Dec. 24, 1968 T. J. WERNER 3,418,640

METHOD FOR STORING AND RETRIEVING INFORMATION ONTO AND FROM AN ELECTROPLATABLE RECORDING MEDIUM

Filed Oct. 22, 1964

FIG. 1

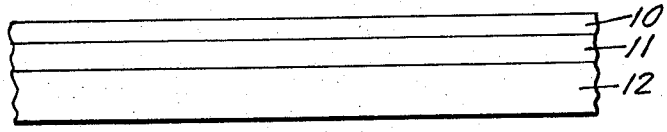


FIG. 2

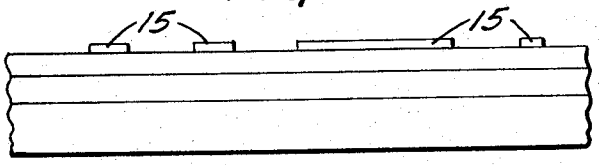
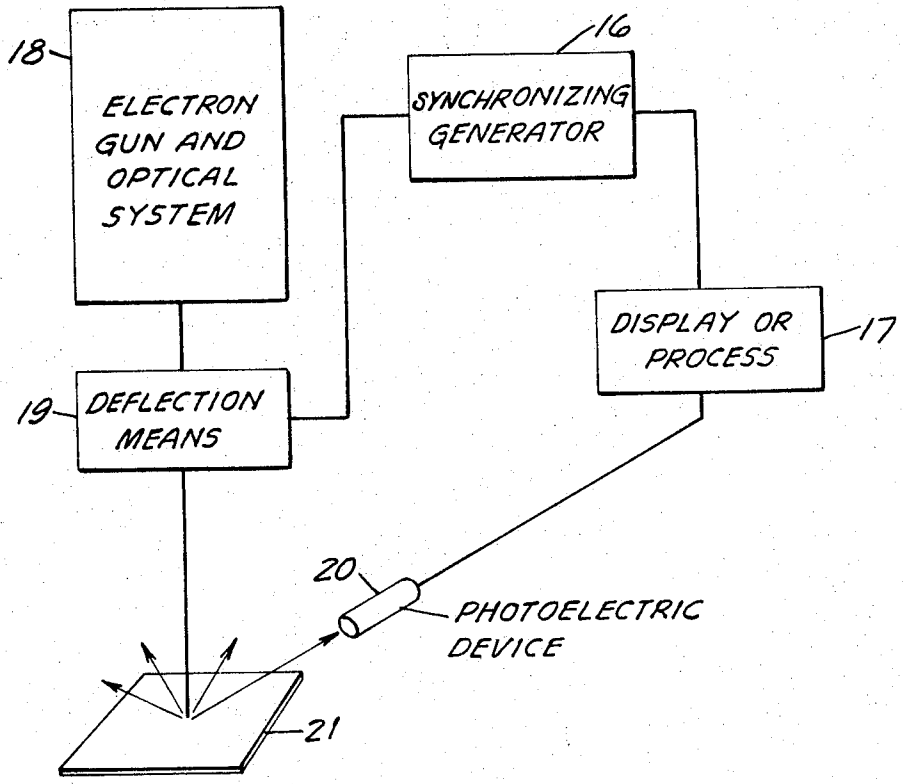


FIG. 3



INVENTOR.

THOMAS J. WERNER

BY

Carpenter, Abbott, Coulter & Kinney

ATTORNEYS

United States Patent Office 3,418,640 Patented Dec. 24, 1968

3,418,640

METHOD FOR STORING AND RETRIEVING INFORMATION ONTO AND FROM AN ELECTROPLATABLE RECORDING MEDIUM

Thomas J. Werner, North St. Paul, Minn., assignor to Minnesota Mining and Manufacturing Company, St. Paul, Minn., a corporation of Delaware

Filed Oct. 22, 1964, Ser. No. 405,724
7 Claims. (Cl. 340—173)

ABSTRACT OF THE DISCLOSURE

A method for storing and retrieving information onto and from a sheet-like recording medium having a facial layer of a composition which is both fluorescent and differentially conductive is shown wherein the recording of information is accomplished by exposing the facial layer with actinic radiation to effect localized selective image-wise changes in electron conductivity normally through the layer forming a pattern representing the information being stored and by subsequently contacting the resulting image with an electrically conductive solution having a developer material which electroplates the developer material on the one surface of the layer to form a developed image. The stored information in the form of a plated image is reproduced by exposing the facial layer having the developed image to a uniform scanning electron beam to produce differential photon emission which is simultaneously photoelectrically detected to produce an electrical signal output representing stored information.

This invention relates to a process for information storage and retrieval using an electron beam.

Heretofore, the art has known how to make graphic images upon strongly photoconductive light-sensitive sheet materials using selective electrolytic deposition; see, for example, the Johnson et al. U.S. Patent Nos. 3,010,883; 3,010,884; and 3,011,963. The art has also known how to use a modulated, scanning electron beam to first create an electrostatic charge pattern upon an insulative surface and thereafter to deposit selectively on such surface particles so as to make a permanent recording of such modulation; see, for example, the Moller U.S. Patent No. 3,099,710.

However, so far as is now known, prior to the present invention, no one ever was able to utilize electrolytic electrophotographic techniques in an electron beam recording and readout system.

