



(51) International Patent Classification:

G01J 5/12 (2006.01) G01J 5/08 (2006.01)
H01L 33/34 (2010.01)

(21) International Application Number:

PCT/GB2017/052907

(22) International Filing Date:

28 September 2017 (28.09.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1616754.6 03 October 2016 (03.10.2016) GB

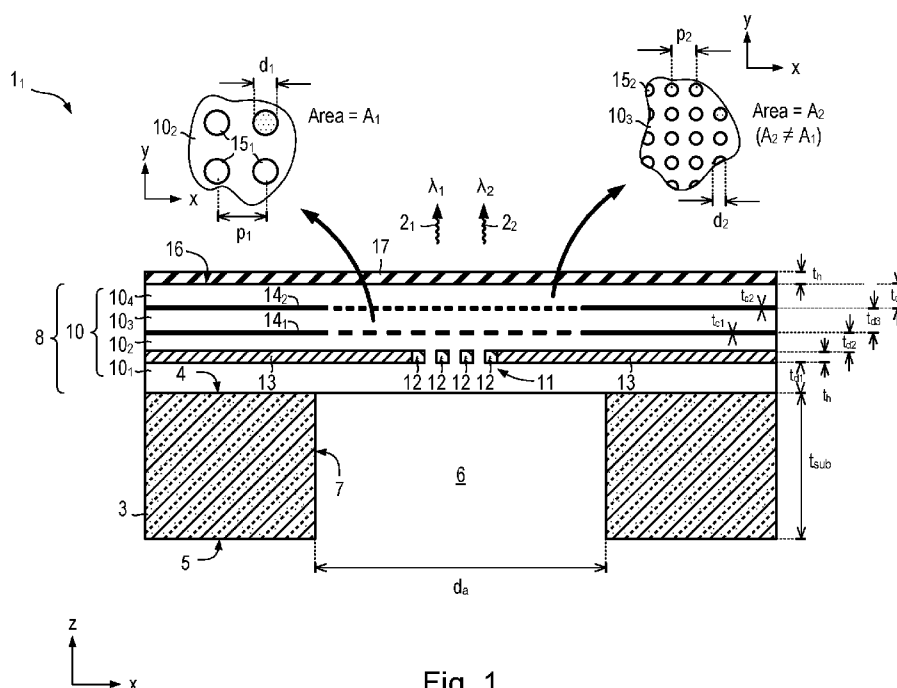
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,

(54) Title: INFRARED EMITTER OR DETECTOR HAVING ENHANCED EMISSIVITY AND/OR SENSITIVITY AT TWO OR MORE DIFFERENT WAVELENGTHS



OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

INFRARED EMITTER OR DETECTOR HAVING ENHANCED EMISSIVITY AND/OR SENSITIVITY AT TWO OR MORE DIFFERENT WAVELENGTHS

Field of the Invention

The present invention relates to an infrared device.

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Background

Surface plasmonic structures and their applications in infrared devices are known. For example, US 2014/0291704 A1 describes an infrared device made using complementary metal-oxide semiconductor (CMOS) processes and which comprises a patterned layer of periodic structures for controlling IR emission and/or absorption.

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Infrared emitters which are tuned are also known. For example, US 2012/0235067 A1 describes tuning emission wavelengths using a plasmonic emitting structure, applying a force in a biaxial direction parallel to the substrate, changing the distance between the features or changing the resistivity and dielectric constant of the dielectric layer. The structure is operable at a temperature up to the melting point of the flexible substrate.

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Summary

The present invention seeks to provide an improved infrared device which is operable as an infrared emitter (or “source”) and/or detector and which has enhanced emissivity and/or sensitivity at two or more different wavelengths.

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According to a first aspect of the present invention there is provided an infrared device. The device comprises a silicon substrate and a membrane supported by the silicon substrate. The membrane includes a stack of at least two layers of dielectric material and at least one patterned layer of conductive material, each patterned layer interposed
10 between respective adjacent layers of dielectric material in the stack. The at least one patterned layer of conductive material comprises laterally-spaced apart regions of the conductive material (or “islands”) and/or holes (or other form of feature) within the conductive material. The regions and/or holes have at least two different shapes and/or at least two different sizes for enhancing emission or absorption of radiation at
15 two or more different wavelengths which lie in a range of 2 to 15 μm .

The at least one patterned layer of conductive material may comprise at least two laterally- spaced apart including holes or islands of different diameter and distribution within the same layer of conductive material, the regions and/or having at least two
20 different shapes and/or at least two different sizes with no periodic repetition for enhancing emission or absorption of radiation at two or more different wavelengths which lie in a range of 2 to 15 μm .

According to a second aspect of the present invention there is provided an infrared
25 device. The device comprises a silicon substrate and membrane supported by the silicon substrate. The membrane includes a stack of at least two layers of dielectric material and at least one patterned layer of conductive material, each patterned layer interposed between respective adjacent layers of dielectric material in the stack. The at least one patterned layer of conductive material comprises at least two laterally- spaced
30 apart including holes or islands of different diameter and distribution within the same layer of conductive material, the regions and/or having at least two different shapes and/or at least two different sizes with no periodic repetition for enhancing emission or absorption of radiation at two or more different wavelengths which lie in a range of 2 to 15 μm .

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The infrared device may be operable as an infrared source.

The at least one patterned layer may be formed of or comprise graphene, diamond, indium tin oxide or titanium nitride.

- 5 The at least one patterned layer may include at least two laterally spaced apart regions of holes or islands have varies distributions and sizes within the same region. This can be used for compensating manufacturing tolerances.

10 The at least one patterned layer may be formed of or comprise coupled structures or structures with different sizes (such as diameter, thickness and/or sidewall angle) and distributions. This can be used for obtaining a narrow angular distribution with an angular separation of emitted wavelengths.

15 The at least one patterned layer may include at least two laterally-spaced apart regions of holes or islands arranged so as to enhance infrared emission at the two or more different wavelengths concomitantly.

20 The device may further comprise a passivation layer and a heater. A patterned layer which is closest to the heater may be configured to reflect infrared light emitted by another patterned layer which is closest to the passivation layer. This can enhance emission from the device.

25 The device may comprise an array of identical and/or different infrared sources arranged on the silicon substrate (or "the same chip"). The sources are operable or are arranged to operate at different temperatures and emit different wavelengths simultaneously.

