iodide alone has been found to change from a bright red to a deep brown or black on heating to about 70° C. and to return to its original color on cooling to about 58° C. Silver mercuric iodide alone also exhibits this effect with color changes to yellow and orange occurring at 47° and 45° C. respectively. Many other thermotropic materials are well known including certain organics such as bianthrone and its vinylene homolog and members of the dianthrone and spiran series may be used. The thermochromism of these compounds is more fully described in the following references:

- (1) Grubb and Kistiakowsky, *Journal of the American Chemical Society*, 72, 419-25 (1950).
- (2) A. Schonberg et al., *Science*, 119, 193 (1954).
- (3) Hirshberg and Fischer, *Journal of Chemical Physics*, 23, 1723 (1955).
- (4) Harnik, *Journal of Chemical Physics*, 24, 297 (1956).

Other materials which exhibit changes in color or transparency are described in U.S. Patent 2,710,274 to Kuehl. In short, any thermotropic material may be used.

Because of color, low power or other requirements in certain applications it may be desirable to select a thermotropic material which has a very narrow or negligible hysteresis effect. In those situations or in other cases where normal ambient temperatures are not within the hysteresis loop of the preferred materials it may be necessary to maintain the temperature of image portions of the image bearing layer at the temperature required for image formation, by continuing current flow through the selected Peltier junctions.

In FIGURE 2, there is illustrated a plan view of a plotting board 22 according to this invention. The plotting board contains a multiplicity of Peltier junctions formed by the intersections of arrays 23 and 24, which are similar to the intersecting arrays 12-15 and 16-19 of FIGURE 1. These arrays are shown in phantom in this view as they are embedded in an upper thermotropic layer 26 similar to layer 21 of FIGURE 1. It should be recognized that, although each of the arrays 23 and 24 is made up of only five parallel members in this view, this is for purposes of illustration only and that, in an actual plotting board, hundreds of parallel members might be utilized in each array so as to allow the activation of any portion of the thermotropic layer. The number of array intersections, and consequently the number of Peltier junctions is optional depending for the most part on considerations of cost, ultimate use, and like. The array configurations are also optional and need not necessarily be mutually perpendicular with each array containing a number of parallel members. For example, one of the arrays may be made in the form of a number of concentric circles while the members making up the second array constitute a number of radial lines extending outwardly from the center of the circles so that a Peltier junction is formed at each point where one of the radial members crosses a concentric member of the other array. Thus it may be seen that almost any shape or configuration of conductor arrays may be utilized as desired. If the arrays are so fabricated that they cover substantially the whole board, any point on the board may be heated or cooled to a point where the thermotropic layer changes color by selective actuation of the proper two intersecting members in the two arrays 23 and 24. Many different switching techniques may be utilized to this end. Because of the thermal inertia inherent in this system relatively slow industrial control switching techniques of the type utilizing relays, thyratrons, and the like may be utilized as well as the faster and more sophisticated digi-

tal switching techniques. For purposes of illustration two selectors 27 and 28 have been illustrated in diagrammatic form. These selectors are made up of line selection matrices which select the members in their respective arrays to be actuated in accordance with input information. These selectors then apply a potential to the selected members from potential source 29, the polarity of the potential being dependent upon the position of double-pole, double-throw switch 30. If the film 26 on the surface of the board was uniformly yellow-orange in color to start with the application of potential in one direction through selected members of arrays 23 and 24 would serve to heat up the Peltier junctions formed at the intersections of those members, thus turning film 26 crimson-red in areas above the heated junctions when the temperature of the film above those junctions reached 70° C. In the alternative if the film were initially uniformly crimson-red current is run through the junctions in the opposite direction causing the selected junctions to accept heat or cool those portions of film 26 above the junctions causing them to turn a yellow-orange. Regardless of which mode of operation is utilized, the film may be completely erased by merely reversing the polarity of the applied potential and placing it across all of the members in both arrays.

