The optical sensor contains an optical waveguide (1) with a substrate (104), waveguiding material (105), a cover medium (106) and a waveguide grating structure (101-103). By means of a light source (2), light can be emitted to the waveguide grating structure (101-103) from the substrate side and/or from the cover medium side. (101-103). With means of detection (11), at least two differing light proportions (7-10) radiated from the waveguide (1) can be detected. For carrying out a measurement, the waveguide can be immovably fixed relative to the light source (2) and the means of detection (11). The waveguide grating structure (101-103) itself consists of one or several waveguide grating structure units (101-103), which if so required can be equipped with (bio-)chemo-sensitive layers. The sensor permits the generation of absolute measuring signals.
OPTICAL SENSOR AND OPTICAL PROCESS FOR THE CHARACTERIZATION OF A CHEMICAL AND/OR BIO-CHEMICAL SUBSTANCE

CROSS REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF INVENTION

[0002] The invention concerns an optical sensor and an optical process for the characterization of a chemical and/or bio-chemical substance.


[0004] In EP 0 226 604 B1 and EP 0 482 377 A2, it is demonstrated, how the effective refractive index (resp., the coupling angle) of a chemo-sensitive grating coupler can be measured as a sensor signal. The sensor signal “effective refractive index” or “coupling angle” is a value which manifests a strong dependence on temperature.

[0005] Front-side in-coupling of light into a waveguide (refer to SPIE Vol. 1141, 192-200) is not practical, because a high positioning accuracy is required. In addition, the front-side of the wave guide has to be of good optical quality. In PCT WO 95/03538 it is demonstrated how the absolute out-coupling angle of a mode is measured. This value, however, without referencing manifests a high dependence on temperature. In PCT WO 97/09594, chirped waveguide gratings are presented, which, however, also manifest a dependence on temperature.

[0006] In Advances in Biosensors 2 (1992), 261-289 it is shown how the disturbing “pore diffusion” can be referenced away with the three-layer waveguide model. The refractive index of the waveguiding film manifests drift, while the layer thickness of the waveguiding film (sensor signal) remains stable. The layout is designed with movable mechanics, which does not permit rapid measurements. In addition, the sensor signal or the light emerging from the waveguide grating structure is recorded from the front side. Front side detection is unsuitable for a two-dimensional layout of waveguide grating structure units. Furthermore, the effective refractive indexes N(TE) and N(TM) for the two polarizations TE and TM are not simultaneously recorded, because for the recording of resonance coupling curves separated by angle a mechanical angular scan is carried out.

[0007] In U.S. Pat. No. 5,479,260, a bi-diffractive or multi-diffractive grating coupler is described, whereby the sensor signal is produced by the interferometry of two out-coupling beams of the same or of differing polarization (with the use of a polarizer). Interferometric measurements are complicated, because the intensities of the two beams have to be matched to one another. In addition, temperature fluctuations due to the interferometric signal generated by differing polarizations (using a polarizer) are only partially compensated.

[0008] In SPIE Vol. 2836, 221-234, a layout for a waveguide grating structure in connection with fluorescence or luminescence measurements is described. This layout, however, is not suitable for an (if necessary simultaneous) (absolute) temperature-compensated measurement on the basis of a direct detection. In addition, the waveguide grating structure is mounted on a revolving table.

[0009] In Applied Optics 20 (1981), 2280-2283, a temperature-independent optical waveguide is described, whereby the substrate is made of silicon. Silicon is absorbent in the visual spectral range. In the case of chemo-sensitive waveguide grating structures, however, the interaction takes place in preference from the substrate side. In addition, Applied Optics 20 (1981), 2280-2283, grating couplers which are not temperature-independent are described.

SUMMARY OF INVENTION

[0010] The invention presented here has the object of creating a (bio-)chemo-sensitive optical sensor and to indicate an optical process for the characterization of a (bio-)chemical substance, which do not have the above disadvantages. With the invention, in particular:

[0011] (1) sensor signals can be generated, which manifest a low dependence on temperature and/or a low dependence on the diffusion of the specimen liquid into the microropes of a waveguiding film;

[0012] (2) both the measurement of (absolute) sensor signals with respect to a direct detection (absolute out-coupling angles φ(TE) and φ(TM) for the TE- or TM-wave, effective refractive indexes N(TE) and N(TM) for the TE- or TM-wave, layer thickness t_p of the waveguiding film etc.) as well as the measurement of (absolute) sensor signals with respect to a marking detection (referenced fluorescence-, luminescence-, phosphorescence signals, etc.), are possible; and

[0013] (3) sensor signals remain stable with respect to a slight tilting and/or displacement of the waveguide grating structure, because (local and angular) differences of sensor signals or referenced sensor signals are measured.

[0014] The optical sensor according to the invention contains at least one optical waveguide with a substrate, waveguiding material, a cover medium and at least one waveguide grating structure, at least one light source, by means of which light can be emitted from the substrate side and/or from the cover medium side onto at least a part of the waveguide grating structure, and means for the detection of at least two differing light proportions, whereby with at least one detection agent light emitted into the substrate side and/or cover medium can be detected, whereby for the carrying out of a measurement the waveguide can be fixed immovably with respect to the at least one light source and the means of detection.
In the case of the optical process according to the invention for the characterization of a chemical and/or bio-chemical substance in a specimen by means of an optical waveguide containing at least one waveguide grating structure, the specimen is brought into contact with the waveguide in at least one contact zone, in the waveguide in the region of the at least one contact zone at least one light wave is excited through the waveguide grating structure, the at least one light wave is brought into interaction with the specimen, light in at least two differing proportions is detected, of which at least one proportion originates from the region of the contact zone, and at least one absolute measuring signal is generated by the evaluation of the detected light.

The waveguide grating structure consists of one or several waveguide grating structure units, which are arranged one-dimensionally or two-dimensionally (e.g., in a matrix shape or circular shape).

A possible xy displacement (or only an x-displacement) of the reading head (the reading heads) from one waveguide grating structure to the other or a possible xy-displacement (or only x-displacement) of the waveguide grating structure can quite well be applied.

A waveguide grating structure unit consists of at least two “sensing pads” (sensor platforms, sensor paths), which differ from one another in at least one of the following characteristics:

(a) The light waves guided in the “sensing pads” differ in their polarization (TE-wave or TM-wave), whereby the generated sensor signal is not produced by interferometric measurement.

(b) The light waves guided in the “sensing pads” differ in their mode number.

(c) The two chemosensitive layers assigned to the “sensing pads” manifest a differing specificity (ligand 1 selectively binds (inside or on the surface) to the chemosensitive layer covering the “sensing pad 1”; ligand 2 selectively binds (inside or on the surface) to the chemosensitive layer covering the “sensing pad 2”).

(d) The chemosensitive layer assigned to the first “sensing pad” manifests specificity for one ligand (with or without “non-specific binding”), while the (chemosensitive) layer assigned to the second “sensing pad” manifests no specificity (with or without “non-specific binding”) (example: Dextran layer, to which no identification molecule (e.g., antibody) is bound).

(e) The light waves guided in the “sensing pads” differ in their wavelength.

(f) A “sensing pad”, in which guided light waves of differing polirization (TE wave or TM-wave) are excited, counts as two “sensing pads” (difference in the polarization!), providing the sensor signal generated is not produced by interferometric measurement.