30 The at least one patterned layer of conductive material may comprise first and second patterned layers, wherein the first patterned layer includes first regions and/or first holes having a first shape and/or a first size and the second patterned layer includes second regions and/or second holes having a second shape and/or a second size which differs from the first shape and/or first size.

35 The at least one patterned layer of conductive material may comprise a patterned layer, wherein the patterned layer includes third regions and/or third holes having a third shape and/or a third size and the second patterned layer includes fourth regions and/or

fourth holes having a fourth shape and/or a fourth size which differs from the third shape and/or third size.

5 The infrared device may be operable as an infrared source, wherein the at least one patterned layer of conductive material is/are operable to enhance infrared emission at the two or more different wavelengths concomitantly.

The device may further comprise a heater interposed between a patterned layer of conductive material which is closest to the silicon substrate and the silicon substrate.
10 In other words, the device may comprise a heater disposed under the patterned layer of conductive material.

At least one of the at least one patterned layers may be disposed between silicon membranes. At least one of the at least one patterned layers may comprise a metal or
15 metal alloy. The at least one patterned layer may comprise two or three patterned layers, each layer comprising a respective metal or metal alloy. The metals or metal alloys may be the same. The metal may be gold or platinum. The at least one patterned layer may comprise a CMOS metal. The CMOS metal may be aluminium, tungsten, molybdenum or titanium.

20 A patterned layer of metal may be arranged to reflect infrared light emitted so as to enhance emission from the device.

The at least one patterned layer may be arranged such that the device is capable of
25 emitting light at a first predetermined wavelength and/or at second predetermined wavelength.

At least one of the at least one patterned layers may comprise laterally spaced apart regions of conductive material.

30 At least one of the at least one patterned layers may comprise laterally spaced apart holes in a layer of the conductive material.

The regions may have a shape that exhibits at least three-fold rotational symmetry. The
35 shape may be a circle, a square, a triangle or other regular polygon.

The regions may have a shape that do not exhibit rotational symmetry or exhibit only one- or two-fold rotational symmetry. Thus, the shape can be used to realize polarisation selectivity. The shape may be an ellipse.

- 5 The regions may be arranged in a periodic array. The period array may be square or hexagonal.

The regions or holes may have a distribution which varies in a periodic manner. This can be used to form a multiplexed structure comprising at least two metal structures of
10 different sizes or different periods in a single unit cell.

The infrared device maybe configured to be responsive to wavelengths between 4.0 and 10.3 μm . Thus, the device can be used for sensing or exciting materials such as carbon dioxide, carbon monoxide, hydrogen sulphide, acetone, ethanol and ammonia. The
15 device may be capable of emitting infrared radiation at more than one wavelength in this range at the same time.

The infrared device may be operable as an infrared sensor or detector.

- 20 The infrared device may comprise a broadband detector structure, wherein the at least one patterned layer provides narrowband enhancement of absorption. The broadband detector may comprise a thermopile.

At least one of the at least one patterned layers may comprise laterally spaced apart
25 regions of conductive material.

At least one of the at least one patterned layers may comprise laterally spaced apart holes or islands in a layer of the conductive material.

- 30 The regions or holes may include symmetric and asymmetric shapes. The symmetric and asymmetric shapes may include a ring, a nanorod, a mushroom, a cross, and/or coupled patterns. The at least one of the at least one patterned layer may be configured to absorb infrared radiation at at least two different wavelengths.

According to a third aspect of the present invention there is provided a system comprising at least two infrared devices according to the first or second aspect of the present invention.

5 According to a fourth aspect of the present invention there is provided a system of infrared devices which is operable as an infrared sensor or detector and which includes a first infrared device and a second infrared device according to the first or second aspect of the present invention. The first infrared device is configured to detect infrared radiation at a first wavelength and the second infrared device is configured to
10 detect infrared radiation at the first wavelength and a second different wavelength. The system may further comprise a differential signal detector coupled to first and second infrared devices and arranged to perform a differential measurement.

The at least two infrared devices may share the same silicon substrate.

15 The at least two infrared devices may include first and second infrared devices, the first infrared device arranged to detect infrared radiation at a first wavelength and the second infrared device arranged to detect infrared radiation at the first wavelength and a second, different wavelength, the system further comprise a differential signal
20 detector coupled to first and second infrared devices and arranged to perform a differential measurement.

Preferably the dielectric and conductive materials are CMOS materials, such as silicon dioxide, silicon, aluminium, tungsten etc.

25 According to a fifth aspect of the present invention there is provided an infrared device comprising a dielectric membrane on a silicon substrate and at least one layer of patterned structures of various shapes and distributions and formed within or on the dielectric membranes for controlling infrared emission/absorption of the infrared
30 device within the range of 2-15 μm .

The device may be an infrared source in which the patterned layer controls the IR emission of the device at specific wavelengths simultaneously.

35 The patterned layer comprising the laterally spaced structures is above a heater. The patterned layer may comprise the laterally spaced structures is between Si membranes.

- The laterally-spaced structures may be a pattern of holes or islands. The holes or islands may have a shape of either symmetric structures, such as circle, rectangle, square, triangle and trapezoid or asymmetric structures, such as ellipsoidal or coupled (fused) shapes and are arranged in a square or a hexagonal pattern. Distribution of holes or islands may vary in a periodic manner to form multiplexed structure comprising at least two metal structures of different sizes or different periods in a single unit cell. The patterned layer may be formed for the wavelengths between 4.0 and 10.3 μm , such as for carbon dioxide, carbon monoxide, hydrogen sulphide, acetone, ethanol and ammonia, and enables emission of these particular wavelengths simultaneously.
- The laterally spaced asymmetric shape structures (holes or islands) may be used to realize polarisation selectivity. Systematic patterning issues that arise during manufacturing process, random manufacturing variations, wafer variations and batch to batch variations can be analysed statistically to obtain parameter variation.
- The infrared device may comprise up to three different patterned metal layers for specific wavelengths, comprising gold or platinum or a CMOS-based metal such as aluminium, tungsten, molybdenum or titanium. One metal layer may act as a reflector for the emitted light at particular wavelength and enhances the IR emission from the device. Metal layers may be patterned to emit light of single specific wavelength, for example, λ_1 , λ_2 or λ_3 or emit light having a plurality of wavelengths, for example, λ_1 and λ_2 , λ_1 and λ_3 , λ_2 and λ_3 , and/or λ_1 and λ_2 and λ_3 .
- The infrared device may be an infrared detector, e.g. a thermopile with a broad band patterned absorber layer which is a multiplexed metal structure and may be configured to control the infrared absorption at various wavelengths. The infrared device may comprise an infrared absorber layer wherein the laterally spaced structures are a pattern of holes or islands and wherein these features have symmetric and asymmetric shapes, for example, ring, nanorod, mushroom, cross, dual cross-shaped or coupled patterns. The absorber layer may contain a plurality of laterally spaced structures specific for various wavelengths. The infrared device may comprise at least two IR detectors within a package for differential signal measurements, one detecting a specific wavelength, λ_1 , and a second detecting two specific wavelengths, λ_1 and λ_2 , including the wavelength, λ_1 , identified by the first detector.

