Nov. 17, 1970 S. R. SHORTES 3,541,384

IMAGE STORAGE APPARATUS

Filed Sept. 9, 1968 2 Sheets-Sheet 1

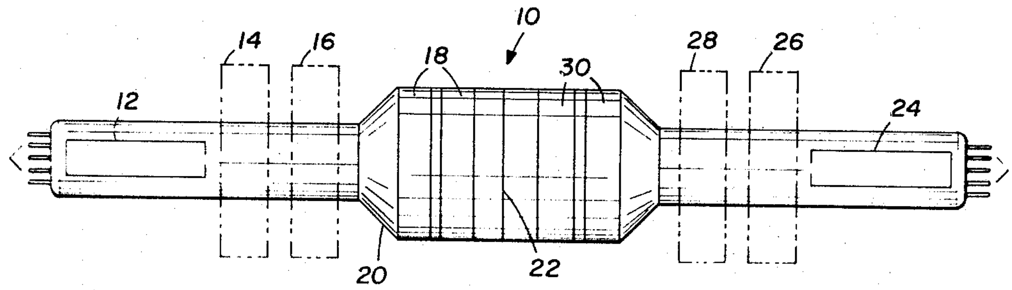

FIG. 1

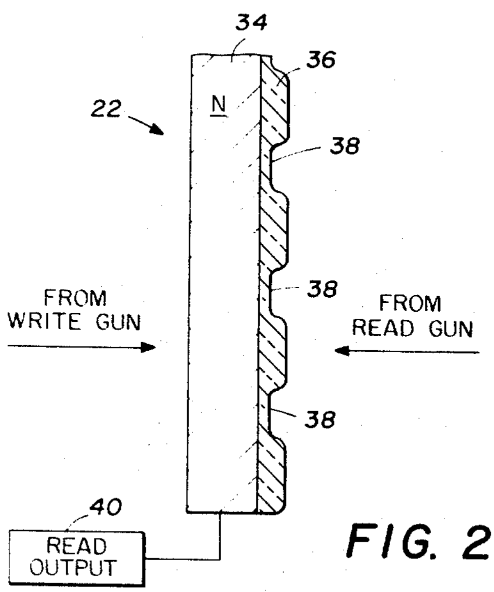

FIG. 2

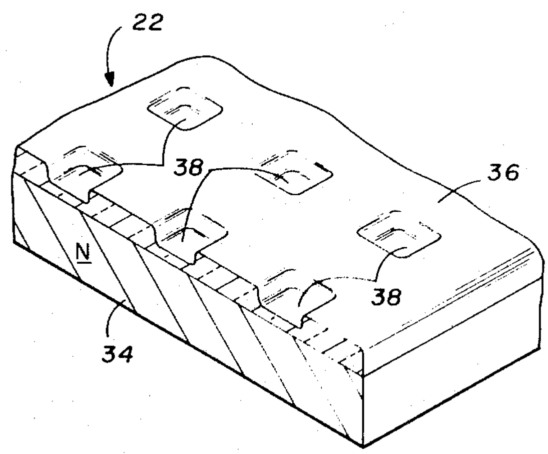

FIG. 3

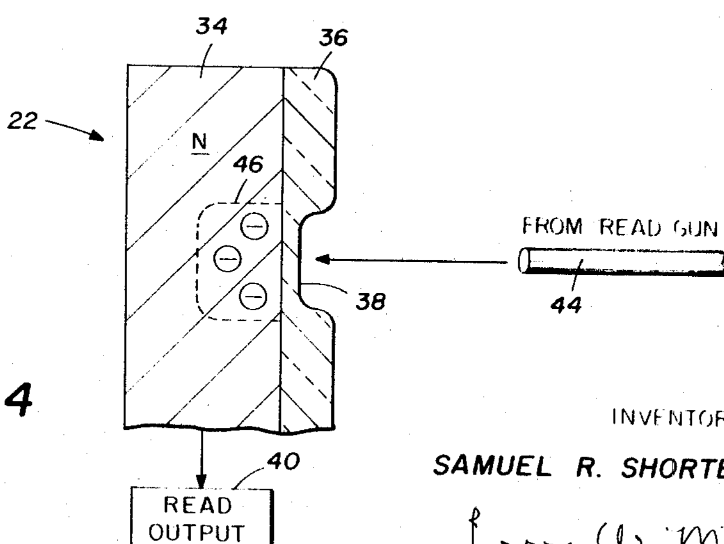

FIG. 4

INVENTOR
SAMUEL R. SHORTES

Jerry W. Mills
ATTORNEY

Nov. 17, 1970 S. R. SHORTES 3,541,384

IMAGE STORAGE APPARATUS

Filed Sept. 9, 1968 2 Sheets-Sheet 2

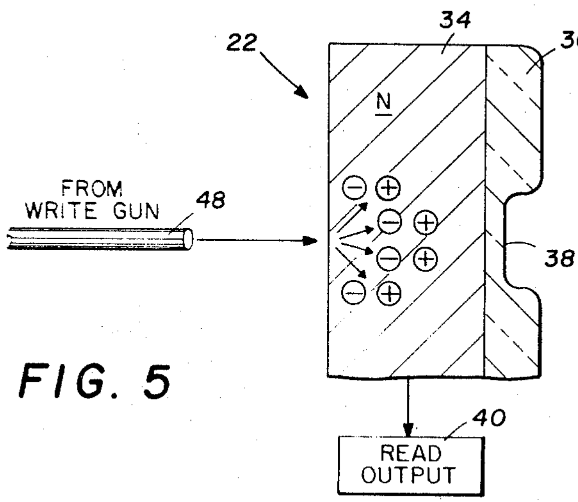

FIG. 5

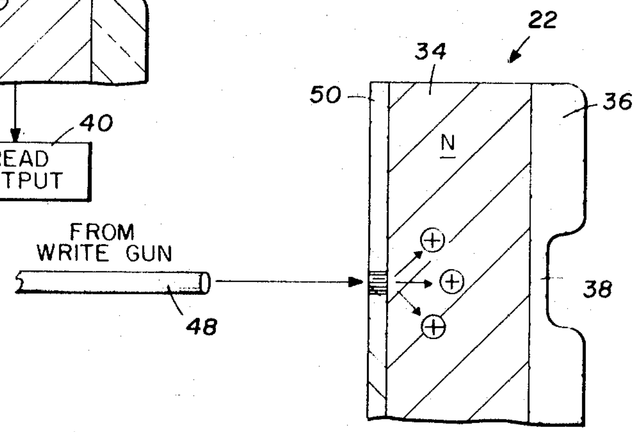

FIG. 6

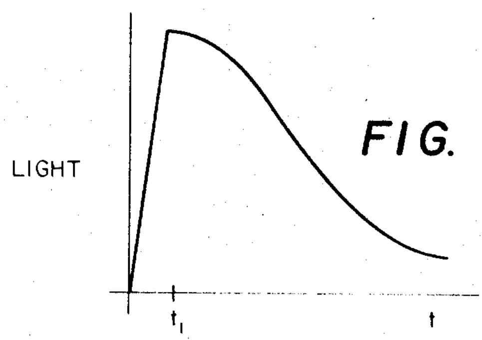

FIG. 7

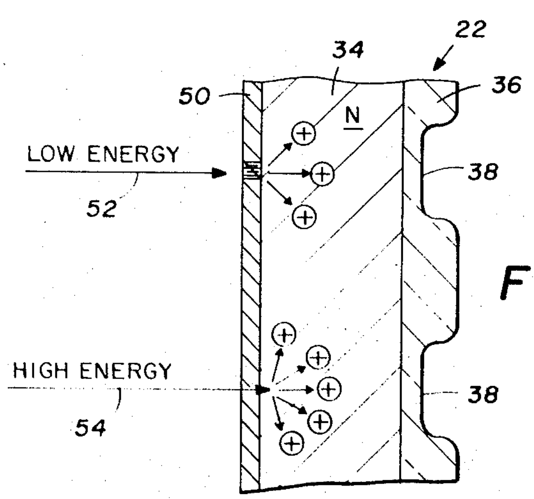

FIG. 8

INVENTOR

SAMUEL R. SHORTES

Jerry W. Mills

ATTORNEY

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IMAGE STORAGE APPARATUS

Samuel Ray Shortes, Dallas, Tex., assignor to Texas Instruments Incorporated, Dallas, Tex., a corporation of Delaware

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Int. Cl. H01j *31/48*
U.S. Cl. 315—11 5 Claims

ABSTRACT OF THE DISCLOSURE

A target is provided for receiving and storing images which includes a body of semiconductor material having opposed surfaces. A layer of insulating material is disposed over one of the surfaces, with a plurality of discrete areas of reduced thickness being formed in the insulating layer. Images are transmitted by a write source to the surface of the body opposite the insulating layer. A read electron source then scans the insulating layer to provide indications of changes in the electrical charge of areas of the semiconductor material as a result of the transmitted images. Scan conversion is provided by the system by utilizing different scan patterns for the write and read sources.

