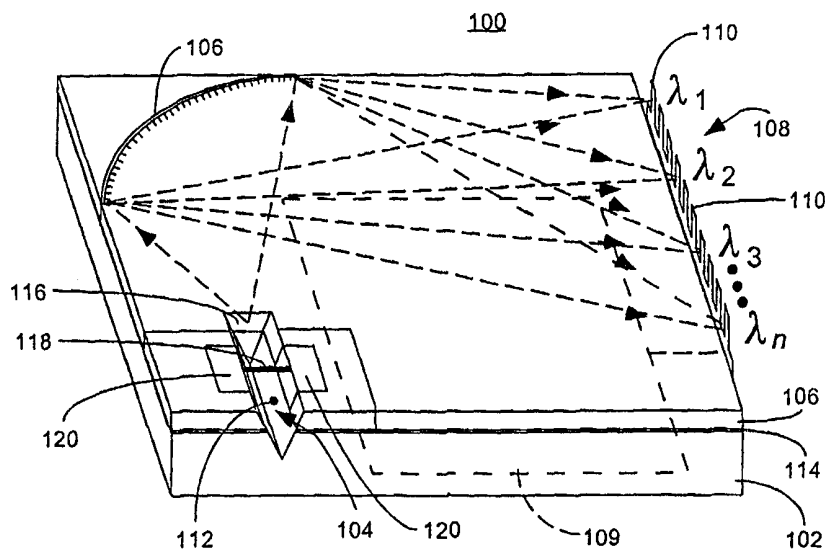


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : G01N 21/00	A2	(11) International Publication Number: WO 00/54030 (43) International Publication Date: 14 September 2000 (14.09.00)
(21) International Application Number: PCT/US00/06075 (22) International Filing Date: 9 March 2000 (09.03.00) (30) Priority Data: 09/267,292 12 March 1999 (12.03.99) US (71) Applicant: LOCKHEED MARTIN ENERGY RESEARCH CORPORATION [US/US]; Bethel Valley Road, P.O. Box 2008, Oak Ridge, TN 37831-6255 (US). (72) Inventors: RAJIC, Slobodan; 1006 Royal Mew Court, Knoxville, TN 37922 (US). DATSKOS, Panagiotis, George; 8444 Mecklenburg Court, Knoxville, Tennessee 37923 (US). EGERT, Marybeth; 109 Culver Road, Oak Ridge, TN 37830 (US). (74) Agents: STEELE, J., Rodman, Jr. et al.; Quarles & Brady LLP, Suite 400, 222 Lakeview Avenue, P.O. Box 3188, West Palm Beach, FL 33402-3188 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>

(54) Title: INTEGRATED CALORIMETRIC SPECTROMETER



(57) Abstract

A micro-instrument for detecting a chemical is formed on a coin-sized semiconductor substrate. A waveguide is formed by a semiconductor layer disposed on the substrate. The waveguide semiconductor layer has a groove forming an entrance aperture for receiving polychromatic radiation. An infrared emitter is disposed in the groove for generating the polychromatic radiation. An array of micro-mechanical thermal detectors can be formed integrally with the substrate. Each of the thermal detectors has a measurable characteristic physical parameter and each of the thermal detectors has a coating exhibiting a preferential adsorption of at least one chemical to be sensed. A self focusing reflection grating is formed integrally with the waveguide semiconductor layer for directing a monochromatic spectrum onto the array responsive to the polychromatic radiation, such that each of the thermal detectors receives different wavelengths of the monochromatic spectrum.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

INTEGRATED CALORIMETRIC SPECTROMETER

Statement Regarding Federally-Sponsored
Research or Development

This invention was made with government support under contract
5 DE-AC05-96OR22464, awarded by the United States Department of Energy to Lockheed
Martin Energy Research Corporation, and the United States Government has certain rights in
this invention.

Background of the Invention1. Field of the Invention

10 This invention relates to the field of calorimetric spectroscopy, and in particular, to an
integrated calorimetric spectrometer embodied as a micro-instrument integrated on a
semiconductor substrate.

2. Description of Related Art

Determining the presence and identity of unknown chemical species is challenging.
15 Gravimetric, that is mass based, sensor technologies such as surface acoustic wave devices,
quartz crystal micro-balances, micro-cantilever chemical detectors, and the like, sometimes
have the required sensitivity but typically lack chemical specificity. These kinds of sensors
achieve chemical selectivity through the use of highly specific chemical binding coatings.
This approach may work in some cases, however it is not usually possible to find an
20 absolutely selective coating. Even if a preferentially adsorbing coating is located, it will
likely adsorb an entire family of chemicals which will provide a good clue as to the identity
of the target's species but not a unique identification. Available chemical sensors such as

those described above, which can detect the presence and identity of unknown chemical analytes with enhanced sensitivity are either too large, too cumbersome, lack high selectivity and specificity or too costly for most purposes.

