



(51) International Patent Classification:
G01N 21/00 (2006.01)

(21) International Application Number:
PCT/US2009/038916

(22) International Filing Date:
31 March 2009 (31.03.2009)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **THE GOVERNMENT OF THE UNITED STATES OF AMERICA, AS REPRESENTED BY THE SECRETARY OF THE NAVY** [US/US]; Naval Research Laboratory, 4555 Overlook Avenue, SW, Code 1008.2, Washington, DC 20375 (US).

(72) Inventor: **JOHNSON, Lee, James**; 1601 Van Buren Street Nw, Washington, DC 20012 (US).

(74) Agent: **KARASEK, John, J.**; Naval Research Laboratory, Associate Counsel (patents), 4555 Overlook Avenue, SW, Washington, DC 20375-5325 (US).

(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, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

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

(54) Title: EVANESCENT FIELD PLASMON RESONANCE DETECTOR

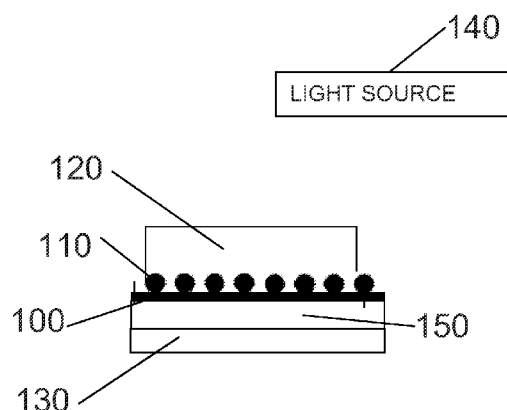


FIG. 3b

(57) Abstract: An embodiment of the invention includes a device comprising a plurality of nanoparticles and a noble metal film comprising a first side and a second side, the plurality of nanoparticles being located on the second side of said metal film. The device also includes a binding sample contacting the second side of said metal film and a light-sensitive, semiconductor detector array located at a distance less than 200 nanometers from the first side of the metal film.

EVANESCENT FIELD PLASMON RESONANCE DETECTOR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Serial No.
5 61/041,341, entitled "EVANESCENT FIELD PLASMON RESONANCE DETECTOR,"
to Johnson.

TECHNICAL FIELD

This invention relates generally to a device for detecting a Surface Plasmon
10 Resonance peak, and, more particularly, to a semiconductor detector for detecting a
Surface Plasmon Resonance peak.

BACKGROUND ART

Surface plasmon resonance requires the coupling of incident light to oscillations
15 in the conducting electrons in the surface of a metal. These oscillations are called
plasmons. The plasmons yield an evanescent field which propagates on either side of the
surface and the resonant wavelength at which maximal absorption occurs is sensitive to
the index of refraction of the surrounding medium.

The coupling of the incident light to the plasmon modes of the metal is typically achieved in a Kretschmann Prism configuration with a metal coated prism yielding total internal reflection at a specific angle of incident light. An example of the Kretschmann Prism configuration is shown in FIG. 1. The Kretschmann Prism is the prism 10 located
5 operatively between a light source 60 and a light detector 20. If the prism 10 were coated with an infinitely high index of refraction, then total internal reflection would occur for all light reflected at angles greater than a critical angle, and all of the light reflected toward the surface of the prism would be reflected away from the surface. If light is totally internally reflected off the inside of prism 10, then some of the light will exist
10 outside of the surface of the prism. This light is called the evanescent wave.

Instead of coating the prism with a material that approximates an infinite refractive index and thus allows for almost no evanescent wave, the prism 10 is attached to a sensor chip 30 via a thin layer of metal 40 and glass 50. A sample holder 70 is attached to the sensor chip 30. The sea of free electrons in the metal 40 has waves in it.
15 Motion of electromagnetic waves in the surface of the metal is called the surface plasmon. When the surface plasmon has similar properties to the evanescent wave, the surface plasmon and the evanescent wave couple. This phenomenon is called Surface Plasmon Resonance, or SPR.

When SPR occurs, it uses energy. Thus, the intensity of light reflected back from the surface is less than that incident on the surface. This intensity can be measured to determine when SPR has occurred. If a sensor chip can be fabricated which changes the nature of its surface plasmon in the presence of an analyte, then the presence or
5 concentration of that analyte can be determined, and a useful sensor has been built.

The resonance angle and wavelength are detected at a distance as a minimum intensity in the reflected light. The light detector 20 is at a distance much greater than the wavelength of light, the far-field. This requires the use of a focusing lens or fiber optic. The use of the prism and the far-field detection scheme results in a complex
10 optical design that is often temperature sensitive. This temperature sensitivity is due to changes in temperature less than 0.1° C or an illumination angle less than 0.0001 degree affecting the angle of reflection as much as the changes in index of refraction from analyte binding.

A less temperature-sensitive method is to use gold nanostructures coated with a
15 thin gold film to couple the light to the plasmon modes. This method has been used in a commercial system manufactured by LamdaGen, Inc. A SPR-detection system consistent with this method is shown in FIG. 2. Light from a light source 72 via a first optical fiber 74 is focused onto a nanoparticle film. The nanoparticle film is comprised of a glass

layer 90 and a gold film 78 with polystyrene nanospheres 80 grown by self-assembly.