In FIGURE 3 there is illustrated a simple system for the viewing of images formed at a relatively rapid rate. In order to overcome the thermal inertia problem inherent in the hysteretic character of the thermotropic films used, three boards 31, 32, and 33, similar to board 22, are provided, each with its own intersecting arrays of Peltier junctions. The three boards are fastened together in a triangular form and journaled for rotation about a central axis 35. This system also includes an actuating circuit 36 connected to the three boards through their central shaft 35 by a cable 37. The whole system is enclosed in an optional cabinet 38 with a transparent viewing screen 39. The triangular set of boards is provided with an indexing mechanism which rotates the three boards 120° each time it is actuated. By utilizing the three boards an image may be formed on board 31 while the viewer is studying an image on board 32 and board 33 is being erased prior to the formation of a new image, although any number of boards in any configuration may be used. Preferably, the indexing mechanism is under the control of the viewer so that it may be operated by a push button or the like which is operative only when a new image has been formed on the next successive board. In this case, then, an image would be formed on board 31 while the viewer was studying the image on board 32 and the image on board 33 was being erased.

A mechanism 40 for superimposing a second image upon the thermotropic layer in addition to the one formed by the Peltier junction matrix is shown in FIGURE 3 and in more detail in FIGURE 4. This additional imaging unit 40 carries a raised picture symbol, message, number or single letter such as the E shown on a head 43 which is mounted on a reciprocable ram 42. The ram in turn is connected to a power source which includes a means for heating or cooling the raised image on head 43 (depending on whether the original was formed by heating or cooling) as well as for pressing the image against the face of the thermotropic layer 31 at the image forming station. In this way fixed information which is to be displayed with every new image of variable information may be applied to the thermotropic layer by mechanism 40 while the Peltier junction matrix is used only to apply variable information to the layer. Other techniques for superimposing additional images may also be used such as infrared exposure of the thermotropic layer in fixed image configuration.

The term "display board" as used in this specification and the appended claims should be read in its broadest sense. Thus a display board may be a portion of a continuous belt or drum as well as being one of a number

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of discrete boards, and it may be of any shape such as flat, curved, spherical, etc.

The present invention has been described with reference to certain specific embodiments which have been presented in illustration of the invention. It is to be understood, however, that numerous variations of the invention may be made while still remaining well within the intended scope and spirit of the invention. These variations may include physical variations in shape, size, or configuration, as well as variations in the selections of materials and the substitution of equivalents.

What is claimed is:

1. A recording and display device comprising a layer of a thermotropically color-reversible material having a fixed color hysteresis loop which brackets ambient temperature, contiguous to at least one Peltier junction capable of heating and cooling surrounding material beyond the limits of said loop, means to apply an electrical potential across said Peltier junction and means to reverse the polarity of said applied potential.

2. A recording and display device according to claim 1 in which said layer of thermotropically color-reversible material includes an intimate mixture of silver mercuric iodide and copper mercuric iodide.

3. A recording and display device comprising a layer of a thermotropically color-reversible material having a fixed color hysteresis loop which brackets ambient temperature contiguous to a plurality of spaced Peltier junctions, means to apply an electrical potential across selected Peltier junctions capable of heating and cooling surrounding material beyond the limits of said loop, and means to reverse the polarity of said applied potential whereby an entire cycle of said loop is completed.

4. A display device according to claim 3 in which said layer of thermotropically color-reversible material includes an intimate mixture of silver mercuric iodide and copper mercuric iodide.

5. A recording and display device comprising a layer of a thermotropically color reversible material, in contact with a plurality of spaced Peltier junctions, formed by the intersection of two arrays, each array being made up of at least two lines, said lines so arranged so as to be nonintersecting with the lines of their own array and

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intersecting with the lines of the other array, each array fabricated of a dissimilar material providing good Peltier junctions at said intersections, means to selectively apply an electrical potential simultaneously to selected lines of said arrays in response to electrical input information signals, and means to reverse the polarity of said applied potential.

6. A display device according to claim 5 including means to apply a reversed potential on all the lines of both arrays so as to erase any previously formed images.

7. A display system comprising a viewing station, an image erasing station and an image forming station, a display member including a plurality of display boards, each of said boards including a layer of thermotropically color-reversible material having a fixed color hysteresis loop which brackets ambient temperature, in contact with a plurality of Peltier junctions capable of heating and cooling surrounding material beyond the limits of said loop, means to intermittently advance said display boards through said stations, means to apply a potential of a first polarity to all of the Peltier junctions of said display boards after they have passed from the viewing station to the image erasing station for sufficient time to uniformly erase any image on said boards and provide a uniform color over the entire board, means to apply potentials of a second polarity across selected Peltier junctions in response to informational input signals after the boards have advanced to the image forming station for a period of time sufficient to change the color of the boards at the selected areas.

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