Chemical analysis has been undertaken in a number of different ways, including spectral analysis and thermal analysis. An apparatus used in spectral analysis is the monochromator. A monochromator is a device for isolating a narrow portion of a spectrum. Apparatus which can be used as thermal detectors in thermal analysis include, for example, bolometers, thermopiles, pyroelectrics and micro-cantilevers. A bolometer, for example, is a very sensitive thermometer whose electrical resistance varies with temperature and which is used in the detection and measurement of feeble thermal radiation. Bolometers have been especially useful in the study of infrared spectra.

Alternative methods and apparatus for chemical detection using calorimetric spectroscopy are taught in commonly owned, copending application serial no. 08/899,978, now US Patent No. . In accordance with the calorimetric spectroscopy taught therein, a chemical sensor capable of the selective and sensitive detection of chemical analytes comprises a monochromator and a thermal infrared detector array, for example, a micro-bolometer, a thermopile, a pyroelectrics or a micro-cantilever. Such a chemical sensor can detect the presence of minute amounts of chemical analytes, for example less than parts per trillion (ppt), with increased selectivity by allowing a simultaneous determination of the identity of the unknown species.

A thermal detector surface is provided with an active detector surface of individual sensing elements coated with an appropriate chemical layer having an affinity for a family or a group of the target chemical or chemicals and placed into a chamber into which a sample is drawn. The use of highly selective chemical coatings is not required.

As the sampling continues, molecules of the target chemicals adsorb on the thermal detector surface causing a measurable change in the thermal detector. If a micro-bolometer is used as the thermal detector, for example, its electrical resistance will change during the adsorption. After this passive sampling is complete, a photothermal spectrum can be
5 obtained for the chemicals adsorbed on the thermal detector surface by scanning a broad band wavelength region with the aid of a monochromator or other tunable sources including, for example, light emitting diodes and tunable lasers. During this active sampling, the temperature of the particular detector pixels for the wavelengths at which the adsorbed chemical absorbs photons will rise proportionally to the amount of analyte deposited and heat
10 absorbed. Signal-to-noise ratios and detection speed are both improved. Since different pixels will be exposed to different wavelengths, a very sensitive and unique photothermal signature response can thus be obtained. Since the passive sampling is not selective and can be measured only in real time, the passive sampling can act as a trigger for the active sampling.

15 The thermal detector surface can be regenerated after the test, for example by ohmic heating of the detector element or by focusing the radiation from a hot blackbody radiation source or laser source onto the detector surface.

Notwithstanding the improvements in selectivity and resolution achieved by the methods and apparatus for calorimetric spectroscopy taught in serial no. 08/899,978, there is
20 a need to improve selectivity and resolution even more, and to produce chemical detection sensors in a less expensive and more efficient manner.

Summary of the Invention

The need to improve selectivity and resolution even more, and to produce chemical

detection sensors in a less expensive and more efficient manner can be satisfied, in accordance with the inventive arrangements, by scaling down the size of the sensors developed for calorimetric spectroscopy described above to coin-sized packages, thus creating true micro-instruments, rather than merely small sensors. In accordance with the inventive arrangements, such sensors have been literally reinvented as micro-instruments in which all components can be integrated on the same semiconductor substrate wafer. In a presently preferred embodiment, a two dimensional waveguide micro-instrument has all of the necessary components integrated on the same semiconductor substrate, namely: an infrared (IR) source, a linear thermal detector array, a dispersive element and a waveguide. Control circuitry can also be integrated on the substrate, for example onto the side opposite the components. The IR source can be an IR receiving channel for an IR source off of the substrate or direct source on the substrate. Micro-cantilevers, micro-bolometers and micro-balances can be integrally formed on the substrate or can be formed separately and bonded to the substrate, for example adhesively bonded. Such a micro-instrument is the solution to achieving minimum size and maximum performance at a lower cost.

A micro-instrument for detecting a chemical, in accordance with the inventive arrangements, comprises: a semiconductor substrate; a waveguide formed by a semiconductor layer disposed on the substrate, the waveguide semiconductor layer having an entrance aperture for receiving polychromatic radiation; an array of micro-mechanical thermal detectors attached to the substrate, each of the thermal detectors having a measurable characteristic physical parameter and each of the thermal detectors having a characteristic chemistry exhibiting a preferential adsorption of at least one chemical to be sensed; and, a self focusing dispersion element formed integrally with the waveguide semiconductor layer for reflecting a monochromatic spectrum onto the array responsive to the polychromatic

radiation, each of the thermal detectors receiving different wavelengths of the monochromatic spectrum.

The micro-instrument can further comprise control circuitry formed integrally with the substrate on a side of the substrate opposite the waveguide semiconductor layer and
5 coupled to the thermal detectors for measuring changes in the characteristic physical parameter after adsorption of at least one chemical to be detected and responsive to the monochromatic spectrum.