The polystyrene nanospheres have gold evaporated on them covering the exposed half 76. The incident illumination resonates with the conduction band electrons of the gold at a particular wavelength dependant on the nanosphere size, spacing and the index of

5 refraction of the surrounding medium (including the analyte). The reflected light is captured and focused onto a second optical fiber 82. The second optical fiber 82 carries the collected light to a detector 84. The analyte 86, such as a protein, is bound to the surface of the nanoparticles and changes the local index of refraction. See, e.g., X. Hong and F. J. Kao, "Microsurface Plasmon Resonance Biosensing Based on Gold-

10 Nanoparticle Film," *Applied Optics* 43, no. 14 (2004): 2868-2873, incorporated herein by reference, and Hiroyuki Takei, Michael Himmelhaus, and Takayuki Okamoto, "Absorption spectrum of surface-bound cap-shaped gold particles," *Optics Letters* 27, no. 5 (March 1, 2002): 342-344, doi:10.1364/OL.27.000342, incorporated herein by reference. The problem with this prior art method is that it still relies on distant detection
15 which requires bulky optics 88 and potentially only yields a reduced signal.

Another approach is to detect the plasmon resonance in the near field or within the rapidly decaying evanescent field of the plasmons. This has been done by DeVlamink et al. by fabricating gold nanoparticles onto SiO₂ directly on GaAs

detectors, as discussed in I. De Vlaminck et al., "Local Electrical Detection of Single Nanoparticle Plasmon Resonance," *Nano Lett* 7, no. 3 (2007): 703-706, incorporated herein by reference, and U.S. Patent Application Serial No. 20090027681, incorporated herein by reference. DeVlaminck's method removes the contribution of the incident light from the plasmon resonance detection by using a pair of detectors, one with a nanoparticle and one without. The problem with this method is that the incident light can overwhelm the signal, resulting in a less sensitive system. DeVlaminck et al. suggest the use of a continuous film of gold in combination with nanoscale semiconductor photodetectors. In the likely event of larger detectors (e.g., a few microns in width) they suggest the use of additional topological nanofeatures in the gold film, such as grooves or indentations. This is based upon the well studied method of enhanced transmission through gold films with nanoscale holes. C. Genet and T. W. Ebbesen, "Light in tiny holes," *Nature* 445, no. 7123 (January 4, 2007): 39-46, doi:10.1038/nature05350, incorporated herein by reference.

15

DISCLOSURE OF THE INVENTION

An embodiment of the invention includes a device comprising a plurality of nanoparticles and a noble metal film comprising a first side and a second side, the

plurality of nanoparticles being located on the second side of said metal film. The device also includes a binding sample contacting the second side of said metal film and a light-sensitive, semiconductor detector array located at a distance less than 200 nanometers from the first side of the metal film.

5 Optionally, the noble metal film comprises gold, silver, copper, or platinum.

 Optionally, the semiconductor detector array comprises a GaAs detector array, an InGaAs detector array, a Si detector array, or a HgCaTe detector array.

 Optionally, the nanoparticles comprise one of noble-metal-coated nanoparticles and noble metal nanoparticles. Optionally, the noble-metal-coated nanoparticles
10 comprise gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, or platinum-coated nanoparticles, and wherein the noble metal nanoparticles comprise gold nanoparticles, silver nanoparticles, copper nanoparticles, or platinum nanoparticles.

 Optionally, the detector array comprises a focal plane array coupled to a readout
15 integrated circuit.

 Optionally, the device further includes a wavelength-restricted or wavelength-selectable light source operable to illuminate the binding sample. Optionally, the light source comprises a light-emitting diode, a laser diode, or a laser..

Optionally, the device further includes an insulator located between the detector array and the noble metal film.

Optionally, the binding sample comprises a biological sample or a chemical compound. Optionally, the biological sample comprises a protein.

- 5 Optionally, the device further includes an insulator and a semiconductor located between the light-sensitive, semiconductor detector array and the first side of the noble metal film. Optionally, the insulator comprises air and glass, and the semiconductor comprises silicon, SiO₂, GaAs oxide, InGaAs oxide, or HgCaTe oxide.

- 10 Another embodiment of the invention includes a device comprising a plurality of nanoparticles, and a noble metal film comprising a first side and a second side, the plurality of nanoparticles being located on the second side of the noble metal film. The device further includes a binding sample coating said second side of said metal film, a light-sensitive, semiconductor detector array located at a distance from the first side of the noble metal film, and an insulator located between the noble metal film and the light-
15 sensitive, semiconductor detector array. The insulator is optionally comprised of air, glass, a microlens, and/or a microchannel plate glass. Optionally, the insulator is comprised of a semiconductor oxide.

Optionally, the noble metal film comprises gold, silver, copper, or platinum.

Optionally, the semiconductor detector array comprises a GaAs detector array, an InGaAs detector array, a Si detector array, or a HgCaTe detector array.