A “sensing pad”, in which guided light waves of differing mode number are excited, counts as two “sensing pads” (difference in the mode number!).

A “sensing pad”, in which guided light waves of differing wavelengths are excited, counts as two “sensing pads” (difference in the wavelength!).

The first and second “sensing pad” can also be considered as signal and reference path. The two “sensing pads” can (but do not have to) have the same structure.

The (bio-)chemo-sensitive contacts the waveguiding film in a contact zone. This contact zone normally in the case of the direct detection contains at least one grating. (In the case of interferometric measurements with the same polarization, for a direct detection the (bio-)chemo-sensitive layer can also only be located between two gratings (also refer to EP 0 226 064)). (In the case of interferometric measurements with two differing polarizations (using a polarizer), the (bio-)chemo-sensitive layer can also be located on a multi-diffractive (bi-diffractive) grating (refer to U.S. Pat. No. 5,479,260)).

On principle, for example, the value S (signal path) cS (reference path) can serve as a possible referenced sensor signal, whereby S (signal path) and S (reference path) are the sensor signals in the first “sensing pad” (signal path) or in the second “sensing pad” (reference path) and c is a calibration factor. In the case of the same polarization, sensibly c=1. In the case of different polarizations, with c the differing sensitivities of the two polarizations can be taken into account. In the case of different wavelengths or mode numbers, with c the differing sensitivities of the wavelengths or of the mode numbers can be taken into account. Advantageously, signal path and reference path are as close together as possible.

The referenced sensor signal in the case of the same polarization furthermore has the advantage that disturbances δ, such as, e.g., those caused by temperature fluctuation, light wavelength fluctuation, undesired diffusion of molecules in the waveguides, resp. in the chemosensitive layer, unspecific bindings, fluctuations of the concentration of the molecules not to be detected, etc., or combinations of these, can be referenced away, i.e., the referenced sensor signal is independent of δ, because S (signal path)−δ=S (reference path)−δ=S (signal path)−S (reference path).

In preference, mono-mode waveguides are utilized, which only carry the fundamental TE-mode or only the fundamental TE-mode and the fundamental TM-mode. The waveguiding film should preferably consist of a high-refractive material, which guarantees the generation of high sensitivities. The waveguiding film can be coated with a chemosensitive layer (e.g., an anti-body layer (e.g., suitable for the detection of a corresponding antigen), a dextran layer with identification molecule (e.g., anti-bodies), receptors, DNA- sections, a silicon layer for the detection of hydrocarbons, etc.). The waveguiding film itself, however, can also represent a chemosensitive layer. Rib waveguides can also be utilized.

A “sensing pad” comprises at least one grating, but can also comprise a (possibly more strongly modulated) in-coupling grating and at least one out-coupling grating. The grating periods of in-coupling grating and out-coupling grating can be different (and are in most cases different).

In-coupling grating and out-coupling grating can be uni-diffractive or multi-diffractive grating structures (bi-
diffractive gratings, gratings with changing grating period and/or with changing grating diffraction vector, etc.).

[0034] A preferred “sensing pad” arrangement consists of three gratings, whereby the middle grating represents the in-coupling grating and the two outer gratings two out-coupling gratings. With a strongly modulated in-coupling grating, for example, one succeeds in exciting modes in forward and reverse direction with a sole (resp., with two) incident (if so required slightly focussed) light beam(s). While a slight displacement of the incident light beam in the mode propagation direction or a slight tilting of the waveguide grating structure with respect to the incident light beam (in the plane of incidence) change the intensity of the modes (running in forward and/or reverse direction) as a result of the changed coupling geometry, not, however, the out-coupling angle(s) or the difference of the out-coupling angles (=double absolute out-coupling angle), which represent possible sensor signals.

BRIEF DESCRIPTION OF DRAWINGS

[0035] FIG. 1 shows the above preferred “sensing pad” arrangement both for the TE-mode as well as for the TM-mode, whereby the two “sensing pads” are located adjacent to one another.

[0036] FIG. 2 illustrates further waveguide grating structure units.

[0037] FIG. 3 shows an optical sensor according to the invention.

DETAILED DESCRIPTION

[0038] A further preferred “sensing pad” arrangement also consists of three gratings, whereby the two outer gratings form (possibly more strongly modulated) in-coupling gratings and the middle grating the out-coupling grating.

[0039] In case of the detection of (bio-)molecular interactions with the arrangement according to FIG. 1 (or equivalent arrangements), the waveguide structure unit is coated with a (bio-)chemo-sensitive layer, to which then in an experiment a specific binding partner binds, which leads to a change of the out-coupling angles \( \alpha_{\text{TE}} = \alpha_{\text{TE}+} - \alpha_{\text{TE}-} \)/2 and \( \alpha_{\text{TM}} = \alpha_{\text{TM}+} - \alpha_{\text{TM}-} \)/2 (notation: e.g., \( \alpha_{\text{TE}+} \): out-coupling angle of the TE-mode running in +x-direction or to a change of the effective refractive indexes \( N_{\text{TE}} \) and \( N_{\text{TM}} \) and of the integrated optical values derivable from it such as, e.g., the layer thickness \( \text{IF} \) of the waveguiding film in the three-layer waveguide model (see further below). Different waveguide grating structure units can be coated with different chemo-sensitive layers.

[0040] The out-coupling angle of the two out-coupling gratings (resp., of the out-coupling grating) of the preferred “sensing pad” arrangement enable an absolute determination of the out-coupling angle (resp., of the effective refractive index), although the out-coupling of the two light beams does not take place at one and the same location.

[0041] In case of two adjacent “sensing pads” for the TE- and the TM-mode according to the preferred “sensing pad” arrangement (see FIG. 1), the out-coupling even takes place at four different locations.

[0042] The “sensing pad” for the TE-mode enables the determination of the effective refractive index \( N_{\text{TE}} \) of the TE-mode. The “sensing pad” for the TM-mode enables the determination of the effective refractive index \( N_{\text{TM}} \) of the TM-mode. In case of simultaneous illumination of the two “sensing pads” (with, e.g., a single light field with 45° linear polarized light or circular (or elliptical) polarized light), the determination of the out-coupling angle (of the effective refractive index) for the TE- and TM-mode can take place simultaneously.

[0043] FIG. 1 illustrates an advantageous embodiment of a waveguide grating structure unit. The “sensing pad” for the TE-mode consists of an in-coupling grating \( G_{\text{TE}} \) and the two out-coupling gratings \( G_{\text{TE}+} \) and \( G_{\text{TE}-} \) located on the left and right of the in-coupling grating. The sensing pad for the TM-mode consists of the in-coupling grating \( G_{\text{TM}} \) and the two out-coupling gratings \( G_{\text{TM}+} \) and \( G_{\text{TM}-} \) located on the left and right of the in-coupling grating and it is located adjacent to the “sensing pad” for the TE-mode. In order to keep the influence of disturbances (e.g., temperature fluctuations) low, the two “sensing pads” should be located as closely as possible adjacent to one another. The grating lines are aligned parallel to the y-axis.

