(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 October 2007 (11.10.2007)

PCT

(10) International Publication Number
WO 2007/113727 A2

(51) International Patent Classification: **Not classified**

(21) International Application Number: PCT/IB2007/051045

(22) International Filing Date: 26 March 2007 (26.03.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
06112243.8 5 April 2006 (05.04.2006) EP

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

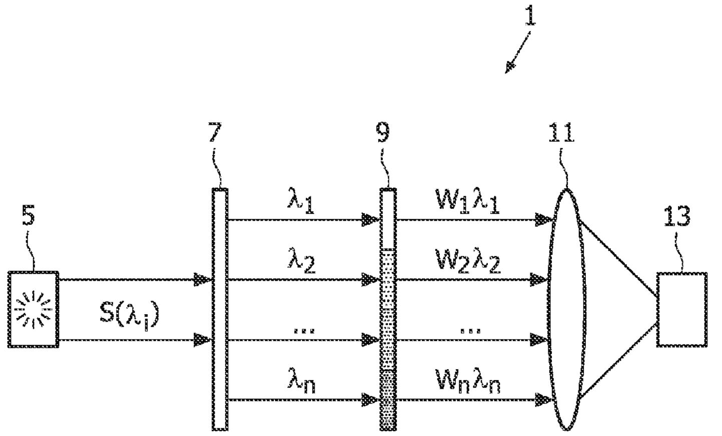
(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** A PORTABLE FOOD AND/OR BEVERAGE ANALYZER AND A METHOD OF ANALYZING A FOOD AND/OR BEVERAGE IN THE FIELD



(57) **Abstract:** The invention concerns a portable food and/or beverage analyzer comprising an optical analysis system for performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising a plurality of wavelengths emanating from a sample of the food and/or beverage to be analyzed, the plurality of wavelengths originating from illumination of the sample using a light source, the optical analysis system comprising a spectroscopic device comprising a dispersive element on which the optical signal is incident, for spatially separating the optical signal into its constituent plurality of wavelengths, a multivariate optical element being arranged so that the plurality of wavelengths is incident on the multivariate optical element, the multivariate optical element for transmitting the plurality of wavelengths with a respective weight coefficient depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, the spectroscopic device comprising a further optical element for performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient, the optical analyzer further comprising a single channel detector arranged to receive the summation wherein an output of the detector is directly indicative of a concentration of the chemical in the food and/or beverage.

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A portable food and/or beverage analyzer and a method of analyzing a food and/or beverage in the field

TECHNICAL FIELD

The invention relates to a portable food and/or beverage analyzer and a method of analyzing a food and/or beverage in the field.

BACKGROUND TO THE INVENTION AND PRIOR ART

A healthy diet is of importance for the welfare and the health of a person. For these reasons, the food industry employs various techniques in order to control the quality of food and/or beverages. For example, chemical and spectroscopic techniques are implemented to monitor food quality parameters such as moisture, protein and fat concentrations as well as other product specific attributes. Conventional chemical and spectroscopic techniques are complex and expensive requiring expensive apparatus. For example, until now the use of expensive devices costing hundreds of thousands of dollars is a privilege of large manufacturers. As a result, in contrast to big food product industries where very expensive and often time consuming analyses are used, consumers, small businesses, general population as well as populations in poor and/or remote areas still have to rely on such old fashioned techniques as visual inspection and sense of smell. A decrease in the cost of spectroscopic devices for food and beverage inspective would make such inspection techniques available for individual customers and small businesses.