Optionally, the nanoparticles comprise noble-metal-coated nanoparticles and noble metal nanoparticles. Optionally, the noble-metal-coated nanoparticles comprise
5 gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, and platinum-coated nanoparticles, wherein the noble metal nanoparticles comprise gold nanoparticles, silver nanoparticles, copper nanoparticles, or platinum nanoparticles.

Optionally, the detector array comprises a focal plane array coupled to a readout integrated circuit.

10 Optionally the detector array comprises a standard CMOS or standard CCD imaging chip

Optionally, the device comprises a wavelength-restricted or wavelength-selectable light source operable to illuminate the binding sample. Optionally, the light source comprises a light-emitting diode, a laser diode, or a laser.

15 Optionally, the device further includes an insulator located between the detector array and the noble metal film.

Optionally, the binding sample comprises a biological sample and a chemical compound. Optionally, the biological sample comprises a protein.

An embodiment of the invention is less temperature sensitive, more compact, more affordable and/or has a higher sensitivity than presently available alternatives in the market. For example, the embodiment does not require a prism.

5

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a prior art Surface Plasmon Resonance detector using a Kretschmann Prism configuration.

FIG. 2 is a block diagram of another prior art Surface Plasmon Resonance detector.

10

FIGs. 3a and 3b is a top view and side view, respectively, of a detector according to an embodiment of the instant invention.

FIG. 4 is a graph illustratively showing the detection of a resonance shift with a single wavelength source.

15

FIGs. 5a and 5b are side views of two variations of a detector assembly according to another embodiment of the instant invention.

FIG. 6 is a graph illustrating the enhanced transmission of gold nanoparticles on a gold film as compared to a gold film alone. The arrow indicates that unlike the other wavelengths in the spectrum, at ~920nm the intensity of transmitted light is greater for the gold nanoparticle - gold film combination than gold film alone. The addition of

material increases the transmission of light. The same 60nm gold film is used in both cases.

BEST MODES OF CARRYING OUT THE INVENTION

5 An embodiment of the invention includes a device shown by way of example in FIGs. 3a and 3b. The device comprises a plurality of nanoparticles 100 and a noble metal film 110 comprising a first side and a second side, the plurality of nanoparticles being located on the second side of said metal film. For the purposes of this specification, the phrase noble metal is defined as a non-reactive metal that has conduction band electrons
10 capable of resonating with incident illumination to generate Surface Plasmon Resonance. Examples of noble metals are copper, gold, platinum, and silver. The device also includes a binding sample 120 coating the second side of said metal film and a light-sensitive, semiconductor detector array 130 located at a distance less than 200 nanometers from the first side of the metal film.

15 The binding sample, for example, includes one or more proteins or other molecular compounds. An example of such a binding sample is an olfactory receptor protein, which can be used to bind to molecules such as certain odorants. An example of such a olfactory receptor protein is bacteriorhodopsin.

Optionally, the noble metal film comprises gold, silver, copper, or platinum.

Optionally, the semiconductor detector array comprises a GaAs detector array, an InGaAs detector array, a Si detector array, or a HgCaTe detector array.

Optionally, the nanoparticles comprise one of noble-metal-coated nanoparticles and noble metal nanoparticles. Optionally, the noble-metal-coated nanoparticles
5 comprise gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, or platinum-coated nanoparticles, and wherein the noble metal nanoparticles comprise gold nanoparticles, silver nanoparticles, copper nanoparticles, or platinum nanoparticles.

Optionally, the detector array comprises a focal plane array coupled to a readout
10 integrated circuit.

Optionally, the device further includes a wavelength-restricted or wavelength-selectable light source 140 operable to illuminate the binding sample. Optionally, the light source comprises a light-emitting diode, a laser diode, or a laser.

Optionally, the device further includes an insulator 150 located between the
15 detector array and the noble metal film.

Optionally, the binding sample comprises a biological sample or a chemical compound. Optionally, the biological sample comprises a protein.

Optionally, the device further includes an insulator and a semiconductor located between the light-sensitive, semiconductor detector array and the first side of the noble

metal film. Optionally, the insulator comprises air and glass, and the semiconductor comprises silicon, SiO₂, GaAs oxide, InGaAs oxide, or HgCaTe oxide. A layer of oxide or other insulating material between the detector and the noble metal film may be needed to tune the resonance wavelength or insulate the detector array from the noble metal film.

- 5 See, e.g., I. De Vlaminck et al., "Local Electrical Detection of Single Nanoparticle Plasmon Resonance," *Nano Lett* 7, no. 3 (2007): 703-706, incorporated herein by reference.

Applicant determined that the opaque nature of a noble metal film would allow removal of the contribution of the incident illumination to the plasmon resonance
10 detection. A light source illuminates the elements of the semiconductor detector array, but is not required to cover a large range of wavelengths. For example, the range of wavelengths is a single band/wavelength. Alternatively, the band is preferably 10nm or less. More than 100nm for a band would likely diminish the signal from a change in the index of refraction to zero. The shift in resonant peaks observed with substance binding
15 is, for example, detected as a decrease or increase in signal intensity at a particular pair of wavelengths, such as shown by way of illustration in FIG. 4. By extension, the signal intensity shift is optionally detected by observing multiple wavelengths simultaneously as is shown in the spectrum in FIG. 4.

