(12) UK Patent Application (19) GB (11) 2 029 642 A

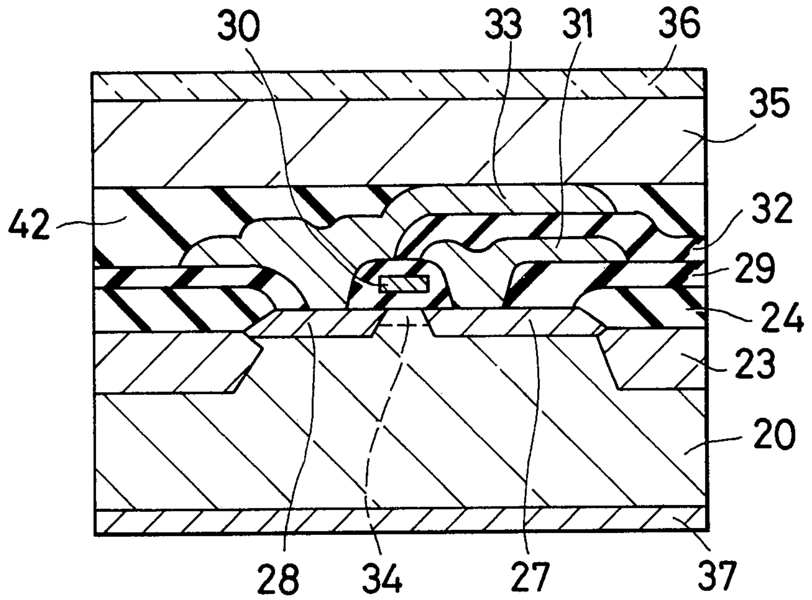
(21) Application No **7928748**
(22) Date of filing **17 Aug 1979**
(23) Claims filed **17 Aug 1979**
(30) Priority data
(31) **53/100060**
54/103031U
(32) **18 Aug 1978**
27 Jul 1979
(33) **Japan (JP)**
(43) Application published
19 Mar 1980
(51) **INT CL^3**
H01L 27/14
(52) Domestic classification
H1K 1CA 1CC1 1EB 2S10 2S17 2S1D 2S1E 2S20 2S2B 2S2C 2S2D 2S2P 2S6 2SU1 4C11 4C14 5B1 5B2 5B3 5B4 5B5 9C3 9D1 9N1A 9N2 9R2 ECB
(56) Documents cited
US 4064521A
Solid State Communication Vol. 20 No. 10 Dec 1976, pp 969-972. "Doping Schutting Barrier and P-N Junition Formation in Amorphous Ge and Si by R.F. Sputtering" By W Paul et al (See p 969, Col. 1 and p 972, Col 2)
(58) Field of search
H1K

(71) Applicants
Hitachi, Ltd.,
1-5-1 Marunouchi,
Chiyoda-ku,
Tokyo,
Japan.
(72) Inventors
Toshihisa Tsukada,
Eiichi Maruyama,
Toru Baji,
Saburo Ataka,
Yoshinori Imamura,
Akira Sasano,
Masaharu Kubo,
Norio Koike,
Shusaku Nagahara.
(74) Agents
Mewburn Ellis & Co.

(54) Solid state imaging device

(57) A solid state imaging device has a plurality of photosensitive regions corresponding to picture elements, formed above a semiconductor substrate 20 which includes or carries scanning means (MOSFET 27,28,30) for scanning the photosensitive regions in succession. The photosensitive regions have a layer 35 of a photosensitive material overlying the semiconductor substrate 20 and a transparent conductive film 36 overlying the layer 35. The layer 35 is an amorphous material composed of Si (and optionally C and Ge) which contains hydrogen. The hydrogen content is preferably 5 to 30 atomic-%. This material gives the device excellent properties, it is of high resistivity and has a very small number of trap levels. It is stable against temperature change and has relatively high mechanical strength. Defects of the prior art are thus avoided. An insulating layer 42 may be provided so that the layer 35 lies on a flat upper surface.