It is an object of the present invention to address those problems encountered in conventional food and beverage analysis. In particular, it is an object to provide a low cost effective food and/or beverage analyzer, which may be affordable and usable by small businesses and consumers as well as large businesses. There is a need for a low cost portable food and/or beverage analyzer.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a A portable food and/or beverage analyzer comprising an optical analysis system for performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising a plurality of wavelengths emanating from a sample of the food and/or beverage to be analyzed, the plurality of wavelengths originating from illumination of the sample using a light source, the optical analysis system comprising a spectroscopic device comprising a dispersive element on which the optical signal is incident, for spatially separating the optical signal into its constituent plurality of wavelengths, a multivariate optical element being arranged so that the plurality of wavelengths is incident on the multivariate optical element, the multivariate optical element for transmitting the plurality of wavelengths with a respective weight coefficient depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, the spectroscopic device comprising a further optical element for performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient, the optical analyzer further comprising a single channel detector arranged to receive the summation wherein an output of the detector is directly indicative of a concentration of the chemical in the food and/or beverage. In this way, a low cost and portable food and/or beverage analyzer is provided without the need for additional computing resources. The analyzer may be used in the field by users without any specialist training.

In one embodiment, the spectroscopic device comprises only one multivariate optical element. In this way, the cost and bulkiness of the device is further reduced with respect to conventional spectroscopic devices comprising a plurality of multivariate optical elements.

In a further, embodiment, the multivariate optical element is a variable multivariate optical element.

In yet a further embodiment, the multivariate element comprises a liquid crystal device or a digital micro mirror, or a liquid crystal on silicon (LCoS).

In a further embodiment, the multivariate optical element is arranged so that its output may be used to identify one or more predetermined optical spectra from the food and/or beverage by identifying the specific spectral pattern for one or more predetermined chemicals, respectively. In this way, various chemicals' concentrations may be determined from complex mixtures having an unknown composition.

In one embodiment, the analyzer is arranged to analyze ingredients in food and/or beverages, such as fat, salts, water content and other such ingredients.

In a further embodiment, the analyzer is arranged to analyze one or more food decay products, impurities, such as impurities in water and other beverages.

According to a second aspect of the present invention, there is provided a method of analyzing a food and/or beverage in the field, the method comprising: performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising analyzing a plurality of wavelengths emanating from a sample of the food and/or beverage to be analyzed, the plurality of wavelengths originating from illumination of the sample using a light source, providing a spectroscopic device which:

-spatially separates the optical signal into its constituent plurality of wavelengths, using a multivariate optical element being arranged so that the plurality of wavelengths is incident on the multivariate optical element, to transmit the plurality of wavelengths with a respective weight coefficient depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient, the method further comprising using a single channel detector to receive the summation wherein an output of the detector is directly indicative of a concentration of the chemical in the food and/or beverage.

According to a third aspect of the invention, there is provided a use of a multivariate optical element to analyze a food and/or a beverage.

According to a fourth aspect of the invention, there is provided an in-line process control system for controlling the processing of a food or beverage product comprising a food and/or beverage analyzer according to claim 1. The invention is not limited to analysis of ready-to-use foods and beverages. It may also be applied for example, in in-line process control at food and beverage factories. In this way, the products in production in a production line may be readily monitored at various stages during and after their production.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more fully understood, embodiments thereof will now be described by way of example only, with reference to the figures in which:

Figure 1 shows a food and/or beverage analyzer according to an embodiment of the invention;

Figure 2 shows a graph depicting measured Raman spectra of 96% ethanol (solid line) and 99.8% methanol (dotted line), and

Figure 3 shows a graph depicting measured Raman spectrum of pure 99.8% methanol (a) and the Raman difference spectrum of mixtures containing 47.2% ethanol and 1.6% methanol in water and 48% ethanol in water respectively (b).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a food and/or beverage analyzer according to an embodiment of the invention. The food and/or beverage analyzer includes a multivariate optical element. In particular, a low cost spectroscopic device is provided for quantitative chemical analysis and has been developed by the applicants, based on variable multivariate optical element (VMOE). The variable multivariate optical element uses multivariate calibration (MC) to quantify concentrations of analyses, such as chemicals, of interest. The analysis may be carried out in mixtures with complex composition, such as food and beverages.