This invention relates to the storage of images, and more particularly to an image storage device suited for use as a target in a scan conversion system.

It is often desirable to utilize a scan converter to change a scan format such as a circular-type scan to a horizontal television-type scan. One type of scan converter heretofore developed utilizes a thin metal screen with a substance such as calcium floride or zinc sulfide applied at points to the screen. The screen is used as a target which is disposed between two opposed electron guns. One electron gun is utilized as a write source for scanning the target and varying the charge density of areas of the target. The second electron gun then scans the target with a different scan pattern. A read collector grid collects electrons reflected by the varying charge density of the target to provide an indication of the stored image in the format of the second gun's scan pattern. However, spurious signals have often been introduced into the output of converters heretofore developed due to cross-talk occurring when the opposed electron beams interact. Further, the reading of the stored image on the target often partially destroys the stored image, thereby limiting the possibility of additional readings of the target.

In an effort to eliminate cross-talk problems, scan converters have been developed which utilize photon coupling through a target. Examples of such devices include a cathode ray tube, in combination with a fiber optics faceplate which transmits the tube image to a vidicon tube. However, the cost of such fiber optics faceplates are prohibitively high for use in many applications. Cathode ray tubes have also been coupled to television cameras to provide scan conversion, but problems have arisen in obtaining satisfactory resolution with such systems.

A solid state image storage device is described in U.S. Pat. No. 3,011,089, entitled "Solid State Light Sensitive Storage Device," issued to F. W. Reynolds on Nov. 28, 1961. This device utilizes an array of discrete p-n junctions which are selectively capacitively charged and discharged to store information. However, such solid state devices have proved difficult and expensive to fabricate, and have been limited in their storage time to the lifetime of hole carriers.

In accordance with the present invention, a body of semiconductor material has opposed surfaces, with a plurality of areas defined on one of the surfaces which

have an electrical charge dependent upon images impinging upon the opposite surface. Structure is provided for sensing changes in the electrical charge of the areas in order to provide an electrical output representative of the images impinging upon the body.

In a specific aspect of the invention, insulating material is disposed on a body of semiconductor material and is provided with discrete areas of reduced thickness in order to allow the variance of the electrical charge of portions of the semiconductor material. In one embodiment, a layer of phosphorescent material is applied to the semiconductor body to increase the persistence of the image storage of the device.

For a more complete understanding of the invention and for further objects and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a scan converter according to the invention;

FIG. 2 is a diagrammatic cross-sectional view of a portion of the present image target;

FIG. 3 is a perspective view of the device shown in FIG. 2;

FIGS. 4 and 5 are diagrams which illustrate the theory of operation of the present image target;

FIG. 6 is a diagrammatic illustration of another embodiment of the present image target;

FIG. 7 is a graph illustrating characteristics of phosphorescent material; and

FIG. 8 is a diagram illustrating the theory of operation of the device shown in FIG. 6.

Referring to FIG. 1, a scan converter designated generally by the numeral **10** comprises a write electron gun **12** which includes a focus coil **14** and a deflection yoke **16**. Collimators **18** are disposed within a vacuumized glass tube **20** in order to properly focus the beam of electrons emitted by the gun **12**. A target and storage device **22** is disposed within the glass tube **20** midway between the writing gun **12** and a read electron gun **24**. A focus coil **26** and a deflection yoke **28** provides a selected scanning motion to the electron beam from the read electron gun **24**. A pair of collimators **30** assist in properly focusing the read electron beam upon the target **22**.

It will be seen that the present scan converter **10** is constructed in a somewhat similar manner to previous scan converters, with the exception of the target device **22** which eliminates the necessity for write and read electrodes and which eliminates problems in cross-talk and the like. Examples of suitable write and read electron guns are the guns utilized in scan converters manufactured and sold as Model H–1161 and H–1203 by the Hughes Aircraft Company of Los Angeles, Calif.

Referring to FIGS. 2 and 3, the target **22** comprises a relatively thin body **34** which is preferably constructed from n-type silicon. A layer **36** of insulating material, such as silicon oxide, is formed on the face of the target **22** which faces the read gun **24**. A plurality of discrete areas **38** having a much smaller thickness than the main part of layer **36** are symmetrically formed throughout the insulating layer **36**. In the preferred embodiment, the areas **38** have generally rectangular configurations, but it will be understood that other configurations may be utilized if desired. The size and spacing of the discrete areas **38** will be dependent upon the desired resolution of the target **22**. An output sensor **40** is connected to the n-type semiconductor material body **34** to provide indications of the image stored by the device **22**. When device **22** is used in a scan converter system, the scanning operation of the read gun **24** is synchronized with the read output sensor **40** to provide scan conversion.