According to a sixth aspect of the present invention there is provided a method of operating an infrared device. The method may comprise applying a signal to the infrared device. Applying the signal to the infrared device may comprise applying a signal to a heater in the infrared device. The method may comprise measuring a signal
5 generated by the infrared device. Measuring the signal generated by the infrared device may comprise measuring a signal generated by a thermocouple.

Brief Description of the Drawings

Certain embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross section of a first infrared device operable as an infrared emitter which includes a heater embedded in a dielectric membrane and two, periodically-patterned layers disposed in the membrane above the heater for enhancing emission at specific wavelengths;

Figure 2 is a schematic cross section of a second infrared device operable as an infrared emitter which includes a heater embedded within a dielectric membrane and a periodically patterned layer disposed in the membrane above the heater for enhancing emission at specific wavelengths;

Figure 3 is a schematic cross section of a third infrared device operable as an infrared emitter which includes a heater embedded in a dielectric membrane, two, periodically-patterned layers disposed in the membrane above the heater for enhancing emission at specific wavelengths and a reflector interposed between the heater and the patterned layers;

Figure 4 is a schematic cross section of a fourth infrared device operable as an infrared detector which includes a thermocouple and an absorber layer having a plurality of laterally spaced structures specific for various wavelengths; and

Figure 5 is a schematic cross section of a fifth infrared device operable as an infrared detector which includes a multiplexed patterned metal structure for enhancing infrared absorption at specific wavelengths.

Detailed Description of Certain Embodiments

In the following, like parts are denoted with like reference numerals.

First infrared device 1₁

Referring to Figure 1, a first infrared device 1₁ is shown. The first device 1₁ is operable as an infrared source capable of emitting infrared radiation 2₁, 2₂ at first and second different wavelengths, λ_1 , λ_2 , where $\lambda_1 \neq \lambda_2$.

The device 1₁ comprises a silicon substrate 3 having a principle surface 4 (herein referred to as the “front surface”) and a reverse surface 5 (herein referred to as the “back surface”). The substrate 3 includes an etched through-hole 6 (herein also referred to as an “air gap”) between the front and back surfaces 4, 5, through the

substrate 5, bounded by side walls 7. The substrate 3 supports a membrane 8. The through-hole 6 has a diameter, d_a , of at least 100 μm .

5 The membrane 8 includes a layer structure which includes a first layer 10₁ of dielectric material (hereinafter referred to as the “first dielectric layer”) having a first dielectric thickness t_{d1} . The first dielectric thickness t_{d1} may be at least 100 nm. The dielectric material is preferably silicon dioxide (SiO_2) although other CMOS-compatible dielectric materials can be used.

10 A resistive heater 11 is disposed on the first dielectric layer 10₁. The resistive heater 11 comprises a conductive track 12 formed of, for example, tungsten or heavily-doped p-type polycrystalline silicon (or “p⁺ polysilicon”). The track 12 (as seen in plan view) is arranged in a loop or to follow a meandering path. The track 12 has dimensions (for example, transverse cross-sectional area and length) which, for the resistivity of the
15 conductive track, provides sufficient Joule heating in response to appropriate values of applied voltages (for example of the order of volts). Electrical connection to the track 12 is provided by low-resistance metal tracks 13.

A second layer 10₂ of dielectric material (hereinafter referred to as the “second
20 dielectric layer”) having a second thickness t_{d2} overlies the tracks 12, 13 and first dielectric layer 10₁. The second dielectric thickness t_{d2} may be at least 100 nm.

A first patterned layer 14₁ of conductive material having a first conductive layer thickness t_{c1} overlies the second dielectric layer 10₂. The first conductive layer thickness
25 t_{c1} may be between 400 and 600 nm. The conductive material may be polycrystalline silicon or a metal, preferably a CMOS metal, such as tungsten.

The first patterned layer 14₁ is arranged to exhibit plasmonic-enhancement of emission or absorption. A patterned layer which is configured to exhibit plasmonic-
30 enhancement of emission or absorption of radiation is herein also referred to as “plasmonic layer”.

The first patterned layer 14₁, at least over the air gap 6, comprises coplanar, laterally spaced-apart isolated regions 15₁ (herein referred to as “islands”) of conductive material
35 having a first area A_1 . The islands 15₁ take the form of circular disks having a first diameter d_1 and having centre-to-centre pitch p_1 . Other shapes of regions can be used,

such as ellipses, regular polygons (such as squares or rectangles) or irregular polygons can be used. Elongated structures, such as ellipses or rectangles, can provide linear polarization selectivity. Regions 15₁ can be arranged in a regular pattern, e.g. a square array, hexagonally, *etc.*, or randomly distributed.

5

The patterned layer 14₁ may comprise a web of conductive material having laterally spaced-apart through holes (not shown) having a first area A₁. The holes (not shown) can take the form of circular disks having a first diameter d_1 and having centre-to-centre pitch p_1 . Other shapes of holes can be used, such as ellipses, regular polygons (such as squares or rectangles) or irregular polygons can be used. Elongated holes, such as ellipses or rectangles, can provide linear polarization selectivity.

10

The first patterned layer 14₁ may comprise a combination of features 15₁ which may be islands or holes.

15

The features 15₁ have the same shape and the same size. Size may be defined by virtue of area or a characteristic length, e.g. in diameter, average diameter, side length, major axis length *etc.* As will be described in more detail hereinafter, in some embodiments, a patterned layer can include features of at least two different shapes and/or of two or more different sizes.