In conventional multivariate calibration an expensive (50k$) multichannel light detector is used to register optical spectra, followed by mathematical computations performed in computer software. Unlike conventional multivariate calibration, the VMOE according to an embodiment of the invention performs all the necessary computations in the optical domain. This makes a multichannel detector redundant, which dramatically decreases the cost of the device.

The potentially low cost of the technique according to an embodiment of the present invention of using a multivariate optical element in combination with a single channel detector (less then 100$ for an apparatus) and its rapid and non-destructive analytical capability allow a consumer food & beverages control application to be developed. Embodiments of the present invention may have various applications, including, but not limited to a device, aimed at individual customers and able to analyze fat, salts, water content and other ingredients in food products. In this way, consumers can readily find out "healthy" a food product is. In a further embodiment, a device is provided which may be used to identify whether a food or beverage is fresh or fit for consumption. For example, in countries, such as developing countries, where the quality of food is often low and their food certificates issued by local authorities may not be reliable. In such embodiments, an apparatus is used to control food aging (for example, by detecting food decay products), water purity monitoring, beverages quality monitor, etc. In particular, it is desirable to be able to monitor the quality of beverages, since low quality beverage products, containing an increased amount of certain potentially damaging chemicals, such as methanol, often result in high lethality upon consumption of the product.

Devices according to embodiments of the present invention may be employed as a mobile/portable food product control for governmental organizations, small businesses as well as consumers or consumer groups. According to an embodiment of the present invention, as described with reference to Figures 2 and 3, the analyzer includes a spectroscopic device. In one embodiment, the VMOE device has been developed for Raman spectroscopy at 532 nm excitation and for emission wavelength of ~ 640 nm. The present invention is not limited in this respect and may be readily adapted for the majority of spectroscopic modes/processes, including fluorescence, phosphorescence, light scattering, UV, VIS, NIR and MIR absorption. It will be understood that the light source according to embodiments of the present invention, will provide a source of radiation in accordance with the particular spectroscopic mode/process chosen. Embodiments of the present invention are capable of analyzing component concentration in liquid, solid and gas phases of a matter.