The present invention provides an improved electron beam storage and retrieval process whereby to record one first irradiates the surface of a suitable sheet-like storage medium with actinic radiation modulated with information to be stored and retrieved and thereafter deposits by electrodeposition on such surface selectively a photon masking material, and to retrieve one scans the resulting surface with a substantially uniform electron beam and simultaneously collects the differential photon emission thus produced photoelectrically so as to produce a serial electrical output which is representative of the original modulated actinic radiation.

In one embodiment of the present invention, one stores information by first scanning with an electron beam modulated with the information to be stored the surface of a storage medium both capable of uniformly emitting photons in response to uniform electron excitation and capable of selectively altering its ability to conduct electrons across such surface in response to electron bombardment, and then depositing electrolytically on such scanned surface a differential pattern of masking material which corresponds to the beam modulation.

In another embodiment of the present invention, one retrieves information from a pre-recorded medium of the general type indicated above by exposing such medium to uniform scanning electron excitation so as to produce differential photon emission from the masked surface and simultaneously detecting photoelectrically such differential photon emission and converting same into a serial electric signal output which, taken as a whole, is representative of the originally recorded information.

It is an object of this invention to provide a method for storing and retrieving information using an electron beam.

It is another object of this invention to provide an improved information storage and retrieval process whereby differential actinic irradiation is used to effect selective electrical conductivity changes across one face of a storage medium which conductivity change is then made to serve as an image-wise mask of photon energy by selectively electrochemically depositing photon masking material on such one face in regions corresponding to the original differential irradiation of that surface.

It is another object of this invention to provide an improved information storage and retrieval process whereby electron excitation is used to produce differential photon output from the surface of an electrochemically masked fluorescent prerecorded storage medium.

It is another object of this invention to provide a method for recording the modulation in a scanning electron beam by a two step process involving first bombarding the surface of a suitable storage medium with such a scanning beam and then depositing by electrodeposition a differential photon mask on such exposed surface.

It is another object of this invention to provide a method for reading out prerecorded information from a fluorescent medium bearing an electrolytically differentially deposited masking layer using uniform electron excitation with simultaneous photon detection and conversion to serial electrical output.

Other and further objects will become apparent to those skilled in the art from a reading of the present invention taken together with the drawings wherein:

FIGURE 1 diagrams one form of medium construction useful in practicing the process of this invention before the same is used for storing information;

FIGURE 2 shows diagrammatically the construction of FIGURE 1 after such construction has been used for storing information; and

FIGURE 3 illustrates diagrammatically the manner in which information is retrieved from the construction of FIGURE 2 in accordance with the present invention.

For purposes of clarity, it is deemed advisable to define certain terms as used in this application as follows:

By the term "fluorescent" reference herein is had to substances which emit photon energy when electron excited.

By the term "differentially conductive" reference herein is had to substances which become selectively or differentially electrically conductive of electrons normally therethrough when normally struck by actinic radiation, the change in electrical conductivity through any given portion of such a substance being proportional to the total energy of actinic radiation striking such portion.

By the term "conductive" reference herein is had to substances which offer relatively low resistance to the passage of electrical current therethrough.

By the term "photoconductive" reference herein is had to a material which experiences an increase or decrease (change) in ability to conduct electrons responsive to photon energy radiation. The amount of change in such conductivity in any given location being proportional to the amount of photon radiation normally striking same.

When a photoconductor conducts, it will be appreciated that the electrons are conducted normally therethrough.

By the term "photon energy" reference herein is had to radiant energy ranging from gamma radiation up through infrared radiation thus including the visible light spectrum (i.e., energy having wavelengths of from about 400 to 700 millimicrons).

By the term "actinic radiation" reference herein is had not only to photon energy, but also to ionizing radiation (including particulate energy such as alpha particles, protons, electrons, neutrons, nucleids, and other subatomic particles).

By the term "photon masking" reference herein is had to a material which absorbs or differentially transmits photon energy, the amount of absorption or transmission for a given material being dependent upon material thickness up to certain maximum values characteristic of the given particular material.

Media and methods for making

In general, storage media useful in the processes of this invention are sheet-like and can be constructed in either of two ways. In one type of construction, the storage media contain both a fluorescent material and a differentially conductive material. In the second type of construction, storage media contain essentially one composition which is both fluorescent and photoconductive.

As those skilled in the art will appreciate, fluorescent materials are generally very well known. In storage media of this invention, one can employ virtually any conventional fluorescent material. Each of these materials have associated with it a characteristic persistence time by which is meant the period of time following removal of excitation required for the photon emission to decay to approximately 1% of its value at the time of cessation of excitation. For example, the *p*–1 phosphor (the zinc silicate type) has a persistence of .05 second, while the *p*–15 phosphor (zinc oxide type) has a persistence of one microsecond. Organic fluorescent materials dissolve in appropriate polymer binders (generally referred to as scintillators) have persistence times commonly of 10^{-8} seconds or less; for example that of p-terphenyl is about 10^{-8} seconds. In general, luminescence persistence values for conventional fluorescent materials fall in the range of from about 0.05 second to times of the order of 10^{-9} seconds. For best results, the luminescence persistence of a fluorescent layer should have approximately the same time duration as the period of the highest readout frequency associated with a given prerecorded mass of information to be read out.

In general, the selection of a particular fluorescent material for use in a given medium depends upon the manner in which the recording medium is to be used in practicing the processes of the present invention. Thus, for example, it may be desirable in some instances when extremely high resolution recording and readout is desired to use a fluorescent material which is essentially optically homogeneous so that no individual particles of fluorescent material are detectable and resolution capabilites are essentially unlimited down to the dimensions of the actinic or photon radiation itself.