FIG. 15



The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1

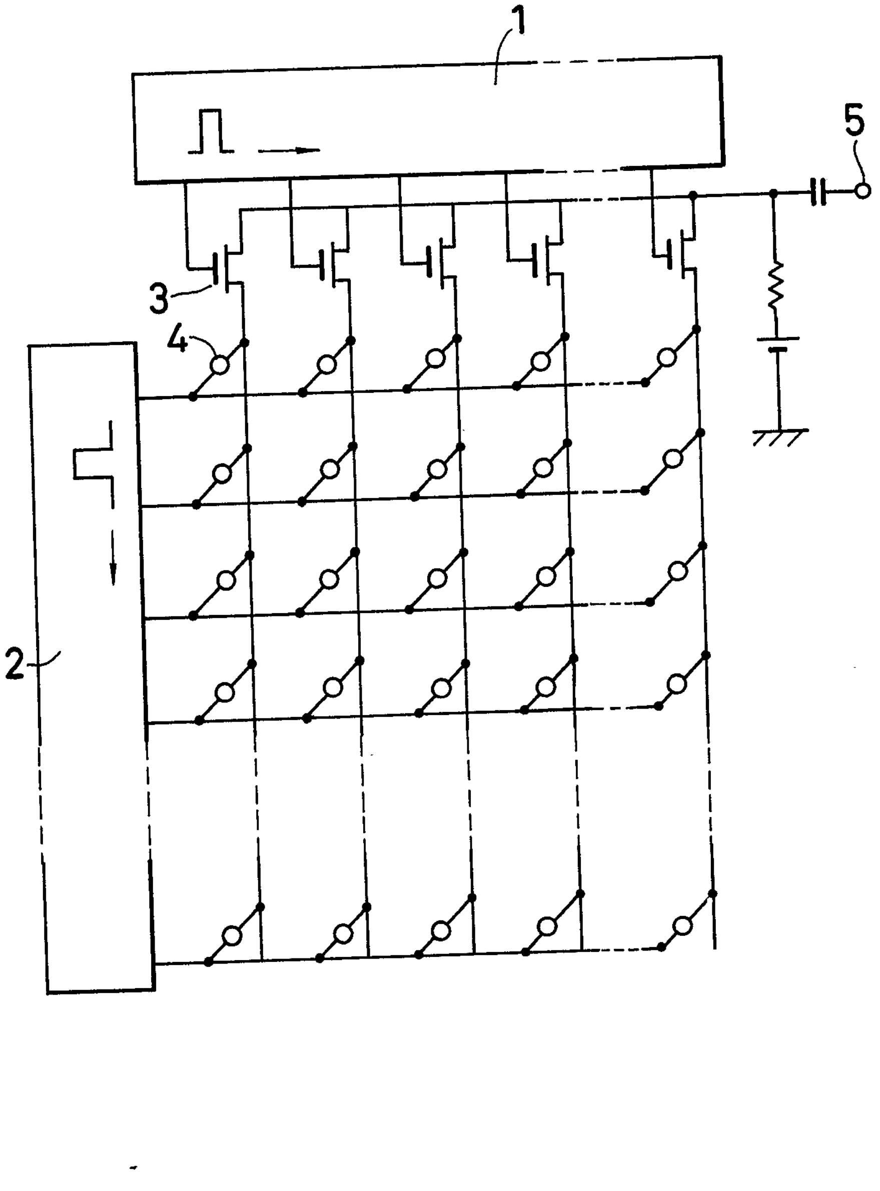
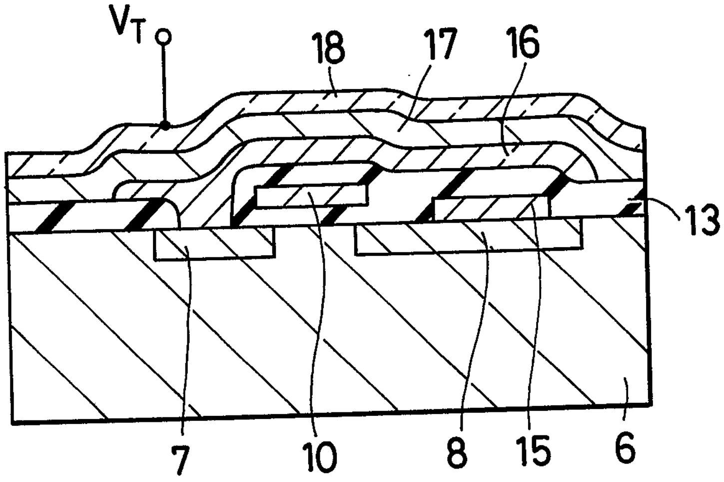
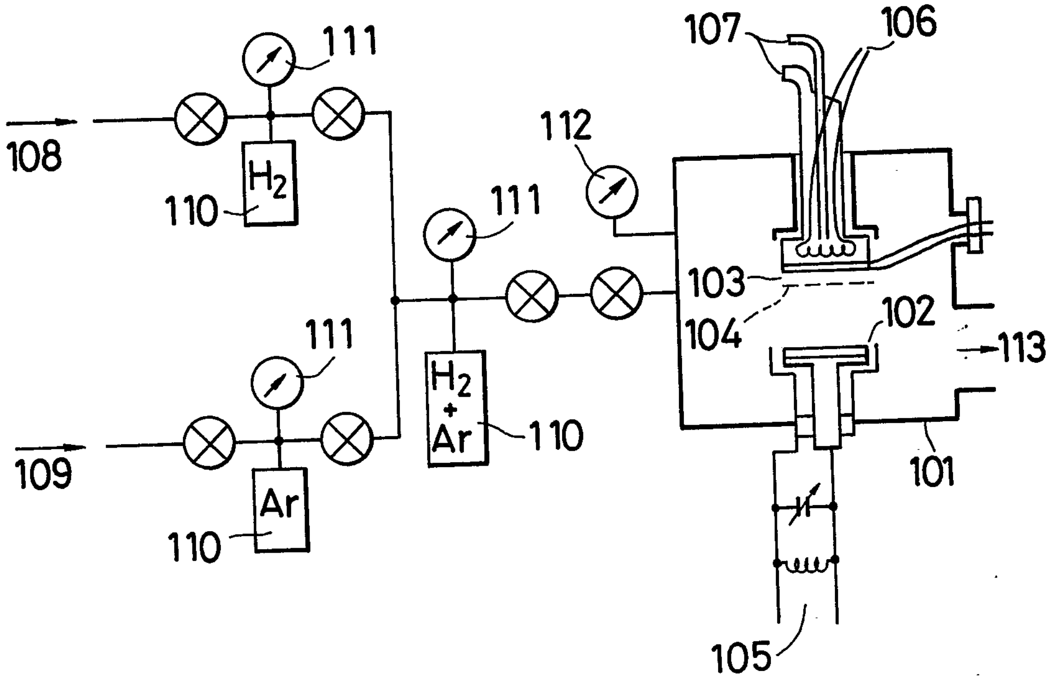


FIG. 2



V_T
18
17
16
13
7
10
8
15
6

FIG. 3



107
106
111
112
108
H_2
110
111
103
104
102
113
111
H_2 + Ar
110
109
Ar
110
101
105