Figure 1 shows a low cost spectroscopic device for quantitative chemical analysis according to an embodiment of the invention. The portable food and/or beverage analyzer comprising an optical analysis system for performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising a plurality of wavelengths emanating from the food and/or beverage to be analyzed. These wavelengths originate from illumination of the sample using a light source, such as laser, light emitting diode, or a white light source, e.g. a halogen lamp, or any other light source. The optical analysis system comprising a spectroscopic device 1. The principle behind the variable multivariate optical element of the present invention is as follows: in multivariate calibration, a specific spectral pattern for a particular analyze (chemical) of interest, called a regression vector, is identified based on the optical spectra of the optical signal S(lambda i) emanating from the chemical to be analyzed present in the sample 5. This spectral pattern allows for accurate prediction of analyze concentration in mixtures with unknown composition. In particular, the spectroscopic device may comprise a dispersive element 7 on which the optical signal S(lambda i) is incident. The dispersive element 7 spatially separates the optical signal S(lambda i) into its constituent plurality of wavelengths lambda 1, lambda 2...lambda n. The spectroscopic device further includes a multivariate optical element 9. The multivariate optical element 9 is arranged so that the plurality of wavelengths lambda 1, lambda 2...lambda n is incident on the multivariate optical element 9. The multivariate optical element 9 transmits the plurality of wavelengths with a respective weight coefficient W1lambda1, W2lambda 2...Wnlamba n depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, as mentioned above. The spectroscopic device comprises a further optical element 11 for performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient W1lambda1, W2lambda 2...Wnlamba n. The spectroscopic device further comprises a single channel detector 13 arranged to receive the summation. An output of the detector 13 is directly indicative of a concentration of the chemical in the food and/or beverage. In the embodiment shown in Figure 1, the variable multivariate optical element concept is based on the multivariate optical element being a transmissive liquid crystal display (LCD) panel. The signal S(lamba) from the sample 5 falls on the dispersive element 7. The LCD 9 is placed downstream of the dispersive element 9. The dispersive element 7 spatially separates the wavelengths. The LCD panel comprises a plurality of individual pixels, and is arranged so that the plurality of wavelengths address individual pixels. By addressing individual pixels of the LCD their optical transmittance is changed. As a result, individual wavelengths are transmitted with different weight coefficients W1lambda1, W2lambda2...Wnlamdan. The resulting signal is focused by a lens 11 on a single photodiode 13. The weight coefficients are components of the regression vector, thus multiplication of a regression vector by optical spectrum is performed. By focusing the transmitted signal by a lens, summation over the wavelength dimension is performed. So, the overall effect is equivalent to mathematic computation usually performed in computer software. In this way, the concentration can be directly inferred from the output of the detector. Thus, mathematic computation usually performed in computer software is avoided. Thus, rendering the device simpler, cheaper and more portable than conventional spectroscopic devices. In one embodiment, the spectroscopic device comprises only one multivariate optical element. In this way, the cost is further reduced with respect to conventional spectroscopic devices, such as that disclosed in WO2005/062006, which comprises two multivariate optical elements. As mentioned, the multivariate optical element may be a variable multivariate optical element. In the embodiment shown in Figure 1, the multivariate optical element comprises a liquid crystal device. However, in an alternative embodiment, the multivariate optical element may comprise a digital micromirror device (DMD) or a liquid crystal on silicone (LCoS). In a further embodiment, the multivariate optical element is arranged so that its output may be used to identify one or more predetermined optical spectra from the food and/or beverage by identifying the specific spectral pattern for one or more predetermined chemicals, respectively. In this way, a variety of chemicals can be determined quantitively in complex mixtures. Further, the one or more specific patterns may be a regression vector. The regression vector allows an accurate prediction of a concentration of the one or more chemical in the food and/or beverage having an unknown composition. In this way, the accuracy of the prediction is improved. Different coefficients of the individual wavelengths may be components of the regression vector. As mentioned, the further optical element is a focusing element, such as a lens, and the single channel detector is a single photo detector, wherein the focusing element is arranged to focus the transmitted signal onto the single photo detector. The portable food and/or beverage analyzer may be arranged to analyze ingredients in food and/or beverages, such as fat, salts, water content and other such ingredients. Alternatively or in addition, the portable food and/or beverage analyzer may be arranged to analyze one or more food decay products, impurities, such as impurities in water and other beverages.

Figure 2 shows a graph depicting measured Raman spectra of 96% ethanol (solid line) and 99.8% methanol (dotted line), and Figure 3 shows a graph depicting measured Raman spectrum of pure 99.8% methanol (a) and the Raman difference spectrum of mixtures containing 47.2% ethanol and 1.6% methanol in water and 48% ethanol in water respectively (b). With reference to Figures 2 and 3, the experimental results obtained using the device shown in Figure 1 of the principles of the developed technique to detect small amounts of the analyze of interest in complex environment are demonstrated. A practically relevant system was considered, where small amounts of methanol in ethanol/water mixture (vodka) were detected. This is important for quality control of beverages, where methanol concentrations could be varying within the range of 0.2 – 2% (v/v).

If the concentration of methanol is too high it is known that it may lead to severe poisoning. Exact values depend on food standards accepted by different countries. Nevertheless it is relevant to be able to detect the concentration of methanol in a mixture of ethanol and water.

Figure 2 shows the measured Raman spectra of 96 % ethanol (solid line) and 99.8 % methanol (dotted line). The assignment of Raman shifted frequencies is given in accordance to literature.

