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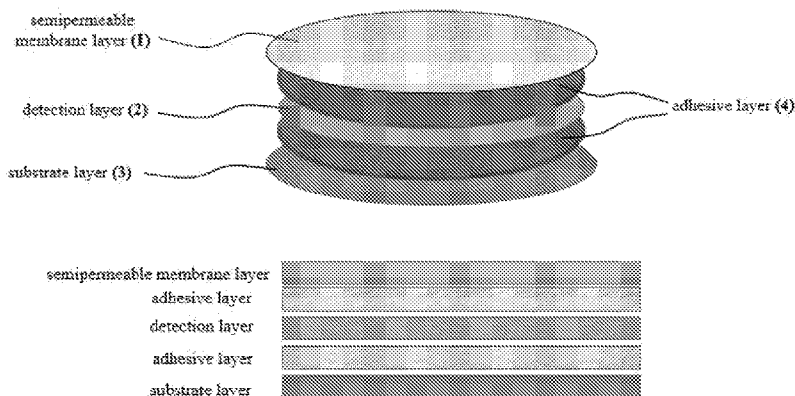


FIG. 1

(57) Abstract: System, device and method adapted for analyzing volatile organic compounds (VOCs). The system or the device comprises a semipermeable membrane layer (1), which the VOCs can pass through; a detection layer (2), which comprises a detection substance which can react to the VOCs and a matrix substance; optionally, a substrate layer (3).

VOLATILE ORGANIC COMPOUND DETECTION DEVICE

FIELD OF THE INVENTION

[0001] The present invention generally relates to device, systems and method for detecting of volatile organic compounds (VOCs). More particularly, the invention relates detecting of VOCs using a device or systems comprising a semipermeable membrane and a detecting substance and the invention relates the method using the said device or systems.

BACKGROUND OF THE INVENTION

[0002] Volatile organic compounds (VOCs) are a class of molecules with high vapor pressure at room temperature, and many have the potential to cause damage to both

environment and human health. Some VOCs are also indicators or biomarkers for diseases.

The ability to accurately detect the presence of VOCs may therefore be helpful in areas such as air quality monitoring, biomedical diagnostics, industrial processes, security and occupational health, etc. Conventional techniques for the detection of volatile organic compounds include mass spectrometry, gas chromatography, and ion mobility spectroscopy.

However, those are bench-top techniques, which require trained personnels, large setups, high operational cost and sophisticated equipment, and require a significant amount of time to generate results, thereby limiting their on-site applicability.

[0003] However, conventional electronic gas sensors also suffer from a number of drawbacks. Therefore, there is a need for new and improved systems and methods for detecting target analytes such as VOCs.

BRIEF SUMMARY OF THE INVENTION

[0004] In one aspect, the present disclosure provides a device for detecting volatile organic compounds (VOC), comprising:

(a) a semipermeable membrane layer, wherein the VOC can pass through the said semipermeable membrane layer;

(b) a detection layer, wherein the detection layer comprising (i) a detecting substance which responses to the VOC, and (ii) a matrix substance; and

(c) optionally a substrate layer.

[0005] In some embodiments, the semipermeable membrane allows the pass through of the VOC but does not allow the pass through of the detecting substance in the detection layer.

[0006] In some embodiments, the semipermeable membrane is water permeable.

- [0007] In some embodiments, the semipermeable membrane is detecting substance impermeable.
- [0008] In some embodiments, the semipermeable membrane is natural.
- [0009] In some embodiments, the semipermeable membrane is synthetic.
- 5 [0010] In some embodiments, the semipermeable membrane is cellulosic.
- [0011] In some embodiments, the semipermeable membrane is made of the substance selected from the group consisting of cellophane, cellulose acetate (CA), polyurethane (PU), polytrifluorochloroethylene (PCTFE), polyvinyl chloride (PVC), polysulfone (PS), polyvinylidene fluoride (PVDF), polyethylene (PE), polyacrylonitrile (PAN), polyvinyl
- 10 alcohol (PVA) and polyimide (PI).
- [0012] In some embodiments, the semipermeable membrane is made of cellulose acetate (CA).
- [0013] In some embodiments, the VOC is hazardous to human health.
- [0014] In some embodiments, the VOC is a marker for a disease.
- 15 [0015] In some embodiments, the VOC is a metabolite of a mammal.
- [0016] In some embodiments, the VOC comprising aldehydes, ketones, amines, thiols, esters, or carboxylic acids.
- [0017] In some embodiments, the VOC is generated by the spoilage of food.
- [0018] In some embodiments, the VOC is an amine.
- 20 [0019] In some embodiments, the VOC is tryptamine, β -phenylethylamine, putrescine, cadaverine, histamine, octopamine, tyramine, spermidine or spermine.
- [0020] In some embodiments, the detecting substance is a pH indicator.
- [0021] In some embodiments, the detecting substance is a protein, a nucleic acid, a polymer, a small molecule, or a nanomaterial.
- 25 [0022] In some embodiments, the detecting substance is nano gold, nano silver, CdS quantum dots or carbon quantum dots.
- [0023] In some embodiments, the detecting substance is nano silver.
- [0024] In some embodiments, the detecting substance is an organometallic complex.
- [0025] In some embodiments, the detecting substance is a bimetallic complex.
- 30 [0026] In some embodiments, the detecting substance can generate a signal when respond to the VOC.
- [0027] In some embodiments, the measurable signal is a change in fluorescence spectrum or visible spectrum of the detecting substance.

[0028] In some embodiments, the measurable signal is a change in refractive index of the detecting substance.

[0029] In some embodiments, the measurable signal is a change in the volume or thickness of the detection layer.

5 [0030] In some embodiments, the matrix substance is a polymer.

[0031] In some embodiments, the matrix substance is a natural polymer.

[0032] In some embodiments, the matrix substance is cellulose or chemically modified cellulose.

[0033] In some embodiments, the matrix substance is PVA.

10 [0034] In some embodiments, the matrix substance is hydrogel.

