

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
17 September 2009 (17.09.2009)

(10) International Publication Number  
**WO 2009/114536 A2**

(51) International Patent Classification:  
A61C 17/06 (2006.01)

(21) International Application Number:  
PCT/US2009/036674

(22) International Filing Date:  
10 March 2009 (10.03.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
61/035,266 10 March 2008 (10.03.2008) US  
61/036,673 14 March 2008 (14.03.2008) US  
61/036,646 14 March 2008 (14.03.2008) US  
61/148,297 29 January 2009 (29.01.2009) US

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

(84) Designated States (unless otherwise indicated, for every  
kind of regional protection available): ARIPO (BW, GH,  
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,  
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,  
TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE,  
ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,  
MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR),  
OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML,  
MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: APPARATUSES AND METHODS FOR EXTRACTING CHEMICALS FROM THE ORAL CAVITY AND BREATH

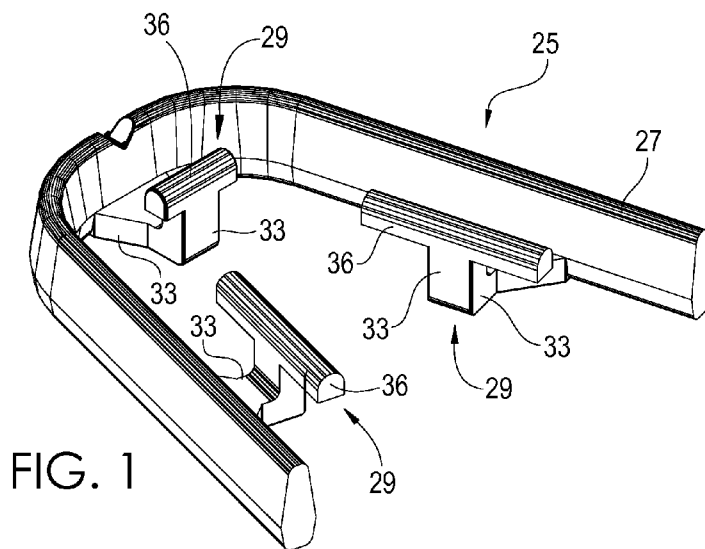


FIG. 1

(57) Abstract: The present disclosure generally pertains to chemical extraction apparatuses and methods for extracting volatile, semi-volatile, and non-volatile chemicals from a user's oral cavity. In one exemplary embodiment, a chemical extraction apparatus is composed of absorbent material, which is positioned within the oral cavity of a user for a period of time. Volatile, semi-volatile, and non-volatile chemicals are extracted from the breath and saliva of the user. By keeping the absorbent material in the oral cavity for an extended period of time, such as several minutes or hours depending on the types of materials selected, even trace levels of a chemical can be concentrated in the absorbent material thereby enabling conventional analytical techniques to detect the chemical.

WO 2009/114536 A2

**Published:**

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

**APPARATUSES AND METHODS FOR EXTRACTING CHEMICALS  
FROM THE ORAL CAVITY AND BREATH**

**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/035,266, entitled "Method and Apparatus for Extracting Volatile and Semi-Volatile Compounds from the Oral Cavity and Breath," and filed on March 10, 2008, which is incorporated herein by reference. This application also claims priority to U.S. Provisional Patent Application No. 61/036,673, entitled "Chewing Device for Extracting Volatile and Semi-Volatile Compounds from the Oral Cavity and Breath, and Method for Making Same," and filed on March 14, 2008, which is incorporated herein by reference. This application claims priority to U.S. Provisional Patent Application No. 61/036,646, entitled "Method and Apparatus for Extracting Volatile, Semi-Volatile Compounds from the Oral Cavity and Breath," and filed on March 14, 2008, which is incorporated herein by reference. This application claims priority to U.S. Provisional Patent Application No. 61/148,297, entitled "Apparatuses and Methods for Extracting Chemicals from the Oral Cavity and Breath," and filed on January 29, 2009, which is incorporated herein by reference.