[0044] It is advantageous if the out-coupling gratings \( G_{\text{TE}+} \), \( G_{\text{TE}-} \), \( G_{\text{TM}+} \), \( G_{\text{TM}-} \) are completely illuminated by the guided light waves, as a result of which it is ensured that in case of the respective out-coupling grating the sensor surface corresponds to the surface of the out-coupling grating. This is achieved by selecting (a) the width of the out-coupling grating in y-direction smaller than/equal to the width of the in-coupling grating in y-direction and (b) the illumination spot on the in-coupling grating having a y-width, which is greater than/equal to the y-width of the out-coupling gratings, and the illumination spot including the complete y-width of an out-coupling grating.

[0045] An advantageous embodiment is the one, in the case of which the two in-coupling gratings \( G_{\text{TE}} \) and \( G_{\text{TM}} \) are simultaneously illuminated with one (or two (wedge-shaped) light field(s) linear polarized under 45°. With this, simultaneously the TE-mode and the TM-mode (in the forward and reverse direction) can be excited and simultaneously all (in the case presented here: four) out-coupling angles can be measured. \( G_{\text{TE}} \) and \( G_{\text{TM}} \) in preference have differing grating periods.

[0046] It is, however, also possible that a “sensing pad” as such carries out the function of a “sensing pad” for the TE-mode and the function of a “sensing pad” for the TM-mode. The second “sensing pad” (located adjacent to it) is then either not present or else is utilized as a check or reference. (This reference “sensing pad” can, e.g., be coated with a second chemo-sensitive layer or with a non-specific layer, i.e., a layer which has no specificity (with or without “non-specific binding”). If the in-coupling grating of a “sensing pad” is illuminated with TE-light as well as with TM-light under the corresponding in-coupling angles (e.g., with 45° linear polarized light), then in the one “sensing pad” both the TE-mode as well as the TM-mode are excited (if so required both in forward as well as in reverse direction).

[0047] It is also possible to excite the TE-mode only in forward direction and the TM-mode only in reverse direction (or vice-versa) or the TE-mode and the TM-mode only in forward direction (or vice-versa). In such a case, then the corresponding two out-coupling angles or their difference are measured.
[0048] Utilized as detectors are advantageously one- or two-dimensional (digital or analogue) position-sensitive detectors (PSD), photo-diode arrays, CCD line- or surface camera(s), etc. The out-coupled light beams are advantageously focussed with a lens, whereby the focus does not indispensably have to be situated exactly on the detector surface. The out-coupling gratings can also be focusing gratings. This has the benefit that the lens-effect is already integrated in the out-coupling grating.

[0049] It is also possible to select the direction of the grating lines of the out-coupling grating in such a manner, that the grating lines are vertical to the propagation direction of the mode. Advantageously, the tilting of the grating lines (resp., of the grating diffraction vectors) of the out-coupling gratings of two adjacent “sensing pads” has an inverse operational sign. With this, a better separation of the out-coupled light waves can be achieved.

[0050] The in-coupling grating can also be selected in such a manner, that the grating period in x-direction or y-direction does not remain constant or is graduated. The requirements of the accuracy of the setting of the angle of incidence are relaxed as a result of this.

[0051] The in-coupling gratings shown in FIG. 1 in preference have a strong modulation and are characterized by a short width in x-direction. As a result, the requirements of the accuracy of the setting of the angle of incidence are relaxed, because the light can now in-couple from a greater angle segment.

[0052] FIGS. 2(a) and 2(b) illustrate two embodiments of waveguide grating structures, whereby here the dimension of the in-coupling gratings in y-direction is smaller than that of the out-coupling gratings. In FIG. 2(b), a uniform out-coupling grating $G_{\text{out}}$ for the TE- and TM-wave running in (x-) direction and a uniform out-coupling grating $G_{\text{out}}$ for the TE- and TM-wave running in (x+) direction are depicted.

[0053] FIG. 3 illustrates an embodiment of a sensor according to the invention. The sensor contains a waveguide 1 with a substrate 104, a waveguiding material 105 and a cover medium 106 as well as with a waveguide grating structure according to FIG. 1. A light source 2 generates, for example, 45° linearly polarized light; for this purpose, a linearly polarized laser with a polarization plane inclined to the drawing plane by 45° can be utilized. Through a beam splitter 3 or a mirror 4, two impinging light beams 5, 6 are produced. The light beams 5, 6 impinge on the two in-coupling gratings 101 (of which in the side view of FIG. 3 only one is visible) of the two “sensing pads” through the substrate 104 and in the first “sensing pad” generate a TM wave in forward and reverse direction. The light waves are out-coupled through four out-coupling gratings 102, 103 (of which in the side view of FIG. 3 only two are visible) from the waveguide grating structure and radiated into the substrate 104. After passing through the substrate 104 they spread as light fields 7-10 and impinge on a two-dimensional CCD-detector 11. If so required, there can be a lens system (not illustrated) between the waveguide 1 and the detector 11.

[0054] If in the two “sensing pads” one operates with differing polarization and with a chemo-sensitive layer assigned to the waveguide grating structure, then, for example, the sensor signal $S_{\text{TE}}$ (layer thickness of the waveguiding film in the three-layer waveguide model) can be generated (also see further below). If now a second waveguide grating structure unit, which also permits the generation of the sensor signal $S_{\text{TE}}$, is laid next to the first waveguide grating structure unit (now to be considered as a whole as signal path) and the second waveguide grating structure unit (now to be considered as a whole as reference path) coated with, for example, a chemo-sensitive layer of differing specificity or with a non-specific chemo-sensitive layer with or without “non-specific binding” (e.g., a dextran layer, to which no identification molecule is bound), then, for example, the value $I_{\text{TE}}$ (measured in the signal path) $I_{\text{TE}}$ (measured in the reference path) can serve as sensor signal.

[0055] Although the effective refractive indexes $N(\text{TE})$ and $N(\text{TM})$ of the TE- or TM-mode are possibly not measured at the same point (the two “sensing pads” are, however, in the case of a chemo-sensitive sensor coated with the same chemo-sensitive layer), with the waveguide grating structure unit the interesting sensor signals $S$ and/or $\Delta S$ with $\Delta S=N(\text{TM})-N(\text{TE})=(N(\text{TM})=N(\text{TE})$ (equation 1) $(\Delta S=\delta(N(\text{TE})=\delta(N(\text{TM}))$).

[0056] $(\alpha=\text{out-coupling angle})$

[0057] whereby the layer thickness of the waveguiding film in preference should be selected in such a manner, that for the sensitivity of the refractive index of the cover medium $\delta(N(\text{TE})/\delta n_c=N(\text{TM})/\delta n_c$ is applicable, which at least eliminates the influence the refractive-index changes of the cover medium on the sensor signal have on the sensor signal (the refractive index $n_c$ of the cover medium depends on the temperature, i.e., $n_c=n_c(T)$, whereby $T$ is the temperature).