Similarly, differentially conductive materials are well known to those skilled in the art. A major class of such materials comprises photoconductors. One simply selects a suitable photoconductor for the particular type of medium to be constructed. Suitable classes of photoconductive materials and methods for using same in the construction of media useful in the processes of the present invention are described in U.S. Patent No. 3,138,458. Another class of suitable differentially conductive materials is described in U.S. Patent Nos. 3,010,883 and 3,010,884. Still another such material is described in U.S. Patents Nos. 3,087,869 and 3,085,051.

When one uses photoconductive materials it will be appreciated that such can be organic or inorganic. It is preferred to use photoconductive materials having dark conductivities in the range of from about 10^{-12} to 10^{-9} (ohm cm.)$^{-1}$ in the dark state and increasing by an order of magnitude but in no event smaller than 10^{-9} (ohm cm.)$^{-1}$ or greater than about 10^{-6} (ohm cm.)$^{-1}$ when exposed to actinic radiation not in excess of 500 foot-candle seconds. Such materials have the further characteristic of maintaining said high conductivity for a period of time following exposure to actinic light to permit the subsequent electrolytic development to be performed while a useful conductivity differential between the exposed and unexposed areas of the medium is maintained. This phenomenon of natural recovery of original dark conductivity value is called light conductivity decay time and should for practical purposes be selected so that useful execution of an entire storing process can be performed. For example, if in a given performance of the process, an elapsed time of thirty seconds following actinic radiation exposure is required to effect the electrolytic development of a suitable photon-masking pattern, a photoconductive material should be selected so that a no greater than 70–80 percent decrease in actinic radiation induced conductivity is experienced during that thirty second period. Similar considerations govern selection of photoconductive materials where process conditions require longer or shorter elapsed times for completion.

In practicing this invention, it is convenient and even preferred to combine the fluorescent material and the differentially conductive material together into a composite mixture. Many substances are known which are both fluorescent and differentially conductive. Examples of such materials include anthracene, cadmium sulfide, metal phthalocyanins, zinc sulfide, and the like.

Storage media of this invention will preferably contain incorporated therein a layer of conductive material. Examples of such materials include aluminum, copper, silver and carbon particles, which, when in the form of a continuous film or particulate layer, conduct electrons. It is preferred to associate a layer of such a conductive material with the layer of composite fluorescent and photoconductive composition so as to be able to drain off electrons from a medium of the invention when such layer of conductive material is grounded and so as to be able to conduct electrons through the composite fluorescent and differentially conductive composition layer when depositing material electrochemically upon a surface of a medium after exposure thereof to differential actinic irradiation.

Because both the layer of composite fluorescent and differentially conductive composition and the layer of conductive material are commonly each so thin as to have poor tensile strength characteristics, it is convenient to equip a sheet-like storage medium used in this invention with a backing layer or supporting layer, which is designated in the construction of FIGURE 1 in its entirety by the numeral **12**, so that an entire storage medium construction can be handled, stored, etc., with ease. Suitable materials for support layers in storage media include glass, wood, metal (e.g. aluminum foil), paper, cloth, cellulose esters (e.g. cellulose acetate, cellulose propionate, cellulose butyrate, etc.), polyesters, polystyrene, and other plastic compositions. Those skilled in the art will appreciate that a support layer may have in or on its surface suitable conventional materials necessary or desirable for the purpose of facilitating anchorage of other layers thereon.

Preparation of media is easily carried out by conventional techniques. For example, the conductive material layer can be a foil (in which event no backing layer may be necessary) or it can be a vacuum vapor deposited layer on a supporting layer. The composite fluorescent and differentially conductive composition can be coated from a liquid or paste composition by conventional coating procedures over the conductive layer and then allowed to dry. Preferably the composite fluorescent and differentially conductive composition layer is kept as thin as possible

consistent with the manner in which the invention is to be practiced in any given instance. In some media constructions, such as those which are intended to be transmissive of visible light, the composite fluorescent and differentially conductive layer as well as the conductive material layer are each so chosen as to be at least partially light transmissive.

While no critical dimensions are associated generally with storage media useful in practicing this invention, it will be appreciated that it is usually necessary to design a storage medium to meet the particular conditions of recording and readout arising in the practice of this invention in any particular set of process parameters. Thus, a given storage medium used in any particular process situation should have sufficient respective quantities of, and/or sufficient respective thicknesses of, fluorescent material, material which selectively changes its ability to conduct electrons and (optionally) conductive material to make both recording and readout possible in that particular situation in which such medium is to be employed. Since media constructions can vary widely, no specific size, thickness, composition, etc., specifications can be stated that will be applicable or even optimum for all possible use situations. A medium is always constructed so that when, after a recording or storage operation, the fluorescent material in such medium is excited to luminescence by energized electrons, there results the desired differential output of photon energy from one surface of said medium uniquely corresponding to the original radiation image or pattern.

In general, the composite fluorescent and photoconductive composition is conveniently used in the formation of media for practicing the processes of the invention by coating a layer of such composition upon a supporting surface, the layer being uniform so as to be uniformly photon emissive when uniformly electron excited.

Referring to FIGURE 1, there is seen a preferred form of medium construction useful in this invention. Here, the composite fluorescent and differentially conductive composition comprises a layer designated in its entirety by the numeral **10**.

A layer of conductive material is used in the construction shown in FIGURE 1 and is designated in its entirety by the numeral **11**.