At least the waveguide semiconductor layer can have a groove, one end of the groove exposing a portion of an edge of the waveguide semiconductor layer, the exposed portion of
10 the edge forming the entrance aperture. Another end of the groove is open for receiving the polychromatic radiation from a source external to the instrument.

Alternatively, the micro-instrument can further comprise a source of the polychromatic radiation disposed in the groove. A micro-bridge can extend across the groove, the micro-bridge having a coating, for example tungsten, which emits the
15 polychromatic radiation responsive to heating.

The micro-instrument can further comprise a thermal barrier, for example a coating, between the waveguide semiconductor layer and the source of the polychromatic radiation disposed in the groove.

The array of micro-mechanical thermal detectors can be formed integrally with the
20 substrate or can be formed from at least one different substrate material and bonded in position.

The self focusing dispersion element can comprise a self focusing reflection grating.

Brief Description of the Drawings

Figure 1 is a perspective view of a chemical detection micro-instrument in accordance with the inventive arrangements.

Figures 2 and 3 illustrate alternative embodiments for forming and integrating micro-mechanical thermal detectors.

Figures 4 and 5 illustrate respective micro-mechanical thermal detectors which can be used with and formed integrally with the substrate of the micro-instrument.

Figure 6 is a diagrammatic representation of a chemical detector, useful for understanding the context and operational principles of the inventive arrangements.

Detailed Description of the Preferred Embodiments

A chemical detector which is not a micro-instrument in accordance with the inventive arrangements taught herein, but which is nevertheless useful for explaining the underlying principles of operation of the micro-instruments embodied in the inventive arrangements taught herein, is shown in Figure 6. The chemical detector, generally designated by reference numeral 10, comprises a broad band light source 12, a monochromator 14 and an array 16 of sensing elements, for example thermal sensing elements. Broad band is defined as polychromatic. The array forms a thermal infrared detector array and can be embodied as a micro-bolometer, as shown. Chemical detector 10 can detect the presence of minute amounts of chemical analytes, for example less than parts per trillion (ppt), with increased selectivity by allowing a simultaneous determination of the identity of the unknown species.

The thermal detector array 16 comprises a plurality of individual sensing elements 18, 20, 22, . . . , 24. The individual sensing elements are provided with respective active detector surfaces 26, 28, 30, . . . , 32 coated with an appropriate chemical layer having an affinity for

the family or group of the target chemical or chemicals. A layer of gold, for a first example, can be utilized for detecting mercury or sulfur containing chemicals. A layer of hydrated silica or platinum or other gas chromatograph coating, for a second example, can be utilized for detecting trinitrotoluene (TNT). The use of highly selective chemical coatings is not
5 required. The application of the chemical layer corresponds to a first step of a method.

The sensing elements have respective read out terminals 34, 36, 38, . . . , 40, but are coupled to a source of ground potential 42 by a common bus 44. The sensing elements have a characteristic physical parameter which can be measured. In the case of a bolometer, for example, this parameter is electrical resistance. In the case of a micro-cantilever, for
10 example, this parameter is the amount of bending. The read out terminals provide respective electrical signals representative of the physical parameter of the individual sensing elements.

The array 16 can be placed into a chamber 46, into which a sample is drawn through an inlet or opening 48 defined by a valve 50, shown diagrammatically by a conical ring.

As passive sampling continues, molecules of the target chemicals adsorb on the
15 coated individual sensing elements. This adsorption will result in physical changes on the thermal detectors. If a micro-bolometer is used as the thermal detector, for example, its electrical resistance will change during the adsorption. If a micro-cantilever is used as the thermal detector, for example, its bending characteristics will change during the adsorption. If a thermopile array is used as the thermal detector, for example, its voltage will change
20 during the adsorption. If a pyroelectric array is used as the thermal detector, for example, its capacitance and/or current will change during the adsorption. Exposing the sensing elements to the sample, in a chamber as described, or otherwise, is a further method step.

After adsorption and passive sampling are complete, a photothermal spectrum can be obtained for the chemicals adsorbed on the surfaces of the sensing elements by scanning a

broad band wavelength region with the aid of the broad band light source 12 and the monochromator 14. In this active sampling scheme, the monochromator 14 directs different wavelengths of light onto different ones of the individual sensing elements in the array 16. The monochromator generates a monochromatic spectrum responsive to the polychromatic source. The array 16 can be removed from the chamber 46 or the chamber 46 can be provided with another aperture or opening, or infrared transmissive window or panel, for the light coming from the monochromator 14. Removing the array 16 from contact with or exposure to the sample, by evacuating the sample from chamber 46 and/or removing the array 16 from the chamber 46, or otherwise terminating the exposure, is another method step.