$\Delta S=\Delta S_{\alpha}=\cos\delta(N(\text{TE})/\delta T)^2\cdot N(\text{TE})_{\alpha}-(N(\text{TM})/\delta T)^2\cdot N(\text{TM})_{\alpha}$ (equation 1)

[0058] in which $\cos\delta(N(\text{TE})/\delta T)^2\cdot N(\text{TE})_{\alpha}-(N(\text{TM})/\delta T)^2\cdot N(\text{TM})_{\alpha}$ and the change of the layer thickness $\Delta \lambda_c$ is calculated from the system of equations

$\Delta S(\text{TE})=\lambda_c=\delta N(\text{TE})/\delta T\cdot \lambda_c=(\text{TE})/\delta T\cdot \lambda_c$ (equation 1)

$\Delta S(\text{TM})=\lambda_c=\delta N(\text{TM})/\delta T\cdot \lambda_c=(\text{TM})/\delta T\cdot \lambda_c$ (equation 1)

[0059] and $\delta N(\text{TE})/\delta T$ is the temperature coefficient of the waveguide complete with cover (specimen) for the corresponding mode (of $\delta N(\text{TM})$ is calculated taking into account the temperature coefficient (of $\delta N(\text{TE})/\delta T$) of the grating experimentally (or according to theory) also see further below).

[0060] $\Delta S=\Delta \lambda_c$ whereby the layer thickness $\lambda_c$ is calculated with the three-layer waveguide model (with $\text{N(TE)}$ and/or $\text{N(TM)}$ as input parameter).

[0061] $\Delta S=\Delta \lambda_c$ whereby the change of the additional layer thickness $\lambda_c$ is calculated from the system of equations

$\Delta S(\text{TE})=\lambda_c=\lambda_c=\delta N(\text{TE})/\delta T\cdot \lambda_c=(\text{TE})/\delta T\cdot \lambda_c$ (equation 2)

$\Delta S(\text{TM})=\lambda_c=\lambda_c=\delta N(\text{TM})/\delta T\cdot \lambda_c=(\text{TM})/\delta T\cdot \lambda_c$ (equation 2)

[0062] $\Delta S=\Delta \lambda_c$ whereby the additional layer thickness $\lambda_c$ is calculated with the four-layer waveguide model (resp., five-layer waveguide model).
The sensor signals S and AS can be recorded in function of the time. One can, however, also only measure and compare an initial and a final condition on a waveguide grating structure unit, whereby, for example, in the interim other waveguide grating structure units can be evaluated or the even the waveguide grating structure can be removed from the measuring unit in the meantime, because absolute angles or differences of angles (resp., distances (differences of distances) of light points) are measured and these values remain stable with respect to a tilting or displacement. The determination of a measured value can be carried out by means of an individual measurement, also, however, by means of a statistical evaluation (e.g., averaging) of several individual measurements. If apart from temperature changes ΔT, other interferences are also present, such as, e.g., diffusion of the specimen liquid into the micro-pores of a porous waveguiding film (which leads to a change in the refraction index Δn_r of the waveguiding film) or tensions (such as, compressive strain or tensile stress) or changes in stress are present or if in general only pore diffusion is present, then (in the first case under certain conditions (e.g., the course in function of time of the pore diffusion with the temperature T as group of parameters is known) (approximately), then a (common) interference value $\xi$ with $N(t_1, n_2, 1), n_3(1), n_4(2), n_5(1), n_6(2), n_7(1)$) can be introduced. Equation (1) or (2) then take on the form

$$\Delta N(TE) = \Delta N(TE)/\Delta S + \Delta N(TE)/\Delta \Delta T$$

$$\Delta N(TM) = \Delta N(TM)/\Delta S + \Delta N(TM)/\Delta \Delta T$$

whereby AS is the sensor signal $\Delta \xi_0$ (or $\Delta \xi_1$) and, for example, in the case of the three-layer waveguide model $\partial N/\partial \xi_0 = \partial N/\partial n_2(n_3(n_4(n_5 n_6(n_7(1)))))$ and $\partial N/\partial \xi_1 = \partial N/\partial n_2(n_3(n_4(n_5 n_6(n_7(2)))))$, providing $t_1$ for $n_4(3)$. Logically directly from $\xi = T$ formula (1) or formula (2) follows. $\xi \approx n_4$, describes, e.g., the diffusion at a constant temperature. Also in the case of the presence of several interferences, it is possible to operate with the three-layer waveguide model and the modes equation solved (example: input: N(TE), N(TM), output: $t_1$, $n_2$, $n_3$, $n_4$, $n_5$, $n_6$, $n_7$, $n_8$, $n_9$, $n_{10}$, $n_{11}$, $n_{12}$). In the three-layer waveguide model, waveguiding film, chemosensitive layer and specific binding partner are considered as being a layer with one refractive index. Although $n_2$ and $n_3$ (and if applicable $n_4$) are not precisely known and if applicable change during the experiment on the basis of an interference, the measured value $t_1$ is relatively independent of the interference, dependent on the contrary, however, on the binding process. The interference is so-to-say packed into the second output value, the parameter "refractive index". Fundamentally, pore diffusion and temperature fluctuations are independent manifestations and should be described by two interference values $\xi_0$ and $\xi_1$ (generalization: k independent disturbances are described by k independent disturbance values $\xi_0, \xi_1, ..., \xi_k$). From $N(t_1, \xi_0, \xi_1, ..., \xi_k)$ for both polarizations, for a given mode number and for a given wavelength follows

$$N(t_1, \xi_0, \xi_1, ..., \xi_k) = N(\xi_0, \xi_1, ..., \xi_k) + N(t_1, \xi_0, \xi_1, ..., \xi_k)$$

(4)

Because the disturbance values can influence the waveguide parameters $t_1$, $n_2$, $n_3$, $n_4$, $n_5$, $n_6$, $n_7$, $n_8$, $n_9$, $n_{10}$, $n_{11}$, $n_{12}$, the following is applicable:

$$\Delta N(TE) = \Delta N(TE)/\Delta S + \Delta N(TE)/\Delta \Delta T$$

$$\Delta N(TM) = \Delta N(TM)/\Delta S + \Delta N(TM)/\Delta \Delta T$$

(5)

(6)

For both polarizations, a given mode number and a given wavelength, $\partial N/\partial \xi = \partial N/\partial \xi / \partial \xi = \partial N/\partial \xi / \partial \xi = \partial N/\partial \xi$. In the temperature change $\xi = \xi - T$ from Eq. (4) results

$$N(t_1, \xi_0, \xi_1, ..., \xi_k) = N(\xi_0, \xi_1, ..., \xi_k) + N(t_1, \xi_0, \xi_1, ..., \xi_k)$$

(7)

(8)

In analogy to further above, however, also the sensor signal $t_1$ and the disturbance values from the (three-layer- or four-layer-) mode equations for the two polarizations and for several wavelengths and mode numbers can be determined, this under the prerequisite, that the system of equations can be numerically solved. Fundamentally also the layer thicknesses are to a certain degree dependent on the temperature (also refer to Applied Optics 20 (1981), 2280-2283), which fact, however, has been neglected in the formulas (1), (2) and (3) in the approximation. It is, however, also possible with respect to
at least one specimen select such a combination of (several) layers and substrate, that the temperature coefficient of the waveguide or of the grating coupler (resp., of the waveguide grating structure) with respect to at least one sensor signal $S_1$ (e.g. $S_1(T)$, $S_1(TM_{1})$, $S_1(TM_{2})$, $S_2$, $S_3$, etc.) is practically zero (the sensitivity, however, still remains high). In this, e.g., one of the layers involved can be an SiO$_2$ layer.