Another embodiment of the invention, shown by way of example, in FIGs. 5a and 5b, includes a device comprising a plurality of nanoparticles 100, and a noble metal film 110 comprising a first side and a second side, the plurality of nanoparticles being located on the second side of the noble metal film. The device further includes a binding sample 5 120 coating said second side of said metal film, a light-sensitive, semiconductor detector array 130 located at a distance from the first side of the noble metal film, and an insulator located between the noble metal film and the light-sensitive, semiconductor detector array. The insulator comprises air, glass, a microlens 150 (shown in FIG. 5a), and/or a microchannel plate glass 160 (shown in FIG. 5b). Examples of illustrative insulators are 10 found in U.S. Patent No. 4,695,719 to Wilwerding, incorporated herein by reference.

Optionally, the noble metal film comprises gold, silver, copper, or platinum.

Optionally, the semiconductor detector array comprises a GaAs detector array, an InGaAs detector array, a Si detector array, or a HgCaTe detector array.

Optionally, the nanoparticles comprise noble-metal-coated nanoparticles and 15 noble metal nanoparticles. Optionally, the noble-metal-coated nanoparticles comprise gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, and platinum-coated nanoparticles, wherein the noble metal nanoparticles comprise gold nanoparticles, silver nanoparticles, copper nanoparticles, or platinum nanoparticles.

Optionally, the detector array comprises a focal plane array coupled to a readout integrated circuit.

Optionally, the device comprises a wavelength-restricted or wavelength-selectable light source operable to illuminate the binding sample. Optionally, the light source

5 comprises a light-emitting diode,,a laser diode or, a laser.

Optionally, the device further includes an insulator located between the detector array and the noble metal film.

Optionally, the binding sample comprises a biological sample and a chemical compound. Optionally, the biological sample comprises a protein.

10 Another embodiment of the invention is implemented, for example, as an olfactory protein binding sensor. In this embodiment, the semiconductor detector array is implemented using a focal plane detector array and Read-Out integrated circuit (“ROIC”). The focal plane detector array and the ROIC are used to detect plasmons generated from nanostructural changes in the olfactory receptor complex that occur with

15 odorant binding. The olfactory receptors will be in a complex with G-proteins, a lipid membrane and gold nanoparticles. Odorants reversibly bind to the olfactory receptors and change the mass and nanostructure of the complex. This change in mass results in a plasmon generated in the gold nanoparticles. The plasmon is detected as a decrease in light measured by a photodiode of the focal plane detector array. The change in

photodiode currents within the array is read out by the ROIC and an image of the response of the array of sensors is captured. A decrease in pixel intensity indicates binding of an odorant at the sensor corresponding to that pixel.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings without departing from the true scope and spirit of the invention. It is therefore to be understood that the scope of the invention should be determined by referring to the following appended claims.

What is claimed is:

1. A device comprising:

a plurality of nanoparticles;

5 a noble metal film comprising a first side and a second side, said plurality of nanoparticles being located on said second side of said metal film;

a binding sample contacting said second side of said metal film; and

a light-sensitive, semiconductor detector array located at a distance less than 200 nanometers from said first side of said metal film.

10

2. The device according to claim 1, wherein said metal film comprises one of gold, silver, copper, and platinum.

3. The device according to claim 1, wherein said semiconductor detector array comprises
15 one of a GaAs detector array, an InGaAs detector array, a Si detector array, and a HgCaTe detector array.

4. The device according to claim 1, wherein said nanoparticles comprise one of noble-metal-coated nanoparticles and noble metal nanoparticles.

20

5. The device according to claim 4, wherein said noble-metal-coated nanoparticles comprise one of gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, and platinum-coated nanoparticles,

wherein said noble metal nanoparticles comprise one of gold nanoparticles, silver nanoparticles, copper nanoparticles, and platinum nanoparticles.

6. The device according to claim 1, wherein said detector array comprises a focal plane array coupled to a readout integrated circuit.

7. The device according to claim 1, further comprising a wavelength-selectable light source operable to illuminate said binding sample.

8. The device according to claim 7, wherein said light source comprises one of a light-emitting diode, a laser diode, and a laser.

9. The device according to claim 1, further comprising an insulator located between said detector array and said noble metal film.

10. The device according to claim 1, wherein said binding sample comprises one of a biological sample and a chemical compound.

11. The device according to claim 10, wherein said biological sample comprises a
5 protein.

12. The device according to claim 1, further comprising one of an insulator and a semiconductor located between said light-sensitive, semiconductor detector array and said first side of said metal film.

10

13. The device according to claim 12, wherein said insulator comprises one of air and glass, and said semiconductor comprises one of silicon, SiO₂, GaAs oxide, InGaAs oxide, and HgCaTe oxide.

15

14. A device comprising:

a plurality of nanoparticles;

a noble metal film comprising a first side and a second side, said plurality of nanoparticles being located on said second side of said metal film;

a binding sample contacting said second side of said metal film;

a light-sensitive, semiconductor detector array located at a distance from said first side of said metal film; and

an insulator located between said noble metal film and light-sensitive,

5 semiconductor detector array, wherein said insulator comprises at least one of air, glass, a microlens, and a microchannel plate glass.