Figure 3 shows the measured Raman spectrum of pure 99.8 % methanol (a) and the Raman difference spectrum of mixtures containing 47.2 % ethanol and 1.6 % methanol in water and 48 % ethanol in water respectively (b). The positive Raman bands in the difference spectrum are due to methanol contribution, while the negative bands are due to decreased ethanol contribution. As can be seen from Fig. 3b the small concentration of methanol in mixtures of ethanol and water (vodka) is clearly seen. Therefore, it is demonstrated that it is possible to apply VMOE-based spectrometer for low-level methanol detection. In one embodiment, the accuracy of prediction of methanol concentration may be further improved by a partial least squares (PLS) calibration, principal component regression (PCR) or other method based on a multivariate calibration.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention. Any reference signs in the claims shall not be construed as limiting the scope.

CLAIMS:

1. A portable food and/or beverage analyzer comprising an optical analysis system for performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising a plurality of wavelengths emanating from a sample of the food and/or beverage to be analyzed, the plurality of wavelengths originating from illumination of the sample using a light source, the optical analysis system comprising a spectroscopic device comprising a dispersive element on which the optical signal is incident, for spatially separating the optical signal into its constituent plurality of wavelengths, a multivariate optical element being arranged so that the plurality of wavelengths is incident on the multivariate optical element, the multivariate optical element for transmitting the plurality of wavelengths with a respective weight coefficient depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, the spectroscopic device comprising a further optical element for performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient, the optical analyzer further comprising a single channel detector arranged to receive the summation wherein an output of the detector is directly indicative of a concentration of the chemical in the food and/or beverage.

2. A portable food and/or beverage analyzer according to claim 1, wherein the spectroscopic device comprises only one multivariate optical element.

3. A portable food and/or beverage analyzer according to claim 1, wherein the multivariate optical element is a variable multivariate optical element.

4. A portable food and/or beverage analyzer according to claim 1 or 3, wherein the multivariate element comprises a liquid crystal device, a digital micromirror or a liquid crystal on silicon.

5. A portable food and/or beverage analyzer according to claim 1, wherein the multivariate optical element is arranged so that its output may be used to identify one or more

predetermined optical spectra from the food and/or beverage by identifying the specific spectral pattern for one or more predetermined chemicals, respectively.

6. A portable food and/or beverage analyzer according to claim 1, wherein the one or more specific patterns is a regression vector, wherein the regression vector allows an accurate prediction of a concentration of the one or more chemical in the food and/or beverage having an unknown composition.

7. A portable food and/or beverage analyzer according to claim 1, wherein the multivariate optical element comprises a plurality of individual pixels, and is arranged so that the plurality of wavelengths address individual pixels their optical transmittance is changed, so that the individual wavelengths are transmitted with different weight coefficients.

8. A portable food and/or beverage analyzer according to claim 7, wherein different coefficients of the individual wavelengths are components of the regression vector.

9. A portable food and/or beverage analyzer according to claim 8, wherein the further optical element is a focusing element, such as a lens, and the single channel detector is a single photo detector, wherein the focusing element is arranged to focus the transmitted signal onto the single photo detector.

10. A portable food and/or beverage analyzer according to claim 1, being arranged to analyze ingredients in food and/or beverages, such as fat, salts, water content and other such ingredients.

11. A portable food and/or beverage analyzer according to claim 1, being arranged to analyze one or more food decay products, impurities, such as impurities in water and other beverages.

12. A portable food and/or beverage analyzer according to claim 1, including a partial least squares (PLS) calibration, principal component regression (PCR) or other method based on multivariate calibration.

13. A method of analyzing a food and/or beverage in the field, the method comprising: performing a quantitative chemical analysis of a food and/or beverage by analyzing an optical signal comprising analyzing a plurality of wavelengths emanating from a sample of the food and/or beverage to be analyzed, the plurality of wavelengths originating from illumination of the sample using a light source, providing a spectroscopic device which: spatially separates the optical signal into its constituent plurality of wavelengths, using a multivariate optical element being arranged so that the plurality of wavelengths is incident on the multivariate optical element, to transmit the plurality of wavelengths with a respective weight coefficient depending on a specific spectral pattern of the chemical to be analyzed to achieve a multiplication of the specific spectral pattern, performing a summation over a wavelength dimension of the plurality of wavelengths with a respective weight coefficient, the method further comprising using a single channel detector to receive the summation wherein an output of the detector is directly indicative of a concentration of the chemical in the food and/or beverage.