In summary, storage media useful in this invention are sheet-like. On one face is a layer of material which is both fluorescent and differentially conductive. Preferably immediately underlying said layer and bonded directly thereto is a highly electrically conductive layer.

Process description

Briefly, in practicing the processes of this invention using such a medium as above described one first differentially irradiates with actinic radiation one surface thereof so as to store in the medium a latent image pattern of the radiation by selectively changing the conductivity of the medium. Next, one differentially deposits a photon masking material on one surface of the resulting medium by electrodeposition. Thereafter, one scans the so developed medium with a uniform electron beam to produce a differential photon energy output from the differentially masked surface of the medium and simultaneously photoelectrically detects such photon energy and converts same to an electrical output which serially varies in a manner representative of at least a portion of the original differential actinic radiation used for recording.

(*A*) *Exposure to differential actinic radiation*

In storing information by the processes of this invention, it is necessary to modulate the particular form of actinic radiation to be used for storing so as to have the capacity to differentially or selectively irradiate a surface of a storage medium. Modulation can be effected by any conventional process whereby some characteristic of radiation to be used for storage of information in accordance with the teachings of this invention is varied in such a manner or to such a degree that the resulting differential radiation is capable of producing selective, image-wise alterations in electrical conductivity through the composite fluorescent and differentially conductive composition layer.

Storing can involve optical techniques and the use of light images. Alternatively, it can involve the use of an intensity modulated, scanning electron beam. The type of actinic radiation employed in any given instance depends, of course, upon the spectral sensitivity and response associated with a given composite fluorescent and differentially conductive composition.

It will be appreciated that in some types of storing it is necessary to position the recording medium and the apparatus used for generating or modulating the differential actinic irradiation in a vacuum chamber, such as is the case, for example, when one records using an intensity modulated scanning electron beam where vacuums of the order of from about 10^{-4} to 10^{-6} mm. Hg are conventionally employed, as those familiar with conventional electron beam techniques will readily appreciate, but values greater or smaller can be used. In general, technology for producing differential actinic radiation is well known.

Obviously, the type of information which can be stored can vary very widely and includes video signals and facsimile signals. In general, the processes of this invention are not limited by the nature of the information to be stored.

(*B*) *Development using electrodeposition*

Following such exposure one subjects the irradiated surface of the storage medium to electrodeposition. The term "electrodeposition" includes deposition of a material by charged particle migration, e.g. migration of ions or of a suspended particulate phase, during the passage of an electrical current through an electrically conductive liquid medium, and is generic both to electrolytic and electrophoretic deposition. In general, such development procedure involves the rapid electrolysis of an electrolytic or electrophoretic developer solution with electrodeposition of a metallic or other visibly distinct coating at the actinic radiation exposed surface of the medium. Various development techniques and developing compositions are exemplified in such art as U.S. Pat. Nos. 3,010,883, 3,053,179, 3,095,808, 3,106,156, 3,106,157, 3,057,788 and 3,085,051.

The development procedure involves contacting the exposed medium with an electrically conductive liquid solution containing developer material and creating simultaneously a direct current electrical potential thereby causing a current flow between the metal layer and the electrolytic or electrophoretic solution while the exposed surface of the medium is in contact therewith. Such simultaneous treatment with electrically conductive liquid solutions and direct current flow results in the deposition of a material upon the exposed surface of the medium which is derived from the developer material in the solution and which creates on such exposed surface an image-wise photon mask.

The electrical development may be carried out under widely varying conditions as regards time, voltage and other variables. For practical purposes, it is desirable that development be completely within a minimum of time, for example, within not more than about 10 seconds per frame (i.e. one individual image). It is also desirable to restrict operating voltages during development to those which can be easily provided and controlled without elaborate and expensive equipment or danger and inconvenience to the operator. Voltages up to not more than about 50 volts fulfill these requirements.

It is preferred to have the conductivity of the actinically irradiated area of the exposed surface of a recording medium just prior to electrodeposition development have a conductivity of the order of from about 10^{-4} to

10^{-7} mho per centimeter. At the same time, if one desires to obtain good contrast between imaged areas and non-imaged areas the conductivity of the areas not struck by actinic radiation should be preferably not greater than of the order of one-tenth to one-hundredth that of an actinically irradiated area.

The nature of a medium which has thus been exposed to differentially actinic irradiation and developed by electrodeposition is illustrated by FIGURE 2, which shows the medium of FIGURE 1 with deposits of photon masking material on the layer **10**. These deposits are collectively designated in their entirety by the numeral **15**. When a layer **10** is excited to fluorescence by electrons impinging against the surface thereof, photons are emitted therefrom selectively owing to the deposits **15**.

(C) Readout by electron excitation

In general, retrieval is accomplished using uniform electron excitation of the previously actinically irradiated and electrolytically or electrophoretically developed storage medium. Thus, after storage and development a storage medium is placed in a vacuum chamber and one surface thereof is exposed to a scanning electron beam such as is produced by an electron gun. The energy associated with the excited electrons is sufficient to cause the composite fluorescent and differentially conductive composition layer to emit photon energy at beam struck areas. The resulting differences in photon energy emission from the masked surface of the storage medium provide the desired photon energy differentials for readout.

This differential photon energy emission is detected photoelectrically by some form of photon energy detector. Photon energy detectors are well known; they sense and convert photon energy into electrical energy.

Since photoelectric devices can be very sensitive to photon emission, it is possible to use a wide variety of photon-emissive, electron-excitable materials for photoelectric detection. Indeed, by the present invention one can detect photoelectrically photon emission which cannot be detected visually and/or by means of conventional optical systems, such as photon energy in the ultraviolet and infrared ranges.