[0035] In some embodiments, the matrix substance is paper pulp.

[0036] In some embodiments, the detection layer further comprising a stabilizer for stabilizing the detecting substance.

15 [0037] In some embodiments, the detection layer further comprising a suspending agent.

[0038] In some embodiments, the detection layer further comprising a moisturizer.

[0039] In some embodiments, the moisturizer is glycol or glycerol.

[0040] In some embodiments, the device further comprising a first adhesive layer between the semipermeable membrane layer and the detection layer.

20 [0041] In some embodiments, the device further comprising a second adhesive layer between the substrate layer and the detection layer.

[0042] In some embodiments, the detection layer comprising an adhesive agent which can assemble the substrate layer and the semipermeable membrane layer.

25 [0043] In another aspect, the present disclosure provides an adhesive tape for detecting volatile organic compounds (VOC), comprising:

(a) the semipermeable membrane layer described herein;

(b) the detection layer described herein;

(c) a release layer;

30 (d) optionally, a first adhesive layer between the semipermeable membrane layer and the detection layer; and

(e) optionally, a second adhesive layer between the semipermeable membrane layer and the detection layer.

[0044] In another aspect, the present disclosure provides a system for detecting volatile organic compounds (VOC), comprising a container and the device described herein.

[0045] In some embodiments, the system further comprising an observation window.

[0046] In another aspect, the present disclosure provides the use of the system described herein, comprising

- (a) placing the food in the container;
- (b) allowing the device described herein to contact the VOC,
- (c) observing a change of the detection layer.

[0047] In another aspect, the present disclosure provides the use of the device described herein in diagnosis of a disease, comprising:

- (a) allowing the device described herein to contact the exhaled VOC,
- (b) observing a change of the detection layer.

[0048] In some embodiments, the disease is a cancer, an infectious disease or a chronic disease.

[0049] In some embodiments, the cancer is selected from the group consisting of neuroblastoma, lymphoma, leukemia, melanoma, glioma, small cell lung cancer, breast carcinoma, ovarian cancer, soft tissue sarcomas, osteosarcoma, Ewing's sarcoma, desmoplastic round cell tumor, rhabdomyosarcoma, retinoblastoma, non-small cell lung cancer, renal cell cancer, Wilms tumor, prostate cancer, gastric cancer, endometrial cancer, pancreatic cancer, and colon cancer.

[0050] In some embodiments, the disease is an infectious disease

[0051] In some embodiments, the disease is a chronic disease.

[0052] In some embodiments, the disease is Alzheimer's disease.

[0053] In some embodiments, the disease is diabetes.

[0054] In yet another aspect, the present disclosure provides a kit for disease diagnosis comprising the device described herein.

BRIEF DESCRIPTION OF THE FIGURES

[0055] The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present disclosure. The disclosure may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

[0056] FIG. 1 shows an exemplary design of the device with five layers.

[0057] FIG. 2 shows an exemplary design of the device with three layers, wherein the detection layer comprising a detecting region and an adhesive region.

[0058] FIG. 3A depicts the response of the label fabricated with pH paper and Red litmus paper to TME (trimethylamine). FIG. 3B depicts the response of the label fabricated with pH paper and Blue litmus paper to acetic acid. FIG. 3C depicts the response of the label fabricated with a FeFe-based filter paper to TME (trimethylamine).

5 DETAILED DESCRIPTION OF THE INVENTION

[0059] In the Summary of the Invention above and in the Detailed Description of the Invention, and the claims below, and in the accompanying drawings, reference is made to particular features (including method steps) of the invention. It is to be understood that the disclosure of the invention in this specification includes all possible combinations of such particular features. For example, where a particular feature is disclosed in the context of a particular aspect or embodiment of the invention, or particular claim, that feature can also be used, to the extent possible, in combination with and/or in the context of other particular aspects and embodiments of the invention.

[0060] Throughout the present disclosure, the articles “a,” “an,” and “the” are used herein to refer to one or to more than one (i.e., to at least one) of the grammatical object of the article. By way of example, “a compound” means one compound or more than one compound.

[0061] As used herein, the term “and/or” indicates that one or more of the stated cases may occur, alone or in combination with at least one of the stated cases, up to with all of the stated cases, and in the invention generally.

[0062] The term “comprises” and grammatical equivalents thereof are used herein to mean that other components, ingredients, steps, etc. are optionally present. For example, an article “comprising” (or “which comprises”) components A, B, and C can consist of (i.e., contain only) components A, B, and C, or can contain not only components A, B, and C but also one or more other components.

[0063] Where reference is made herein to a method comprising two or more defined steps, the defined steps can be carried out in any order or simultaneously (except where the context excludes that possibility), and the method can include one or more other steps which are carried out before any of the defined steps, between two of the defined steps, or after all the defined steps (except where the context excludes that possibility).

[0064] Where a range of value is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictate otherwise, between the upper and lower limit of that range and any other stated or intervening value in

that stated range, is encompassed within the disclosure, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure.

[0065] The term “at least” followed by a number is used herein to denote the start of a range beginning with that number (which may be a range having an upper limit or no upper limit, depending on the variable being defined). For example, “at least 1” means 1 or more than 1. The term “at most” followed by a number is used herein to denote the end of a range ending with that number (which may be a range having 1 or 0 as its lower limit, or a range having no lower limit, depending upon the variable being defined). For example, “at most 4” means 4 or less than 4, and “at most 40%” means 40% or less than 40%. When, in this specification, a range is given as “(a first number) to (a second number)” or “(a first number)–(a second number),” this means a range whose lower limit is the first number and whose upper limit is the second number. For example, 25 to 100 mm means a range whose lower limit is 25 mm, and whose upper limit is 100 mm.

[0066] It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant function being described. Also, the description is not to be considered as limiting the scope of the implementations described herein. It will be understood that descriptions and characterizations of the embodiments set forth in this disclosure are not to be considered as mutually exclusive, unless otherwise noted.

Detection device

[0067] The invention provides a multilayer detection device, which physically isolates the subject to be detected from the detected substance but does not affect the detection performance.