15. The device according to claim 14, wherein said metal film comprises one of gold, silver, copper, and platinum.

10

16. The device according to claim 14, wherein said semiconductor detector array comprises one of a GaAs detector array, an InGaAs detector array, a Si detector array, and a HgCaTe detector array.

15 17. The device according to claim 14, wherein said nanoparticles comprise one of noble-metal-coated nanoparticles and noble metal nanoparticles.

18. The device according to claim 17, wherein said noble-metal-coated nanoparticles comprise one of gold-coated nanoparticles, silver-coated nanoparticles, copper-coated nanoparticles, and platinum-coated nanoparticles,

wherein said noble metal nanoparticles comprise one of gold nanoparticles, silver nanoparticles, copper nanoparticles, and platinum nanoparticles.

19. The device according to claim 14, wherein said detector array comprises a focal plane array coupled to a readout integrated circuit.

20. The device according to claim 14, further comprising a light source operable to illuminate said binding sample.

21. The device according to claim 20, wherein said light source comprises one of a light-emitting diode, a laser diode, and a laser.

22. The device according to claim 14, further comprising an insulator located between said detector array and said noble metal film.

23. The device according to claim 14, wherein said binding sample comprises one of a biological sample and a chemical compound.

24. The device according to claim 23, wherein said biological sample comprises a
5 protein.

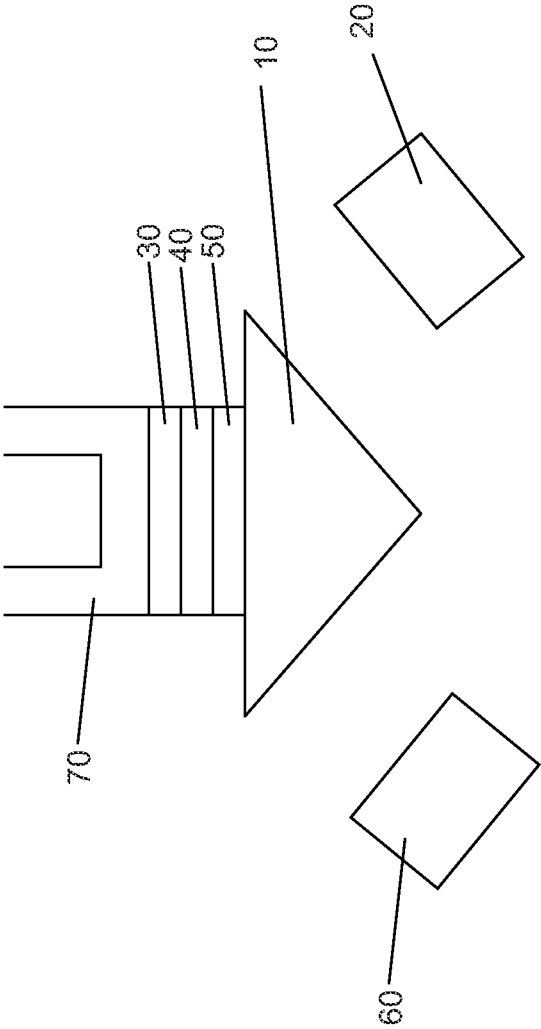
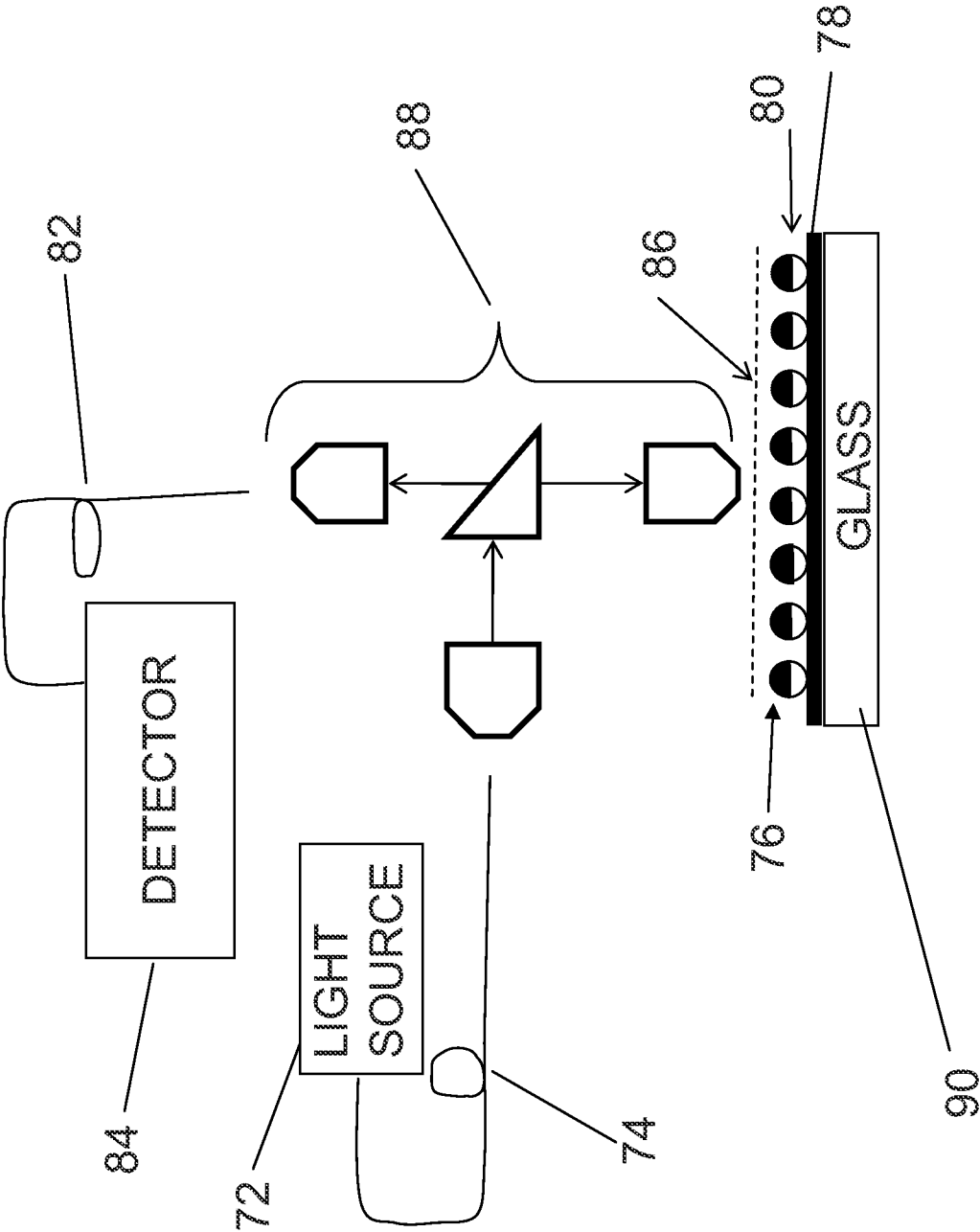