Examples of photoelectric devices capable of converting photon energy into a serial electrical output include photomultipliers, photo tubes, photo cells, and the like. Sometimes the current output of these devices is so small as to require further amplification before practical utilization can be made, but such detection and amplification procedures are well known to those of ordinary skill in the art. Naturally one employs a photoelectric device which is capable of sensing the photon output associated with the particular fluorescent material employed in the recording medium.

Technology for producing electron beams is well known and electron beams can be conveniently employed to scan the surface of a storage medium with energized electrons of relatively uniform density.

Usually it is desirable to employ an electron optical system with an electron gun to produce electron beams for retrieval in accordance with this invention.

Any conventional electron beam-electron optical system equipped for scanning in some sort of a raster pattern over the recorded media can be used for readout in accordance with the teachings of this invention.

In general, readout is used to cause, within a predetermined surface area of a recorded medium, incremental photon emission in an ordered pattern, such that the sum total of individual increments equals the whole predetermined surface area. In serial readout, the rate of electron excitation is suitably matched with the medium persistence time so as to cause only localized photon emission in areas electron excited. It involves simultaneous coordinated use of both scanning electron excitation and photoelectric detection. Readout usually involves auxiliary electronic equipment.

The resolution efficiency of retrieval when practicing the processes of this invention depends upon the relationship between unmodulated scanning beam size and the respective resolution elements comprising the stored input information in the masking layer of the recording medium. In order not to lose or fail to retrieve recorded information on readout, the general relationship between the unmodulated scanning electron beam and each resolution element desired on retrieval, within a specified area of a storage medium surface should be such that the electron beam width measured in terms of the direction of relative velocity between the storage medium and the beam is not greater than the width of individual resolution elements to be read out (retrieved) measured in the same direction.

While the efficiency of retrieval is dependent upon such relationship between beam size and resolution elements, it will be appreciated that the processes of this invention can be practiced even when the beam size exceeds the size of the resolution elements, and indeed there are situations where the beam size should be necessarily larger than the size of the resolution elements as where in serial readout one desires to read out information as an integral or summation of more than one discrete resolution element. In a special situation as just indicated, the serial retrieval (readout) may involve parallel retrieval of a specified group or series of resolution elements in a given time or space sequence during a serial retrieval operation.

While in general the scanning electron beam used to excite the fluorescent material during retrieval is referred to herein as being "unmodulated," or "substantially uniform" or the like, those skilled in the art will appreciate that, during the tracing of a raster pattern, for example one involving horizontal and vertical deflection by the beam in a scan field, some sort of blanking may be employed during beam return for a new scan path in such raster pattern, so that in this sense the beam is truly unmodulated only during its passage across a scan field. Furthermore, in certain situations, it may be desirable to impose upon the unmodulated portion of such beam pulsed signal information, or the like, for example, to cause particular effects upon, in, or about a recording or storage medium during readout. However, for retrieval purposes in this invention, differential photon emission from the masked surface of the storage medium is achieved by a beam which is essentially uniform during residence time upon a storage medium. It will be appreciated that, as a consequence, the differential fluorescent pattern produced from the surface of such storage medium as a result of such uniform beam impact produces photon emission bearing information which need not be at all associated with or carried by an essentially unmodulated scanning readout electron beam.

In general, for serial readout there are two convenient methods. In one method, a medium with information stored therein is maintained in a fixed or stationary position and a scanning electron beam is moved over a predetermined portion of the surface thereof in a raster pattern involving both vertical and horizontal deflection.

In the second and preferred method of serial readout, the medium bearing recorded information is continuously moved, usually at a constant velocity, past a readout station. In the station, an unmodulated scanning electron beam is moved, usually transversely across the medium, that is, in the direction normal to the tape velocity axis or vector. During the sequence the beam is continuously scanning only transversely across the continuously moving tape, and is not scanning in the direction of tape motion. It will be appreciated that the unmodulated beam scanning the recorded information upon the moving tape must be synchronized with the prerecorded scan pattern in such a way that the scanning unmodulated beam follows as closely as practicable the precise path pursued by the modulated recording beam. Any conventional

method of synchronization can be employed here for this purpose, such as a conventional television synchronizing generator and conventional electrostatic or magnetic deflection equipment.

(D) Photoelectric photon emission detection

In general, a photoelectric device positioned in the vicinity of the storage medium being irradiated with excited electrons as above described can be used for direct electronic conversion of the photon emission so produced into a modulated or variable electric signal output uniquely characteristic of the original input information.

It will be recognized by those skilled in the art that the minimum photon output level requirements are a function of desired signal-to-noise ratio, electronic bandwidth, and the like. In general, the wider the bandwidth, the brighter must be the luminescence or photon output associated with a particular recording medium employed. In the case of video recording on 16 mm. film, for example, using a 10 micron beam and current densities of the order of 2 amperes per square centimeter, one should have a phosphor material capable of producing, when excited by such electron beam at the photon-sensing or photoelectric device, a light intensity of at least 50 microlumens contrast to deliver a high quality conventional television signal-to-noise ratio in the electron current output from the photon-sensing electron output device.

It will be recognized that the brightness of a fluorescing spot generated depends on the electron beam energy and the photon energy level incident on the photoelectric device depends on the juxtaposition of the photoelectric detector and/or any optical lens arrangement employed with respect to the luminescing spot on a recording medium.