**RELATED ART**

[0002] Advances in instrumentation have resulted in new generations of reliable, accurate, and precise tools for the scientist (analytical chemist, food scientist, biochemist, biologist). Technical advances have opened new areas for research including the field of metabolomics, the study of metabolites produced in the body related to disease. Metabolomics is a rapidly growing research field and promises to make disease detection and diagnosis less invasive and much more rapid. Difficult and

time consuming procedures that currently require blood, stool, urine, or even more invasive tissue collection samples will be required much less frequently, or not at all. Sources of metabolites include blood, urine, feces, sweat, and breath. Breath analysis is challenging because compounds present are smaller (lower molecular weight, typically less than 300g/mole), volatile (exist preferentially in the gas state), and reactive. Trace levels of metabolites in breath add another dimension of difficulty because of the quantity of breath needed to pull out sufficient mass of compound to permit detection is relatively large.

[0003] Current methods for breath collection for subsequent analysis include exhaling one or two breaths directly into an instrument, or collecting from 2 or 3 breaths to many (0.6 to 250L) into a Tedlar bag – an air-tight bag made of Teflon, plastic, or other inert material. Problems with these methods, however, limit their usefulness. For example, very low levels, *e.g.*, less than 1 part per trillion, of metabolites present in the amount of breath analyzed are not typically sufficient to detect, or are detected with difficulty, by the most sensitive instrumentation. Also, methods for breathing directly into an instrument are cumbersome, inconvenient, and require that the user and instrument be present in the same location.

[0004] For example researchers at Menssana Research have developed Breathscanner 2.5, an instrument that incorporates gas chromatography and a detector to identify volatiles from the breath of users (*e.g.*, patients) who breathe directly into an interface with the instrument. This device is cumbersome, and results are dependent upon the amount of a substance present in breath collected in the short time a user exhales into the device. U.S. Patent No. 5,465,728 describes a hand held device measuring breath components. While portable, this device appears to lack trace level detection capability. Other methods for measuring breath include US Patent Pub. No. 2008/0008666 A1, which describes a method for monitoring the effectiveness of oral malodor treatment by

measuring for specific chemicals listed. It does not appear to allow for novel extraction and detection means. Finally, a major flaw associated with collecting large quantities of breath with a Tedlar bag is the problem of transferring the metabolite present in a large volume of air into an instrument while eliminating the dilution effect. This method provides no means for concentrating metabolites. Also with bags, some volatile metabolites are absorbed into the bag construction materials, or stick (adsorb) to the sides thus unavailable for detection and measurement.

[0005] Accordingly, a device is needed to extract low levels (trace levels) of volatile, semi-volatile, and non-volatile compounds from the oral cavity, including breath and saliva, for the purpose of advancing the field of breath metabolomics. Such a device would also be useful in dental, food and flavor sciences. For example, in dental science, oral health may be assessed by sampling metabolites present in the saliva and breath. Common maladies such as gum health may be diagnosed based on the presence and concentration of known metabolites generated by infection including compounds associated with foul odor such as carbon disulfide, methyl mercaptan, and dimethyl sulfide. In food and flavor sciences, flavor and taste are known as chemosenses, meaning the sense of taste and smell (flavors, tastes and fragrances) are the brain's interpretation of signals generated by interactions of chemicals (from foods and fragrances) with receptors in the mouth and nose. By detecting and measuring these chemicals in the oral cavity, improvements in flavor and fragrance technologies, duration, and efficacy may be successfully measured at a level currently unavailable. For example how long a product freshens your breath, or how long a product provides a pleasant taste may be more accurately assessed by measuring the time a breath freshening chemical resides in the oral cavity before being rinsed away in saliva or exhaled in air.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0006] The disclosure can be better understood with reference to the following drawings. The elements of the drawings are not necessarily to scale relative to each other, emphasis instead being placed upon clearly illustrating the principles of the disclosure. Furthermore, like reference numerals designate corresponding parts throughout the several views.