FIG. 1 PRIOR ART



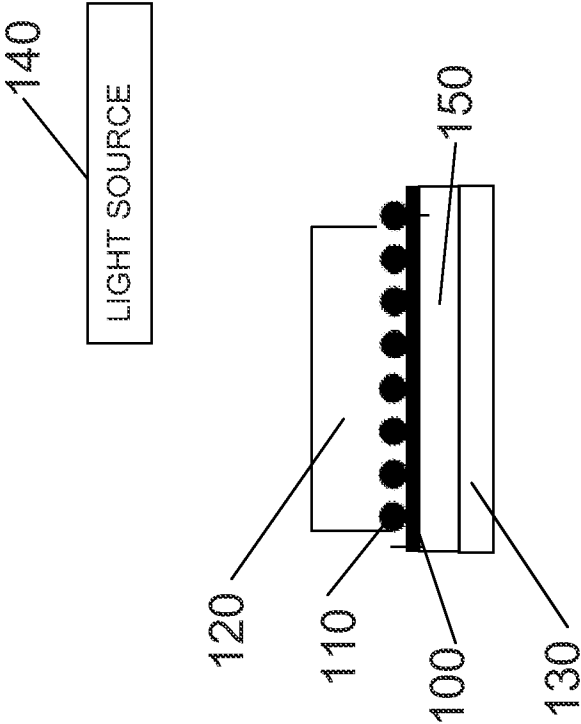


FIG. 3a

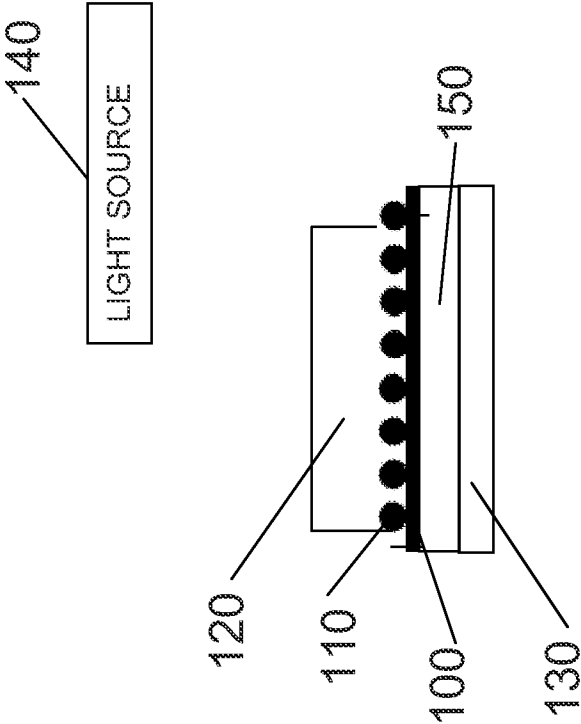