If an electron beam-electron optical system used for readout is equipped with means for intensity modulating an electron beam, the same system can be used both for storing and for retrieving in accordance with the teachings of this invention. Such a system has utility in such applications as computerized storage and retrieval of information where rapid access is required.

A photoelectric device is positioned in the neighborhood of the recorded medium being so scanned so as to permit the photon-sensing device to sense, either in a fixed position adapted to sense all photon emission from the medium surface over a fixed area, or in a variable position adapted to follow the scan pattern associated with the scanning, unmodulated electron beam. Thus, as a prerecorded medium differentially fluoresces and gives off photon energy in a pattern corresponding to the modulation of the originally recorded information, the photon-sensing element picks up a fraction of such output and converts same into a current which can be used for any purpose desired, for example, to operate a viewing screen for visual display of the initially recorded information.

Naturally, the frequencies to be read out affect the fluorescence persistence to be associated with the medium used. For example, the readout of television frequencies requires a fluorescing material with a persistence of less than one microsecond. On the other hand, the readout of lower frequencies, such as audio, requires a persistence in the order of less than 2 milliseconds, a much longer persistence time. This is because, as the beam is incident on one bit or piece of information, a certain light level will be detected. As the beam moves to a new bit or piece of information, the light level must change to the value appropriate for the new piece of information. The time required to move from one bit to another is, therefore, obviously limited by the persistence of the phosphor. The higher the readout frequency, the shorter must be the persistence time. For the readout of one megacycle information, for example, one might select zinc oxide with a persistence of about 1 microsecond, whereas the readout of 20 cycle information could be easily done with the P-1 phosphor (zinc silicate). These values can, of course, be somewhat improved by those familiar with the art of electronic peaking, non-linear pulse processing and noise reduction techniques.

By the term "readout frequency" reference is had to the number of bits of information per unit of time being retrieved. For purposes of this application, readout frequency will be measured in terms of bits per second. Naturally, as those skilled in the art will appreciate, readout frequency is a function of readout beam velocity and of recorded bit density in terms of recorded bits per unit area.

Obviously, the cross-sectional area of the readout beam should be no larger than the area of the smallest bit of information which has been recorded. Characteristically, the cross-sectional area of a single bit of information can range over very wide values. In the case of video recording on a 16 mm. format and with television resolution, the beam spot size, and, consequently, the bit diameter, is fixed in the range of 20 microns in diameter. In this case, the bit density is in the range of about 250,000 bits per square centimeter. In this same example for television readout, one would be reading out a maximum of about 250 cycles per horizontal scan line in 50 microseconds. The time per cycle would thus be approximately .2 microsecond, requiring a luminescence persistence of less than .2 microsecond.

For a coherent readout or detection of the recorded information, there must be a specific order to the scanning readout beam.

Whether the information is recorded by light means or by the electron beam, there must be a preknown and controlled relationship between the instantaneous position of the readout beam and the position of the beam in the display unit. The desired relationship of the two scans can be assured by a conventionally designed synchronizing generator which provides the proper and identical timing pulses to both the readout beam and the display unit. If the object is to process the information such as in character recognition, etc., there still must be a unique known beam position-time relationship.

(E) Serial readout method

Referring to FIGURE 3, there is seen in block diagrammatic form a system for practicing a preferred readout method of the present invention. There is seen a conventional synchronizing generator **16**, which synchronizes a readout display monitor **17** and an electron gun and optical system **18**. Pulses from the synchronizing generator **16** are used to initiate the generation of deflection ramp currents within vertical and horizontal deflection amplifiers (not shown).

The vertical and horizontal blanking pulses from synchronizing generator **10** are amplified to a level sufficient to properly blank during retrace the beam of the electron gun-electron optical system **18**. Because the control grid (not shown) and the cathode (not shown) of the electron gun-electron optical system **18** are maintained at negative high potential, it is necessary to couple the blanking signals through a high voltage isolation device (not shown) such as a capacitor.

The electron gun-electron optical system **18** employs a conventional triode gun assembly comprising filament, a control grid, and a grounded anode. The electron gun-electron optical system **18** also includes a conventional deflection yoke **19**.

For readout, one can position a photoelectric device **20** (such as a photomultiplier) in the vicinity of a target area in which is placed a prerecorded storage medium **17**. The output of device **20** is fed to a suitable amplifier means (not shown) from which the output electrical signal is displayed using monitor **17**.

Examples

The following examples further illustrate media useful in the processes of this invention and should not be construed as unnecessarily limiting.

Example a

An electron photo-sensitive copy sheet is prepared according to the procedures detailed in Example 1, columns 2–5 of U.S. Patent No. 3,010,884. Specifically, a coating composition is prepared by first mixing together 640 grams of photoconductive zinc oxide pigment (New Jersey Zinc Co. "USP–12"), 533 grams of a 30% solution of a 30:70 copolymer of butadiene and styrene in toluene ("Pliolite S–7" solution), and 353 grams of acetone. The mixture is then milled for about 8 hours in a one-gallon ball mill loaded to about half its volume with ½ inch diameter porcelain balls. The resulting slurry or suspension is thick and viscous but flows readily and can be spread with a coating knife to form a smooth uniform coating.

The suspension is coated on the clean metal surface of a laminate of thin paper and thin aluminum foil, and the solvent removed by evaporation, to provide a smooth uniform dried coating about 0.8 mil thick. The resulting sheet is flexible and the coating remains firmly bonded to the metal during handling or rolling of the sheet.