[0007] FIG. 1 illustrates a chemical extraction apparatus in accordance with an exemplary embodiment of the present disclosure.

[0008] FIG. 2 illustrates a top view of the chemical extraction apparatus depicted by FIG. 1.

[0009] FIG. 3 illustrates a back view of the chemical extraction apparatus depicted by FIG. 1.

[0010] FIG. 4 illustrates a chemical extraction apparatus.

[0011] FIG. 5 illustrates the chemical extraction apparatus of FIG. 4 and the front two teeth of the user.

[0012] FIG. 6 illustrates the chemical extraction apparatus of FIG. 4 after sample elements have been removed from the apparatus.

[0013] FIG. 7 illustrates a chemical extraction apparatus in accordance with an exemplary embodiment of the present disclosure.

[0014] FIG. 8 illustrates a top view of the chemical extraction apparatus depicted by FIG. 7.

[0015] FIG. 9 illustrates the chemical extraction apparatus of FIG. 7 after the application a has been secured to the front teeth of a user.

[0016] FIG. 10 illustrates the chemical extraction apparatus of FIG. 8 after sample elements have been removed from the apparatus.

- [0017] FIG. 11 illustrates a chemical extraction apparatus in accordance with an exemplary embodiment of the present disclosure.
- [0018] FIG. 12 illustrates a top view of the chemical extraction apparatus depicted by FIG. 11.
- [0019] FIG. 13 illustrates a side view of the chemical extraction apparatus depicted by FIG. 11.
- [0020] FIG. 14 illustrates a chemical extraction apparatus in accordance with an exemplary embodiment of the present disclosure.
- [0021] FIG. 15 illustrates a chemical extraction apparatus in accordance with an exemplary embodiment of the present disclosure.
- [0022] FIG. 16 illustrates a top view of the chemical extraction apparatus depicted by FIG. 15.
- [0023] FIG. 17 illustrates a side view of the chemical extraction apparatus depicted by FIG. 15.
- [0024] FIG. 18 illustrates a cross-sectional view of the chemical extraction apparatus depicted by FIG. 17.

### **DETAILED DESCRIPTION**

- [0025] The present disclosure generally pertains to apparatuses and methods for extracting volatile, semi-volatile, and non-volatile chemicals from the oral cavity and breath. An apparatus for extracting chemicals in one exemplary embodiment is portable, convenient, and designed to easily fit in the mouth. It is composed of absorbent material that is intended to remain in the oral cavity for a period ranging from minutes to hours, although other time periods are possible. With each exhalation, air flows over the absorbents, and quantities of chemicals present in the breath are absorbed and/or adsorbed. As many (*e.g.*, thousands) of breaths flow over the absorbent material,

chemicals present in the breath are retained. Even trace levels of volatile chemicals present in the breath are sufficiently concentrated in the absorbent material over time to enable detection of these small amounts of chemicals via known analytical techniques. After a period of time, the apparatus is removed from the mouth, and the absorbent material is analyzed by appropriate analytical instrumentation to determine the chemical compounds absorbed from the breath and oral cavity (e.g., saliva).

[0026] Various types of materials may be used to absorb and/or adsorb chemicals from the breath and saliva. Such materials include, but are not limited to, polydimethylsiloxane (PDMS), polyvinyl acetate, polyisoprene, styrene-butadiene rubber (SBR), polybutylene, polyacrylate, as well as other polymers that are known in the art, or may become known in the art, that are safe for use in dental applications. Such materials may be used in different ratios in combination with one another or alone by themselves. Softening agents such as microcrystalline wax may also be utilized to provide a softer, easy to mold polymer. Additional absorbent materials that may be incorporated into the device described herein include all forms of activated carbon with engineered pore sizes such as CarboPack or Carboxen materials, structures known as zeolites, an absorbent material called Tenax, and cyclodextrins.