[0074] The absolute temperature coefficient with respect to a sensor signal $S$ is $dS/dT$, the corresponding relative temperature coefficient is $(S)/S dS/dT$, with $dN(TM)/dT=0$ or $dN(TM)/dT=0$, also $S=\Delta N(TM)$ or $S=\Delta N(TM)$ become interesting sensor signals independent of the temperature.

[0075] If in a “sensing pad” only one grating is present, then, for example, with the reflection arrangement described in the European patent application 0 482 377 A2 (possibility with a sensor chip with tilting of the grating plane versus the lower substrate plane) measurements are possible. The measurement with the reflection arrangement on weakly or more strongly modulated (mono-diffractive or multi-diffractive) waveguide gratings (homogeneous gratings, superimposed gratings with different grating periods and/or grating orientations, chirped gratings, etc.) can be carried out both for TE- as well as for TM-waves. The mode excitation can take place from the left, the readout from the right or vice-versa. For example, in a “sensing pad” the excitation of the TE-wave can take place from the left and the excitation of the TM-wave from the right. In a second “sensing pad” (possibly with a different grating period and/or grating orientation) the excitation can be in reverse to the first “sensing pad”. The readout can take place in the reflected and transmitted light field in the zero-th or higher diffraction order. With this, it is also possible to determine absolute coupling angles with the reflection arrangement. The measured absolute coupling angle, which in essence in case of the same grating period (and the same diffraction order) corresponds to half of the angle difference between the two corresponding resonance minimums, does not change, even if the sensor chip is slightly tilted. From the absolute angles for the TE-wave or the TM-wave, the corresponding effective refractive indexes and further integrated optical measured values can be determined, such as, e.g., the layer thickness $d_{n}$ of the waveguiding film in the three-layer waveguide mode, etc.

[0076] It is of course also possible that in the first “sensing pad” the excitation of the TE- and TM-wave takes place from the left and the readout from the right (if so required with only one CCD) and in the second “sensing pad” (possibly with a differing grating period) in reverse.

[0077] It is also possible that the plane of incidence of the beam guidance responsible for the reference path (second “sensing pad”) is rotated or tilted and tilted versus the plane of incidence of the beam guidance responsible for the signal path (first “sensing pad”). First and second “sensing pads” can also coincide. The coupling angles for the TE-wave and the TM-wave can also be measured at different wavelengths and/or mode numbers.

[0078] A further “sensing pad” arrangement consists of two (identical) chirped gratings (gratings with graded grating period), whereby one grating serves as in-coupling grating and one grating as out-coupling grating. Chirped gratings are known from the literature (refer to, e.g., the patent application WO 97/09594). The signal “sensing pad” and the reference “sensing-pad” can have the same or also an opposing chirp direction (direction, in which the grating period changes (e.g., becomes bigger), it is vertical to the direction of the mode propagation). The “sensing pads” can be coated with the same (bio-)chemo-sensitive layer (see below) or else have differing (biolayers, whereby the (bio-)chemo-sensitive layer of the second “sensing pad” (reference “sensing pad”) is a different (bio-)chemo-sensitive layer or a non-specific binding layer with or without “non-specific binding” (e.g., dextran without identification molecule) or else a purely protective layer.

[0079] The chirped grating, which is responsible for the in-coupling, is illuminated with a (not wedge-shaped or if so applicable (slightly wedge-shaped) light strip, of which a certain proportion, in the case of which the in-coupling conditions are fulfilled, is in-coupled to the waveguide. It is also possible to simultaneously illuminate the in-coupling chirped gratings of the signal—“sensing pad” and reference—“sensing pad” (if so required with a single, longer light strip) (if so required with 45° linear polarized or circular (or elliptically) polarized light (for the excitation of modes of both polarizations)). In the case of an excitation of modes of differing polarization under a fixed angle of incidence, the corresponding grating periods of the two “sensing pads” are different.

[0080] In the case of the same polarization and opposite chirp direction of signal “sensing pad” and reference “sensing pad” (both “sensing pads” are coated with the same (biolayer), the two out-coupled light strips, (bio)binding travel (practically vertical) to the direction of propagation of the modes towards one another or away from one another (depending on the chirp direction or the chirp orientation). The position of the light spots is measured with PSDs or with a one- (or two-) dimensional CCD. Through the change of the distance of the two light spots, the change of the effective refractive index of the corresponding polarization can be calculated. The distance of the two light spots is an absolute value, because the distance of the two light spots is independent of displacements or of small tilting. (If the signal and reference paths have a differing polarization, then the measuring signal $\Delta N(TM)$–$\Delta N(TM)$ can be determined.) In the case of the same polarizations, same chirp directions of the two “sensing pads”, but differing (bio)chemo-sensitive layer (e.g., on the signal path a specific layer, on the reference path a non-specific layer), the distance of the two light spots forms a referenced (absolute) sensor signal.

[0081] The arrangement described in the paragraph before the last one can once again be duplicated for the other polarization (with an adaptation of the grating period) and can once again as a whole be considered as reference path for the complete layout described in the paragraph before the last one (to be interpreted now as signal path). Here the change of the effective refractive index of the other polarization can be measured. (If, however the polarization(s) remains (remain) the same and instead another chemo-sensitive layer (with or without non-specific binding) or a non-specific layer with or without non-specific binding (e.g., dextran layer without identification molecule) is utilized, then the referenced measured values (measured value (first
arrangement) measured value (second arrangement)) of the measured values $\Delta N(TE)$ or $\Delta N(IM)$ or $\Delta N(TM) - \Delta N(TE)$ can be determined.

[0082] It is also possible, that only the in-coupling grating is present as a chirped grating, the out-coupling grating, however, e.g., is mono-diffractive (or multi-diffractive). The two light spots described three paragraphs above do not anymore travel vertically to the mode propagation direction on the basis of the (bio-)chemical binding, because the out-coupling grating also deflects in the plane of incidence (possibly better referred to as the outlet plane) (i.e., the out-coupling angle changes.

[0083] If on the other hand for signal "sensing pad" and reference "sensing pad" one operates with three gratings each (one in-coupling grating and two out-coupling gratings or two in-coupling gratings and one out-coupling grating), whereby modes in forward and reverse directions are excited, if the in-coupling grating is a chirped grating (with the same or with opposite chirp orientation between the two "sensing pads") and if the in-coupling gratings are, e.g., mono-diffractive (or multi-diffractive), then displacements or tilting of the x- and y-axis (orientation of the axis as in FIG. 1) can be identified and eliminated on the basis of the absolute measurement. For the chemo-sensitive layer(s), the same remarks are applicable as in the case of the "sensing pad", which consists of two chirped gratings. If, for example, only the absolute out-coupling angle (and/or measured values which can be derived from it) are considered as sensor signals, then the chirped in-coupling grating can also be illuminated with a light strip impinging in a wedge-shape. Here too, the above arrangement (signal and reference path) can be duplicated and considered as a new reference path (with or without differing chemo-sensitive layer or with a non-specific layer) to the above arrangement (now as a whole as signal path).

[0084] The specimen liquid(s) is/are brought into contact with the waveguide or with the chemo-sensitive substrate(s) through a "well" or a matrix of "wells", a through-flow cell or a matrix of through-flow cells, a capillary vessel or a matrix of capillary vessels.