[0068] In one aspect, the present disclosure provides a device for detecting volatile organic compounds (VOC), comprising:

- (a) a semipermeable membrane layer, wherein the VOC can pass through the said semipermeable membrane layer;

(b) a detection layer, wherein the detection layer comprising (i) a detecting substance which responses to the VOC, and (ii) a matrix substance; and
(c) optionally a substrate layer.

[0069] In some embodiments, the device further comprising a first adhesive layer
5 between the semipermeable membrane layer and the detection layer.

[0070] In some embodiments, the device further comprising a second adhesive layer
between the substrate layer and the detection layer.

[0071] An exemplary design is shown in FIG.1. From top to bottom, the device
comprising a semipermeable membrane layer (1), a first adhesive layer (4), a detection layer
10 (2), a second adhesive layer (4), and a substrate layer (5).

[0072] In some embodiments, the detection layer comprising an adhesive agent which
can assemble the substrate layer and the semipermeable membrane layer.

[0073] Another exemplary detection device is shown in FIG. 2. In another aspect, the
present disclosure provides a for detecting volatile organic compounds (VOC), comprising:
15 (a) a semipermeable membrane layer (1), wherein the VOC can pass through the
said semipermeable membrane layer;
(b) a detection layer (2), wherein the detection layer comprising
(i) a detecting region (21) comprising a detecting substance which response to
the VOC, and a matrix substance, and
20 (ii) an adhesive region (22); and
(c) optionally a substrate layer (3).

Semipermeable membrane

[0074] Semipermeable membrane is a kind of membrane that only allows certain
molecules or ions to diffuse in and out.

25 [0075] In some embodiments, the semipermeable membrane allows the pass through
of the VOC but does not allow the pass through of the detecting substance in the detection
layer.

[0076] In some embodiments, the semipermeable membrane is water permeable.

[0077] In some embodiments, the semipermeable membrane is detecting substance
30 impermeable.

[0078] In some embodiments, the semipermeable membrane is natural. Natural semi-
permeable membranes including frog skin, bladder membrane or parchment.

[0079] In some embodiments, the semipermeable membrane is synthetic. Artificial semipermeable membranes include a variety of materials designed for the purposes of filtration, such as those used in reverse osmosis, which only allow water to pass. In some embodiments, the semipermeable membrane is cellulosic. In some embodiments, the semipermeable membrane is made of the substance selected from the group consisting of cellophane, cellulose acetate (CA), polyurethane (PU), polytrifluorochloroethylene (PCTFE), polyvinyl chloride (PVC), polysulfone (PS), polyvinylidene fluoride (PVDF), polyethylene (PE), polyacrylonitrile (PAN), polyvinyl alcohol (PVA) and polyimide (PI). In some embodiments, the semipermeable membrane is made of cellulose acetate (CA).

10 Volatile organic compounds

[0080] The systems and methods described herein may be used to detect VOCs in a nearby or surrounding environment (e.g., for detection and/or tracking of threats). In some variations, such detection systems and methods may sense the presence and/or distance of trace species (e.g., explosives, gunpowder, ammonium nitrate, opioids, biological agents, other trace VOC species, etc.). As another example, in some variations, systems and methods such as that described herein may be used to detect VOCs in the breath of a user for diagnosis and/or tracking of medical conditions or other health state (e.g., COVID-19).

[0081] In some embodiments, the VOC is hazardous to human health.

[0082] In some embodiments, the VOC is a marker for a disease. In some

embodiments, the VOC is a metabolite of a mammal. In some embodiments, the VOC comprising aldehydes, ketones, amines, thiols, esters, or carboxylic acids.

[0083] As used herein, the term “metabolite” are derivatives resulting from metabolic process in the body of a subject. For example, such metabolites may result from oxidation, reduction, hydrolysis, amidation, deamidation, esterification, deesterification, enzymatic cleavage, and the like, of a compound

[0084] Patient's exhaled breath detection technology is a new method for disease diagnosis, which has been widely concerned by researchers since its development. In recent years, some progress has been made in the diagnosis of non-infectious diseases (such as bronchial asthma, lung cancer, breast cancer, colorectal cancer, etc.) and infectious diseases (such as tuberculosis, COVID-19). For infectious diseases, pathogenic microorganisms can produce a wide range of VOCs, such as hydrocarbons, alcohols, ketones, nitrogen-containing and sulfur-containing compounds, etc. after infecting the body.

[0085] Metabolism of pathogenic microorganisms may affect exhaled breath components. Different species of microorganisms produce different kinds of VOC when they grow and metabolize in human tissue microenvironment, which makes it possible to detect their metabolic spectrum and specific substances. The detection of exhaled VOC has the advantages of non-invasive, simple sampling and high speed, and has great application value.

[0086] In some embodiments, the VOC is generated by the spoilage of food. In some embodiments, the VOC is an amine. Protein-rich foods, such as seafood and meat, will be invaded by microorganisms during food processing and manufacturing, and proteins will be decomposed, and then converted into biogenic amines by decarboxylase. Biogenic amines are one of the markers of food spoilage. Therefore, the monitoring of biogenic amines is very important for freshness evaluation. In some embodiments, the VOC is tryptamine, β -phenylethylamine, putrescine, cadaverine, histamine, octopamine, tyramine, spermidine or spermine.

Detecting substance

[0087] Appropriate detecting substance can be selected according to the VOC to be detected. The detecting substance may be a protein, a nucleic acid, a polymer, a small molecule, or a nanomaterial.

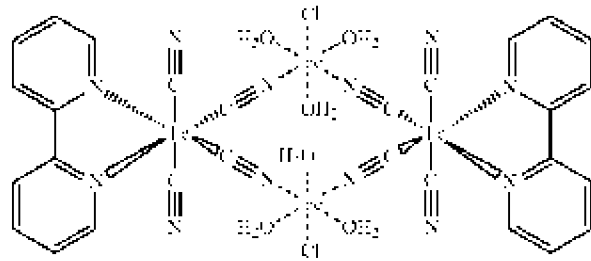
[0088] In some embodiments, the detecting substance is a pH indicator. In some embodiments, the detecting substance is bromocresol green, bromocresol purple, bromocresol blue, methyl red, anthocyanin, beta-carotene, curcumin, alizarin, or alkannin.