[0027] Note that PDMS alone may be used as the absorbent material. One characteristic of PDMS is that it is hydrophobic. It does not bind water appreciably, but it does extract other volatile components present in a sample matrix (immersed in a liquid or from headspace) by absorption into the polymer liquid phase, making it ideal for use in the oral cavity environment.

[0028] Some absorbent material, such as activated carbon, may be hydrophilic. If such material is exposed to saliva for prolonged periods of time, the material may absorb significant quantities of water from the saliva thereby inhibiting the material's ability to absorb other compounds. In such embodiments, the material's contact with saliva may

be limited. For example, as will be described in more detail hereafter, the absorbent material is positioned in a protection element that helps to reduce the material's contact with saliva. However, the protection element has at least one opening that allows breath to enter the protection element and contact the absorbent material. The use of the protection element helps to enhance the absorbent material's ability to absorb and/or adsorb compounds in the breath.

[0029] Moreover, regardless of which type of absorbent material is used, the absorbent extracts and retains volatile, semi-volatile, and non-volatile components from the breath and oral cavity by absorption and adsorption. Forces and mechanisms responsible for the absorption and/or adsorption include Van der Waals forces, polarity, and hydrophobicity or hydrophilicity.

[0030] After absorption and/or adsorption, chemical components may be desorbed, analyzed, and measured by any of various types of analytical procedures and instruments. Such methods include, but are not limited to, thermal desorption and chemical desorption by exposure to solvent as with high performance liquid chromatography (HPLC). For thermal desorption, the absorbent is placed in a thermal desorption unit or heated chamber, equipped with inert gas flushing and temperature control. Upon heating the chamber, volatiles desorb from the absorbent material, are swept by inert gas (*e.g.*, helium, nitrogen, argon) into a trap mechanism (*e.g.*, a liquid nitrogen cooled cryo-trap, an absorbent material, or a combination thereof). The trap mechanism may be rapidly heated to release components and deposit them as a tight band on a capillary column for separation by a gas chromatograph (GC) and detection and measurement by a detector (*e.g.*, mass spectrometer (MS), flame ionization, or flame photometric). Alternatively, the volatiles may be desorbed by solvent and analyzed by GC as previously described, or by HPLC. HPLC may utilize various

detectors, such as MS, infra-red, ultraviolet, diode array, and/or other wavelength of electromagnetic radiation.

[0031] Data from the analysis may be used in a variety of ways. As an example, it may be determined that the presence of certain chemicals in certain quantities and/or a pattern of certain chemicals over time within the oral cavity and/or breath may indicate the presence of a certain disease or condition. Thus, the data may be analyzed to predict or diagnose whether a user has or will have a certain disease or condition. By keeping the absorbent in the oral cavity for an extended period (*e.g.*, several minutes or hours), even trace levels of chemicals can be concentrated in the absorbent allowing detection of such trace levels by conventional analytical equipment.

[0032] FIGS. 1-3 depict a chemical extraction apparatus 25 in accordance with an exemplary embodiment of the present disclosure. The apparatus 25 comprises a curved support element 27 that helps to support and appropriately position other components of the apparatus 25, as will be seen. The support element 27 has a shape corresponding with the expected shape of the teeth of a user who is to wear the apparatus 25. In this regard, the support element 27 is shaped such that it can be positioned along an outer side of the user's upper teeth. Thus, the support element 27 fits between the user's upper teeth and his or her upper lip. In other embodiments, the support element 27 could be shaped to fit around the user's lower teeth. The support element 27 is sufficiently elastic such that it presses against the user's teeth helping to hold the apparatus 25 in place, and it is sufficiently elastic to deform in order to accommodate various teeth dimensions, which can vary slightly from person-to-person.