FIG. 4

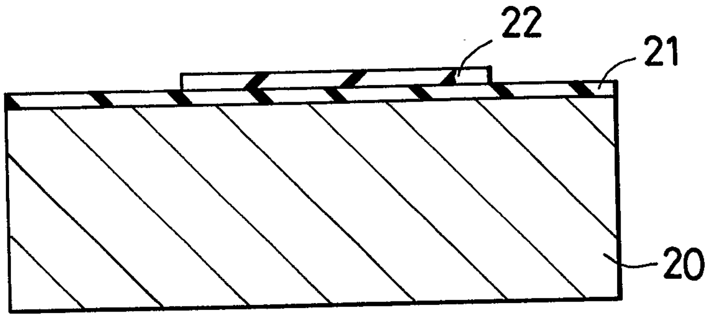


FIG. 5

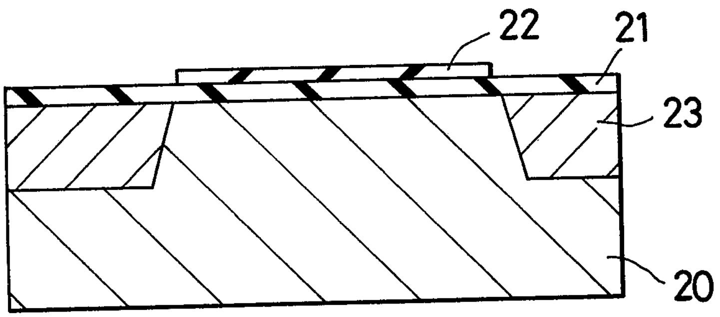


FIG. 6

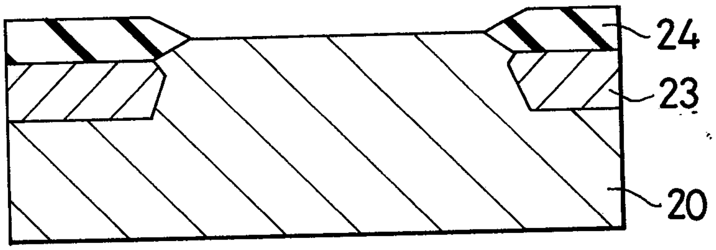


FIG. 7

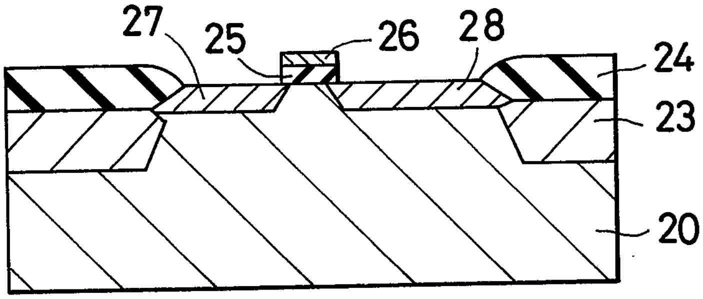


FIG. 8

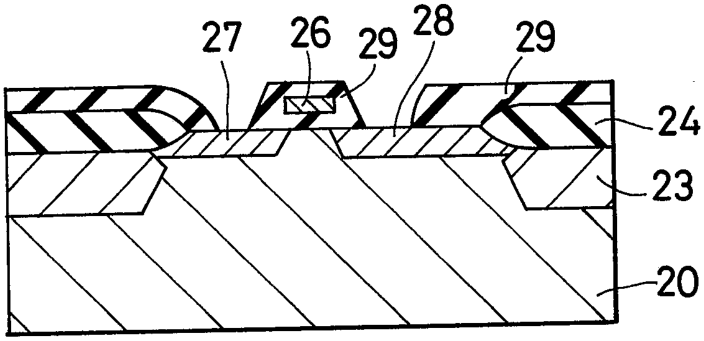


FIG. 9

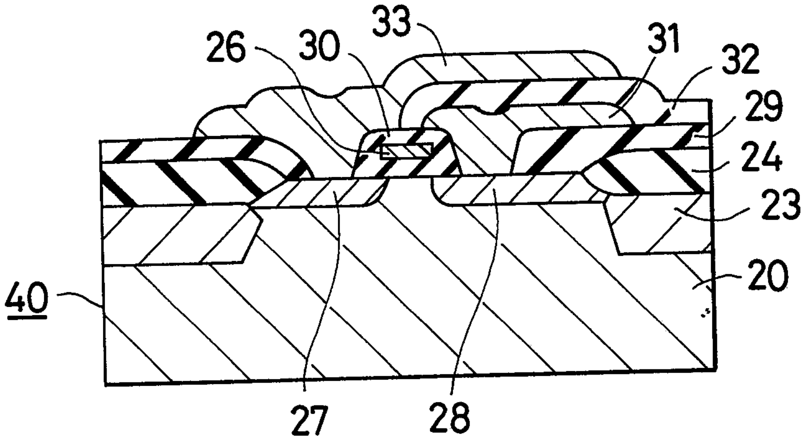


FIG. 10

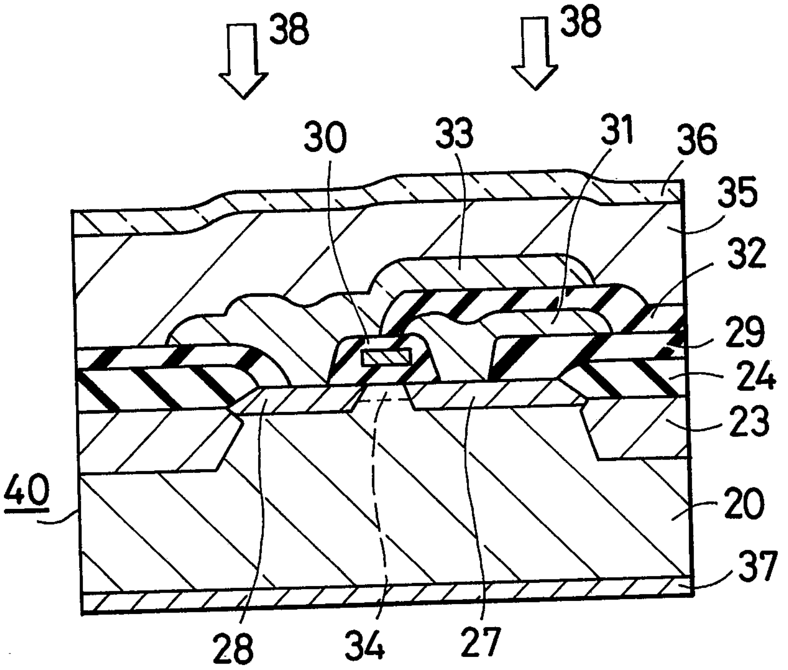

38
38
30
33
31
36
35
32
29
24
23
20
37
40
28
34
27

FIG. 11

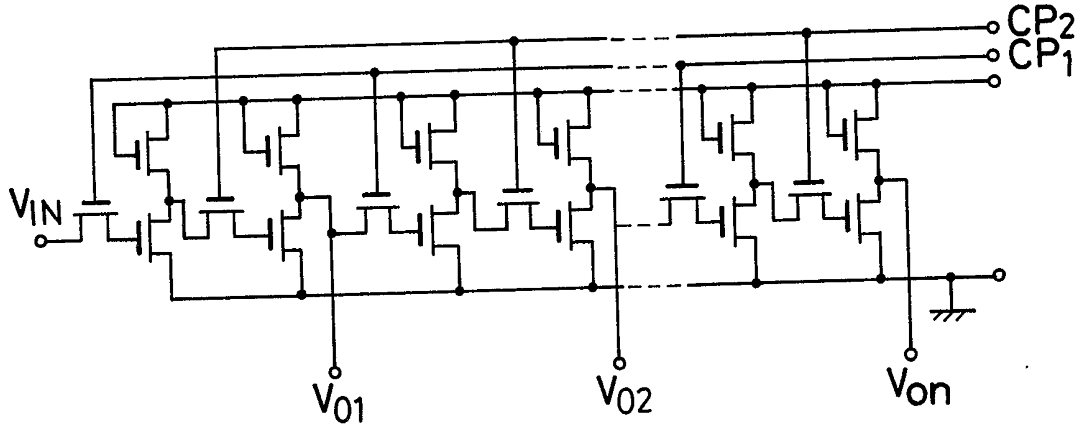

CP2
CP1
VIN
V01
V02
Von

FIG. 12

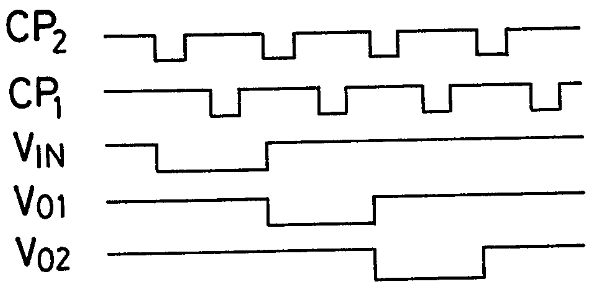


FIG. 13

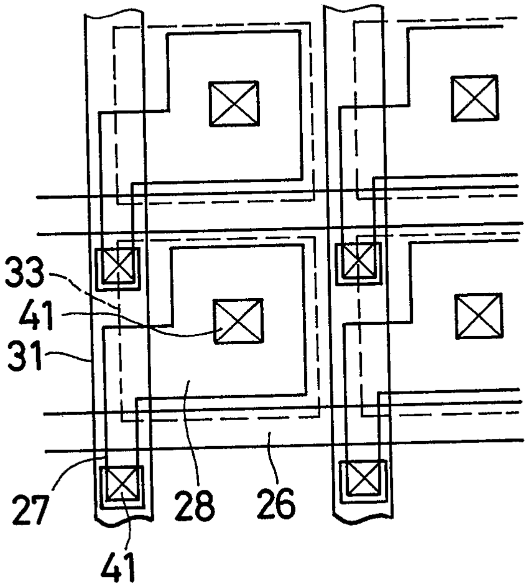


FIG. 14