[0089] The detecting substance may be nano material. For example, gold nanoparticles can be loaded to determine volatile biogenic amines and sulfides to monitor the freshness of raw meat, raw fish and raw crustaceans. In some embodiments, the detecting substance is nano gold, nano silver, CdS quantum dots or carbon quantum dots.

[0090] In some embodiments, the detecting substance is an organometallic complex.

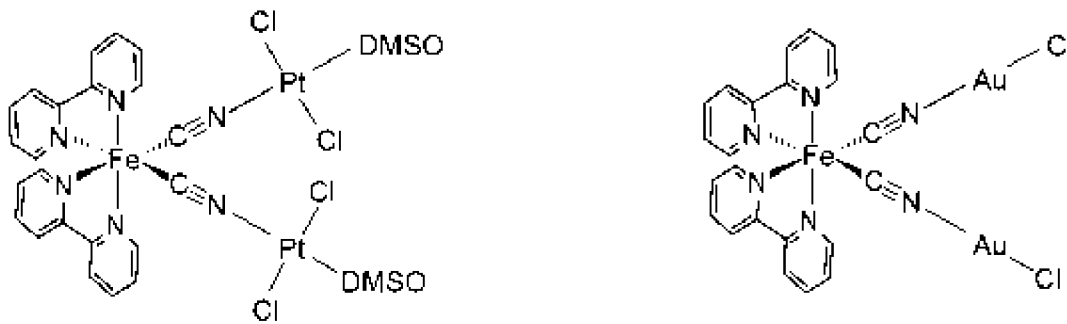
[0091] In some embodiments, the detecting substance is a bimetallic complex.

[0092] In some embodiments, the detecting substance is the compound of formulae I (also called as “FeFe”):



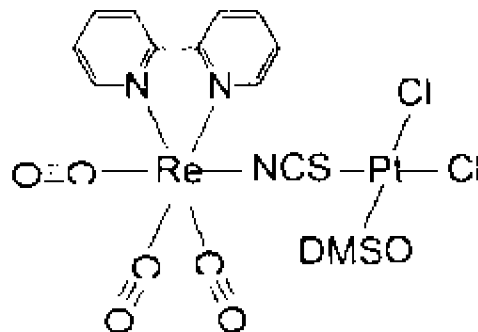
(I).

[0093] In some embodiments, the detecting substance is:



or

[0094] In some embodiments, the detecting substance is:



5

[0095] In some embodiments, the detecting substance can generate a signal when respond to the VOC.

[0096] In some embodiments, the measurable signal is a change in fluorescence spectrum or visible spectrum of the detecting substance.

10 [0097] In some embodiments, the measurable signal is a change in refractive index of the detecting substance.

[0098] In some embodiments, the measurable signal is a change in the volume or thickness of the detection layer.

Matrix substance

[0099] Appropriate matrix materials can improve the practicability of labels, make them into desired forms, such as label type, color block array type, and even distribute pigments throughout food packaging. Common matrix substance are bio-based materials such as filter paper, polymer compound, protein and polysaccharide.

5 **[00100]** In some embodiments, the matrix substance is a polymer.

[0100] In some embodiments, the matrix substance is a natural polymer.

[0101] In some embodiments, the matrix substance is a protein. In some embodiments, the matrix substance is gelatin, soybean protein or zein.

10 **[0102]** In some embodiments, the matrix substance is a polysaccharide. In some embodiments, the matrix substance is chitosan, cellulose, starch, carrageenin alginate, agarose. In some embodiments, the matrix substance is cellulose or chemically modified cellulose.

[0103] In some embodiments, the matrix substance is synthetic polymer.

[0104] In some embodiments, the matrix substance is PVA, or polylactic acid (PLA).

15 **[0105]** In some embodiments, the matrix substance is hydrogel. The detecting substance may be entrapped in hydrogel, for example, hydroxymethylcellulose, gelatin and poly-(methylmethacrylate). The detecting substance may be in the form of microcapsules (for example, liposomes, albumin microspheres, microemulsions, nanoparticles and nanocapsules) or in macroemulsions.

20 **[0106]** In some embodiments, the matrix substance is paper pulp. In some embodiments, the matrix substance is filter paper. A portable, reusable paper-based detection layer can be obtained by techniques known in the art. A typical process is, take a piece of filter paper and immerse it into the detecting substance solution, then air dry the paper to get the paper-based sensors.

25 **[0107]** In some embodiments, the detection layer further comprising a stabilizer for stabilizing the detecting substance. In certain embodiments, compositions of matrix substance containing any appropriate solvents and optionally other compounds such as, but not limited to, stabilizers, antimicrobial agents, antioxidants, pH modifiers, surfactants, modifiers and combinations of these. The carriers and stabilizers vary with the requirements of the
30 particular compound, but typically include nonionic surfactants (Tweens, Pluronics, or polyethylene glycol), sorbitan esters, oleic acid, lecithin, amino acids such as glycine, buffers, salts, sugars or sugar alcohols.

[0108] In some embodiments, the detection layer further comprising a suspending agent. Examples of suspending agents are carboxymethylcellulose, methylcellulose,

hydroxypropylmethylcellulose, sodium alginate, polyvinyl-pyrrolidone, gum tragacanth and gum acacia; dispersing or wetting agents such as lecithin or condensation products of an alkylene oxide with fatty acids (for example polyoxethylene stearate), or condensation products of ethylene oxide with long chain aliphatic alcohols, for example

- 5 heptadecaethyleneoxycetanol, or condensation products of ethylene oxide with partial esters derived from fatty acids and a hexitol such as polyoxyethylene sorbitol monooleate, or condensation products of ethylene oxide with partial esters derived from fatty acids and hexitol anhydrides, for example polyethylene sorbitan monooleate.