[0033] The apparatus 25 has at least one tab 29 coupled to the support element 27. Each tab 29 comprises an arm 33 and a sample element 36, which is composed of absorbent material, such as PDMS or other material for absorbing and/or adsorbing chemicals from the oral cavity and breath. In one exemplary embodiment, the sample

element 36 is composed entirely of an absorbent material, but other configurations are possible. Indeed, it is possible for only a portion of the sample element 36 to be composed of an absorbent material. For example, the sample element 36 may be composed of a non-absorbent material and coated with an absorbent material.

[0034] Each arm 33 extends from the support element 27 beneath at least one tooth of the user. Further, each arm 33 is coupled to a sample element 36 such that the sample element 36 is at a desired position within the oral cavity to enhance its ability for chemical absorption when the apparatus 25 is being worn.

[0035] In one exemplary embodiment, each arm 33 is bent or otherwise curved such that the sample element 36 coupled to it contacts the back of the user's teeth. FIGS. 4 and 5 show one of the sampling elements 36 positioned behind a user's front teeth 41. The other teeth of the user are not shown for simplicity. However, for each sample element 36, at least one tooth is positioned between the sample element 36 and the support element 27. In one exemplary embodiment, the arm 33 is dimensioned such that the at least one tooth fits snugly between the sample element 36 and the support element 27 thereby helping to hold the apparatus 25 in place via frictional forces, thereby securing the apparatus 25 to the tooth. However, in other embodiments, the arm 33 for any sample element 36 may be dimensioned such that the sample elements 36 barely makes contact with at least one tooth or such that sample element 36 is separated from the user's teeth.

[0036] While the apparatus 25 is being worn, each sample element 36 absorbs and/or adsorbs chemicals from the user's breath and oral cavity (e.g., saliva). After exposure for a desired duration, such as several minutes or hours, the apparatus 25 is removed from the oral cavity, and each arm 33 is cut by a razor or other sharp instrument to remove the sample elements 36, as shown by FIG. 6. The removed sample elements 36 can then be analyzed to determine the chemicals and the concentrations of the

chemicals absorbed and/or adsorbed by the sample elements 36. The data from such analysis may then be used for a variety of purposes, such as diagnosing a disease or condition of the user (e.g., patient) or identifying a marker or predictor of a disease or condition.

[0037] In analytical chemistry, statistical validity is generally considered to be achieved after three analyses have been performed. Each of the three sample elements 36 can be separately analyzed in order to provide such statistical validity. However, it is possible for the apparatus 25 to have other numbers of sample elements 36 in other embodiments.

[0038] In one exemplary embodiment, the sample elements 36 are dimensioned according to the size requirements of the analytical equipment that is to be used for analyzing the sample elements 36. For example, many conventional thermal desorption units are designed to receive samples having a width of up to about .08 inches and a length of up to about .4 inches. To facilitate the use of the sample elements 36 with such equipment, each sample element 36 preferably has a width less than about .08 inches and a length less than about .4 inches. However, in other embodiments, other dimensions for the sample elements 36 are possible. Further, the sample elements 36 may be cut or otherwise arranged into any desired size or shape for analysis.

[0039] In addition, as described above, the sample elements 36 are composed of an absorbent material, such as PDMS. The other components of the apparatus 25 may be composed of the same or other materials. In one exemplary embodiment, the other components, such as the support element 27 and the arms 33, are composed of the same material as the sample elements 36. If the other components of the apparatus 25 are composed of an absorbent material, such as PDMS, then such other components may be analyzed as described above for the sample elements 36. If desired, such other

components may be cut or otherwise arranged into any desired size or shape for analysis.

[0040] As shown by FIGS. 4 and 5, one of the sample elements 36 is positioned directly behind the upper front teeth 41 (referred to as "incisors") of the user. In fact, as described above, such sample element 36 may contact and possibly press against the inner side of the front teeth 41. Positioning absorbent material behind the front teeth 41 is generally ideal since breath typically flows across the upper palate of the user directly toward such location while the user is exhaling. Such a location may assist in the detection of trace levels of a chemical in the breath. The other sample elements 36 are positioned behind other teeth of the user, such as molars, bicuspid or canines.

