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M. L. SCHULTZ ET AL
INFORMATION STORAGE DEVICES

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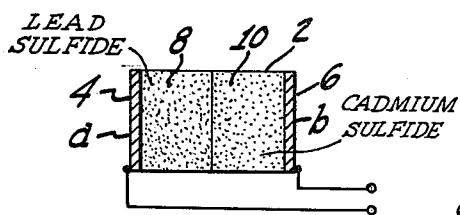


Fig. 1.

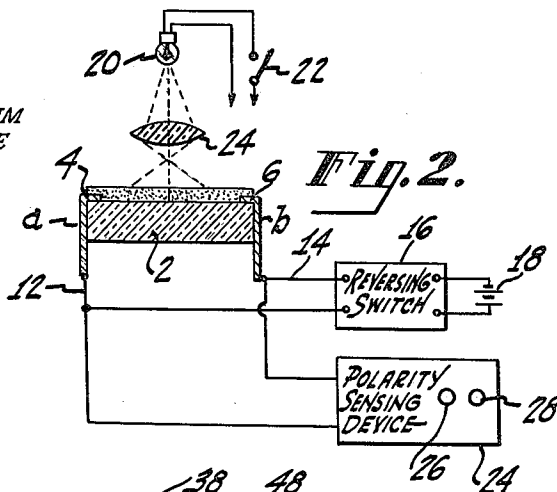


Fig. 2.

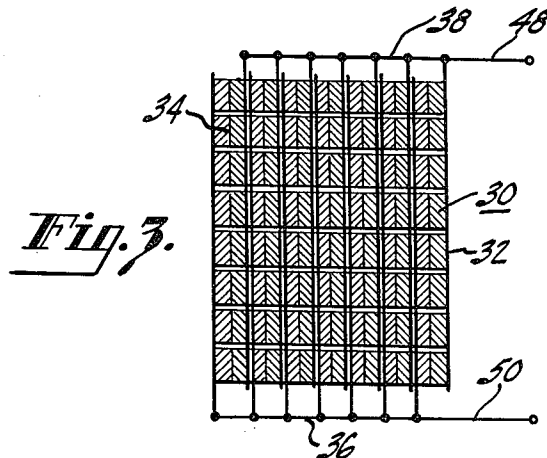


Fig. 3.

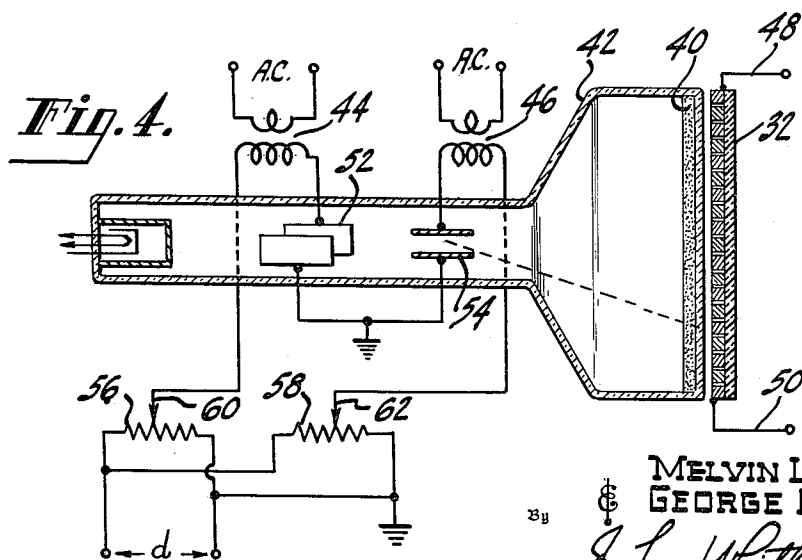


Fig. 4.

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INFORMATION STORAGE DEVICES

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This invention relates to devices for storage of information. More particularly, the invention relates to improvements in devices which store information in response to a light stimulus and release the stored information, also, in response to stimulation of light energy.

The invention is based upon the discovery that a certain light-sensitive material can be made photo-voltaic with a polarity in one sense if current is first passed through in a certain direction, while it can be made photo-voltaic with a polarity in the opposite sense if current is first passed through it in the opposite direction. When a photo-voltaic element of this nature is placed in electrically conductive contact with another element composed of photo-conductive material, which acts as a light switch, apparatus may be constructed for storing information which may exist in either of two different forms and for making this information available at a later time. The storage effect decreases with time, however, the limit of storage length being about 1 hour after activation has occurred. An activated film of lead sulfide is preferred as the directionally sensitive photo-voltaic material, although the selenide or telluride of lead may also be used. The photo-conductive material may be cadmium sulfide, selenide, or telluride, selenium, antimony trioxide or trisulfide, mercuric sulfide, or any one of many other materials well known to have this property.