[0109] In some embodiments, the detection layer further comprising a moisturizer. In
10 some embodiments, the moisturizer is glycol or glycerol.

Detection Systems

[0110] The present invention also provides some designs based on device described herein, which can achieve the same technical effects. It should be understood that variations of these designs are included in the present invention.

- 15 [0111] In another aspect, the present disclosure provides an adhesive tape for detecting volatile organic compounds (VOC), wherein the detection layer is interposed between a release layer and semipermeable membrane layer. The VOC detection device in form of adhesive tape is more simple to use and more efficient.

[0112] The adhesive tape comprising:

- 20 (a) the semipermeable membrane layer described herein;
(b) the detection layer described herein;
(c) a release layer;
(d) optionally, a first adhesive layer between the semipermeable membrane layer and the detection layer; and
25 (e) optionally, a second adhesive layer between the semipermeable membrane layer and the detection layer.

[0113] The release layer covers the top surface of the adhesive layer prior to use of the device to protect the adhesive layer from inactivation by ambient dust or other contaminants. The release layer has a sufficient surface area and shape to extend at least to
30 the peripheral edges of the adhesive layer. The release layer can be any convenient release layer or system as known in the art. For example, the layer can comprise a siliconized polyester release tab or siliconized release paper.

[0114] The process of making such tape may refer to U.S. Pat. No. 6,010,715, and the disclosure of which is incorporated herein by reference.

[0115] In another aspect, the present disclosure provides a system for detecting volatile organic compounds (VOC), comprising a container and the device described herein.

5 [0116] In some embodiments, the system further comprising an observation window.

[0117] The system comprising the device and an observation window can be a food package. Example of food package can refer to U.S. Pat. No. 9,983,185.

[0118] In another aspect, the present disclosure provides the use of the system described herein, comprising

- 10 (a) placing the food in the container;
(b) allowing the device described herein to contact the VOC,
(c) observing a change of the detection layer.

Wearable sensors

[0119] Human exhaled breath is becoming an attractive clinical source as it is
15 foreseen to enable noninvasive diagnosis of many diseases. Because mask devices can be used for efficiently filtering exhaled substances, mask-wearing has been required in the past few years in daily life since the unprecedented COVID-19 pandemic. In recent years, there is a new development of mask devices as new wearable breath samplers for collecting exhaled substances for disease diagnosis and biomarker discovery.

20 [0120] The device described herein can be integrated into a mask (or in other ways) to detect the exhaled VOCs by the human body, so as to achieve the purpose of detecting biomarkers.

[0121] In another aspect, the present disclosure provides the use of the device described herein in diagnosis of a disease, comprising:

- 25 (a) allowing the device described herein to contact the exhaled VOC,
(b) observing a change of the detection layer.

[0122] In some embodiments, the disease is a cancer, an infectious disease or a chronic disease.

[0123] In some embodiments, the cancer is selected from the group consisting of
30 neuroblastoma, lymphoma, leukemia, melanoma, glioma, small cell lung cancer, breast carcinoma, ovarian cancer, soft tissue sarcomas, osteosarcoma, Ewing's sarcoma, desmoplastic round cell tumor, rhabdomyosarcoma, retinoblastoma, non-small cell lung

cancer, renal cell cancer, Wilms tumor, prostate cancer, gastric cancer, endometrial cancer, pancreatic cancer, and colon cancer.

[0124] In some embodiments, the disease is an infectious disease

[0125] In some embodiments, the disease is a chronic disease.

5 [0126] In some embodiments, the disease is Alzheimer's disease.

[0127] In some embodiments, the disease is diabetes.

Kits

[0128] In yet another aspect, the present disclosure provides a kit for disease diagnosis comprising the device described herein.

10 [0129] Such kits can further include, if desired, one or more of various conventional pharmaceutical kit components, such as, for example, containers with one or more pharmaceutically acceptable carriers, additional containers etc., as will be readily apparent to a person skilled in the art. Instructions, either as inserts or as labels, indicating quantities of the components to be administered, guidelines for administration, and/or guidelines for
15 mixing the components, can also be included in the kit.

EXAMPLE

Example 1. Detection of aldehyde

[0130] A formaldehyde detecting device was assembled according to FIG.2, using commercially available formaldehyde test paper as the detection layer, with the
20 semipermeable membrane layer is CA, the substrate layer is PVC film. Double sided tape was used for assembling of these layers.

[0131] Place the device in a 50mL beaker, and drop 100uL formaldehyde in another 50mL beaker. The two beakers are positioned closely in a 500mL beaker, and the 500mL beaker was sealed.

25 [0132] The color of formaldehyde test paper was changed within 15mins, indicating the response of the device to the formaldehyde gas.

Example 2. Detection of acid and base

[0133] A pH detecting device was assembled according to FIG.2, using commercially available pH paper as the detection layer, with the semipermeable membrane layer is CA, the
30 substrate layer is PVC film. Double sided tape was used for assembling of these layers.

[0134] Place the device in a 50mL beaker, and drop 100uL triethylamine in another 50mL beaker. The two beakers are positioned closely in a 500mL beaker, and the 500mL

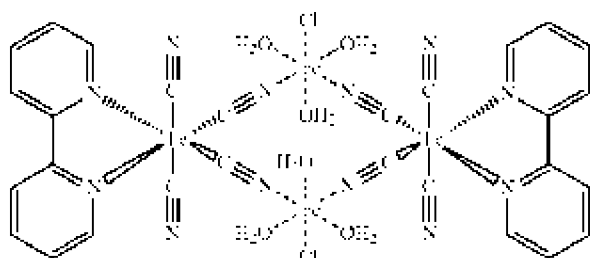
beaker was sealed. The color of pH paper was changed within 15mins, indicating the response of the device to the triethylamine gas.

[0135] Place the device in a 50mL beaker, and drop 100uL acetic acid in another 50mL beaker. The two beakers are positioned closely in a 500mL beaker, and the 500mL beaker was sealed. The color of pH paper was changed within 15mins, indicating the response of the device to the acetic acid gas.