[0041] FIGS. 7 and 8 depict a chemical extraction apparatus 55 in accordance with an exemplary embodiment of the present disclosure. In the exemplary embodiment depicted by FIGS. 7 and 8, the apparatus 55 is configured such that multiple sample elements 56 can be positioned directly behind the front teeth 41.

[0042] In this regard, the apparatus 55 has a support element 57 that is coupled to three sample elements 56 by arms 63. In other embodiments, other numbers of sample elements 56 may be coupled to the support element 57. Each of the sample elements 56 is composed of an absorbent material, such as PDSM. In one exemplary embodiment, the sample elements 56 are composed entirely of an absorbent material, but other configurations are possible. Indeed, it is possible for only a portion of each sample element 56 to be composed of an absorbent material. For example, the sample elements 56 may be composed of a non-absorbent material and coated with an absorbent material.

[0043] As shown by FIGS. 7 and 8, the support element 57 is generally circular, but has sufficient elasticity such that it can deform and stretch. Further, the support element 57 is dimensioned such that it can be sufficiently stretched, like a rubber band, to extend

around at least one tooth. In one exemplary embodiment, the support element 57 is dimensioned such that it can be sufficiently stretched to extend around the upper front two teeth 41 (referred to as "incisors") of the user. The inner diameter of the support element 57 is about .394 inches prior to stretching and deformation, and the outer diameter of the support element 57 is about .472 inches prior to stretching and deformation. Further, like the sample elements 36 of FIGS. 1-6, each of the sample elements 56 for the embodiment shown by FIGS. 7 and 8 has a length less than about .4 inches and a width less than about .08 inches in order to facilitate analysis of the sample elements 56 for some analytical equipment. Other dimensions for the support element 57 and the sample elements 56 are possible in other embodiments. Indeed, in other embodiments, the support element 57 can be dimensioned to fit around other numbers of teeth.

[0044] In one exemplary embodiment, the support element 57 is positioned such that it snugly fits around the upper front two teeth 41, and the sample elements are positioned directly behind the front two teeth 41, as shown by FIG. 9. Thus, breath being exhaled should flow toward and contact the sample elements 56. The stretching of the support element 57 induces a frictional force that helps to hold the apparatus 55 in place while it is being worn as shown by FIG. 9.

[0045] After chemicals in the breath and oral cavity have been absorbed, the apparatus 55 can be removed by sliding the support element 57 down the tooth or teeth around which the support element 57 is wrapped until the support element 57 separates from the tooth or teeth. Using a razor or other sharp instrument, the arms 63 are cut to remove the sample elements 56 from the support element 57. The sample elements 56 can then be analyzed by analytical equipment, as described above for the sample elements 36.

[0046] As shown by FIGS. 8-10, the support element 57 has a tab 68 that can be grasped by a user to facilitate positioning and/or removal of the support element 57. In this regard, the tab 68 can be pinched between the fingers of the user or other person.

[0047] As described above, the sample elements 56 are composed of an absorbent material, such as PDMS. The other components of the apparatus 55 may be composed of the same or other materials. In one exemplary embodiment, the other components, such as the support element 57 and the arms 63, are composed of the same material as the sample elements 56. If the other components of the apparatus 55 are composed of an absorbent material, such as PDMS, then such other components may be analyzed as described above for the sample elements 56. If desired, such other components may be cut or otherwise arranged into any desired size or shape for analysis.