20

A third layer 10₃ of dielectric material (hereinafter referred to as the “third dielectric layer”) having a third thickness t_{d3} overlies the first patterned layer 14₁ and second dielectric layer 10₂. The third thickness t_{d3} may be at least 100 nm.

25

A second patterned layer 14₂ of conductive material having a second conductive layer thickness t_{c2} overlies the third dielectric layer 10₃. The second conductive layer thickness t_{c2} may be between 400 and 600 nm. The first and second conductive layers 14₁, 14₂ may have the same thickness. The conductive material may be polycrystalline silicon or a metal, preferably a CMOS metal, such as tungsten. The conductive material in the second patterned layer 14₂ may be the same as the conductive material in the first patterned layer 14₁.

30

Similar to the first patterned layer 14₁, the second patterned layer 14₂, at least over the air gap 6, comprises coplanar, laterally spaced-apart isolated regions 15₂ (“islands”) of conductive material having a second area A₂. The islands 15₂ take the form of circular

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disks having a second diameter d_2 and having centre-to-centre pitch p_2 . Other shapes of islands can be used, such as ellipses, regular polygons (such as squares or rectangles) or irregular polygons can be used. Elongated structures, such as ellipses or rectangles, can provide linear polarization selectivity. The first and second patterned layers 14₁, 14₂ need not share the same shape of region. Islands 15₂ can be arranged in a regular pattern, e.g. a square array, hexagonally, *etc.*, or randomly distributed. The first and second patterned layers 14₁, 14₂ need not share the same arrangement.

The patterned layer 14₂ may comprise a web of conductive material having laterally spaced-apart through holes(not shown) having a second area A_2 . The holes (not shown) can take the form of circular disks having a second diameter d_2 and having centre-to-centre pitch p_2 . Other shapes of holes can be used, such as ellipses, regular polygons (such as squares or rectangles) or irregular polygons can be used. Elongated holes, such as ellipses or rectangles, can provide linear polarization selectivity.

A fourth layer 10₄ of dielectric material (hereinafter referred to as the “fourth dielectric layer”) having a second thickness t_{d2} overlies the second patterned layer 14₂ and third dielectric layer 10₃. The second thickness t_{d2} may be at least 100 nm.

The dielectric layers 10₁, 10₂, 10₃, 10₄ together form a dielectric membrane 10 in which are embedded the heater 11 and patterned layers 14₁, 14₂. The membrane 10 has a principal surface 16.

A passivation layer 17 overlies the principal surface 16 of the membrane 10. The passivation layer 17 can be PECVD silicon nitride (Si₃N₄) or it can be formed from another suitable material, such as silicon dioxide (SiO₂). The passivation layer 17 protects the device surface against contaminants and possible damage due to post-processing, such as dicing and handling of devices.

US 2014/0291704 A1, which is incorporated herein by reference, describes suitable materials for substrates, dielectric layers, heaters, and conductive layers and suitable methods (such as etching) of fabricating structures.

Second infrared device 1₂

Referring to Figure 2, a second infrared device 1₂ is shown.

Referring also to Figure 1, the second infrared device 1_2 is the same as the first infrared device 1_1 except that it has a single patterned layer 14 which contains regions 15_1 , 15_2 , 15_3 having at least two, in this case three, different shapes and/or different sizes in the same layer and the third dielectric layer 10_3 is omitted.

5

Regions 15_1 , 15_2 , 15_3 of the same shape and/or size may be grouped together in blocks or be interspersed between each other.

Third infrared device 1_3

10 Referring to Figure 3, a third infrared device 1_3 is shown.

Referring also to Figure 1, the third device 1_3 is the same as the first infrared device 1_1 except that it includes an additional, fifth layer 10_5 of dielectric material ("fifth dielectric layer") and a reflector layer 18 disposed on the fifth dielectric layer 10_5
 15 interposed between heater layers 12 , 13 (and the underlying first dielectric layer 10_1) and the second dielectric layer 10_2 .

Fourth infrared device 1_4

Referring to Figure 4, a fourth infrared device 1_4 is shown. The fourth infrared device 1_4
 20 is operable as an infrared sensor or detector responsive to infrared radiation 2_1 , 2_2 , 2_3 at first, second and third different wavelengths, λ_1 , λ_2 , λ_3 , where $\lambda_1 \neq \lambda_2 \neq \lambda_3$.

Referring also to Figure 2, the fourth infrared device 1_4 is similar as the second infrared device 1_2 . The fourth infrared device 1_4 differs from the second infrared device in that
 25 instead of heater layers 12 , 13 , the fourth infrared device 1_4 includes a buried oxide layer 19 disposed on the silicon substrate 3 on which is disposed a patterned layer 20 of highly-doped n-type silicon (i.e. n^+ silicon) and a patterned layer 21 of highly-doped p-type silicon (i.e. p^+ silicon) and a metal layers 22 , 23 which form a junction (not shown) between the doped layer 20 , 21 , and a thicker layer(s) of dielectric material 106
 30 overlying the thermocouple. The fourth infrared device 1_4 differs from the second infrared device in that the passivation layer 17 is omitted.

Fifth infrared device 1_5

Referring to Figure 5, a fifth infrared device 1_5 is shown.

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Referring also to Figures 1 and 4, the fifth infrared device 1₅ is the same as the fourth infrared device 14 except that instead of a single patterned layer 14, the fifth infrared device 1₅ includes first and second patterned layers 14₁, 14₂ as used in the first infrared device 1₁.

5

Modifications

It will be appreciated that various modifications may be made to the embodiments hereinbefore described. Such modifications may involve equivalent and other features which are already known in the design, manufacture and use of plasmonic devices and component parts thereof and which may be used instead of or in addition to features
10 already described herein. Features of one embodiment may be replaced or supplemented by features of another embodiment.

A patterned layer may comprise a combination of regions and holes.

