

This Sheet Has Been Replaced



1

ELECTROMAGNETIC WAVE DETECTOR

5 BACKGROUND OF THE INVENTION

The invention relates to an electromagnetic wave detector, notably a detector making use of photoconduction.

- 10 More particularly, the invention relates to detector architecture that enables elimination of the dark current and the background light-current upstream of the reading circuit.

DESCRIPTION OF THE PRIOR ART

15

The dark current and background light-current limit the dynamic response and the range of operating temperatures of matricial and hybrid-type infrared photoelectric detection systems based on silicon circuits. For each pixel of the active detection matrix there is an integration and reading circuit on the

20 silicon chip. As the format of the matrix increases, the surface available per pixel for the reading circuit, and the storage capacity in particular, decrease (the surface available for the reading circuit of a pixel of a matrix whose format exceeds 256^2 is less than $30 \times 30 \mu\text{m}^2$). The background and dark currents generate an offset that limits the capacity of storage of the incident

25 signal. The dark current varies exponentially with the temperature of operation of the detection matrix. The operation of the silicon reading circuit generates noise which adversely affects the storage capacity.

SUMMARY OF THE INVENTION

30

The invention concerns a photoconductor-based electromagnetic wave detector including:

- at least two overlaid plane active photoconducting detector elements separated by a common layer;
- 35 - a first means of connection connected in common to the said detector elements, a second means of connection connected to the

REPLACED SHEETS	SG
☒ Description : paged ...1... to paged ...x...	
☒ Claim(s) : paged ...1... to paged ...n...	
☒ Drawing(s) : paged ...1... to paged ...7/7...	
☒ Abstract : paged ...1... to paged ...1...	
DATE OF RECEIPT	



first detector element, and a third means of connection connected to the second detector element;

- means for applying control voltages to each of said means of connection, the voltage applied to the first means of connection having a value between the ones applied to the second and third means of connection;
- means connected to said first means of connection to detect the difference of the photoconduction currents of said detector elements.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantages of the present invention will become apparent on read the following description of a preferred embodiment, with reference to the attached drawings:

- 15 - figure 1a shows a simplified example of the detector according to the invention;
- figure 1b shows an electric circuit used with the detector in figure 1;
- figure 2 shows details of an embodiment of the detector according to the invention;
- 20 - figures 3a and 3b show a plan view and a sectional view of a matrix of detectors according to the invention;
- figures 4a to 4c show example of a method of fabrication of the detector according to the invention;
- figures 5 to 9 illustrate variants of the invention.

25

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the simplified diagram in figure 1a, the detector according to the invention includes, overlaid on a substrate:

- 30 - a contact layer C2
- an active photoconducting layer D2
- a common contact layer Cc
- an active photoconducting layer D1
- and a contact layer C1

35



The active photoconducting layers D1, D2 can be layers of photoconducting semiconductor such as silicon. They can be also made in the form of a stack of layers constituting of the quantum-well detectors. The two active layers D1, D2 are photoconducting at the same wavelength λ . One of the active layers is highly absorbent at wavelength λ , whereas the other layer offers little or no absorption. This condition can be achieved by using different thicknesses of the active layers, or by heavier doping of the quantum-well layers of the more absorbent active layer.

- 10 The detector being illuminated by the radiation RZ as shown in figures 1a and 2, the active layer D2 receives the radiation first.

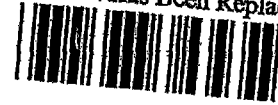
In the case where layer D1 is more absorbent than layer D2, we can provide a diffraction network on the face of the layer D1 that is in contact with the contact layer C1. This network receives the light that is not absorbed when traversing the layer D1 and diffracts it towards the layer D1 where the diffracted light will be fully or almost fully absorbed.

20 In the case where layer D2 has a significantly greater response than that of layer D1, it absorbs almost all radiation at the wavelength in question. In addition, the layer Cc can be provided to block the wavelength λ ; this layer can be for example metallic or a semiconductor that blocks the wavelength λ .

- 25 The contact layers C1 and C2 enable control voltages to be applied. The contact layer Cc is common to the two detector elements comprised of active photoconducting layers. It is held at a reference voltage and enables the detection of the photocurrents generated by the detectors D1, D2.

30 Figure 2a shows a more detailed embodiment of the detector according to the invention in which the detector is encapsulated in an insulating material IS. The connection terminals P1, P2, Pc traverse this insulator and enable contacts to be made on the contact layers C1, C2, Cc respectively.

- 35 The substrate is transparent to the wavelengths to be measured, so the



detector receives the radiation RZ to be detected through the substrate.

When radiation RZ is received by the detector, to detect the wavelength λ (or band of wavelengths), we apply:

- 5 - a voltage V1 to the contact layer C1
 - a voltage V2 to the contact layer C2
 - a floating voltage Vc (or ground) between V1 and V2 to the common contact layer Cc.