Lead sulfide has previously been known as a photo-conductive material sensitive to ordinary light energy and, when specially activated, has also been known to be sensitive to energy in the infra-red portion of the energy spectrum. The present invention, however, is based upon the discovery of another particular novel property of an activated film of lead sulfide. The lead sulfide may be deposited from the vapor phase in vacuo and then activated by heating in the presence of oxygen for about 5 to 20 minutes at 400°–475° C. If a current is then passed through it in one direction, it has now been found that the activated film is modified by electrolytic migration so that if ordinary light energy is directed upon it, it will exhibit a photo-voltaic effect with a polarity in one sense. If the current is passed through in the opposite direction and light is again directed upon the film, it will then exhibit a photo-voltaic effect with polarity in a sense opposite to that exhibited previously.

One object of the present invention is to provide a novel light-sensitive information storage cell.

Another object of the invention is to provide an improved apparatus for storing information of a binary nature.

Another object of the invention is to provide an improved photo-sensitive memory device.

A further object of the invention is to provide an improved apparatus for recording and, later, delivering information.

A still further object of the invention is to provide an improved light-sensitive memory cell which is simple to construct and operate.

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These and other objects will be more apparent and the invention will be more readily understood from the following description, including the drawings, of which:

Figure 1 is a plan view of a novel unit cell constructed in accordance with the present invention,

Figure 2 is a diagrammatic view of apparatus, including the cell of Figure 1 in cross section, for recording information and for later reading the stored information,

Figure 3 is a screen containing a plurality of unit cells such as illustrated in Figure 1, and

Figure 4 is an apparatus utilizing the screen of Figure 3.

Referring now to Figure 1, there is shown one embodiment of a unit cell constructed in accordance with the invention. The cell may comprise an insulating base plate 2, which may be of glass, mica, or other material having electrical insulating and heat resistant properties. One of the major surfaces of the base plate is provided with two oppositely positioned electrodes 4 and 6. These may be prepared by painting a stripe of colloidal graphite suspension along two opposing edges of the surface and then drying. These electrodes may also be of gold or platinum or some other conductive material which does not react with the surface coatings later to be applied.

Upon one-half the surface of the plate, including that part covered by one of the electrodes 4, there is then deposited a coating of lead sulfide 8. This may be deposited by masking the portion of the surface not to be covered, placing the base plate in a vacuum chamber and then evaporating and depositing the lead sulfide. The lead sulfide may be evaporated from a tantalum boat heated with a tungsten filament and the pressure in the vacuum chamber may be of the order of 10^{-5} mm. of mercury. The thickness of the deposited film is not critical. The deposited film is then activated by heating it in the presence of oxygen for about 5 to 20 minutes at a temperature of about 400°–475° C.

The next step of preparing a unit cell is the deposition of the photo-conductive portion 10. This may be done by masking the coating 8 already deposited, placing the partially coated base plate once more in the vacuum chamber and depositing a coating of a photo-conductive material on the unmasked portion of the plate such that the photo-conductive material is in contact with the activated lead sulfide. The deposition may be carried out in a manner similar to the deposition of the lead sulfide previously described. The material is then given such activation treatment as may be required by the particular photo-conductor used. As also indicated previously, the photo-conductive portion may comprise a coating of cadmium sulfide or any one of many other materials.

The cell described above may be utilized in information storage apparatus, one simple example of which is illustrated in Figure 2. The electrodes 4 and 6 of the cell of Figure 1 are connected through leads 12 and 14, respectively, to the poles of a conventional reversing switch 16, which may be either solenoid operated or manually operated. A source of direct current, such as a battery 18, is connected to one side of the switch. There may also be provided a light source 20 having a switch 22 for turning the source off and on as desired. An optical system 24 may also be provided for focusing the light from the source onto the coated surface of the cell.

To store information on the cell, the light source is turned on and the cell illuminated, causing the photo-conductive portion 10 to assume a conductive condition. When used as a binary memory device in which the information may be such as to indicate either one of two different conditions (for example, to indicate 1 or 0), current may be passed through the cell either from a to b

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or from *b* to *a* to establish the reading polarity. The information 1 may correspond to the condition existing when *a* is + and *b* is -. The information 0 will then correspond to the condition existing when *a* is - and *b* is +. If it is then desired to store the information 1, the switch 16 is controlled such that current is made to flow from *a* to *b*. If it is desired to store the information 0, the switch is reversed such that current is caused to flow from *b* to *a*. In order to control the direction of current flow, the reversing switch 16 may either be controlled manually by an operator or automatically from a source such as a punched tape.