The device **22** may be fabricated by a number of well-known processes. For example, an oxide layer of uniform thickness may be grown over a polished silicon wafer. Holes representing the discrete areas **38** may then be etched through the oxide layer and a second relatively thin oxide layer grown to cover the bottom of the holes. The target **22** will normally be extremely thin, with a practical embodiment having a thickness in the micron range.

Referring to FIGS. 4 and 5, a beam of electrons **44** having a constant energy level is scanned across the insulating layer **36** according to a preselected scan pattern. The thickness of the discrete oxide areas **38** is sufficiently thin so that the negative charges of the electrons from the beam **44** "leak through" to cause a charge depletion layer designated generally by the dotted line **46**. The thicker portions of the insulating layer **36** are sufficiently thick such that substantially no depletion layer is formed in the region of body **34** adjacent the thicker portions. In the initial operation of the device **22**, each of the discrete areas **36** of the target **22** have identical reference depletion layers **46** formed by the beam **44**.

Essentially, the plurality of depletion layers thus formed provides a plurality of diode-type devices similar to a p-n junction. The target **22** is thus in a condition to store an image transmitted from the write gun **12** in the manner shown in FIG. 5. A beam **48** of electrons is scanned across the front face of the semiconductor body **34** according to a preselected scan pattern. Beam **48** is modulated during the scanning operation in order that a desired information-containing image is transmitted to the target **22**. In response to the electron beam **48**, the n-type semiconductor body **34** generates hole-electron pairs in the manner shown diagrammatically in FIG. 5.

The number of hole-pairs generated will of course be proportional to the energy magnitude of the beam **48**. The hole carriers thus generated diffuse throughout the n-type semiconductor body **34** and are collected by the depletion layer **46** closest to the point of impingement of beam **48**. This collection of positively charged hole-carriers destroys the depletion layers **46** to a degree dependent upon the number of hole-carriers generated. After scanning of the front face of target **22** by the beam **48**, the transmitted image is stored by the target **22** by means of variances in the electrical charge of the depletion layers **46**.

This stored image is sensed by again scanning the insulating layer **36** with the read gun beam **44** in the manner shown in FIG. 4. When a depletion layer **46** has been partially or completely destroyed by the write gun beam **48**, the read gun beam **44** again charges up the back side of the target **22** to again build up a depletion layer to the previous reference magnitude. Such charging up of the device **22** causes the generation of alternating current signals in the n-type semiconductor body **34** which are sensed by the read output sensor **40**. As the read gun beam **44** is synchronized with the read output **40**, an accurate indication of the charge density state of each discrete area of the target **22** is sensed by the read output **40**.

The magnitude of the alternating current signal will be directly proportional to the energy level of the modulated image transmitted by the write gun beam **48**. As the amount of charging required to provide the reference depletion layer to each discrete area may vary from zero to a preselected magnitude, a substantial amount of tone graduation may be achieved with the present target **22**. By proper selection of the width of the n-type semiconductor body **34** in conjunction with the width of the insulating layer **36**, a substantial amount of resolution may be provided by the target **22**.

It may in some instances be desirable to add a layer of conductive material such as a metal film over the areas **38** of reduced thickness. The device thus formed would be similar in many respects to a MOS device. Additionally, it may be desirable to dope the thicker regions of the oxide layer to prevent "charging" of the areas below the thicker regions.

With the use of the previously described target, the storage time of the target is limited substantially to the

lifetime of the generated hole-carriers, or in the microsecond range. For some applications, it is advantageous to lengthen this storage time in order to allow greater flexibility in reading of the target. FIG. 6 illustrates an embodiment of the target wherein a phosphor layer **50** has been added to the front face of the semiconductor body **34**. When the write gun electron beam **48** impinges upon the phosphor layer **50**, secondary emission will occur from the phosphor layer **50** for a time after the electron beam **48** is removed.

FIG. 7 illustrates a typical persistence curve for a phosphor, wherein it may be seen that after an initial application of light thereto from 0 to t_1, substantial secondary emission occurs for a substantial time after the removal of the light. In response to the secondary emission by the phosphorescent layer **50**, the n-type semiconductor body **34** generates hole-electron pairs in the manner previously described in order to provide image storage within the target. Due to the fact that the secondary emission occurs for a substantial time after the write gun beam **48** moves to a different area, a long storage interval is provided by the present device.