Example b

An electron photo-sensitive copy sheet is prepared according to the procedures detailed in Example 2, columns 5 and 6 of U.S. Patent No. 3,010,884. Specifically, a clean-surfaced aluminum foil and paper laminate as used in Example 1 is coated with a thin layer of a smooth suspension of 80 grams of "USP–12" high conductivity zinc oxide in a solution, in 80 grams toluene, of 40 grams of "D–C 803" silicone solution (a 50% solution in xylol of alkyl aryl silicone resin capable of curing in one hour at 480° F. to a hard and somewhat brittle polymer). The suspension is milled in a one-pint ball mill with one-half inch porcelain balls for about 4 hours until smooth, and is coated at a thickness of 405 mils. After air drying the coating is about .8 mil thick.

The following examples are recited as a better understanding of the processes of the present invention and should not be construed as unnecessarily limiting thereto.

Example 1

A sample of the copy sheet construction of Example *a* above, having been previously held under dark conditions for at least about ½ hour, is exposed to a light-image for about five seconds.

Then, the negative pole of a 20 volt D.C. source of potential is connected to the metal foil of the sheet, as by means of edge clamps, the positive pole being connected to a narrow strip of fine-grained cellulosic sponge partly saturated with an electrolytic developer solution of 3 parts by weight of cadmium nitrate tetrahydrate, 0.5 part each of tartar emetic and silver nitrate, and 100 parts of water. The sheet is drawn past the sponge at a constant rate such that each point of the surface remains in contact with the sponge for about 0.4 second. A dark deposit is formed at the light-struck areas, while the unlighted areas remain white. The sheet remains substantially dry. The dark image areas are effectively permanent.

Example 2

Another sample of the copy sheet material of Example *a* above, having been previously held under dark conditions for at least ½ hour, is placed in a vacuum of about 10^{-5} mm. Hg and exposed to a scanning beam of 20 kilovolt electrons having a maximum current of about 100 microamperes and a spot size of about 2.5 mils for 1/30 second using a standard television raster pattern of 525 lines in a raster size of about 1" x 1". This scanning beam is modulated with the same light image using an iconoscope camera as employed in the first recording and development above.

Thereafter, the sheet construction is removed from the vacuum and developed in accordance with the same procedure used in the first recording and development above.

Example 3

A sample of the copy sheet material prepared according to Example *b* above having previously been held under dark conditions for at least ½ hour is placed in a vacuum of about 10^{-5} mm. Hg and exposed to a scanning modulated electron beam. This electron beam has a spot diameter of about 2 mils, a 1 inch raster in a television format (525 lines interlaced in 1/30 of a second), a beam voltage of 20 kilovolts, and a beam current which is 0 in background areas and 50 microamps in imaged areas. The modulation of the electron beam is a signal derived from a 35 millimeter slide projector imaged on an iconoscope camera tube. After the medium is imaged by such exposure it is removed from the vacuum chamber and developed according to the same procedure described in Example No. 1 above. Under magnification the so-imaged surface of the developed recording material appears as a microimage of the originally projected image.

Example 4

When the prerecorded media of Examples 1, 2 and 3 are prepared, each is electronically read out as follows: The samples are positioned on a turntable in a vacuum chamber. One portion of the turntable is adapted to be scanned by an unmodulated electron beam. Above this area, and inclined at an angle of about 45° thereto, is a rod of "Plexiglas" [a trade designation of Rohm and Haas Co. for its thermoplastic poly (methyl methacrylate) type polymers]. The distance of this forward end of the plastic rod from the axis of the beam is about 2½ inches. This rod extends by appropriate vacuum feed throughs through the wall of the vacuum chamber and its rear end portion is adapted to directly rest against the face of a photomultiplier tube, such as an RCA type 6199 having an applied voltage of 1,000 volts D.C. and an anode resistance of 2,500 ohms. The signals from the photomultiplier tube is fed to an amplifier having a gain of about 10 and the output from this amplifier is fed to a conventional television type video monitor.

The electron beam used for scanning in the vacuum chamber has a beam voltage of 7 kilovolts and a spot diameter of about 2 mils. This beam is substantially unmodulated except for retrace blanking pulses. The scanning electron beam is synchronized with the video monitor by a sync generator.

When each of the prerecorded media of Examples 1, 2 and 3 placed as described on the turntable is positioned under the beam and successively scanned using a standard television raster pattern of 525 lines and the instantaneous photon energy generated by such beam is simultaneously detected by the photomultiplier tube there is produced a serial electrical output which when displayed on the monitor produces an image pattern substantially identical to that of the originally recorded image in each case. Owing to the angle of inclination of the plastic rod with respect to the recorded medium, some distortion of the image on readout is observed, parts thereof which are most remote from the end of the rod being somewhat attentuated, while parts thereof nearest the rod being somewhat higher level. When the procedure is repeated using a plurality of photomultiplier tubes positioned over the raster and such tubes are connected in parallel and the output displayed on a video monitor, no distortion is observed.

In general for readout it is desirable to use a voltage consistent with the generation of desired photon output from the fluorescent medium because, as those skilled in the art will appreciate the higher the accelerating voltage, the greater the chance of degradation or damage to a recording medium being read out.