The current may be passed through the cell for a length of time from the order of a few hundredths of a second to several seconds; i. e., 4 or 5. The voltage of the current source may be from a few volts, say, about 10, to several hundred. Although neither time or passage of the current nor magnitude of voltage is critical, the subsequent output of photo current will depend upon the magnitude of these two factors. The longer the time of passage of current and the higher the voltage the higher the output current up to saturation.

To read back the stored information, the current from the source 18 is cut off and the coated surface of the cell, including the photo-voltaic portion 8 is again illuminated by the light source 20. This activates both the photo-conductive and the photo-voltaic portion and a small current will be generated in the electrode leads, the electrodes having a polarity depending upon the manner in which current was originally passed through the cell when the information was stored. To detect the polarity, any polarity-sensing device 24, such as a galvanometer or a high impedance amplifier is connected to the electrode leads of the cell. This may have visible indicating means, such as lamps 26 and 28, one of which lights when the voltage is of one polarity and the other of which lights when the voltage is of opposite polarity. For example, if a galvanometer is used, deflection of the armature in one direction can be utilized to close contacts to one of the lamps, while opposite deflection of the armature can be used to close another pair of contacts closing a circuit through the other lamp. The information may also be recorded on a photographic, magnetic, or punched tape.

In order to store a large number of items of information, a plurality of storage elements, such as described in connection with Figure 1, may be incorporated on a screen 30 such as illustrated in Figure 3. This screen comprises a relatively large base plate 32, which may be of glass, with a large number of cells 34 on one of its surfaces. Each cell has electrodes similar to those described in connection with the single cell. All corresponding electrodes on the side of each cell containing the photo-voltaic material are connected in parallel to one of the main leads 36, while all the electrodes in contact with the photo-conductive material portion of each cell are connected to another main lead 38. Information can then be stored rapidly upon or read from each element, using any well known system such as that illustrated in Figure 4.

Referring now to Figure 4, a multi-element screen 30 is placed, preferably with its coated face adjacent the phosphor coated screen 40 of a cathode ray tube 42 having horizontal deflection yoke transformer coils 44 and vertical yoke transformer coils 46. The phosphor employed in this type of tube is of the short-decay period type. Each of the deflection yokes is provided with a source of A.-C. potential for sweep voltage purposes. As the electron beam is swept across the face of the tube, the spot of light illuminates each unit cell in turn and as each cell is illuminated, the reversing switch (as shown in Figure 2) is operated and D.-C. potential is applied to the leads 48 and 50 such that current flows through the illuminated cell in either one direction or the other. This operation conditions each cell so that when it is later

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illuminated to read the information it contains, it will exhibit a polarity either in one sense or the other.

Instead of a cathode ray tube, a conventional light beam scanning device may be used to illuminate each of the unit cells.

The stored information is read from each cell by again scanning with the moving spot of light and applying the output voltage to a polarity sensing device such as that previously described. The reversing switch is held at a neutral position so that no current from the D.-C. source is being applied to the cell.

Instead of applying and reading information from a multi-element screen by means of a flying spot scanning device, the apparatus may be used by directing a beam of energy at any particular element of the screen desired without scanning the entire screen. Using a two-dimensional coordinate system, a focused light beam may be directed to one particular element, or, a beam of electrons may be directed to a corresponding part of a phosphor screen. This may be done with suitable *x, y* coordinate controls for directing either the light beam or the electron beam to the desired point on the screen. Conventional oscillographs have controls for thus directing the electron beam. The apparatus illustrated in Figure 4 includes controls for applying any desired relative potentials to each of the horizontal deflection plates 52 and to each of the vertical deflection plates 54. These control means may comprise potentiometers 56 and 58 connected to a common source of D.-C. potential. The sliding contact 60 of potentiometer 56 may be connected to one of the horizontal deflection plates, the other plate of the pair being grounded. In a similar manner, the sliding contact 62 of potentiometer 58 is connected to one of the vertical deflection plates, the other being connected to ground. By varying the settings of the sliding contacts in conventional manner, the potentials applied to the horizontal and vertical deflection plates may be varied so as to direct the beam of electrons to any desired part of the viewing screen 40.