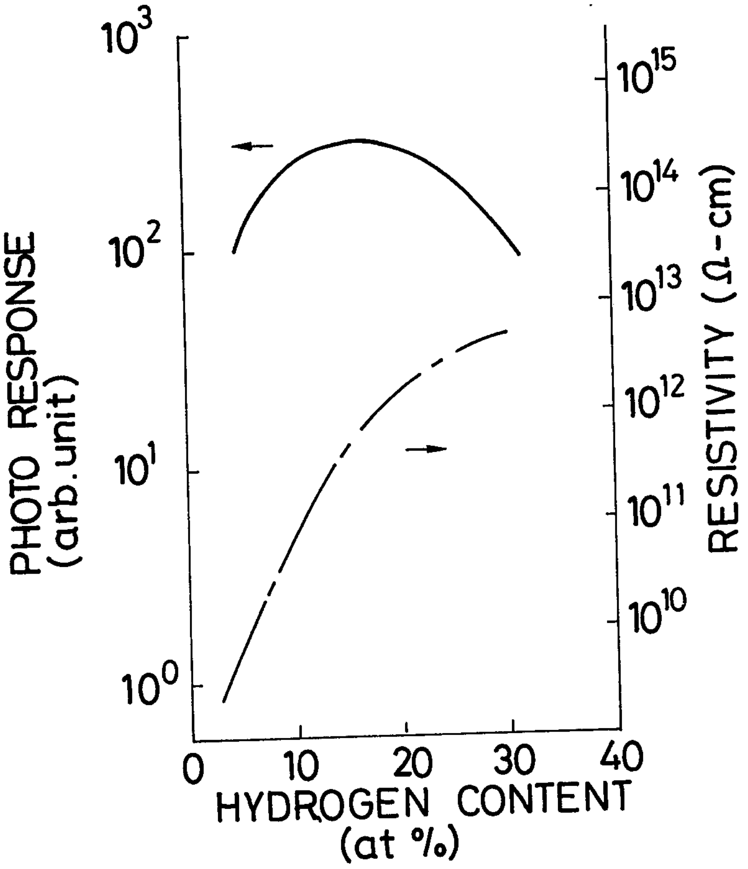

10^3
10^2
10^1
10^0
PHOTO RESPONSE (arb. unit)
10^15
10^14
10^13
10^12
10^11
10^10
RESISTIVITY (Ω-cm)
0
10
20
30
40
HYDROGEN CONTENT (at %)

FIG. 15

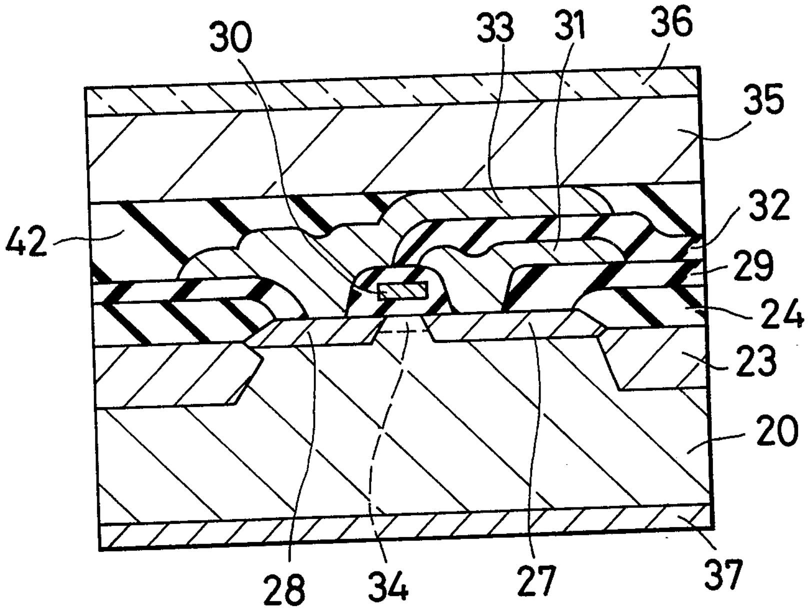

30
33
31
36
35
42
32
29
24
23
20
28
34
27
37

FIG. 16

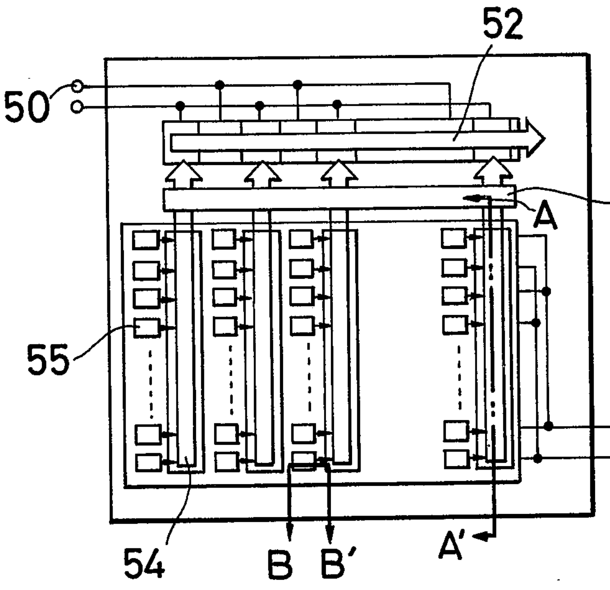


FIG. 17

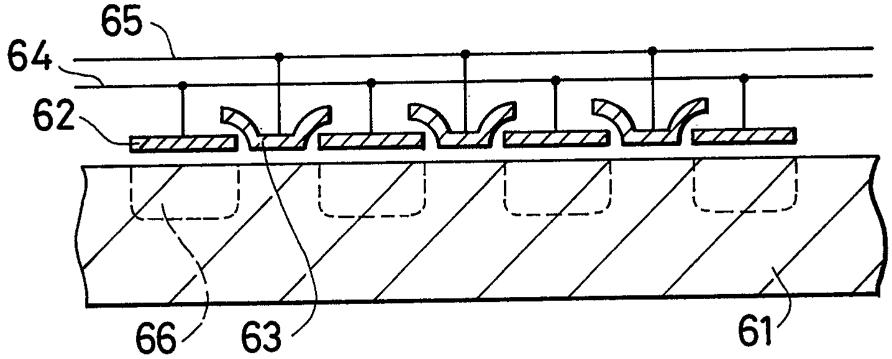
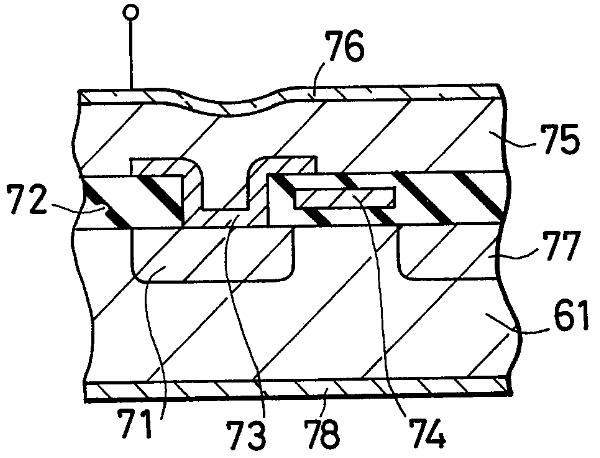


FIG. 18



SPECIFICATION

Solid state imaging device

This invention relates to a photo-sensor or solid-state imaging device which is fabricated on a semiconductor substrate, e.g. a single crystal substrate.