15

Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present invention also includes any novel features or any novel combination of features disclosed herein either explicitly or implicitly or any generalization thereof, whether or
20 not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

25

Claims

1. An infrared device comprising:
a silicon substrate; and
5 a membrane supported by the silicon substrate, the membrane including:
a stack of at least two layers of dielectric material; and
at least one patterned layer of conductive material, each patterned layer
interposed between respective adjacent layers of dielectric material in the stack;
wherein the at least one patterned layer of conductive material comprises laterally-
10 spaced apart regions of the conductive material and/or holes within the conductive
material, the regions and/or having at least two different shapes and/or at least two
different sizes for enhancing emission or absorption of radiation at two or more
different wavelengths which lie in a range of 2 to 15 μm .
- 15 2. An infrared device according to claim 1, wherein the at least one patterned layer
of conductive material comprises at least two laterally- spaced apart including holes or
islands of different diameter and distribution within the same layer of conductive
material, the regions and/or having at least two different shapes and/or at least two
different sizes with no periodic repetition for enhancing emission or absorption of
20 radiation at two or more different wavelengths which lie in a range of 2 to 15 μm .
3. An infrared device comprising:
a silicon substrate; and
a membrane supported by the silicon substrate, the membrane including:
25 a stack of at least two layers of dielectric material; and
at least one patterned layer of conductive material, each patterned layer
interposed between respective adjacent layers of dielectric material in the stack;
wherein the at least one patterned layer of conductive material comprises at least two
laterally- spaced apart including holes or islands of different diameter and distribution
30 within the same layer of conductive material, the regions and/or having at least two
different shapes and/or at least two different sizes with no periodic repetition for
enhancing emission or absorption of radiation at two or more different wavelengths
which lie in a range of 2 to 15 μm .
- 35 4. An infrared device according to any preceding claim, operable as an infrared
source.

5. An infrared device according to any preceding claim, wherein the at least one patterned layer is formed of or comprise graphene, diamond, indium tin oxide or titanium nitride.

5

6. An infrared device according to any preceding claim, wherein the at least one patterned layer includes at least two laterally spaced apart regions of holes or islands have varies distributions and sizes within the same region.

10

7. An infrared device according to any preceding claim, wherein the at least one patterned layer is formed of or comprises coupled structures or structures with different sizes (such as diameter, thickness and/or sidewall angle) and distributions. This can be used for obtaining a narrow angular distribution with an angular separation of emitted wavelengths.

15

8. An infrared device according to any preceding claim, wherein the at least one patterned layer includes at least two laterally-spaced apart regions of holes or islands arranged so as to enhance infrared emission at the two or more different wavelengths concomitantly.

20

9. An infrared device according to any preceding claim, wherein the device further comprises:

a passivation layer; and

a heater,

25

wherein the patterned layer closest to the heater is configured to reflect infrared light emitted by another patterned layer which is closest to the passivation layer.

10. An infrared device according to any preceding claim, wherein the device comprises:

30

an array of identical and/or different infrared sources arranged on the silicon substrate,

wherein the sources are operatable or are arranged to operate at different temperatures and emit different wavelengths simultaneously.

11. An infrared device according to any preceding claim, wherein the at least one
5 patterned layer of conductive material comprises first and second patterned layers,
wherein the first patterned layer includes first regions and/or first holes having a first
shape and/or a first size and the second patterned layer includes second regions and/or
second holes having a second shape and/or a second size which differs from the first
shape and/or first size.
- 10 12. An infrared device according to any preceding claim and 11, wherein the at least
one patterned layer of conductive material comprises a patterned layer, wherein the
patterned layer includes third regions and/or third holes having a third shape and/or a
third size and the second patterned layer includes fourth regions and/or fourth holes
15 having a fourth shape and/or a fourth size which differs from the third shape and/or
third size.
13. An infrared device according to any preceding claim, which is operable as an
infrared source, wherein the at least one patterned layer of conductive material is/are
20 operable to enhance infrared emission at the two or more different wavelengths
concomitantly.
14. An infrared device according to any preceding claim, further comprising:
a heater interposed between a patterned layer of conductive material which is
25 closest to the silicon substrate and the silicon substrate.
15. An infrared device according to any preceding claim, wherein at least one of the at
least one of patterned layer is between silicon membranes.
- 30 16. An infrared device according to any preceding claim, wherein at least one of the at
least one patterned layers comprises a metal.
17. An infrared device according to claim 16, wherein the at least one patterned layer
comprises two or three patterned layers; each layer comprising a respective metal.

18. An infrared device according to claim 16 or 17, wherein at least one patterned layer comprises gold or platinum.
19. An infrared device according to claim 16, 17 or 18, wherein at least one patterned
5 layer comprises a CMOS metal.
20. An infrared device according to any one of claims 16 to 19, wherein a patterned layer of metal is arranged to reflect infrared light emitted so as to enhance emission from the device.
- 10 21. An infrared device according to preceding claim, wherein the at least one patterned layer is/are arranged such that the device is capable of emitting light at a first predetermined wavelength and/or at second predetermined wavelength.
- 15 22. An infrared device according to preceding claim, wherein at least one of the at least one patterned layers comprises laterally spaced apart regions of conductive material.
- 20 23. An infrared device according to preceding claim, wherein at least one of the at least one patterned layers comprises laterally spaced apart holes in a layer of the conductive material.
24. An infrared device according to claim 22 or 23, wherein the regions have a shape that exhibits at least three-fold rotational symmetry.
- 25 25. An infrared device according to claim 22 or 23, wherein the regions have a shape that do not exhibit rotational symmetry or exhibit only one- or two-fold rotational symmetry.
- 30 26. An infrared device according to claim 22, 23, 24 or 25, wherein the regions are arranged in a periodic array.
27. An infrared device according to any one of claims 22 to 26, wherein the regions or holes have a distribution which varies in a periodic manner.
- 35

28. An infrared device according to preceding claim, configured to be responsive to wavelengths between 4.0 and 10.3 μm .
29. An infrared device according to any preceding claim, which is operable as an
5 infrared sensor or detector.
30. An infrared device according to claim 29, comprising:
a broadband detector structure;
wherein the at least one patterned layer provides narrowband enhancement of
10 absorption.
31. An infrared device according to claim 30, wherein the broadband detector comprises a thermopile.
- 15 32. An infrared device according to any one of claims 29 to 31, wherein at least one of the at least one patterned layers comprises laterally spaced apart regions of conductive material.
33. An infrared device according to any one of claims 29 to 32, wherein at least one of
20 the at least one patterned layers comprises laterally spaced apart holes or islands in a layer of the conductive material.
34. An infrared device according to claim 32 or 33, wherein the regions or holes include symmetric and asymmetric shapes.
25
35. An infrared device according to claim 34, wherein the at least one of the at least one patterned layer is configured to absorb infrared radiation at at least two different wavelengths.
- 30 36. A system comprising at least two infrared devices according to any preceding claim.
37. A system according to claim 26, wherein the at least two infrared devices share the same silicon substrate.
35

38. A system according to claim 36 or 37, wherein the at least two infrared devices include first and second infrared devices, the first infrared device arranged to detect infrared radiation at a first wavelength and the second infrared device arranged to detect infrared radiation at the first wavelength and a second, different wavelength, the
- 5 system further comprise a differential signal detector coupled to first and second infrared devices and arranged to perform a differential measurement.