[0136] Additional batches of label (using pH paper, Red litmus paper and FeFe testing paper) was prepared and the sensitivity to TME and acetic acid was determined. The results of response to is shown in FIG. 3A-3C.

10 Example 3. Detection of biogenic amine

[0137] A biogenic amine device was assembled according to FIG.2 The semipermeable membrane layer is CA, the substrate layer is PVC film. Double sided tape was used for assembling of these layers. The detection layer is filter paper loaded 50mM compound (I) with DMSO/H₂O=10:90 as solvent:



(I).

[0138] Place the device in a 50mL beaker, and drop 100uL histamine solution (10% in acetone) in another 50mL beaker. The two beakers are positioned closely in a 500mL beaker, and the 500mL beaker was sealed.

[0139] The color of detection layer was changed within 15mins, indicating the response of the device to the histamine gas.

[0140] Antheoth bathch of lable was parepared and the senstitivity to biotambgenic amine was deteriinde. The repisne is shjown in Figure 3A

Example 4. Detection of bacteria

[0141] A calibration curve was prepared to correlate the levels of biological amines with bacterial counts using the label prepared using the structure decirbied herein with the loading of compound (I). Subsequently, the levels of biological amines in food samples (ham, cheese, lobster, lamb fillet, salmon fish) stored for three days was measured to estimate the bacterial counts. The results are presented in Table 1.

[0142] The results demonstrate that the concentration of biogenic amines is below the stipulated standard. The final total bacterial count in the food samples was determined to be below 10^6 . Consequently, the food quality meets the criteria for consumption.

Table 1. Determination of biogenic amine level of food sample.

Sample	Ham	Cheese	Lobster	Lamb Fillet	Salmon Fish
Total bacteria count in the beginning CPU/gram	1800	59000	=N/A (lower than the detection limit)	=N/A (lower than the detection limit)	3100
Final Total bacteria count (after 3 days) CFU/gram	13800	86000	86000	5000	52000
Result	satisfied	satisfied	satisfied	satisfied	satisfied

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[0143] The previous description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the disclosure. Rather, the previous description of the exemplary embodiments will provide those skilled in the art with an enabling description for implementing one or more exemplary embodiments. It is understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention. Several embodiments were described herein, and while various features are ascribed to different embodiments, it should be appreciated that the features described with respect to one embodiment may be incorporated within other embodiments as well. By the same token, however, no single feature or features of any described embodiment should be considered essential to every embodiment of the invention, as other embodiments of the invention may omit such features.

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[0144] Specific details are given in the previous description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits, systems, networks, processes, and other elements in the invention may be shown as components in block diagram form in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

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[0145] Also, it is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process,

many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process may be terminated when its operations are completed, but could have also included additional steps or operations not discussed or included in a figure.

5 **[0146]** Furthermore, not all operations in any particularly described process may occur in all embodiments. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

10 **[0147]** Furthermore, embodiments may be implemented, at least in part, either manually or automatically. Manual or automatic implementations may be executed, or at least assisted, through the use of machines, hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine readable medium. A processor(s)
15 may perform the necessary tasks.

20 **[0148]** While detailed descriptions of one or more embodiments have been give above, various alternatives, modifications, and equivalents will be apparent to those skilled in the art without varying from the spirit of the invention. Moreover, except where clearly inappropriate or otherwise expressly noted, it should be assumed that the features, devices, and/or components of different embodiments may be substituted and/or combined. Thus, the above description should not be taken as limiting the scope of the invention. Lastly, one or more elements of one or more embodiments may be combined with one or more elements of one or more other embodiments without departing from the scope of the invention.

WHAT IS CLAIMED IS:

1. A device for detecting volatile organic compounds (VOC), comprising:
 - (a) a semipermeable membrane layer, wherein the VOC can pass through the said
5 semipermeable membrane layer;
 - (b) a detection layer, wherein the detection layer comprising (i) a detecting substance
which response to the VOC, and (ii) a matrix substance; and
 - (c) optionally a substrate layer.
- 10 2. The device according to claim 1, wherein the semipermeable membrane allows the pass
through of the VOC but does not allow the pass through of the detecting substance in the
detection layer.
3. The device according to claim 1, wherein the semipermeable membrane is water permeable.
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4. The device according to claim 1, wherein the semipermeable membrane is detecting
substance impermeable.
5. The device according to claim 1, wherein the semipermeable membrane is natural.
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6. The device according to claim 1, wherein the semipermeable membrane is synthetic.
7. The device according to claim 1, wherein the semipermeable membrane is cellulosic.
- 25 8. The device according to claim 1, wherein the semipermeable membrane is made of the
substance selected from the group consisting of cellophane, cellulose acetate (CA),
polyurethane (PU), polytrifluorochloroethylene (PCTFE), polyvinyl chloride (PVC),
polysulfone (PS), polyvinylidene fluoride (PVDF), polyethylene (PE), polyacrylonitrile (PAN),
polyvinyl alcohol (PVA) and polyimide (PI).
- 30 9. The device according to claim 1, wherein the semipermeable membrane is made of cellulose
acetate (CA).

10. The device according to claim 1, wherein the VOC is hazardous to human health.
11. The device according to claim 1, wherein the VOC is a marker for a disease.
- 5 12. The device according to claim 1, wherein the VOC is a metabolite of a mammal.
13. The device according to claim 1, wherein the VOC is selected from the group consisting of aldehydes, ketones, amines, thiols, esters, or carboxylic acids.
- 10 14. The device according to claim 1, wherein the VOC is generated by the spoilage of food.
15. The device according to claim 1, wherein the VOC is an amine.
16. The device according to claim 1, wherein the VOC is tryptamine, β -phenylethylamine, putrescine, cadaverine, histamine, octopamine, tyramine, spermidine or spermine.
- 15 17. The device according to claim 1, wherein the detecting substance is a pH indicator.
18. The device according to claim 1, wherein the detecting substance is a protein, a nucleic acid, a polymer, a small molecule, or a nanomaterial.
- 20 19. The device according to claim 1, wherein the detecting substance is nano gold, nano silver, CdS quantum dots or carbon quantum dots.
- 25 20. The device according to claim 1, wherein the detecting substance is nano silver.
21. The device according to claim 1, wherein the detecting substance is an organometallic complex.
- 30 22. The device according to claim 1, wherein the detecting substance is a bimetallic complex.
23. The device according to claim 1, wherein the detecting substance can generate a measurable signal when respond to the VOC.