In Figure 6, light of wavelength λ_1 is directed from the monochromator 14 to detector 22, light of wavelength λ_2 is directed from the monochromator 14 to detector 20 and light of wavelength λ_3 is directed from the monochromator 14 to detector 18. For the different ones of the wavelengths λ_1 , λ_2 and $\lambda_3, \dots, \lambda_n$ at which the adsorbed chemical or chemicals absorb photons, the temperature of those particular detector pixels will rise proportionally to the amount of analyte deposited at specific wavelengths on the detector surface, and in turn, the amount of heat absorbed by the deposited analyte. Since pixels on different ones of the individual detectors will be exposed to different ones of the wavelengths by the action of the monochromator 14, a very sensitive and unique photothermal signature response, or spectrum, across the array 16 can thus be obtained. If the sensor utilizes micro-bolometers, for example, this spectrum is based on the respective resistance changes of the individual sensing elements. If the sensor utilizes micro-cantilevers, for example, this spectrum is based on the respective bending characteristics of the individual sensing elements. The detection resolution depends on the quality of the optical system and the density and number of thermal detector array pixels used in the array. Recording and processing the photothermal signature,

indicative of the spectral response of the detector array 16, are yet further method steps.

After the test, the thermal detector surface, formed by the sensing elements, can be regenerated by heating the array 16. One alternative, for example, is by focusing the radiation from a hot blackbody radiation source or a laser source onto the detector.

5 A micro-instrument 100, based on the underlying principles explained in connection with Figure 6, but in accordance with the inventive arrangements taught herein, is shown in Figure 1. The instrument 100 is embodied on a silicon semiconductor chip or substrate 102. The chip is illustrated as substantially square, but can be other shapes. The chip is coin-sized, a handy designation which corresponds to dimensions in the range of approximately ½ inch
10 to 1 inch. The dimensions can be expected to decrease as integration technology improves. Arrays of such micro-instruments will of course be larger in the aggregate.

The instrument comprises a plurality of components, which are formed integrally on the chip 102. These components include a source 104 of polychromatic light, a dispersive self focusing waveguide 106 and an array 108 of micro-mechanical thermal detectors 110.

15 The source 104 of polychromatic light is preferably an infrared (IR) source. The source 104 is formed in part by a groove 112, for example a v-shaped groove, which extends through the waveguide layer 106, into the substrate 102 and through an oxide interface layer 114 between the waveguide layer and the substrate. One end of the groove 112 opens a portion 116 of the side edge of the waveguide layer 106 to define an input aperture to the
20 waveguide layer. The other end opens to the exterior of the micro-instrument 100 and provides an input for a beam of polychromatic radiation from an external source.

Alternatively, a free standing micro-bridge 118 can be etched into a thermal barrier 120 can be the structural component of an IR micro-source. The thermal barrier is preferably applied to provide thermal isolation from the larger waveguide layer 106 near the micro-bridge 118.

Tungsten deposited onto the micro-bridge can form the micro-source emitter. Thus, there will be no direct contact between the supporting micro-bridge and the IR transmitting waveguide. However, the IR source and waveguide monochromator will be located on the same silicon substrate wafer. Polychromatic light that enters the waveguide through aperture 116 will be dispersed by the self focusing reflection grating into a monochromatic spectrum falling onto the array of micro-mechanical detectors, each of the detectors receiving radiation of a different wavelength.

The micro-mechanical thermal detectors can include, for example, micro-cantilevers, micro-bolometers and micro-balances. The array 108 of micro-mechanical thermal detectors can be integrally formed on the substrate 102 as shown in Figure 2 or can be formed on a separate substrate 124 and attached, for example by fusion bonding or adhesive bonding such as epoxy adhesive, to the substrate 102. The micro-mechanical detectors can be integrally formed from the same substrate as the other components when the substrate material is suitable for the detectors. The detectors are so thin, for example as thin as 0.5 microns, that merely coating the detectors with a preferential adsorptive coating is likely to distort the detectors even absent thermal loading from the light source. Accordingly, it is an advantage that the selective adsorptive coatings used in the apparatus explained in connection with Figure 6 can be omitted, in many cases, by forming the array from a substrate having the appropriate chemistry to directly adsorb the target chemical to be sensed. One or more different materials can therefore be beneficial with regard to compatibility with a particular adsorption characteristic. Suitable substrates for the thermal detectors in the array can include, for example, Ge, GaAs, InAs, InP, InSb, InGaAs, HgCdTe, SiC and GaN.

The dispersive self focusing waveguide 106 can comprise a self focusing reflection grating. Control circuitry 109 can be disposed on the same substrate 102, but on the opposite

side of the components noted above. The micro-instrument will be capable of detecting many different chemicals, including for example chemical warfare agents, in real-time, based on their photo-thermal signature. The operation of the micro-instrument is similar to the operation of the calorimetric spectrometer 10 explained in connection with Figure 6.

5 If silicon is used as the propagation medium for forming the waveguide layer, photons above 1.1 μm in wave length will be transmitted through the thin waveguide layer, which is preferably approximately 20 μm thick.

 The control circuitry 109 is coupled to the thermal detectors for measuring changes in the characteristic physical parameter after adsorption of at least one chemical to be detected
10 and responsive to the monochromatic spectrum.