It will be understood that various types of phosphors may be utilized for the present invention, as long as the phosphor provides suitable secondary emission for the electron beam **48** to provide the desired storage interval. Different types of phosphors will thus be chosen for various desired applications. For instance, in some applications phosphors will be chosen with secondary emission decay rates which are fast enough to allow a new writing after a relatively short time. For other applications wherein substantially relayed reading is desirable, relatively long storage time will be required of the phosphor layer. Examples of suitable phosphorous for use with the invention are any of the P-22 phosphors commonly used in television applications. Lead activated barium silicate may also be used for some applications.

If desired, integration of successive images may be provided with the use of the phosphor layer by adding or writing new images upon the image stored upon the phosphor layer.

In the normal use of the target **22**, the write gun **12** is biased to deliver electrons at a scanning energy level similar to that used in conventional vidicon tubes. FIG. 8 illustrates the generation of hole-carriers by such a low energy beam, the hole-carriers being collected by the depletion layers formed in the regions of the areas **38** in the manner previously described. However, as shown in FIG. 8, the write gun **12** may selectively be biased to provide a much higher energy write electron beam which has an energy sufficient to penetrate the thickness of the phosphor layer **50**.

When such penetration of the phosphor layer **50** occurs, substantially no electrons are absorbed by the phosphor layer **50** and thus substantially no secondary emission occurs. A relatively large number of hole-carriers are thus directly generated in the n-type semiconductor body **34**, but relatively little persistence of the high energy beam **54** occurs after the lifetime of the hole-carriers.

Utilizing this concept of the invention, it is possible to control the persistence of the transmitted image. Such control is particularly advantageous for use with airport type radar system wherein it is desirable to have substantial persistence of airplane blips in order to indicate the travel path of the airplanes, but wherein it is not desirable to have persistence of identifying tags or titles which identify a particular airplane. With the use of the present invention, relatively low energy beams are utilized to provide persisting indications of the positions of airplanes. Relatively high energy beams are utilized to directly penetrate the phosphor layer to provide titles or tags identifying the airplanes, the titles not persisting and thereby cluttering up the screen.

While specific embodiments of the present invention have been described in detail, it will be understood that various changes and modifications may be suggested to one skilled in the art, and it is desired to encompass such changes and modifications as fall within the scope of the appended claims.

What is claimed is:

1. An image storage device comprising:
(a) a sheet of semiconductor material,
(b) structure disposed on one surface of said sheet for preventing the impingement of an external charge source upon portions of said sheet while allowing said external charge source to form a plurality of discrete depletion layers in said sheet, said structure comprising a layer of insulating material having a plurality of discrete areas of reduced thickness attached to said surface,
(c) means disposed on an opposite surface of said sheet for receiving images and for providing indications of said images for a preselected time after reception of said images due to secondary emission, and
(d) means for sensing the variance of said depletion layers by images impinging on said opposite surface of said sheet.

2. The device of claim 1 wherein said means comprises a layer of phosphorescent material.

3. The device of claim 2 wherein said layer of phosphorescent material has a thickness sufficient that images having less than a preselected energy level are absorbed by said layer and that images having greater than said energy level penetrate said layer without substantial absorption thereby.

4. A scan converter comprising:
(a) a thin body of n-type semiconductor material having first and second opposed surfaces,
(b) a layer of phosphorescent material disposed on said first surface,
(c) a source of images for directing images upon said first surface,

(d) a layer of insulation attached to said second surface having a plurality of discrete areas of reduced thickness, and
(e) a source of electrons for directing a beam of electrons upon selected ones of said discrete areas.

5. The method of storing images comprising:
(a) receiving transmitted images on a first surface of a semiconductor target to vary the electrical charge of discrete areas of an opposed surface of the target in response to said images,
(b) generating representations of said images by secondary emission from a layer of phosphorescent material deposited on said first surface to receive said images, said representations continuing for a predetermined period of time after termination of transmission of said images,
(c) scanning said opposed surface with an electrically charged beam while preventing impingement of said beam on areas of said opposed surface other than said discrete areas, and
(d) sensing the changing of the electrical charge of said discrete areas to provide an electrical indication of said transmitted images.

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RODNEY D. BENNETT, Jr., Primary Examiner

J. G. BAXTER, Assistant Examiner

U.S. Cl. X.R.

313—89, 92; 315—10