[0085] Two-dimensional arrangements lead, e.g., to a "microplate" with 96, 384, 1536 "wells", etc. (But also other two-dimensional formats (e.g., disks) are possible). But also the manufacturing of individual strips (one-dimensional arrangement) is possible. The strips can, e.g., also be inserted into the frame of a microplate. The "wells" can be affixed to the sensorchip plate, which contains the waveguide grating structure units as separate specimen cell (e.g., specimen cell plate). It is also possible to provide the substrate itself with indentations in such a manner, that these indentations already assume the function of the "wells" or of the through-flow vessels or of the capillary vessels. In the two latter cases, the sensorchip plate has to be covered with a covering plate equipped with bores. In the first case, the sensorchip plate can be covered with a covering plate (without bores), in order to, e.g., prevent evaporation. The bores serve for the supply or carrying away of the specimen or for the ventilation. In preference, one works with plastic material and injection-moulding techniques or hot-embossing techniques. But also sol-gel techniques, UV-hardening techniques for organic/inorganic composites, glass embossing techniques (hot-embossing or (injection)-moulding), etching techniques, material removal by laser, etc. present an alternative.

[0086] The grating structures can be manufactured using embossing techniques (hot-embossing, cold-embossing, UV-hardening) or injection-moulding techniques out of plastic material, sol-gel, glass, UV-hardening organic or inorganic materials or organic/inorganic composites, or moccres or nanomeres, with removal by laser in conjunction with interferometry, holography and/or phase mask techniques, photo-lithography in conjunction with wet or dry etching, using photo polymerization (refer to, e.g., P. Coudray et al., Crit. Rev. Opt. Sci. Tech. (SPIE) CR68 (1997), 286-303) or using casting techniques (e.g., in sol-gel), etc. Plastic injection-moulding techniques, such as are utilized in the manufacturing of compact discs (e.g., out of poly-carbonate), are particularly suitable. The grating structure can be in (resp., on) the substrate or in (resp., on) a layer or can be present in a combination of these. The grating structures can be surface relief gratings (resp., interface relief gratings) or refractive-index gratings (resp., volume gratings) or combinations of these. The waveguiding film can be a sol-gel layer (SiO$_2$—TiO$_2$, TiO$_2$ (non-porous) high-refraction lead-silicate glass, etc), an organic/inorganic composite layer, a polymer layer, a PVD-, a CVD-, a PE-CVD-, a PI-CVD layer, a photo-polymerizable, high-refraction layer (e.g., photo-polymerizable TiO$_2$, etc. or combinations of these. It is also possible that a layer (with in preference low refractive index, made, e.g., of SiO$_2$ sol-gel, SiO$_2$—TiO$_2$ sol-gel (with low TiO$_2$ content), lead-silicate glass, sol-gel (with low lead content), sol-gel similar to float-glass, etc.) contains the grating structure and a second layer (e.g., made of SiO$_2$—TiO$_2$, TiO$_2$, Ta$_2$O$_5$, HfO$_2$, ZrO$_2$, Nb$_2$O$_5$, Si$_3$N$_4$, lead-silicate glass, etc) forms the waveguiding film. Due to the fact that the softening point of lead-silicate glass is significantly below the softening point of glass, the lead-silicate glass can be made to melt without damaging the glass in doing so. The melting process leads to a practically pore-free lead-silicate glass. If the substrate and the layer(s) have similar thermal expansion coefficients, then the formation of micro-fissures can be prevented (micro-fissures increase the damping values of the modes). PVD- and CVD-processes make possible the manufacture of very compact waveguiding films.

[0087] The substrate can be made of a plastic material (e.g., polycarbonate, PMMA, polyoxetane, etc.), sol-gel or glass (float-glass, specimen slides, soda-lime glass, boro-silicate glass, alkali-free glass, quartz, etc.). However, also the grating material can be utilized as substrate material (e.g., moscerere, UV-hardening material).

[0088] The specimen cell can consist of indentations (holes, bores), also, however, of through-flow cells. These through-flow cells can also be configured in such a manner, that the specimen liquid can be supplied using the pin of a pipette robot. It is also possible, that a second specimen cell consisting of through-flow vessels is inserted into a first specimen cell with indentations (holes).

[0089] In the substrate or anywhere on the sensorchip plate, positioning marks (holes, indentations, pins, elevations, etc.) can be inserted or affixed. These positioning marks guarantee that the impinging light beam hits the in-coupling grating(s). The identification of the positioning marks is effected through the measuring unit.
[0009] For the separation of the light wave carrying the sensor signal from other light waves (e.g., from the light wave reflected from the bottom of the substrate), it is also advantageous if the waveguiding film is not plane-parallel to the bottom of the substrate. This non-plane-parallelism can be present, among others, in the form of wedges, prisms, cylinder prisms, spherical lenses, cylinder lenses, etc.

[0010] With the chemosensitive waveguide structure, not only a direct detection, but also marking detections can be carried out. The utilization of a “refractive index label” (e.g., of a little plastic ball (e.g., a small latex ball), bio-chemical and biological fragments, etc.), can already be considered as a marking detection. With it, for example, sandwich assays or competition assays can be implemented.

[0012] As light source a monochromatic light source, such as, e.g., a (pulsed) laser, a (pulsed) laser-diode, a (pulsed) LED with or without filter in the infrared or blue-green or ultra-violet spectral range, is advantageously used. But also thermal light sources with a filter can be utilized. Red-blue-green or ultra-violet wavelengths have the advantages that (a) the sensitivity for the direct detection increases and (b) with the same light source apart from “direct sensing” also fluorescence-, phosphorescence or luminescence tests can be conducted, whereby the excitation of the fluorescence, phosphorescence or luminescence takes place through the evanescent wave (in the form of a TE-wave or TM-wave or TE- and TM-wave). The fluorescence-, phosphorescence- or luminescence-light can be observed as a plane wave or also as a guided wave. The fluorescent light caused by the TE-exciting wave (resp., its intensity) can be referenced or compared with the fluorescent light (resp., its intensity) caused by the TM-exciting wave, whereby advantageously the intensity of the exciting wave is jointly taken into account and possibly the detectors are made sensitive to polarization by the use of polarizers. The guided fluorescence-, phosphorescence- or luminescence-light wave can be out-coupled through a grating and conveyed to a detector. Sandwich-assays, competition assays, etc., can be carried out, whereby at least one participating binding partner is fluorescence- (phosphorescence-, luminescence-) marked. The (bio-)chemosensitive layer can be present on the grating, or can also, however, be present solely between the gratings or outside the grating.

[0013] Fluorescence, phosphorescence or luminescence measurements manifest a low dependence on temperature. For fluorescence, phosphorescence or luminescence measurements, purely inorganic waveguide grating structures are particularly suitable (the grating is manufactured in glass or sol-gel (e.g., SiO₂) or in the inorganic waveguiding film, waveguiding film made of inorganic material (e.g., Si₃N₄, or oxide layers such as, e.g., TiO₂ or Ta₂O₅ or lead-silicate layers, etc.)). Inorganic materials manifest, e.g., a low fluorescence of their own. If one works with a plastic material substrate, then it is recommended to apply an inorganic low-refraction intermediate layer (e.g., SiO₂) to the plastic substrate. The layer thickness of this intermediate layer has to be selected as great enough, so that the evanescent wave running in it practically does not anymore “see” the plastic substrate. As a result of this, at least the proprietary fluorescence generated by the guided light wave is strongly reduced.