 Two suitable configurations for the micro-mechanical devices are shown in Figures 4 and 5. In Figure 4 a V-shaped thermal detector 110A is formed on substrate 132. In Figure 5, a thermal detector 110B has a serpentine legs to provide greater movement and thus greater sensitivity.

15 By stacking multiple micro-instruments, each with its own detector array, achieve increases in either spectral resolution or spectral dynamic range, or both, can be achieved. Fabricating the detector array from other materials can accelerate the adsorption of target chemistry, however the selectivity would still be derived from the temperature spectrum and not by preferential chemical adsorption as in other sensors. Numerous applications are
20 envisioned from both the military and industrial sectors requiring a small, low cost chemical detection tool that will have a level of performance approaching a large and delicate laboratory instrument.

What is claimed is:

1 1. A micro-instrument for detecting a chemical, comprising:
2 a semiconductor substrate;
3 a waveguide formed by a semiconductor layer disposed on said substrate, said
4 waveguide semiconductor layer having an entrance aperture for receiving polychromatic
5 radiation;
6 an array of micro-mechanical thermal detectors attached to said substrate, each of said
7 thermal detectors having a measurable characteristic physical parameter and each of said
8 thermal detectors having a characteristic chemistry exhibiting a preferential adsorption of at
9 least one chemical to be sensed; and,
10 a self focusing dispersion element formed integrally with said waveguide
11 semiconductor layer for reflecting a monochromatic spectrum onto said array responsive to
12 said polychromatic radiation, each of said thermal detectors receiving different wavelengths
13 of said monochromatic spectrum.

1 2. The micro-instrument of claim 1, further comprising control circuitry formed
2 integrally with said substrate on a side of said substrate opposite said waveguide
3 semiconductor layer and coupled to said thermal detectors for measuring changes in said
4 characteristic physical parameter after adsorption of at least one chemical to be detected and
5 responsive to said monochromatic spectrum.

1 3. The micro-instrument of claim 1, wherein at least said waveguide semiconductor
2 layer has a groove, one end of said groove exposing a portion of an edge of said waveguide
3 semiconductor layer, said exposed portion of said edge forming said entrance aperture.

1 4. The micro-instrument of claim 3, wherein another end of said groove is open for
2 receiving said polychromatic radiation from a source external to said instrument.

1 5. The micro-instrument of claim 3, further comprising a source of said
2 polychromatic radiation disposed in said groove.

1 6. The micro-instrument of claim 5, further comprising a micro-bridge across said
2 groove, said micro-bridge having a coating which emits said polychromatic radiation
3 responsive to heating.

1 7. The micro-instrument of claim 6, wherein said coating comprises tungsten.

1 8. The micro-instrument of claim 6, further comprising a thermal barrier coating
2 between said waveguide semiconductor layer and said source of said polychromatic radiation
3 disposed in said groove.

1 9. The micro-instrument of claim 1, wherein said array of micro-mechanical thermal
2 detectors is formed integrally with said substrate.

1 10. The micro-instrument of claim 1, wherein said array of micro-mechanical thermal
2 detectors is formed from at least one different substrate material and bonded into position.

1 11. The micro-instrument of claim 1, wherein said self focusing dispersion element
2 comprises a self focusing reflection grating.

1 12. The micro-instrument of claim 1, wherein said semiconductor substrate and said
2 waveguide semiconductor layer are silicon.

1 13. The micro-instrument of claim 12, further comprising an oxide interface layer
2 between said semiconductor substrate and said waveguide semiconductor layer.

1 14. The micro-instrument of claim 1, wherein said source of said monochromatic
2 spectrum is an infrared source.

1 15. A micro-instrument for detecting a chemical, comprising:
2 a semiconductor substrate;
3 a waveguide formed by a semiconductor layer disposed on said substrate, said
4 waveguide semiconductor layer having a groove forming an entrance aperture for receiving
5 polychromatic radiation;
6 an infrared emitter disposed in said groove for generating said polychromatic
7 radiation;

8 an array of micro-mechanical thermal detectors formed integrally with said substrate,
9 each of said thermal detectors having a measurable characteristic physical parameter and each
10 of said thermal detectors having a characteristic chemistry exhibiting a preferential
11 adsorption of at least one chemical to be sensed; and,
12 a self focusing reflection grating formed integrally with said waveguide
13 semiconductor layer for directing a monochromatic spectrum onto said array responsive to
14 said polychromatic radiation, each of said thermal detectors receiving different wavelengths
15 of said monochromatic spectrum.

1 16. The micro-instrument of claim 15, wherein one end of said groove exposes a
2 portion of an edge of said waveguide semiconductor layer, said exposed portion of said edge
3 forming said entrance aperture.