FIG. 3b

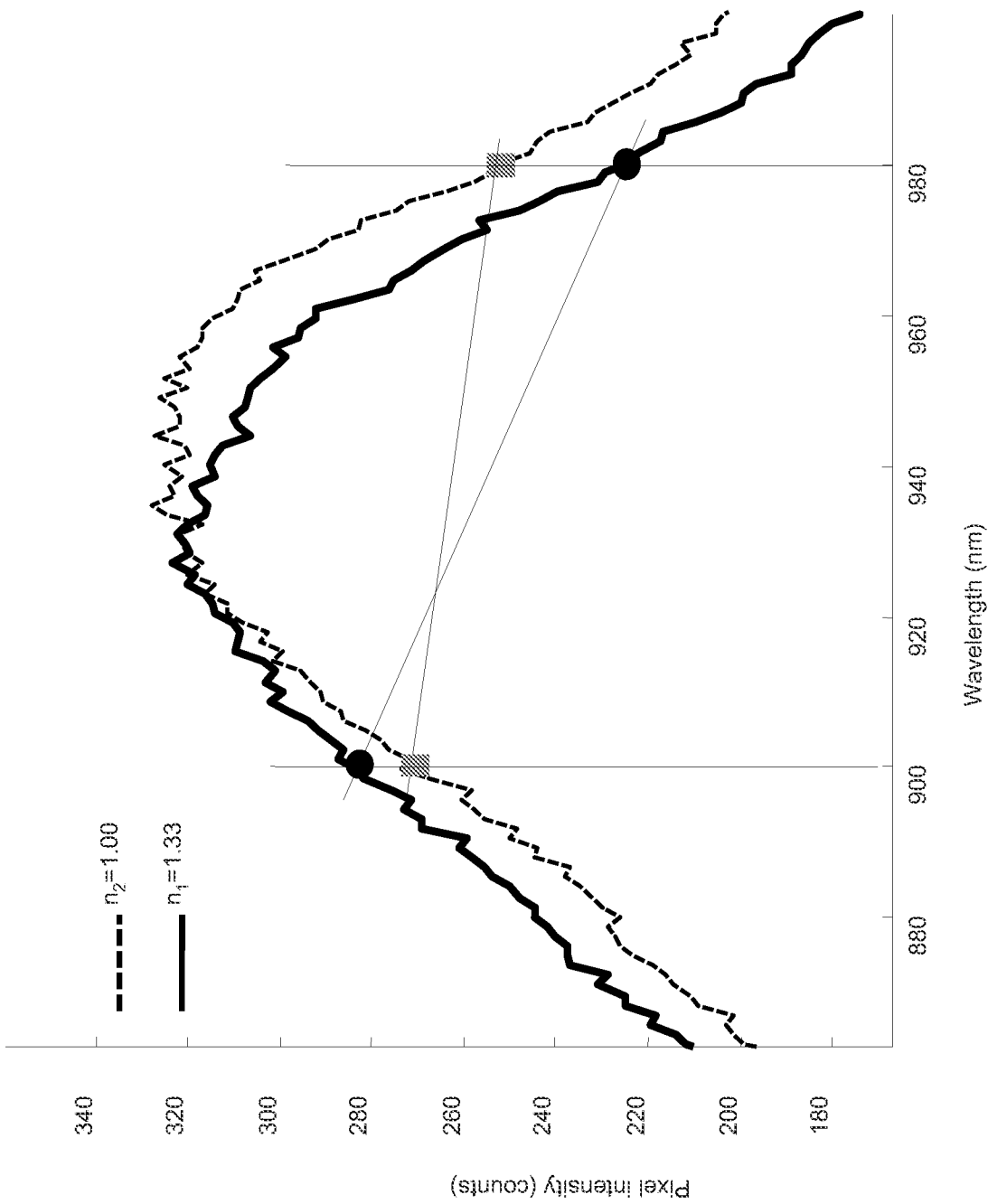
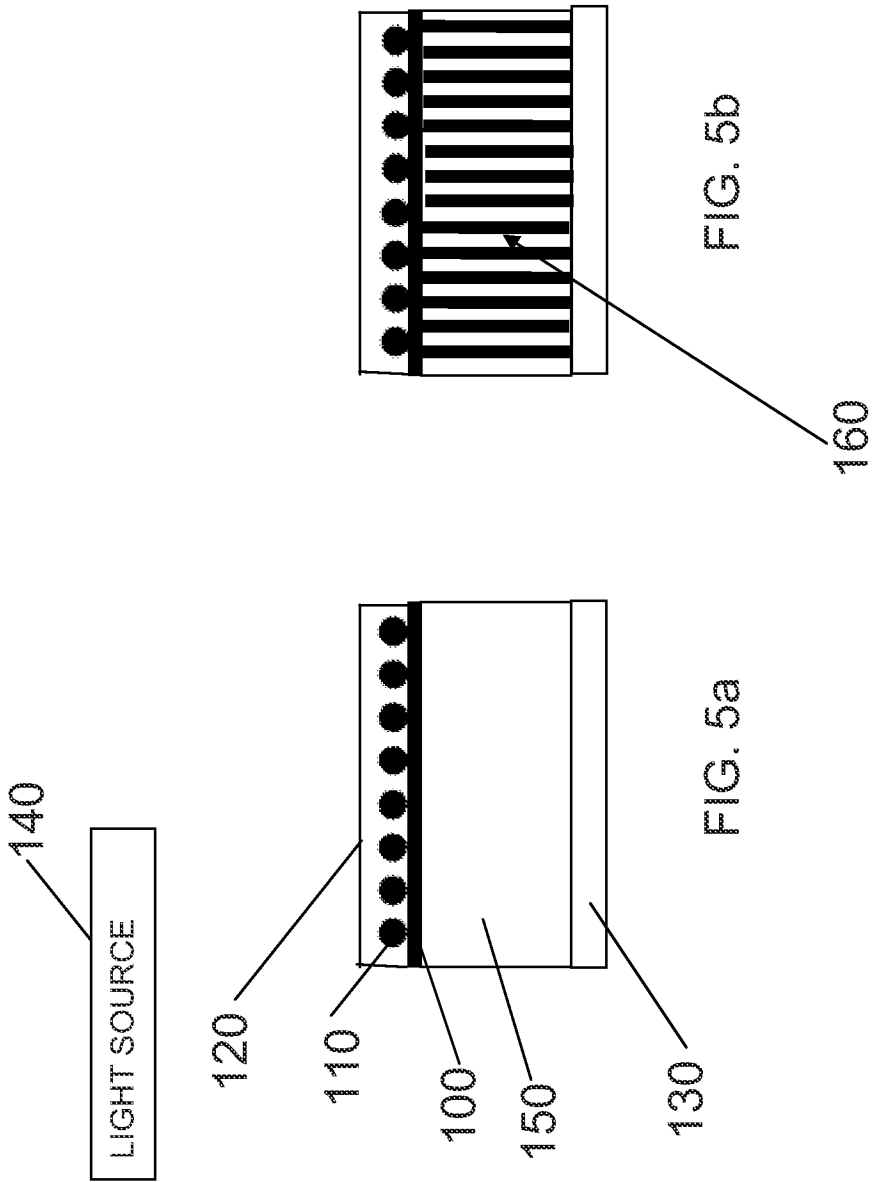