[0048] FIGS. 11-13 depict a chemical extraction apparatus 75 in accordance with an exemplary embodiment of the present disclosure. The apparatus 75 is composed of absorbent material. In addition, the apparatus 75 is chewable so that a user can place the apparatus 75 into his or her oral cavity and chew the apparatus, like gum. During chewing, the apparatus 75 is deformed, and saliva flow is stimulated. Chemicals present in saliva, oral cavity, and breath are extracted and absorbed into the absorbent material. After chewing for a desired time period sufficient to extract chemicals from the breath and saliva, the chewed apparatus 75 is then removed from the oral cavity and analyzed. If desired, the chewed apparatus 75 may be cut or otherwise re-shaped or arranged in an effort to facilitate analysis.

[0049] In one exemplary embodiment, the chewable apparatus 75 is composed of different combinations of heat resistant polymers, including polydimethylsiloxane (PDMS), polyvinyl acetate, polyisoprene, styrene-butadiene rubber (SBR), and polybutylene. Additionally a microcrystalline wax may be utilized as a softener. The apparatus 75 is designed to be chewed in a manner similar to chewing gum, and various

known materials typically used in chewing gum may be used to manufacture the apparatus 75. Further, like other gum products, the apparatus 75 can have many different sizes and shapes, and the apparatus 75 can be manufactured using other known techniques for manufacturing chewing gum.

[0050] In one exemplary embodiment, PDMS is incorporated into the apparatus 75 by placing PDMS and other polymers into a mixer capable of providing sufficient shearing force such as a heated Z-blade mixer. In other embodiments, other types of absorbent material can be used. Contents are blended for a period (*e.g.*, about 15 to 30 minutes) to provide a homogenous product and heated to temperatures that range from 50 degrees Celsius (C) to 200 degrees C. Mixing is conducted until the formulations result in an apparatus 75 that is sufficiently malleable that it may be chewed by most healthy individuals. Formulations include concentrations of PDMS that range from 100% to 0%. Other polymers may be included in concentrations that range from 100% to 0%. Edible wax may be added to increase gum softness. Hydrophobic and hydrophilic nature of gum can be adjusted by selection and concentration of co-polymer utilized.

[0051] Other ingredients which may be added to the gum-like product of the present disclosure include other absorbents such as activated carbon, Carbopack, carboxen, edible wax for softening.

[0052] FIG. 14 depicts a chemical extraction apparatus 100 in accordance with an exemplary embodiment of the present disclosure. The apparatus 100 forms a pacifier that can be used by an infant or other user. The exemplary apparatus 100 of FIG. 14 has a sample element 102, a handle 103, and a support element 105. The handle 103 is in the shape of a ring, but other shapes of the handle 103 are possible in other embodiments. The handle 103 is coupled to the support element 105 and facilitates grasping of the apparatus 100 by a user. The sample element 102 is mounted on the support element 105 and forms a nipple to be inserted into the oral cavity of an infant or

other user. The sample element 102 is composed of an absorbent material, such as PDMS. In one exemplary embodiment, the sample element 102 is composed entirely of an absorbent material, but other configurations are possible. Indeed, it is possible for only a portion of the sample element 102 to be composed of an absorbent material. For example, the sample element 102 may be composed of a non-absorbent material and coated with an absorbent material.

[0053] The sample element 102 is inserted through a user's mouth into the oral cavity of a user, similar to a nipple of a conventional pacifier. While in the oral cavity, the absorbent material of the sample element 102 absorbs and/or adsorbs chemicals from the breath and saliva of the user. After chemicals in the breath and oral cavity have been absorbed for a desired period, such as several minutes or hours, the apparatus 55 is removed from the user's oral cavity. Using a razor or other sharp instrument, the sample element 102 is cut to remove the sample element 102 or at least a portion of the sample element 102 from the support element 57. The removed sample element portion can then be analyzed by analytical equipment, as described above for the sample elements 36.

[0054] It should be noted that there are many different conventional pacifier configurations that can be used to implement the apparatus 100. The embodiment shown by FIG. 14 is exemplary.