There has thus been described a novel method and apparatus for storing information of a binary nature and, later, reading the stored information. The invention is based on the discovery that certain materials, such as lead sulfide, telluride, or selenide, when specially activated, exhibit a photo-voltaic effect with one polarity if current is first passed through in one direction during light activation and the opposite polarity if current is first passed through in the opposite direction while light is directed on a film of the material.

We claim as our invention:

1. Electrical apparatus comprising a cell having a surface, a first portion of which is composed of a photo-conductive material and a second portion of which is composed of a photo-voltaic material capable of changing the direction of its photo-current output and consisting essentially of directionally sensitive photovoltaic lead sulfide in the form of a film that can be given a first polarity when current is passed therethrough in one direction and can be given the opposite polarity when current is passed therethrough in the opposite direction, said second portion being in electrical contact with said first portion, and an electrode in contact with each of said portions.

2. A device according to claim 1 in which said photo-conductive material is cadmium sulfide.

3. Electrical apparatus comprising a cell having a base plate, one portion of said plate being coated with a photo-conductive material and another adjacent portion of which is coated with directionally sensitive photovoltaic lead sulfide in electrical contact with said photoconductive material and in the form of a film that can be given a first polarity when current is passed therethrough in one direction and can be given the opposite polarity when current is passed therethrough in the opposite di-

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rection, and an electrode in contact with each of said portions.

4. Apparatus according to claim 3 including means for applying a potential of desired polarity to said electrodes.

5. Apparatus according to claim 4 including, in addition, means for applying a beam of light to both of said coated portions of said plate.

6. Apparatus according to claim 5 including, also, means connected to said electrodes for detecting the polarity of said electrodes.

7. Apparatus comprising a plate having a surface comprising a plurality of cellular elements, each of said elements comprising one surface portion film of a photo-conductive material and an adjacent surface portion film of a directionally sensitive photo-voltaic material consisting essentially of lead sulfide in electrical contact with said photo-conductive material and that can be given a first polarity when current is passed therethrough in one direction and can be given the opposite polarity when current is passed therethrough in the opposite direction, an electrode connected to each of said portions of each of said elements, means for passing a weak current across said photovoltaic film in either of two opposite directions, means for directing a beam of light to any of said elements, and means for detecting the polarity of any of said electrodes when light is directed to the element connected thereto.

8. An information storage and indicating apparatus comprising an element including a film of material that can be made photo-voltaic with a first polarity when current is passed through said film in one direction and which can be made photo-voltaic with a second polarity opposite to that of said first polarity when current is passed through said film in another direction opposite to said one direction, a film of photo-conductive material adjacent and in contact with said film of photo-voltaic material, and an electrode in contact with each of said films.

9. Apparatus according to claim 8 including means for applying a potential of desired polarity to said electrodes.

10. Apparatus according to claim 9 including means for applying a beam of light to said film.

11. Apparatus according to claim 10 including means for detecting the polarity of said electrodes when light is directed onto both of said films.

12. A method of storing information of a binary nature comprising rendering directionally photo-voltaic in

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a desired sense a film of photo-voltaic material having the property of assuming a polarity in one sense when current is passed through in a first direction and of assuming a polarity in an opposite sense when current is passed through in a second direction opposite to said first direction, and, later, reading said information by directing a beam of light onto said film while detecting the polarity of said film.

13. A method according to claim 12 including placing a film of photo-conductive material adjacent and in contact with said film of photo-voltaic material and directing light onto said photo-conductive film whenever it is desired to pass a current through said photo-voltaic film.

14. Apparatus comprising a plate having a surface comprising a plurality of cellular elements, each of said elements comprising one surface portion film of a photo-conductive material and an adjacent surface portion film of a directionally sensitive photovoltaic material in electrical contact with said photo-conductive material that can be given a first polarity when current is passed through said film in one direction and the opposite polarity when current is passed through in the opposite direction, an electrode connected to each of said portions of each of said elements, means for passing a weak current across said photovoltaic film in either of said two directions, means for directing a beam of light to any of said elements, and means for detecting the polarity of any of said electrodes when light is directed to the element connected thereto.

15. An electrical cell comprising a layer of photo-voltaic material having the property of assuming a polarity in one sense when current is passed therethrough in a first direction and of assuming polarity in an opposite sense when current is passed therethrough in the opposite direction, means for selectively passing current through said layer in either of said directions and means for directing light upon said layer.

16. A cell according to claim 15 in which said photo-voltaic material is lead sulfide.

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