- 10 The currents flowing in the structures D1 and D2 are respectively:

$$I1 = I1d + I1opt$$

$$I2 = I2d + I2opt$$

- 15 The currents I1d and I2d are the dark currents in D1 and D2. The currents I1d and I2d can also represent the sum of a dark current and a background light-current. The currents I1opt and I2opt are the photocurrents generated by the wavelength λ to be detected in D1 and D2.

- 20 We see in figure 1b that the current I collected by the reading circuit is:

$$I = I1 - I2$$

- By adjusting the voltage V1 and/or V2, it is possible to make I1d = I2d, in
25 which case the value of the detected current is:

$$I = I1opt - I2opt$$

- By ensuring that one of the two active layers absorbs only very little of the
30 energy at wavelength λ , the current I is therefore that generated by the active layer having the higher response.

Figures 3a and 3b show a plan view and a sectional view of a matricial embodiment of a detector according to the invention.



The detectors of the matrix are made on a control contact layer C2 common to all the detectors. The connection terminal P2 is therefore common to the whole matrix. Each detector includes a detector element D1, a detector element D2, the contact layers C1 and Cc and the connection terminals P1 and Pc. The connection terminals P1 are all connected together to apply a voltage V1 (see earlier) to all the detector elements D1 of the matrix. The contact layer C2 and the connection terminal P2 being common to the whole matrix, the potential applied to the terminal P2 is applied to all the detector elements D2 of the matrix.

10

To enable reading of the detectors of the matrix, each detector is located at the intersection of a network of line and column conductors. In figure 3c, we have shown only the connection terminal Pc of each detector. Each intersection is equipped with, for example, a transistor Tr whose base is connected to the line wire. The emitter and the collector are connected respectively to a terminal Pc and a column wire. By applying a suitable potential to a line wire we can control all the transistors of the line and connect all the terminals Pc of a line to column wires. It is therefore possible to read on each column wire the photocurrent generated by the detector connected to this column wire.

20

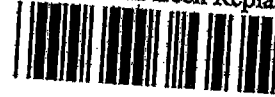
In this embodiment, all the layers C1 are interconnected and held at the same potential. The same applies to the contacts C2 that are connected to the terminal P2.

25

In a variant of the embodiment, the control contact layer C2 is cut into strips such that each strip is common to a line of detectors. We then have one terminal P2 per contact strip C2, i.e. per line of detectors.

30 In a similar manner, instead of interconnecting all the terminals P1, we can interconnect them in lines of detectors, in which case we have one terminal P1 per line of detectors.

35 The terminals Pc of the detectors are interconnected by the column wires of the matrix. The operation of the matrix of detectors is then sequential by



line.

We shall now describe a method of fabrication of a detector according to the invention, with reference to figures 4a to 4c.

5

On a substrate of material transparent to the wavelengths to be detected, we successively make a contact layer C2, one or more photoconducting layers D2 constituting the photodetector element D2, a common contact layer Cc, one or more photoconducting layers D1 constituting the photodetector
10 element D1, and a contact layer C1 (figure 4a).

The upper detector element D1 is formed by engraving of the layers C1 and D1; the engraving stops at the contact layer Cc (figure 4b).

15 The lower detector element D2 is then formed by engraving of the layers Cc and D2; the engraving stops at the contact layer C2 (figure 4c).

The whole structure is then covered with a layer of insulator IS (figure 2).

20 Next, three holes are made in the layer of insulator to access the three contact layers; metal deposits are made in these holes to form the contact terminals P1, P2 and Pc.

For the fabrication of a matrix of detectors, the various detectors are made
25 collectively as described previously. We then obtain a structure such that shown in figure 3b. As we have seen, the terminal P2 is common to the whole matrix. All that remains is therefore to make on the surface of the matrix the interconnecting conductors of the terminals P1, then the matrix of terminals Pc.

30

We have described above the invention making use of vertical transport detectors such as multi-quantum well detectors. We shall now describe the invention with horizontal transport detectors.

35 The detector is composed of two active layers separated by an insulating



layer Cc (see figure 5).

Ohmic contacts are made at the two ends of each active layer D1, D2. At one of the ends of the detector, the ohmic contacts are made common to
5 define the reading contact Pc. This contact Pc (one contact per pixel) will assure the connection with the input stage of the reading circuit. The lower contact P2 is connected to the active layer D2; the upper contact P1 is connected to the active layer D1. We therefore see that when the active
10 layers are suitably polarized the detector operates in a similar manner to the one described previously, with the difference that the current circulates in the plane of the active layers instead of perpendicularly to the plane of the active layers.

15 In figure 5, an insulating layer IS1 is inserted between the active layer D2 and the substrate.

Figure 6 shows a matrix organization of detectors such as those in figure 5. In this organization all the contacts P1 are connected to each other by column wires. The same applies for the contacts P2 and Pc. One central
20 test terminal P1 per detector can be used to perform a current test.