An imaging device which has hitherto been employed is an image pickup tube of the type in which a photo-conductive target operating in the storage mode is scanned with an electron beam. The use of the electron beam leads to the difficulties that a high voltage is required and that miniaturization is difficult. Solid-state imaging devices or imaging plates have been devised to overcome these difficulties.

Figure 1 of the accompanying drawings illustrates the principle of a solid-state imaging device. Picture elements 4 are arranged in a checker pattern. Signals stored in picture elements are read out by the XY-address system one by one, the respective elements 4 being selected by a horizontal scan signal generator 1 and a vertical scan signal generator 2. A switch 3 is connected electrically to the picture elements, and an output terminal 5 is provided.

A first example of the construction of a photo-sensitive region forming the picture element is a diffused region directly formed in an Si substrate, and another example utilizes a photoconductive thin film, etc.

In the said first example, each picture element corresponds to the source region of a MOS switch. Since MOSFET switches in a two dimensional array occupy a considerable area, this type is not satisfactory. Interconnections running in two perpendicular directions occupy the surface of the sensor and reduce the effective photosensitive area. They cause reduction of photosensitivity and diminish the signal output, the reuslt being deterioration of the signal-to-noise ratio (SN ratio).

On the other hand, in a construction using a photoconductive thin film, scanning circuits for the XY-addressing made of the MOSFET switches etc. are formed on an Si substrate, and the thin film is deposited over the scanning circuits to form the light receiving portions. Examples of such solid-state imaging devices are disclosed in Japanese Laid-Open Patent Application No. 95720/1976, etc. Figure 2 of the drawings attached hereto is a sectional view explaining the principle. In an Si substrate 6, diffused regions 7 and 8 are provided as the source and drain of a MOS switch. A gate electrode 10, a drain electrode 15 for leading out a signal, and a source electrode 16 are provided. There is an insulator layer 13. A photoconductive thin film 17 and a transparent electrode 18 are formed over the switching circuit thus constructed.

A capacitance C is formed between the electrode 16 (area S) and the transparent conductive film 18. Between these lies thin film 17 which is made of a substance exhibiting photoconductivity, for example Sb_2S_3, CdS, As_2Se_3 or polycrystalline Si. As the electrode pattern is in the form of a matrix, a matrix of capacitors is correspondingly formed. Since the capacitor includes the photoconductive film, it functions as a photosensitive element and forms a picture element. This photosensitive element has its equivalent circuit expressed by a parallel connection of the capacitance C and a variable resistance R whose electrical resistance varies in response to the intensity of light.

The magnitude of the capacitance C is determined by the electrode area S and the thickness *t* and dielectric constant ϵ of the film 17, being expressed as

$$C = \frac{\varepsilon.S}{t}$$

The magnitude of the resistance is inversely proportional to the intensity of light incident upon the electrode face at the particular position. If no light is incident, the resistance is regarded as infinite though it is also dependent upon the nature of the film 17.

A target voltage (V_T) is applied to the electrode 18, those capacitors upon which no light impinges during a single scanning period holds the voltage V_T as it is. At any part upon which light impinges, the resistance R decreases in accordance with the intensity of the light, so that the charges stored by the capacitances C are discharged and the voltage held in the capacitors decreases in proportion to the quantity of incident light. If U_T denotes the residual voltage after discharge during one scanning period, a charging current corresponding to the voltage $V_T - U_T$ flows. Upon completion of charging, the capacitor has been recharged to the target voltage. The charging current thus becomes a video signal for this period.

In such a solid-state imaging device, imaging characteristics such as spectral response, resolution, SN ratio and lag characteristics are naturally imporant. Also important are the stability against temperature change, mechanical strength etc. of the photoconductive thin film. The transparent electrode must be deposited after formation of the photoconductive thin film on the Si body. The substrate must be heated to 400 - 500°C when SnO_2 (Sn Nesa) is employed for the transparent electrode, and to approximately 250°C even when In Nesa is used for this purpose. For this reason, stability against temperature change is required of the photoconductive film. The transparent electrode may well be replaced by a semitransparent metal thin film, for the formation of which heating of the substrate is unnecessary. However, because of reflection and absorption of light by the metal thin film, the photo response which is important among the imaging characteristics is noticeably reduced. This is especially problematical in the imaging device of Figure 2. In the imaging target of a conventional image pickup tube, a Nesa electrode is formed on a glass faceplate, and a photoconductive film is then deposited, so that it is not a problem, at least in the manufacturing process, whether or not the photoconductive film is resistant to temperature change.

Mechanical strength is also important. After deposition of the photoconductive thin film, the steps of providing the Nesa electrode and also filters etc in the case of a color imaging plate are necessary, so that the mechanical strength is required for easy handling.

It is required that the resistivity of the photoconductive thin film is at least 10^{10} Ω.cm. This is because the charge pattern must not disappear because of diffusion within the scanning interval, i.e. during the storage time.

When polycrystalline Si is employed for the photoconductive thin film, its resistivity is particularly low, and the film needs to be split into a mosaic pattern. This renders the process complicated, and simultaneously reduces the available percentage of the area of the device.

Photoconductive thin films made Sb_2S_3, As_2Se_3 or the like are problematical in respect of mechanical strength and stability against temperature change, and in practice have been found unsuitable for the imaging device of the structure shown in Figure 2.

According to this invention, there is provided a solid-state imaging device having a plurality of photosensitive regions and a semiconductor substrate which includes or carries scanning means for scanning the photosensitive regions, the photosensitive regions including a layer of a photosensitive material extending over the substrate and a transparent electrically conductive film extending over the photosensitive material layer wherein the photosensitive material is an amorphous material composed at least partly of silicon and containing hydrogen.

The amorphous material preferably contains at least 50 atomic-% of silicon and 5 to 50 atomic-% of hydrogen. The hydrogen content is preferably 5 to 30 atomic-%, more preferably 10 to 25 atomic-%. Part of the silicon in the amorphous material can be substituted by at least one of germanium and carbon (which belong to the same group of the periodical table as silicon); substitution up to 30% with respect to the quantity of silicon is especially useful.