1 17. The micro-instrument of claim 16, further comprising:
2 a thermal barrier integrally formed on opposite sides of said groove; and,
3 a micro-bridge formed integrally with said thermal barrier and spanning said groove,
4 said micro-bridge having a coating which emits said polychromatic radiation responsive to
5 heating.

1 18. The micro-instrument of claim 17, further comprising control circuitry formed
2 integrally with said substrate on a side of said substrate opposite said waveguide
3 semiconductor layer and coupled to said thermal detectors for measuring changes in said
4 characteristic physical parameter after adsorption of at least one chemical to be detected and
5 responsive to said monochromatic spectrum.

6 19. The micro-instrument of claim 15, further comprising:

7 a thermal barrier integrally formed on opposite sides of said groove; and,

8 a micro-bridge formed integrally with said thermal barrier and spanning said groove,

9 said micro-bridge having a coating which emits said polychromatic radiation responsive to

10 heating.

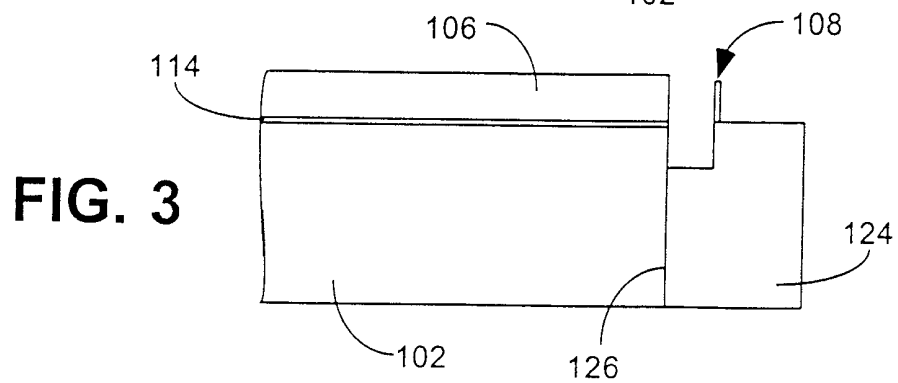
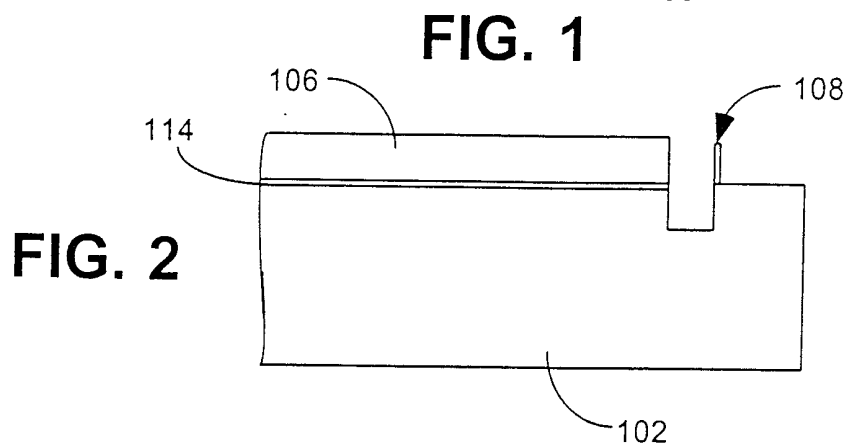
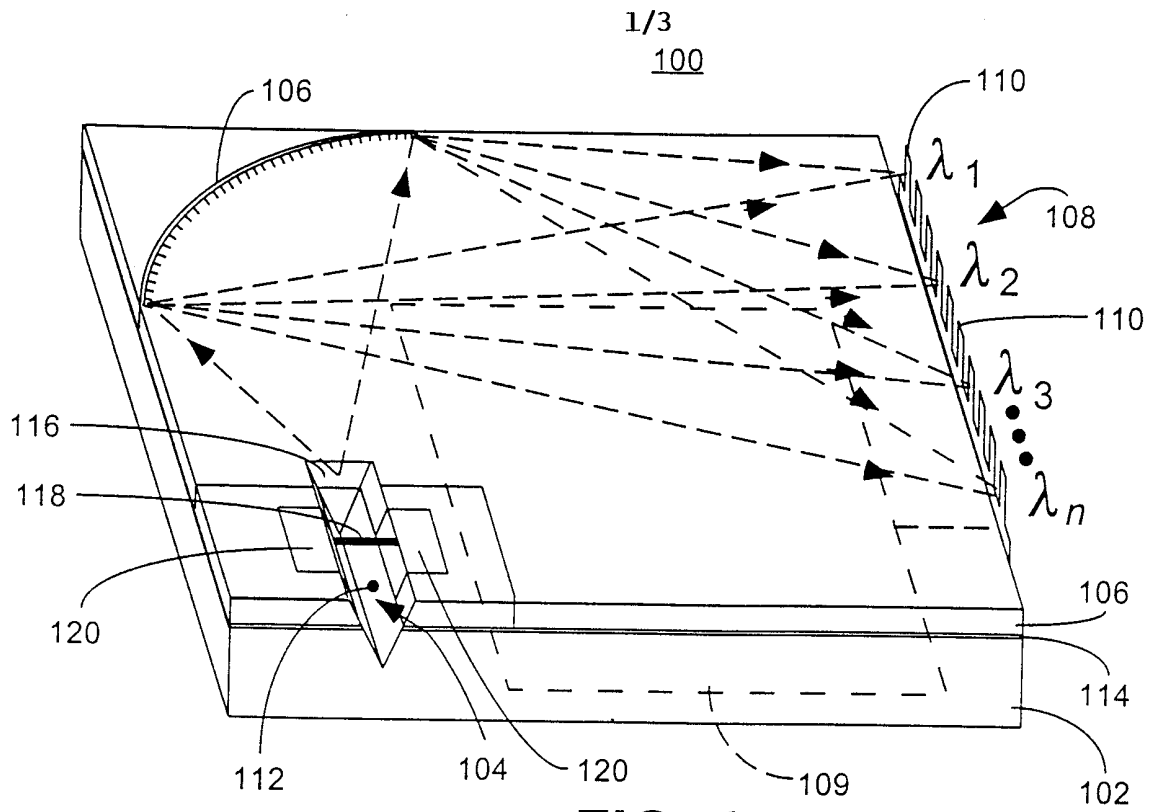
1 20. The micro-instrument of claim 15, further comprising control circuitry formed