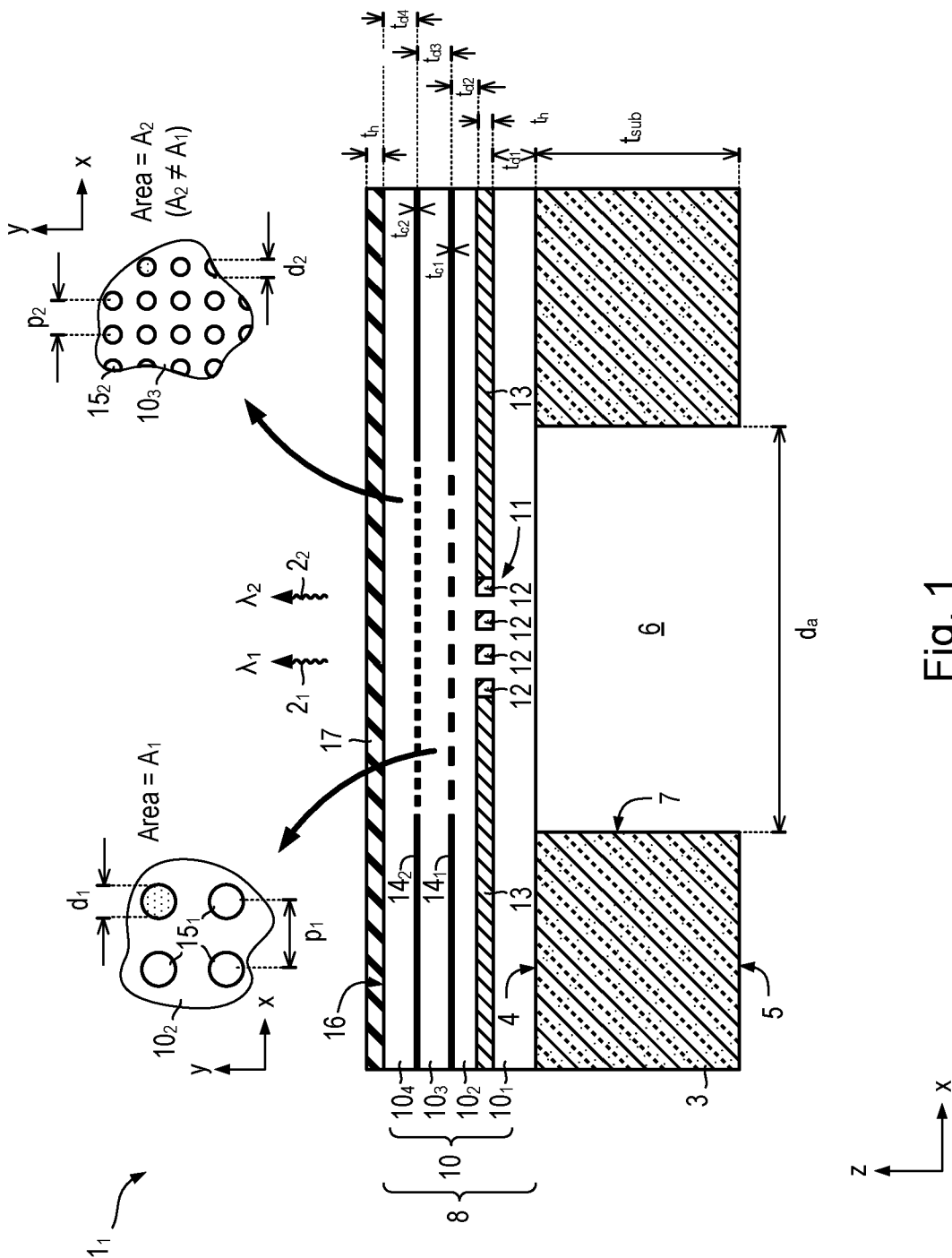


Fig. 1

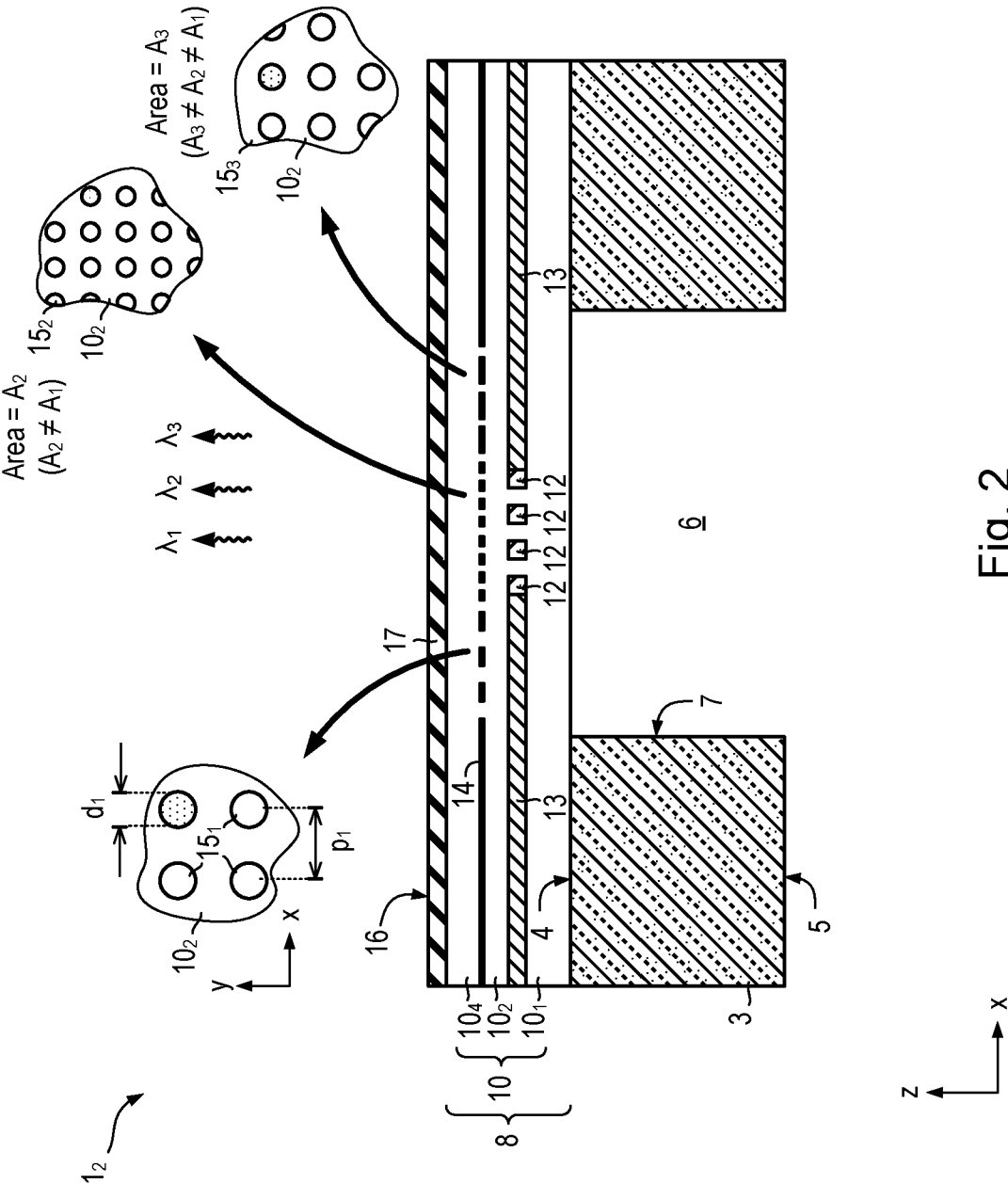


Fig. 2

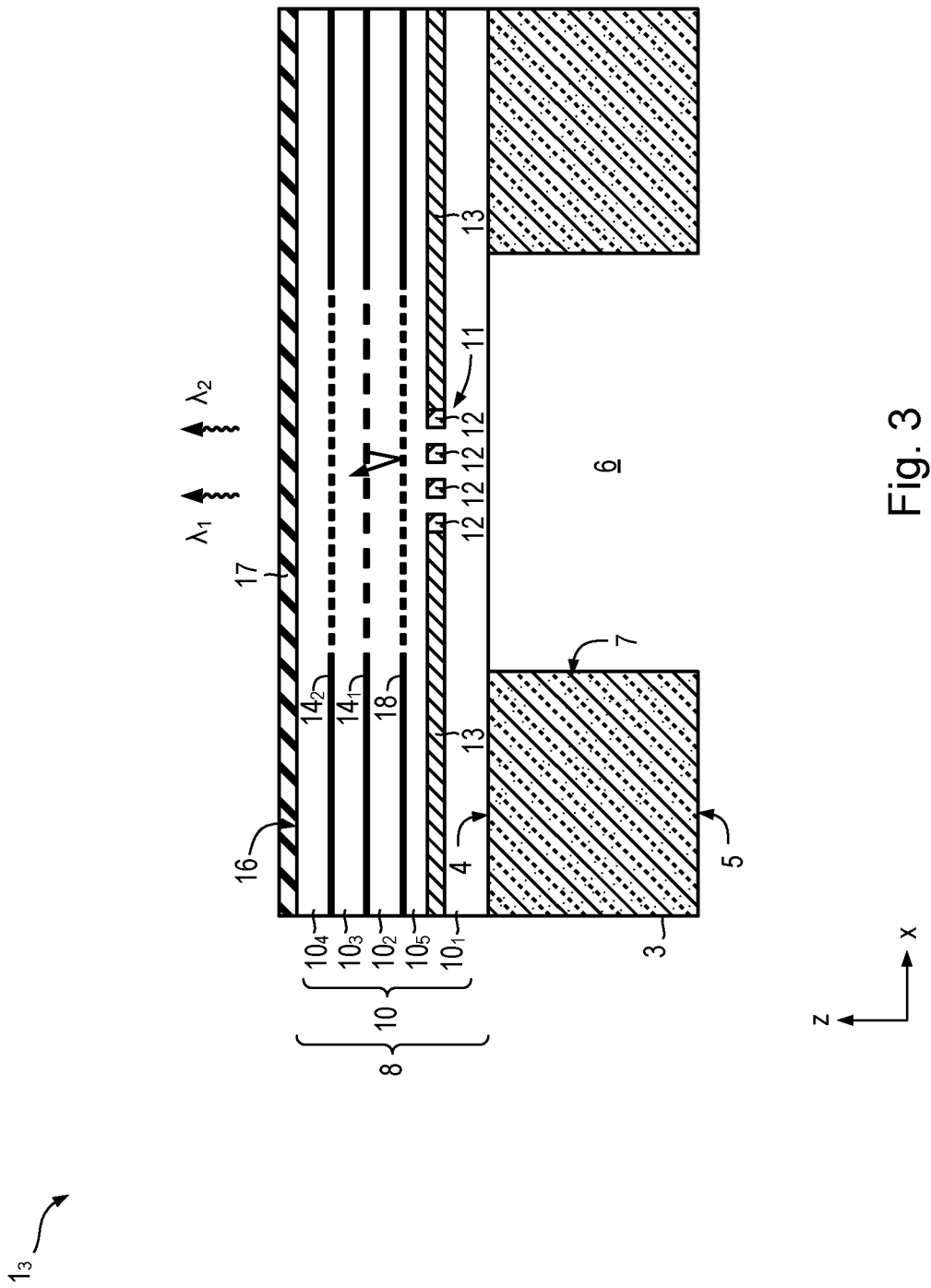


Fig. 3

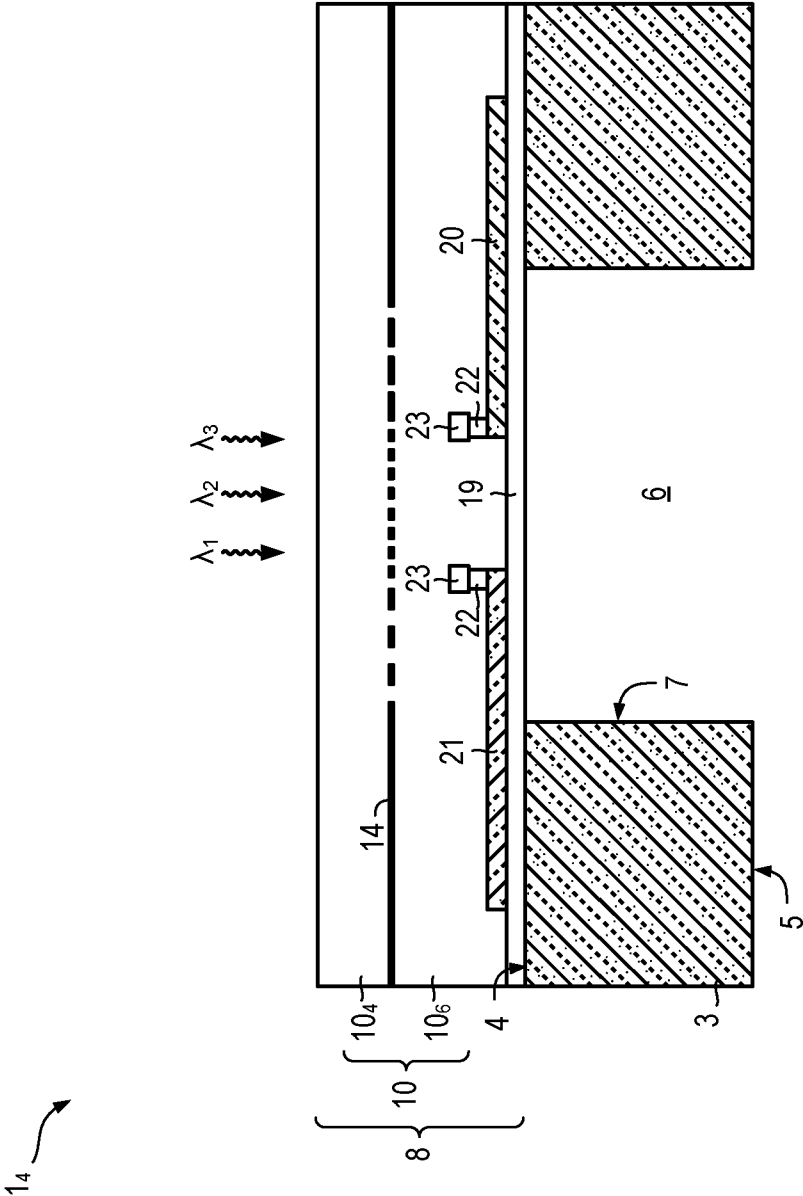


Fig. 4

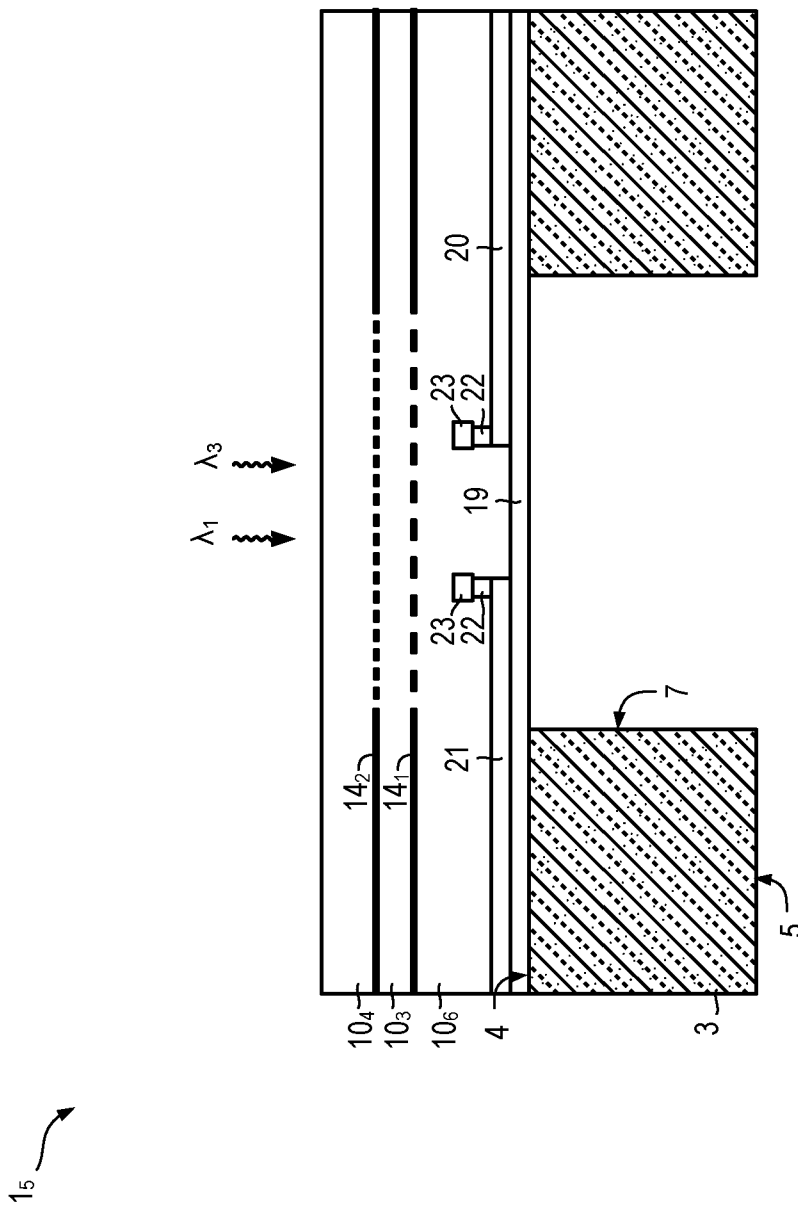


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/052907

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01J5/12 H01L33/34 G01J5/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01J H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/291704 A1 (ALI SYED ZEESHAN [GB] ET AL) 2 October 2014 (2014-10-02) figures 1,14 -----	1-38



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 November 2017

Date of mailing of the international search report

08/12/2017

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2017/052907

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014291704	A1	02-10-2014	NONE