The film is used with a thickness of at least 0.05 μm. In practice, a thickness in the range 0.2 μm - 4μm will often be employed, more particularly in the range 1 μm - 4 μm. The thin film may be a multiple layer or have its continuously varying composition.

An amorphous film of this kind which contains both silicon and hydrogen is an excellent material which can easily achieve a high resistivity of at least 10^{10} Ω.cm and which has a very small number of trap levels hampering the transit of carriers. Detailed characteristics will be explained below.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a diagram showing the principle of a solid-state imaging device and has been described above,

Figure 2 is a sectional view of a picture element portion of a solid-state imaging device, also described above,

Figure 3 is a diagrammatic view of reactive sputtering apparatus,

Figures 4 to *10* are sectional views illustrating manufacture of a solid-state imaging device embodying this invention,

Figure 11 is a diagram of a shift register,

Figure 12 is a diagram of operating timings of the shift register,

Figure 13 is a plan view of a solid state imaging device embodying the invention,

Figure 14 is a graph plotting the hydrogen content of a photoconductive material against its photo-response and resistivity,

Figure 15 is a sectional view of another embodiment of this invention,

Figure 16 is a view of an embodiment of the invention which employs a CCD (charge coupled device) for a scanning circuit, and

Figures 17 and *18* are sectional views of the device of Figure 16.

The fundamental structure of the device of this invention is similar to the structure shown in Figure 2, and comprises at least a Si substrate having scanning circuits etc. and a photoconductive thin layer over said Si substrate. This thin layer has been generally described above. It can be manufactured by various methods, of which typical examples will be described now.

The first method is reactive sputtering. The equipment shown in Figure 3 is a conventional sputtering apparatus having a vessel 101 which can be evacuated to vacuum, a sputter target 102, a sample substrate 103 and a shutter 104. An input 105 from a sputtering radio-frequency oscillator is connected to the target 102. A heater 106 is provided for heating the substrate 103 and a water cooling pipe 107 for cooling the substrate 103. A port 108 is for introducing high-purity hydrogen, and a port 109 for introducing a gas such as argon. Additionally, there is a gas reservoir 110, a pressure gauge 111, a vacuum gauge 112 and a port 113 for connection to an evacuating system.

The target for sputtering may be cut out of fused silica. When forming an amorphous material which contains silicon and germanium and/or carbon, a target which contains these three group-IV elements in combination is used. In this case, it is convenient fro example to place a slice of graphite, germanium or the like on a substrate of silicon and to use the resultant structure as the target. The composition of the amorphous material can be controlled by appropriately selecting the area ratio between silicon and germanium and/or carbon. Of course, it is also possible for example to place a slice of silicon on a substrate of carbon. A target may alternatively be constructed by juxtaposing the two materials or by employing melts of the constituents.

If the sputtering target is of Si already containing, for example, one or more of P, As, B, Ga, Sb, In and Bi, the photoconductive material can be doped with these elements as impurities, to give any desired conductivity type such as n-type or p-type. When seeking a material of high resistivity, an impurity density of at most 0.1 atomic-% will be used, in practice, as in the techniques ordinarily used in the field of semiconductor materials. Such impurity-doping also makes it possible to change the resistance value of the material. A high resistivity of the order of 10^{13} Ω.cm can be realized. As to dark resistivity, a value of 10^{15} Ω.cm may be the upper limit in practice. Impurity doping may be carried out by a method in which diborane or phosphine is mixed in rare gas. The amorphous material may be doped during manufacture with a very small quantity of oxygen as an impurity.

Using the equipment of Figure 3, in an Ar atmosphere containing hydrogen at a mixing ratio of at most 30 mol-%, a radio-frequency discharge is generated to sputter Si and graphite and deposit them on the substrate. Thus, a thin layer can be obtained. The pressure of the Ar atmosphere containing hydrogen may be any value within a range in which the glow discharge can be maintained, and it is usually 0.001 - 1.0 Torr or so. At 0.1 - 1.0 Torr, the discharge is especially stable. Favorably, the temperature of the sample substrate lies in a range of from the room temperature to 300°C. A temperature of 150 - 250°C is the most practical. This is because at too low temperatures, the amorphous material is not conveniently doped with hydrogen, and at too high temperatures, hydrogen trends to be emitted from the amorphous material. The hydrogen content is controlled by controlling the partial pressure of hydrogen in the Ar atmosphere; if the hydrogen in this atmosphere is 5 - 7 mol-%, a content of approximately 30 atomic-% can be produced in the amorphous material. For other compositions, the partial pressure of hydrogen may be set with this rough guide. In order to estimate the hydrogen percentages in the materials, the evolved hydrogen gas from the heated sample was measured by mass spectroscopy.

Ar in the atmosphere can be replaced with another rare gas such as Kr.

To obtain a film of high resistivity, a low-temperature and high-speed sputtering equipment of the magnetron type is preferred.

A second possible method for manufacturing the amorphous material of this invention is a process involving glow discharge. Glow discharge in SiH_4 is carried out to decompose this gas into Si and hydrogen and to deposit them onto the substrate. For a material containing Si and C, a gas mixture consisting of SiH_4 and CH_4 may be employed. In this process, the pressure of the mixed gas of SiH_4 and CH_4 is held between 0.1 - 5 Torr. The proportion of Si and C can be controlled by varying the ratios of these gases. The glow discharge may be established by either the D.C. bias method or radio-frequency discharge. To obtain a material of good quality, the substrate temperature should be kept at 200°C - 400°C.

An amorphous material of p-type or n-type can be prepared by adding B_2H_6 or PH_3, for example, to the gas mixture in an amount of 0.1 - 1% (volumetric ratio).

The amorphous film of this invention can also be produced by electron beam evaporation in an atmosphere containing H_2.

When a film of photoelectric material is formed directly on a semiconductor body in which scanning circuits including, for example, MOS transistor portions, etc. are formed on a semiconductor substrate, the unevenness of the surface of the semiconductor body appears in this film. When the film is thin, a stepped disconnection due to the unevenness of the film surface might possibly occur. Therefore, an insulator may be buried in a concave part of the semiconductor body. In this way, the surface on which the photoelectric material layer is to be formed is flattened. At least part of a source electrode (or drain electrode) is exposed, and the photoconductive film is formed thereon. Of course, other parts are provided with openings as necessary. A heat-resistive polymer resin such as polyimide, polyimide-iso-indroquinazolinedione and polyamide-imide or an inorganic substance such as spin-on-glass can be used as the insulator.