14. The use of a multivariate optical element to analyze a food and/or a beverage.

15. An in-line process control system for controlling the processing of a food or beverage product comprising a food and/or beverage analyzer according to claim 1.

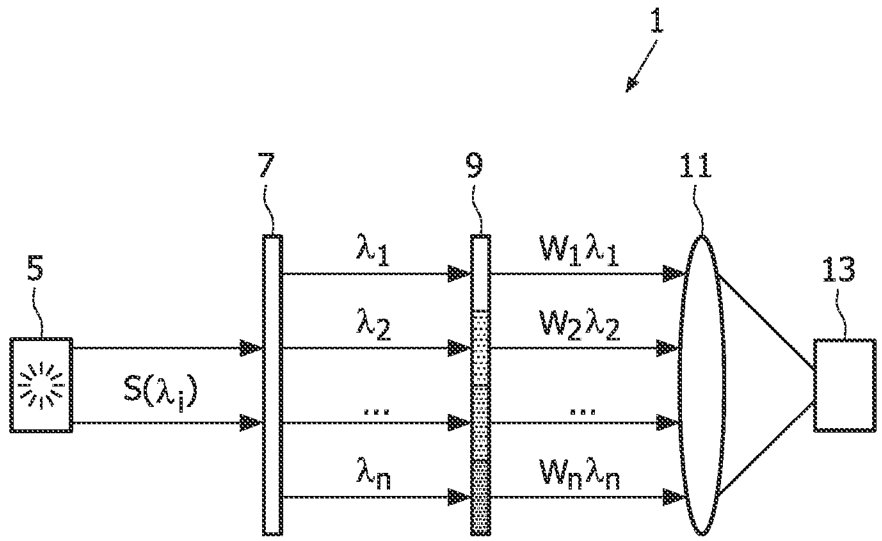
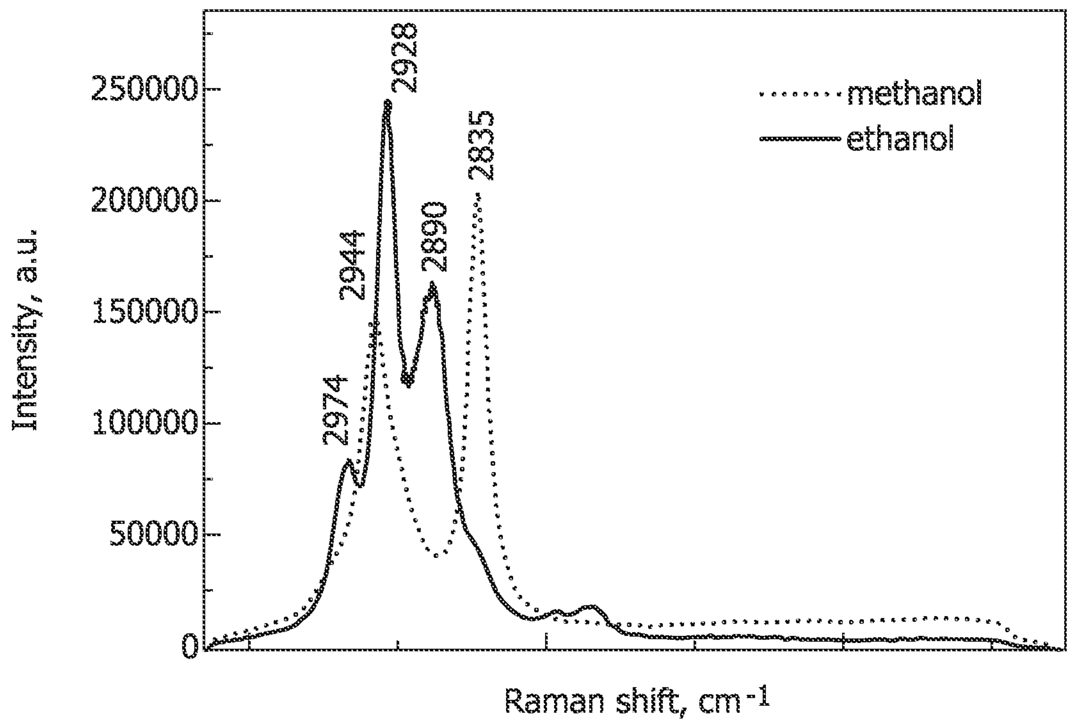