2 integrally with said substrate on a side of said substrate opposite said waveguide

3 semiconductor layer and coupled to said thermal detectors for measuring changes in said

4 characteristic physical parameter after adsorption of at least one chemical to be detected and

5 responsive to said monochromatic spectrum.



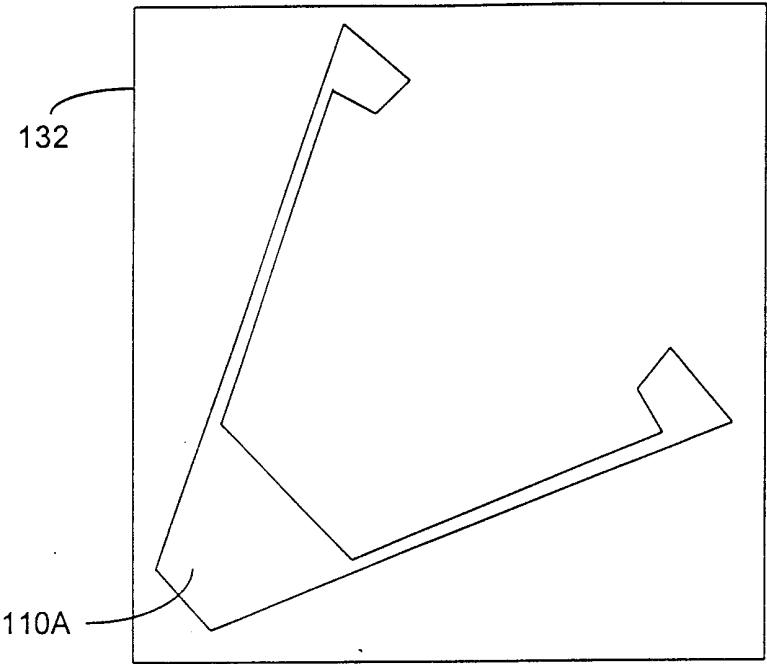


FIG. 4

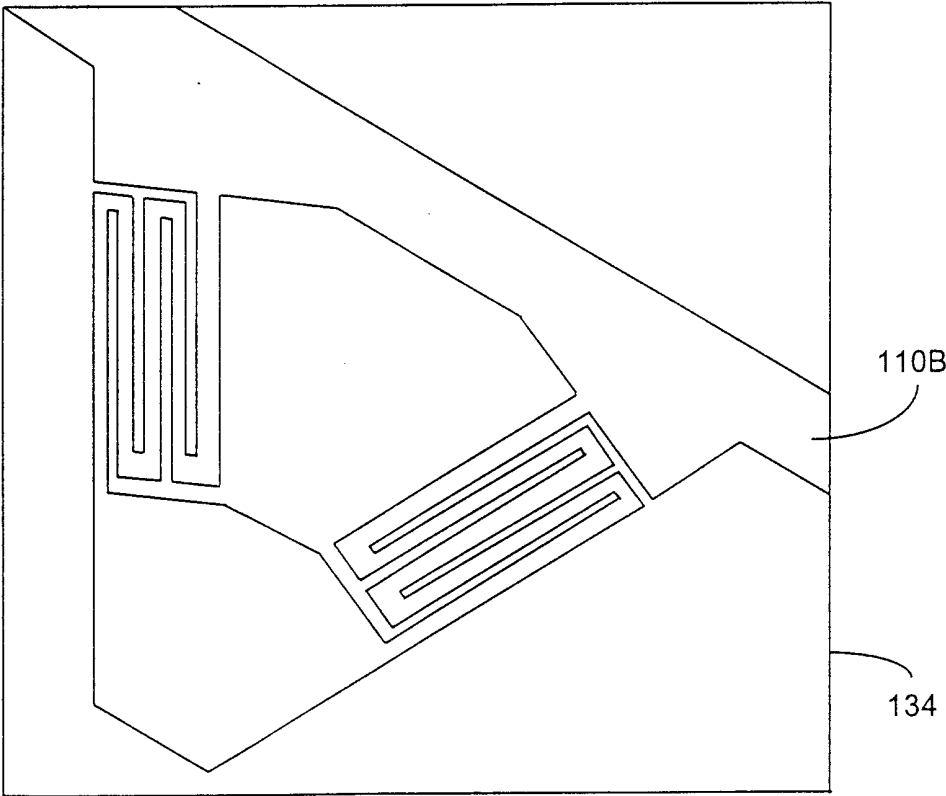


FIG. 5

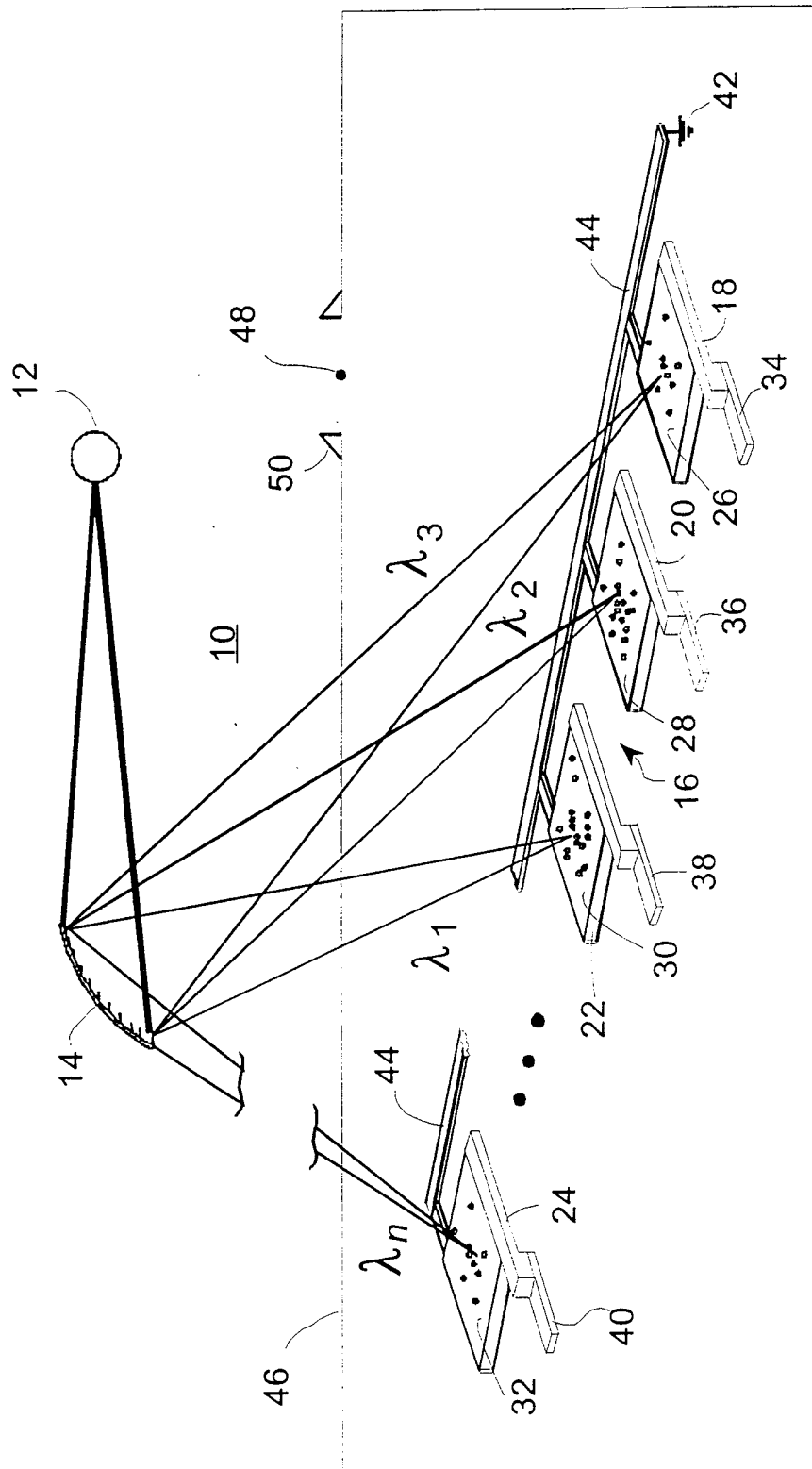


FIG. 6