Example 1:

Referring to Figures 4 to 10, these show a conventional process for forming a scanning circuit portion including switching circuits, etc. in a semiconductor substrate. As shown in Figure 4, a thin SiO_2 film 21 approxiamtely 800 Å thick was formed on a p-type silicon substrate 20, and a Si_3N_4 film 22 of approximately 1,400 Å was formed on a predetermined part of the SiO_2 film. The film 21 was formed by a conventional CVD process (chemical vapour deposition), and the film 22 by a CVD process in which Si_3N_4, NH_4 and N_2 were mixed. A p-type diffused region 23 was formed in the substrate 20 using an ion implantation technique (Figure 5). The region 23 isolates individual elements in the substrate 20. Subsequently, the silicon was locally oxidised in an atmosphere of $H_2 : O_2 = 1 : 8$, to form a SiO_2 layer 24 (Figure 6). This method of the local oxidation of silicon for the isolation of elements is usually termed LOCOS.

After removal of the film 22 and the film 21, a gate insulating film 25 for a MOS transistor was formed from an SiO_2 film. Subsequently, a gate portion 26 of poly-silicon and diffused regions 27 and 28 were formed (Figure 7). A SiO_2 film 29 was formed on the resultant substrate. Electrode apertures for the source 27 and the drain 28 were provided in this film 29 by etching (Figure 8). An Al layer 8000 Å thick was evaporated to form a drain electrode 31. Then an SiO_2 film 32 7500 Å thick was formed whereupon an Al layer 1 μm thick was evaporated to form a source electrode 33 (Figure 9). The electrode 33 was formed to cover the regions 27, 28 and the gate portion. This is because undesirable blooming phenomena take place if light enters the signal processing region between the diffused layers 23.

A shift register portion which is arranged in the periphery of the device may have a conventional construction, as shown by way of example in Figure 11. This is a two-phase dynamic shift register composed of a pair of inverter circuits and a pair of delay circuits, and it achieves stable operation irrespective of the phases of the clock pulses for shifting the scan pulses. When a start pulse $V_{IN}$is applied, sequential shift pulses V_{01}, V_{02} ... synchronous with the clock pulses CP_2 are delivered from respective bit terminals. Figure 12 illustrates the timings of this operation. Needless to say, the particular circuit arrangement of the shift register is not restricted to the one illustrated one. In this way, the MOS transistor portion of the scanning circuit is complete.

Figure 13 is a plan view of a portion of the Si body portion (the reference numerals correspond to those in the sectional views of Figures 4 to 10). A contact hole for an electrode is shown at 41.

The semiconductor body 40 prepared by the steps described above was attached to a magnetron type sputtering equipment, as shown in Figure 3. The atmosphere was a mixture of Ar and hydrogen, under a pressure of 0.2 Torr. The hydrogen content was 6 mol-%. The sputter target was made of silicon. Reactive sputtering was carried out at a frequency of 13.56 MHz and a power input of 300 W, to deposit an amorphous silicon thin film 35 containing hydrogen on the semiconductor body 40 to a thickness of 500 nm (Figure 10). The hydrogen content of this film was 20 atomic-% and its resistivity thereof was 5×10^{13} Ω.cm.

An electrode 36 which is to apply a bias voltage needs to be disposed on the film 35. As the light enters from above (arrows 38 in Figure 10) this electrode should therefore be transparent. A Nesa electrode made of In_2O_3 was employed because the deposition temperature of In_2O_3 is not harmful for the amorphous silicon. On a part of the Nesa electrode which is not the light receiving portion, Cr-Au was deposited by mask evaporation and a wire was bonded here. A second electrode 37 such as a Au film was formed on the rear surface of the semiconductor body. Thus, the solid-state imaging device was completed.

The solid-state imaging device fabricated by this method makes it possible to obtain a good picture free from blooming.

Figure 14 shows the results obtained by varying the quantity of hydrogen in the film 35 and measuring the photo-response of the film. The solid line shows this characteristic. To measure the photo response, a tungsten lamp was used as a source of light. Figure 14 also shows the variation in the resistivity as a function of the amount of hydrogen in the amorphous silicon. The chain-dot line indicates this characteristic.

Figure 14 shows that a value of 5 to 30 atomic-% especially 10 to 25 atomic-%, is preferable for the hydrogen concentration in the amorphous silicon film. If the hydrogen concentration is below 5 atomic-%, the resistivity falls below 10^{10} Ω.cm, for this reason also a low hydrogen content is not favorable.

Example 2:

Using the materials listed in Table 1 for the photoconductive thin films, solid-state imaging devices as described in Example 1 were made by the procedures of Example 1.

Table 1

Sample No.	Amorphous Material	Resistivity (Ω.cm)	Conditions of manufacture
2	$Si_{0.8}H_{0.2}$	5×10^{13}	input for discharge: 300 W substrate temp.: 250°C
3	$Si_{0.85}H_{0.15}$	10^{13}	as above
4	$Si_{0.69}C_{0.01}H_{0.3}$	3×10^{12}	area ratio of Si and C in target = 95:5
5	$Si_{0.5}C_{0.2}H_{0.3}$	10^{12}	C in target = 40:60
6	$Si_{0.75}Ge_{0.05}H_{0.2}$	2×10^{12}	area ratio of Si and Ge in target = 95:5
7	$Si_{0.6}Ge_{0.1}H_{0.3}$	10^{12}	area ratio of Si and Ge in target = 80:20
8	$Si_{0.7}Ge_{0.05}C_{0.05}H_{0.2}$	10^{12}	area ratio of Si and C and Ge in target = 80:10:10

With the following construction for the photo-conductive thin film, spectral response can be improved. First, an amorphous silicon film 1 μm thick containing 25 atomic-% of hydrogen was deposited.

Subsequently, two further layers of amorphous material consisting of (i) 20 atomic-% of hydrogen, 20 atomic-% of germanium and 60 atomic-% of silicon and (ii) 20 atomic-% of hydrogen, 30 atomic-% of carbon and 50 atomic-% of silicon were formed, each 0.5 μ thick. The method of formation was by reactive sputtering as described above. The resultant film was put into a vacuum evaporation equipment, and CeO_2 was evaporated onto it to a thickness of 10 nm by resistance heating. Lastly gold was evaporated to a thickness of 25 nm. At this thickness, even gold can have a light transmission factor of 60% or higher and can provide a satisfactory light intensity.

Favorable results were obtained even when SiO_2, TiO_2 etc. were deposited in lieu of CeO_2 in the above example. The thicknesses of these films were made 100 Å - 300 Å.

Example 3:

As in Example 1, a shift register employing MOS transistors and switching MOSFETS was manufactured on an n-type silicon substrate. The fundamental structure was the same as in Example 1. Since, however, the substrate was of the n-type, the transistors were constructed in a p-type channel. This conforms with a well-known process for fabricating a semiconductor IC.

On an Si body thus provided with scanning circuitry, amorphous silicon containing hydrogen was deposited by glow discharge. The discharge atmosphere was SiH_4 under 1.5 Torr. With the body heated to 500°C, the amorphous material was deposited at an r.f. input frequency of 0.5 MHz, under a pressure of 1.0 Torr, and at a substrate temperature of 300°C. The film thickness of the amorphous material was 2 μm, and its resistivity was 1×10^{12} Ω.cm. A Nesa electrode of In_2O_3 was formed on the amorphous material. The solid-state imaging device was thus completed.