24. The device according to claim 23, wherein the measurable signal is a change in fluorescence spectrum or visible spectrum of the detecting substance.

5 25. The device according to claim 23, wherein the measurable signal is a change in refractive index of the detecting substance.

26. The device according to claim 23, wherein the measurable signal is a change in the volume or thickness of the detection layer.

10 27. The device according to claim 1, wherein the matrix substance is a polymer.

28. The device according to claim 1, wherein the matrix substance is a natural polymer.

15 29. The device according to claim 1, wherein the matrix substance is cellulose or chemically modified cellulose.

30. The device according to claim 1, wherein the matrix substance is selected from the group consisting of PVA, zein, chitosan, polylactic acid (PLA), alginate, starch, cellulose, agarose or the combination thereof.

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31. The device according to claim 1, wherein the matrix substance is hydrogel.

32. The device according to claim 1, wherein the matrix substance is paper pulp.

25 33. The device according to claim 1, wherein the detection layer further comprising a stabilizer for stabilizing the detecting substance.

34. The device according to claim 1, wherein the detection layer further comprising a suspending agent.

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35. The device according to claim 1, wherein the detection layer further comprising a moisturizer.

36. The device according to claim 35, wherein the moisturizer is glycol or glycerol.

37. The device according to claim 1, wherein the device further comprising a first adhesive layer between the semipermeable membrane layer and the detection layer.

5 38. The device according to claim 1, wherein the device further comprising a second adhesive layer between the substrate layer and the detection layer.

39. The device according to claim 1, wherein the detection layer comprising an adhesive agent which can assemble the substrate layer and the semipermeable membrane layer.

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40. The device according to claim 1, wherein the substrate layer is identical to the semipermeable membrane layer.

41. An adhesive tape for detecting volatile organic compounds (VOC), comprising:

- 15 (a) the semipermeable membrane layer according to any of the preceding claims;
(b) the detection layer according to any of the preceding claims;
(c) a release layer;
(d) optionally, a first adhesive layer between the semipermeable membrane layer and the detection layer; and
20 (e) optionally, a second adhesive layer between the semipermeable membrane layer and the detection layer.

42. A system for detecting volatile organic compounds (VOC), comprising a container and the device according to any of the preceding claims.

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43. The system according to claim 42, which further comprising an observation window.

44. The use of the system according to claim 42-43 in detection food freshness, comprising

- (a) placing the food in the container;
30 (b) allowing the device according to any of the preceding claims to contact the VOC,
(c) observing a change of the detection layer.

45. The use of the device according to any of the preceding claims in diagnosis of a disease, comprising:

- 35 (a) allowing the device to contact the exhaled VOC,
(b) observing a change of the detection layer.

46. The use according to claim 45, wherein the disease is a cancer, an infectious disease or a chronic disease.

47. The use according to claim 46, wherein the cancer is selected from the group consisting of neuroblastoma, lymphoma, leukemia, melanoma, glioma, small cell lung cancer, breast carcinoma, ovarian cancer, soft tissue sarcomas, osteosarcoma, Ewing's sarcoma, desmoplastic round cell tumor, rhabdomyosarcoma, retinoblastoma, non-small cell lung cancer, renal cell cancer, Wilms tumor, prostate cancer, gastric cancer, endometrial cancer, pancreatic cancer, and colon cancer.

48. The use according to claim 45, wherein the disease is an infectious disease.

49. The use according to claim 45, wherein the disease is a chronic disease.

50. The use according to claim 45, wherein the disease is Alzheimer's disease.

51. The use according to claim 45, wherein the disease is diabetes.

52. A kit for disease diagnosis comprising the device according to any of the preceding claims.

53. A device for detecting volatile organic compounds (VOC), comprising:

(a) a semipermeable membrane layer, wherein the VOC can pass through the said semipermeable membrane layer;

(b) a detection layer, wherein the detection layer comprising

(i) a detecting region comprising a detecting substance which response to the VOC, and a matrix substance, and

(ii) an adhesive region; and

(c) optionally a substrate layer.