FIG. 4



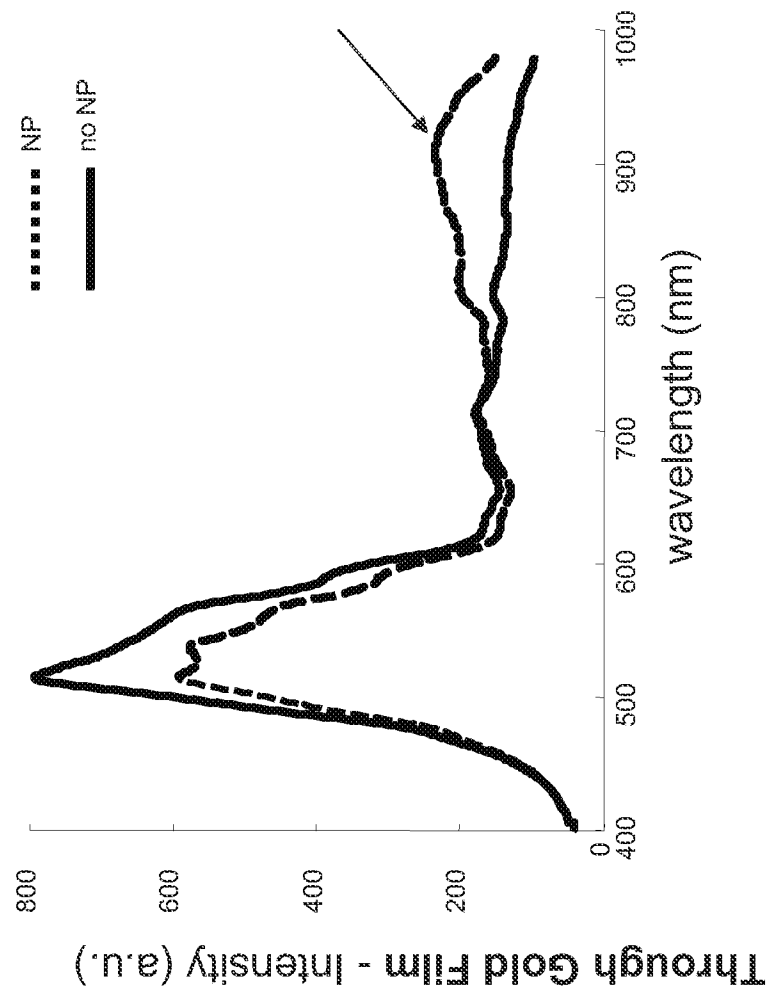


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/038916

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01N 21/00 (2009.01)

USPC - 977/954

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)

IPC(8) - G01N 21/00 (2009.01)

USPC - 257/431-466; 435/287.1-288.7; 977/954,957-959

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)

USPTO EAST System (US, USPG-PUB, EPO, JPO, DERWENT), GoogleScholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0034729 A1 (POPONIN) 16 February 2006 (16.02.2006) entire document	1-24
Y	US 2007/0154967 A1 (SUNDARARAJAN et al) 05 July 2007 (05.07.2007) entire document	1-24
Y	US 6,579,721 B1 (NATAN et al) 17 June 2003 (17.06.2003) entire document	11, 24

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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

27 May 2009

Date of mailing of the international search report

04 JUN 2009

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774