1
7
9
11
5
13
λ1
λ2
...
λn
S(λi)
W1λ1
W2λ2
...
Wnλn

FIG. 1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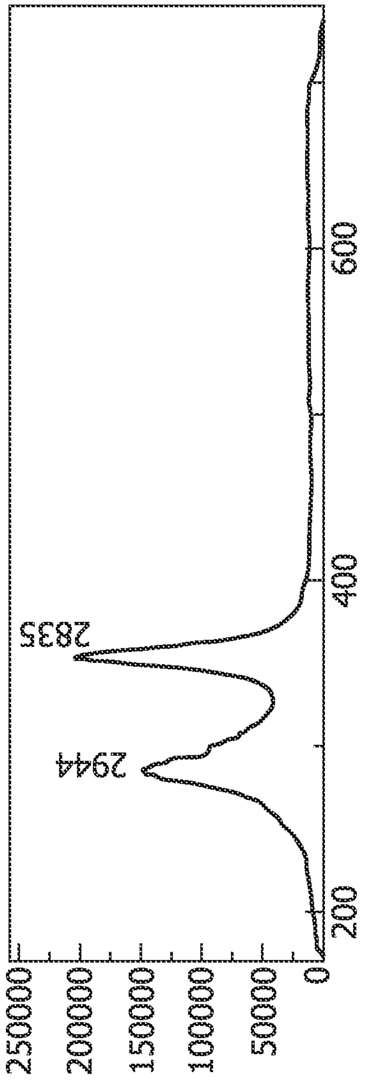
ethanol
Raman shift, cm-1

FIG. 2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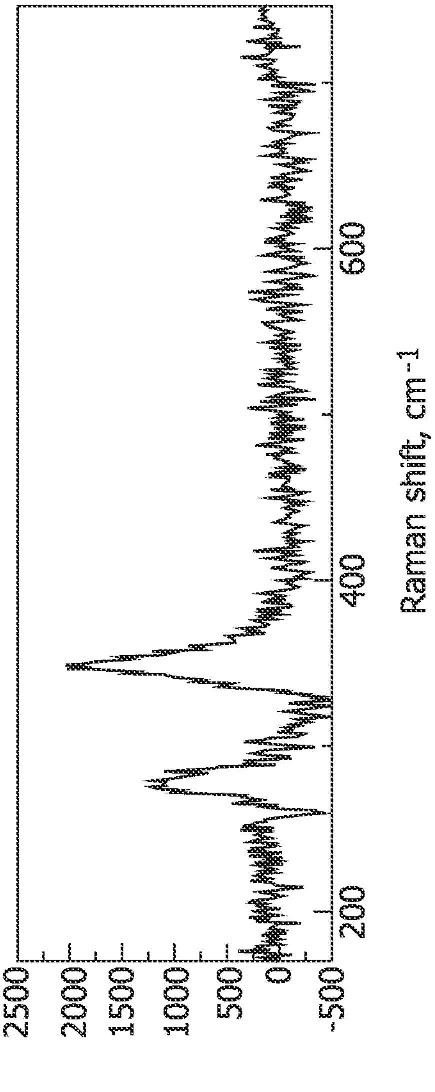
400
600

FIG. 3a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2000
1500
1000
500
0
-500
200
400
600
Raman shift, cm⁻¹

FIG. 3b