[0014] If both the intensity of the (possible out-coupled) excitation wave as well as that of the (possibly out-coupled) emission wave are measured, then various interference factors (such as, e.g., those, which are caused by intensity fluctuations of the exciting wave) can be eliminated by referencing. The referenced sensor signal is then, for example, the intensity of the fluorescence (phosphorescence, luminescence) divided by the intensity of the exciting light wave. The intensity of the excitation wave can be measured prior to the penetration of the exciting wave into the chemosensitive layer or after the exit of the exciting wave from the chemosensitive layer or at both points. With referenced marking detections, absolute kinetic measurements as well as absolute end point measurements can be carried out. In the case of absolute (end point) measurements, the (bio-)chemical interaction on the waveguide grating structure can also take place outside the measuring instrument.

[0015] It is also to be noted that with a (digital or analogue) PSD (position sensitive detector) (one-dimensional or two-dimensional), a photo-diode-array (PDA) (one-dimensional or two-dimensional) or a CCD-array (one-dimensional or two-dimensional), not only (positions of) light field distributions but also intensities can be measured.

[0016] It is possible (but it is not absolutely necessary) to in part with the same detectors carry out a direct detection as well as a marking detection (on a fluorescence, phosphorescence or luminescence basis). Evanescent field excitation can also be combined with measuring techniques resolved over time (e.g., time-resolved fluorescence or luminescence). In the case of time-resolved techniques, the marking is excited with a pulsed light wave (primarily in the visible or ultra-violet wavelength range). The fading times for the fluorescence (luminescence, phosphorescence) of free and bound marking molecules (with or without energy transfer between two different fluorescence molecules (refer to, e.g., the Förster theory in C.S. Bio International, November 1998, No. 3)) are different. The depth of penetration of the guided excitation wave into the specimen determines the “observation volume”.

[0017] It is interesting that with the waveguide grating structures presented here absolute measurements can be carried out both free of marking as well as fluorescence (phosphorescence, luminescence) marked (if so required also simultaneously). In both cases, for the in-coupling of light one can make do without movable mechanics. It goes without saying that also (continuous) kinetic measurements or real-time measurements can be carried out on a non-absolute basis.

[0018] With a “sensing pad” (signal path) (with or without chemosensitive layer), it is also possible to carry out light absorption measurements, inasmuch as the intensities of the light beams out-coupled (through grating, prism, taper or front side) (if so required with the same detectors) can be measured, possibly also at different wavelengths. The change in light absorption can come about directly or indirectly (e.g., through enzymes) through the (bio-)chemical interaction of the specimen with the chemosensitive layer or through the specimen itself or through the reactions taking place in the specimen (with or without an additional reaction partner). The chemosensitive layer can be present on the grating, between the gratings or outside the grating. Fluctuations in light intensity of the light source can be eliminated by referencing (e.g., with a beam-splitter and a reference detector or through a non in-coupled diffraction
order and a reference detector). Referencing can also be carried out by the method in which the second “sensing pad” (reference path) is covered with a protective layer and therefore cannot interact with the specimen. The referenced sensor signal is then the intensity of the signal path detector divided by the intensity of the reference path detectors.

[0099] The protective layer, however, can also be a (porous) (chemo-sensitive) layer, which has no specificity (with or without “non-specific binding”) or specificity for another ligand.

[0100] Referencing can also (but does not have to) take place through one half of a “sensing pad” (e.g., signal path: mode in forward direction, reference path: mode in reverse direction).

What is claimed is:

1. An optical sensor configuration for the characterization or detection or detection and characterization of at least one chemical or bio-chemical or chemical and bio-chemical substance, comprising a sensor chip, which includes a waveguide that is formed by a substrate and waveguiding material provided thereon, and a waveguide grating structure, wherein the waveguide or the waveguide grating structure or the waveguide and the waveguide grating structure are operable to emit light proportions towards a substrate side or a cover medium side or the substrate side and the cover medium side when light impinges on the waveguide grating structure,

the optical sensor configuration further comprising at least one light source for emitting light towards at least a part of the waveguide grating structure,

wherein the waveguide grating structure comprises at least two sensing pads,

wherein the at least two sensing pads each comprise at least one unidiffractive or multidiffractive incoupling grating and at least one unidiffractive or multidiffractive outcoupling grating,

wherein the grating lines of one incoupling grating define a plane with a first direction parallel to the grating lines and a second direction perpendicular to the first direction and

wherein the width of the incoupling grating is confined in the first direction and in the second direction,

wherein the incoupling grating of a first sensing pad is arranged at a distance in the first direction from the incoupling grating of a second sensing pad,

and wherein the light source’s and the sensor chip’s mutual position is such that the light source is operable to illuminate the incoupling grating of at least one sensing pad as a whole.

2. The optical sensor configuration according to claim 1, wherein the incoupling grating of at least one sensing pad is arranged at a distance in the second direction from the incoupling grating of said at least one sensing pad.

3. The optical sensor configuration according to claim 1, wherein the width of the incoupling grating of at least one sensing pad is smaller in the first direction than the width of the outcoupling grating of said at least one sensing pad in the first direction.

4. The optical sensor configuration according to claim 1, wherein the width of the incoupling grating of at least one sensing pad in the first direction is equal to the width of the outcoupling grating of said at least one sensing pad in the first direction or wherein the width of the incoupling grating of at least one sensing pad in the first direction is larger than the width of the outcoupling grating of said at least one sensing pad in the first direction.

5. The optical sensor configuration according to claim 1, wherein the grating periods of the incoupling grating and of the outcoupling grating of at least one sensing pad are different.

6. The optical sensor configuration according to claim 1, wherein the light waves guided in the at least two sensing pads differ in at least one of their polarization, of their mode number, and of their wavelength.

7. The optical sensor configuration according to claim 1, wherein the incoupling gratings of at least two sensing pads are illuminable simultaneously by the light source.

8. The optical sensor configuration according to claim 7, wherein light may be radiated from the substrate side into both a first sensing pad and a second sensing pad of said at least two sensing pads or light may be radiated from the cover medium side into both, the first sensing pad and the second sensing, and wherein the sensor chip is operable to emit light from both sensing pads into the substrate or from both sensing pads into the cover medium side or from both sensing pads into the substrate and into the cover medium side when light impinges on the sensing pads.

9. The optical sensor configuration according to claim 1, wherein the combination of layers and the substrate of the waveguide, of a grating coupler or of the waveguide grating structure is such that the temperature coefficient dS/dT of the waveguide or of the grating coupler or of the waveguide grating structure with reference to at least one sample and at least one sensor signal S is approximately zero.

10. The optical sensor configuration according to claim 1, wherein the width of an incoupling grating in the second direction is constant as a function of the position along the first direction.

11. The optical sensor configuration according to claim 1, wherein light from the substrate side illuminates a first sensing pad and light from the substrate side illuminates a second sensing pad and light from the first sensing pad is radiated at least into the substrate and light from the second sensing pad is radiated at least into the substrate, or

wherein light from the cover medium side illuminates a first sensing pad and light from the cover medium side illuminates a second sensing pad and light from the first sensing pad is radiated at least into the cover medium and light from the second sensing pad is radiated at least into the cover medium.