Example 4:

An example will now be described in which a desired insulator was buried in an uneven part of a semiconductor body so as to form a flat surface, on which a photoconductive film was formed.

As in Example 1, scanning means including switching circuits, etc. were formed on a semiconductor substrate (see Figure 9). Subsequently, a film 42 (Figure 15) of polyimide-iso-indoloquinazolinedione as heat-resistive polymer resin was formed to a thickness of 1,0 μ. The resin film could be formed by applying a solution of the resin onto the substrate on a rotating disc and then hardening it.

Subsequently, in order to expose at least part of the electrode 33 the resin film was etched by using a photolithographic technique. It is advisable that openings including the lead-out port of the electrode 31, etc. are formed simultaneously by this step. As in Example 1, the amorphous material 35 was deposited on the resultant structure, and the transparent electrode 36 was formed thereafter. Since the uneven part of the surface of the semiconductor body was rendered flat by the heat-resistive polymer resin, the formation of the film of the amorphous material 35 as well as the transparent electrode 36 was much facilitated.

Example 5:

This example employed a CCD (charge coupled device) transfer region as a scanning circuit. Figure 16 is an explanatory plan view of the arrangement of various constituents. There is a horizontal clock terminal 50, a vertical clock terminal 51, an output horizontal shift register 52, a vertical transfer gate 53, a vertical analog shift register 54, and a portion 55 of a picture element in which a diffused region and a MOSFET switch with its source being the aforesaid diffused region are combined.

Figure 17 is a sectional view of a CCD transfer region (a sectional view taken along, for example, the line A-A′ in Figure 16) and Figure 18 is a sectional view of the portion of the light-receiving or picture element (a sectional view taken along, for example, the line B-B′ in Figure 16).

As Figure 17 shows, electrodes 62 and 63 are formed on an Si substrate 61 through an insulating layer and clock voltages in two phases are respectively applied to them through lines 64 and 65. Thus, a potential well within the Si substrate moves so as to transfer charges. In Figure 18, there is shown a diffused layer 71, an insulating layer 72, a metal electrode 73, a gate electrode 74, a photoconductive film 75, a transparent electrode 76, another diffusion region 77 and another electrode 78. The CCD transfer region shown in Figure 17 is connected to the light receiving region. The electrode 76, the film 75 and the electrode 73 form a photosensitive portion. A switching region which moves carriers induced in the photosensitive portion to the transfer portion includes the gate 74, which in substance forms a MOSFET switch.

The Si substrate formed with these CCD transfer regions and the MOSFET switch portions was prepared by known processes, and was set up in the magnetron type sputtering equipment, for formation of the film 75. The atmosphere was a mixed gas of Ar and hydrogen, under 0.2 Torr. The hydrogen content was 6 mol-%. The sputter target was made of silicon. Reactive sputtering was performed at a frequency of 13.56 MHz and an input of 300 W, to deposit the thin film 75 of the amorphous material containing hydrogen, in the photosensitive region of the Si substrate, to a thickness of 500 nm. The hydrogen content of the amorphous material was 20 atomic-%, and its resistivity was 5×10^{13} Ω.cm. The In_2O_3 Nesa electrode was formed on the amorphous material. Cr - Au was deposited on parts of the Nesa electrode by the evaporation through a mask and wires were bonded thereto.

The operation of this device will be explained briefly with reference to Figure 16. When light falls on a photosensitive portion through the transparent electrode, carriers induced by the photo-signal are shifted to the vertical analog shift register 54 by application of a voltage to the gate electrode between the diffused region in the photosensitive region 55 and the vertical shift register 54. The vertical shift CCD is driven through the 2-phase vertical clock terminals 51, and the signals of each column of the photosensitive portions are transmitted to the output horizontal shift register 52 through the vertical transfer gate 53. The horizontal shift register is also the CCD which is driven through the 2-phase horizontal clock terminals 50, and it transfers the charges corresponding to the signal towards an output terminal so as to deliver them out as a signal output. The frequency of the 2-phase drive may be selected so that the shift of the horizontal shift register may be completed within the period of the voltage pulses applied to the vertical transfer gate.

Imaging devices of this invention as described in the foregoing examples have such useful features as good matching of the spectral response with visibility good sensitivity and noise characteristics, high resolution, and avoidance of blooming. Also they have low power dissipation, small size, light weight, and high reliability.

CLAIMS

1. A solid-state imaging device having a plurality of photosensitive regions and a semiconductor substrate which includes or carries scanning means for scanning the photosensitive regions, the photosensitive regions including a layer of a photosensitive material extending over the substrate and a transparent electrically conductive film extending over the photosensitive material layer wherein the photosensitive material is an amorphous material composed at least partly of silicon and containing hydrogen.

2. A device according to claim 1, wherein the photosensitive material layer is formed by reactive sputtering in an atmosphere containing hydrogen.

3. A device according to claim 1, wherein the photosensitive material layer is formed by a glow discharge process in an atmosphere which contains at least silane.

4. A device according to any one of claims 1 to 3, wherein said scanning means comprises field-effect transistors.

5. A device according to any one of claims 1 to 4 wherein the hydrogen content of said amorphous material is in the range 5 to 30 atomic-%.

6. A device according to claim 5 wherein the hydrogen content of said amorphous material is in the range 10 to 25 atomic-%.

7. A device according to any one of the preceding claims wherein said amorphous material includes germanium and/or carbon in an amount up to 30 atomic-% based on the total amount of Si, Ge and C.

8. A device according to any one of the preceding claims wherein the dark resistivity of said amorphous material is not less than 10^{10} Ω.cm.

9. A device according to any one of the preceding claims wherein the semiconductor is divided into cells in which field-effect transistors are formed, and said layer of a photosensitive material is in electrical contact with source electrodes or drain electrodes of the field-effect transistors, the cells being arranged in two dimensions in correspondence with individual picture elements, and there being a common connection line for each column and each row in the two dimensional arrangement which connects in common gate electrodes of the field-effect transistors in each column (or row) for selection of the column (or row), a common connection line which connects in common the drain electrodes (or source electrodes) of the field-effect transistors in each row (or column) so as to select the row (or column) and common output means connected to the common connection line of the drain electrodes (or source electrodes) for successively taking out electric signals from the cells corresponding to the respective picture elements.

10. A device according to any one of claims 1 to 8 wherein the semiconductor is divided into cells in each of which a charge coupled device is formed, the cells corresponding to individual picture elements, electric signals from the respective picture elements being transferred to the charge coupled device and thereafter taken out successively.

11. A device according to any one of claims 1 to 8 wherein an insulator layer and the photosensitive material layer are arranged on the semiconductor substrate and are overlain by the transparent conductive film, at least the scanning means and the photosensitive material layer being electrically connected.

12. a solid state imaging device substantially as any herein described with reference to and as shown in Figures 4 to 18 of the accompanying drawings or in the Examples.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon Surrey, 1980.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.