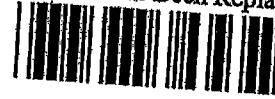
Figure 7 shows a variant of the embodiment in figure 5 including a conducting layer C3 placed on the substrate and on which the structure in figure 5 is formed.

25

Figure 8 shows a matrix organization of detectors of figure 7. In this matrix organization, the layer C3 enables a single terminal connection P2 to be used that is common to all the detector pixels.

30 It will be clear to professionals of the art that there are additional possibilities of improvement while remaining within the framework of the invention:

- inclusion of diffraction networks engraved on the top of the detector to minimize the thickness of the active layer and increase the detection sensitivity of the device; they also enable the responses of
35 the two stages to be desymmetrized;



- use of a "serpentine" geometry (see figure 9) which increases the resistance of the pixel (by increasing the developed length and decreasing the equivalent electric surface without substantially changing the optical area); this geometry also provides some flexibility as regards metallurgical defects, since these then cause only local short-circuits.

**WHAT IS CLAIMED IS**

1. Photoconductor-based electromagnetic wave detector including:
 - 5 - at least two overlaid plane active photoconducting detector elements separated by a common layer;
 - a first means of connection connected in common to the said detector elements, a second means of connection connected to the first detector element, and a third means of connection connected to
10 the second detector element;
 - means for applying control voltages to each of said means of connection, the voltage applied to the first means of connection having a value between the ones applied to the second and third means of connection;
 - 15 - means connected to said first means of connection to detect the difference of the photoconduction currents of said detector elements.
2. Detector according to claim 1, wherein said common layer is an electrical contact layer to which said first means of connection is
20 connected, and said first and second detector elements are enclosed between two electric control contact layers, said second and third means of connection each being connected to one of said control contact layers.
- 25 3. Detector according to claim 1, wherein said common layer is an insulating layer, said first means of connection is connected to a first end of each detector element, and said second and third means of connection are each connected to a second end of a detector element, said first and second ends of each detector element being opposite
30 ends of the detector element.
4. Detector according to claim 1, wherein the response of one of said detector elements is significantly greater than that of the other detector element, such that it absorbs almost all the incident light energy at the
35 wavelength at which it is photoconducting.

This Sheet Has Been Replaced



5. Detector according to claim 1, wherein said common layer is not transparent at the wavelength to be detected, such that the active layer of one of said detector elements does not receive this wavelength.
- 5 6. Detector according to claim 1, wherein one of said voltages applied to said second or third means of connection is adjusted such that the dark currents, or the sums of the dark currents and background light-currents, of the two detector elements are equal.
- 10 7. Detector including a matrix of detectors according to claim 2, made on a substrate, a first control contact layer being made on the face of the substrate and being common to a set of detectors, each detector including, on this first control contact layer, a first detector element of photoconducting material, a contact layer for reading, a second
15 detector element of photoconducting material, and a second control contact layer which is connected to this same respective second control contact layer of all the other detectors of the matrix.
- 20 8. Detector according to claim 7, including a matrix of line conductors and column conductors superposed on said matrix of detectors, each detector being located substantially at an intersection of the matrix of line conductors and column conductors and being connectable to the column wire at the intersection via a switching device that can be controlled by a voltage applied to the line wire at the intersection.
- 25 9. Detector according to claim 7, wherein:
- said first control contact layer is made in the form of strips, a row of detectors being made on each strip;
 - said second contact layers of the detectors of each row of detectors
30 are also interconnected;
 - said reading contact layers of a detector of each row of detectors are interconnected to form columns of detectors.
- 35 10. Method of fabrication of a detector according to claim 2, including the following stages:

This Sheet Has Been Replaced





- fabrication on a substrate of:
 - a first contact layer,
 - at least one first layer of photoconducting material,
 - a second contact layer,
 - 5 • at least one second layer of photoconducting material,
 - a third contact layer;
 - engraving of the third contact layer and the second layer of photoconducting material to define a first detector element;
 - engraving of the second contact layer and the first layer of photoconducting material to define a second detector element;
 - 10 • encapsulation of said layers in an insulating material;
 - engraving of holes in the insulating layer to access the contact layers, and metallization of these holes.
- 15 11. Method of fabrication of a matrix of detectors according to claim 10, wherein several detectors are collectively made on the same substrate, the first contact layer being common to all the detectors, the process also including the engraving of the first layer of photoconducting material before encapsulation by the insulator, and the interconnection
- 20 of holes connected to the third contact layer in the different detectors.
- 25 12. Detector including a matrix of detectors according to claim 3, made on a substrate, a conducting layer common to all the detectors being made on the face of the substrate, this layer being covered by an insulating layer, each detector including, on this insulating layer, a first detector element of photoconducting material, a common insulating layer, a second detector element of photoconducting material, said second means of connection all being interconnected and said third means of connection all being interconnected.

This Sheet Has Been Replaced