12. The optical sensor configuration according to claim 1 wherein the substrate is made of plastics or of glass.

13. The optical sensor configuration according to claim 12, wherein the substrate is made of plastic and on the substrate an inorganic low refractive index intermediate layer is arranged.

14. The optical sensor configuration according to claim 1, wherein the waveguiding material includes a waveguiding film of a high refractive index material.

15. The optical sensor configuration according to claim 14, wherein the waveguiding material forms a waveguiding film of a high refractive index material and a polymer layer.
16. The optical sensor configuration according to claim 1, wherein the waveguiding material forms a waveguiding film that is not coplanar to a side of the substrate opposed to the waveguiding material.

17. The optical sensor configuration according to claim 16, wherein said side of the substrate opposed to the waveguiding material comprises at least one of wedges, prisms, cylindrical prisms, spherical lenses and of cylindrical lenses.

18. The optical sensor configuration according to claim 1, wherein the waveguiding material comprises at least one sol-gel-layer or a high refractive index lead-silicate glass layer or a photopolymerizable high refractive index layer or a polymer layer or a PVD layer or a CVD layer or a combination thereof.

19. The optical sensor configuration according to claim 1, wherein the grating structures consist of UV curable organic or inorganic materials or organic/inorganic composites.

20. The optical sensor configuration according to claim 1, wherein the grating structures have been manufactured by an embossing technique, a photolithographic technique or a casting technique or an injection molding technique or by laser ablation combined with at least one of an interferometric technique, a holographic technique and of a phase mask technique.

21. The optical sensor configuration according claim 1, comprising at least one chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substances which is arranged in a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive layer and which is in contact with the waveguide or with the waveguide grating structure.

22. The optical sensor configuration according claim 1, wherein the waveguide contains at least one chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substances.

23. The optical sensor configuration according to claim 22, wherein a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substance of a first sensing pad shows specificity for one ligand with or without non-specific binding, whereas a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substance of a second sensing pad shows no specificity with or without non-specific binding.

24. The optical sensor configuration according to claim 22, wherein a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substance of a first sensing pad shows a first specificity for one ligand with or without non-specific binding, whereas a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substance of a second sensing pad shows a second specificity different from the first specificity for a second ligand with or without non-specific binding.

25. The optical sensor configuration according to claim 22, wherein disturbances of the measuring signal which are caused by non-specific bindings at a chemosensitive or bio-chemosensitive or chemosensitive and bio-chemosensitive substance in one sensing pad may be eliminated, by referencing, by means of a measurement at an other sensing pad.

26. The optical sensor configuration according to claim 22, wherein the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substances are such that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad at the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the interior, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the interior, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface, or that a first ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the first sensing pad at the surface and in the interior and a second ligand binds to the bio-chemosensitive or chemosensitive or bio-chemosensitive and chemosensitive substance of the second sensing pad in the surface.
31. The optical sensor configuration according to claim 1, wherein a flow-through cell or a matrix of flow-through cells is arranged on the waveguide grating structure or in the waveguide grating structure.

32. The optical sensor configuration according to claim 1, wherein a capillary vessel or a matrix of capillary vessels is arranged on the waveguide grating structure or in the waveguide grating structure.

33. The optical sensor configuration according to claim 1, wherein the waveguiding material on the substrate comprises a plurality of layers.

34. The optical sensor configuration according to claim 1, wherein the waveguide is a monomode waveguide.

35. The optical sensor configuration according to claim 1, wherein in the waveguide grating structure unit or in at least one of said waveguide grating structure units one sensing pad is formed to be a signal sensing pad and one sensing pad is formed to be a reference sensing pad.

36. The optical sensor configuration according to claim 1 comprising means for the detection of at least one of a light distribution, of positions, and of intensities of light proportions emitted by the sensing pads.

37. The optical sensor configuration according to claim 1 wherein the incoupling gratings of the two sensing pads are not chirped and wherein their grating periods are constant.

38. The optical sensor configuration according to claim 1, wherein the light source or at least one light source is a light emitting diode or a laser diode.

39. The optical sensor configuration according to claim 1, wherein at least one grating comprises in addition to the zeroth diffraction order also higher diffraction orders.

40. An optical method for the characterization or detection or characterization of at least one chemical or bio-chemical or chemical and bio-chemical substance, by means of a sensor chip, which comprises an optical waveguide with a waveguide grating structure, wherein a sample is brought into contact with the waveguide in at least one contact zone, at least one light wave is excited across the waveguide grating structure in the region of the at least one contact zone and is brought into interaction with the sample, wherein the waveguide grating structure comprises at least to sensing pads,

wherein the at least two sensing pads each comprise at least one unidiffractive or multidiffractive incoupling grating and at least one unidiffractive or multidiffractive outcoupling grating,

wherein the grating lines of one incoupling grating define a plane with a first direction parallel to the grating lines and a second direction perpendicular to the first direction and

wherein the width of the grating is confined in the first direction and in the second direction,

wherein the incoupling grating of a first sensing pad is arranged at a distance in the first direction from the incoupling grating of a second sensing pad,

and wherein the incoupling grating of at least one sensing pad is illuminated as a whole by the light source.

41. An optical sensor configuration for the characterization or detection or detection and characterization of at least one chemical or bio-chemical or chemical and bio-chemical substance, comprising a sensor chip, which includes a waveguide and a waveguide grating structure, wherein the waveguide or the waveguide grating structure or the waveguide and the waveguide grating structure are operable to emit light proportions when light impinges on the waveguide grating structure,

the optical sensor configuration further comprising at least one light source for emitting light towards at least a part of the waveguide grating structure,

wherein the waveguide grating structure comprises at least two sensing pads,

wherein the at least two sensing pads each comprise at least one incoupling grating and at least one outcoupling grating, the grating lines of the incoupling gratings of a first and a second sensing pad being parallel,

wherein the grating lines of the first and second incoupling gratings define a plane with a first direction parallel to the grating lines and a second direction perpendicular to the first direction and wherein the width of the incoupling grating is confined in the first direction and in the second direction,

wherein the incoupling grating of a first sensing pad is arranged at a distance in the first direction from the incoupling grating of a second sensing pad,

wherein the outcoupling grating of the first sensing pad is arranged at a distance in the second direction from the incoupling grating of the first sensing pad and the outcoupling grating of the second sensing pad is arranged at a distance in the second direction from the incoupling grating of the second sensing pad,

wherein the width of the incoupling grating of at least one sensing pad is smaller in the first direction than the width of the outcoupling grating of said at least one sensing pad in the first direction and wherein the light source’s and the sensor chip’s mutual position is such that the light source is operable to illuminate the incoupling grating of the first and the second sensing pad as a whole.

42. The optical sensor configuration according to claim 41, wherein a well or a matrix of wells is arranged on the waveguide grating structure or in the waveguide grating structure.

43. The optical sensor configuration according to claim 41, wherein a flow-through cell or a matrix of flow-through cells is arranged on the waveguide grating structure or in the waveguide grating structure.

44. The optical sensor configuration according to claim 41, wherein a capillary vessel or a matrix of capillary vessels is arranged on the waveguide grating structure or in the waveguide grating structure.

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