Having described my invention, I claim:

1. A method for storing in, and retrieving information from, a sheet-like recording medium characterized by having a facial layer of a composition which is both fluorescent and differentially conductive, said method comprising the steps of

(a) exposing one surface of said facial layer with differential actinic radiation modulated with information to be stored, the energy associated with said radiation being such as to effect localized selective image-wise changes in electron conductivity normally through said facial layer, the resulting pattern of changes being systematically representative of said information,

(b) subsequently contacting said one surface with an electrically conductive liquid solution containing a developer material while said resulting pattern is effective and creating a direct current electrical potential thereacross causing a current flow through said one facial layer and said electrically conductive solution to deposit said developer material on said one surface to produce an image-wise photon mask of said developer material which is plated on said one surface and which represents said stored information, and

(c) thereafter exposing said plated one surface having said information stored thereon to a uniform scanning electron beam to produce differential photon emission therefrom while simultaneously photoelectrically detecting said emission and producing an electrical signal output representing said information.

2. A method for storing and retrieving information onto and from a sheet-like recording medium characterized by having a facial layer of a composition which is both fluorescent and differentially conductive and which has two sheet-like surfaces and a conductive layer contiguous at least one of said surfaces, said method comprising the steps of

(a) exposing the other surface of said facial layer with an electron beam which scans said other surface in a scan pattern while said electron beam is intensity modulated with information to be stored which effects localized selective image-wise changes in electron conductivity normally through said facial layer, the resulting pattern of changes being systematically representative of said information,

(b) subsequently contacting said other surface with an electroplating solution containing a developer material while said resulting pattern is effective and creating a direct current electrical potential thereacross causing a current flow through said electrically conductive solution and said facial layer to said conductive layer to deposit said developer material on said other surface of said facial layer to produce an image-wise photon mask of said developer material which is plated on said other surface and which represents said stored information, and

(c) thereafter exposing said plated other surface of said facial layer to a scanning, uniform electron beam to produce differential photon emission therefrom while simultaneously photoelectrically detecting said emission and producing an electrical signal output which represents said information.

3. In a method for storing information in a sheet-like recording medium characterized by having a facial layer of a composition which is both fluorescent and differentially conductive, said method comprising the steps of

(a) exposing one surface of said facial layer to differential actinic radiation modulated with information to be stored, the energy associated with said radiation being such as to effect localized selective image-wise changes in electron conductivity normally through said facial layer, the resulting pattern of changes being systematically representative of said information, and

(b) subsequently contacting said one surface with an electrically conductive liquid solution containing a developer material while said resulting pattern is effective and creating a direct current electrical potential thereacross causing a current flow through said one facial layer and said electrically conductive solution to deposit said developer material on said one surface to produce an image-wise photon mask of said developer material which is plated on said one surface and which represents said stored information.

4. In a method for developing and retrieving information from a sheet-like storage medium having a pattern representing said information formed on a facial layer having a composition which is both fluorescent and differentially conductive, said pattern being formed by localized selective image-wise changes in electron conductivity normally through said facial layer, said method comprising the steps of

selectively electrodepositing a developer material on one surface of said layer while said pattern is formed to produce an image-wise photon mask of said developer material which is plated on said one surface and which represents said information; and

exposing said plated one surface to a uniform scanning electron beam to produce differential photon emission therefrom while simultaneously photoelectrically detecting said emission and producing an electrical signal output which represents said information.

5. A method for recording and reproducing information onto and from a recording medium having a layer which is capable of uniformly emitting photons in response to uniform excitation and a layer which is capable of becoming differentially conductive in response to actinic radiation, said method comprising the steps of

imaging one surface of said differentially conductive layer with differential actinic radiation in a radiation pattern representing said information to be stored, said actinic radiation having sufficient energy to differentially change the conductivity of said differentially conductive layer forming a latent image of said radiation pattern for a predetermined period of time;

electrically depositing a developer material from an electroplating solution on said one surface while said latent image is formed on said conductive layer by pasing an electrical current through said solution and said differentially conductive layer to develop said latent image with a visibly distinct coating of said developer material wherein the thickness of said coating forming said developed image is determined by the differential conductivity of said differentially conductive layer which defines said latent image; and

exposing said medium containing said developed image to uniform excitation having sufficient energy to excite said photon emitting layer to produce differential photon emission therefrom representing said stored information.

6. The method of claim 5 wherein said uniform excitation is directed upon said medium so as to pass through said one surface having said developer image to excite said photon emitting layer.

7. A method for recording information onto a recording medium having a layer which is capable of uniformly emitting photons in response to uniform excitation and a layer which is capable of becoming differentially conductive when one surface of said differentially conductive layer is irradiated by actinic radiation, said method comprising the steps of

imaging said one surface with differential actinic radiation in a radiation pattern representing said in-

formation being stored on said medium, said differential actinic radiation having sufficient energy to differentially change the conductivity of said layer forming a latent image of said radiation pattern for a predetermined period of time; and

electrically depositing a developer material from an electroplating solution on said one surface while said latent image is formed on said differentially conductive layer by passing electrical current through said solution and said differentially conductive layer to develop said latent image with a visibly distinct coating of said developer material wherein the thickness of said developed image coating is determined by the differential conductivity of said differentially conductive layer which defines said latent image.

References Cited

UNITED STATES PATENTS

2,921,201	1/1960	Lieb	252—301.6 X
3,002,835	10/1961	Kostelec	96—1.7
3,003,869	10/1961	Schaffert	96—1.5
3,121,006	2/1964	Middleton et al.	96—1.5
3,303,341	2/1967	Fram et al.	250—65

BERNARD KONICK, *Primary Examiner.*

J. BREIMAYER, *Assistant Examiner.*

U.S. Cl. X.R.

346—1, 74