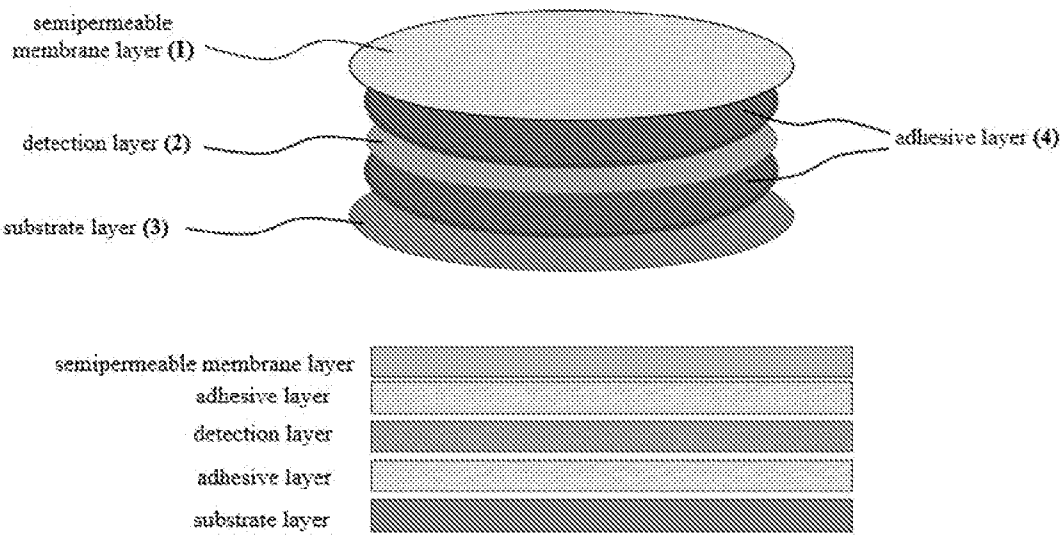


FIG. 1

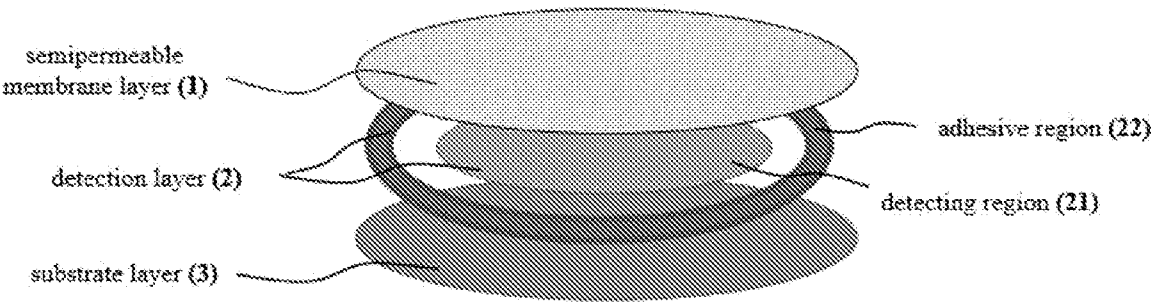


FIG. 2

Testing with 1mL 35%TME
The TME concentration in the lunch box = 275ppm

	pH paper	Red litmus paper
30s	C: 30% M: 43% Y: 98% K: 0%	C: 30% M: 40% Y: 37% K: 0%
60s	C: 30% M: 43% Y: 98% K: 0%	C: 30% M: 40% Y: 37% K: 0%
90s	C: 39% M: 47% Y: 0% K: 0%	C: 35% M: 42% Y: 39% K: 0%
120s	C: 30 % M: 43% Y: 98% K: 0%	C: 46 % M: 42% Y: 32% K: 0%
150s	C: 75 % M: 67% Y: 82% K: 41%	C: 46 % M: 42% Y: 32% K: 0%
180s	C: 80 % M: 70% Y: 79% K: 48%	C: 48 % M: 42% Y: 32% K: 0%
210s	C: 80% M: 70% Y: 75% K: 44%	C: 48% M: 42% Y: 31% K: 0%

FIG. 3A

Testing with 1mL 35% Acetic Acid
The concentration of Acetic Acid = 351ppm

	pH paper	Blue litmus paper
30s	C: 30% M: 43% Y: 98% K: 0%	C: 48% M: 42% Y: 31% K: 0%
60s	C: 30% M: 43% Y: 98% K: 0%	C: 48 % M: 42% Y: 32% K: 0%
90s	C: 39% M: 47% Y: 0% K: 0%	C: 46 % M: 42% Y: 32% K: 0%
120s	C: 30 % M: 43% Y: 98% K: 0%	C: 46 % M: 42% Y: 32% K: 0%
150s	C: 75 % M: 67% Y: 82% K: 41%	C: 35% M: 42% Y: 39% K: 0%
180s	C: 32 % M: 70% Y: 100% K: 0%	C: 30% M: 40% Y: 37% K: 0%
210s	C: 32% M: 83% Y: 100% K: 0%	C: 30% M: 40% Y: 37% K: 0%

FIG. 3B

Testing with 1mL 35%TME
The TME concentration in the lunch box = 275ppm

	FeFe Testing Paper	
30s	C: 45% M: 28% Y: 40% K: 0%	
60s	C: 45% M: 28% Y: 40% K: 0%	
90s	C: 41% M: 30% Y: 39% K: 0%	
120s	C: 39 % M: 32% Y: 37% K: 0%	
150s	C: 33 % M: 32% Y: 37% K: 0%	
180s	C: 27 % M: 37% Y: 35% K: 0%	
210s	C: 20% M: 35% Y: 34% K: 0%	

FIG. 3C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/099583

A. CLASSIFICATION OF SUBJECT MATTER

G01N33/04(2006.01)i; G01N33/02(2006.01)i; G01N21/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G01N33, G01N21

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

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

CNTXT,ENTXT,ENTXTC,DWPI:semipermeable,VOC,volatile organic compounds, fluorescen+,colorimetr+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021010942 A1 (UNIV WASHINGTON STATE) 14 January 2021 (2021-01-14) claims; abstract; paragraphs 7-66; figs. 2, 12A-13C	1-53
A	CN 111650005 A (JIANGSU GAIYA ENVIRONMENTAL SCIENCE AND TECHNOLOGY CO., LTD.) 11 September 2020 (2020-09-11) the whole document	1-53
A	CN 112630092 A (FUYANG KEYOU TESTING TECHNOLOGY CO., LTD.) 09 April 2021 (2021-04-09) the whole document	1-53
A	EP 0663239 A2 (LANGE GMBH DR BRUNO) 19 July 1995 (1995-07-19) the whole document	1-53
A	Liu Ying et al. "Research Progresses on the Application of Membrane Interface Probe in the Investigation of Organic Contaminated Sites" <i>Research of Environmental Sciences</i> , Vol. 35, No. 7, 31 July 2022 (2022-07-31), 1725-1734 the whole document	1-53

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

24 September 2024

Date of mailing of the international search report

26 September 2024

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/099583

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2021010942	A1	14 January 2021	None			
CN	111650005	A	11 September 2020	None			
CN	112630092	A	09 April 2021	None			
EP	0663239	A2	19 July 1995	ATE	156036	T1	15 August 1997
				DE	59500421	D1	04 September 1997
				EP	0663239	A3	11 October 1995
				EP	0663239	B1	30 July 1997