[0055] FIGS. 15-17 depict an exemplary embodiment of a chemical extraction apparatus 125 in accordance with an exemplary embodiment of the present disclosure. The apparatus 125, like the apparatus 100 shown by FIG. 14, forms a pacifier. As shown by FIGS. 15-17, the apparatus 100 has a support element 127 that is coupled to a hollow protection element 133 via an arm 135. The protection element 133 is inserted into the oral cavity of an infant or other user. It is possible for the protection element 133 to be composed of absorbent material that can be later analyzed similar to the apparatus 100

shown by FIG. 14. However, other materials for the protection element 133 are possible.

[0056] As shown by FIG. 18, at least one sample element 149 is positioned within a cavity 145 of the protection element 133. In one exemplary embodiment, the apparatus 125 has three sample elements 149 to provide statistical validity, but other numbers of sample elements 149 are possible in other embodiments. Each sample element 149 is composed of an absorbent material that extracts chemicals from the user's breath. In one exemplary embodiment, each sample element 149 is composed entirely of an absorbent material, but other configurations are possible. Indeed, it is possible for only a portion of each sample element 149 to be composed of an absorbent material. For example, each sample element 149 may be composed of a non-absorbent material and coated with an absorbent material. In addition, each sample element 149 is dimensioned similar to the sample elements 36 described above for FIGS. 1-6. However, other dimensions of the sample elements 149 are possible in other embodiments.

[0057] In the embodiment shown by FIG. 18, each sample element 149 is coupled to an inner wall of the protection element 133 via a respective arm 152, which may be cut by a razor or other sharp instrument in order to separate the sample element 149 from the protection element 133. Other techniques for coupling the sample elements 149 to the protection element 133 and/or positioning the sample elements 149 within the cavity 145 are possible.

[0058] A hole 142 in the protection element 133 allows the user's breath to flow into the cavity 145 and contact the sample elements 149, which absorb or adsorb chemicals from the breath while protection element 133 is in the oral cavity. However, the protection element 133 helps to keep saliva from reaching the sample elements 149, although it is possible for some saliva to enter the cavity 145 via the hole 142. Limiting

the amount of saliva that contacts the sample elements 149 may be particularly beneficial when the absorbent material of any of the sample elements 149 is hydrophilic. In this regard, limiting the exposure of hydrophilic absorbent material to saliva reduces the amount of water absorbed by such material thereby enhancing the material's ability to extract chemicals from the user's breath. Note that the hole 142 may be located at positions other than that shown by FIG. 15, and the protection element 133 may have any number of holes. The number and size of the holes can be selected depending on the degree to which contact of the absorbent material with saliva is to be limited.

[0059] The protection element 133 is inserted through a user's mouth into the oral cavity of a user, similar to a nipple of a conventional pacifier. While in the oral cavity, the absorbent material of each sample element 149 absorbs and/or adsorbs chemicals from the breath of the user. After chemicals in the breath have been absorbed for a desired period, such as several minutes or hours, the apparatus 125 is removed from the user's oral cavity. Using a razor or other sharp instrument, the protection element 149 to provide access to the sample elements 149, which are then removed from the cavity 145. In the embodiment shown by FIG. 18, the arms 152 are cut to remove the sample elements 149. However, it is possible for the sample elements 149 to reside in the cavity 145 without being coupled to the protection element 133. If desired, the sample elements 149 may be cut or otherwise rearranged for analysis. The absorbent material of the sample elements 149 can be analyzed by analytical equipment, as described above for the sample elements 36.

[0060] In various embodiments described above, absorbent material is positioned within the oral cavity of a user for a period of time. Volatile, semi-volatile, and non-volatile chemicals are extracted from the breath and saliva of the user. By keeping the absorbent material in the oral cavity for an extended period of time, such as several minutes or hours depending on the types of materials selected, even trace levels of a

chemical can be concentrated in the absorbent material thereby enabling conventional analytical techniques to detect the chemical.

**CLAIMS**

Now, therefore, the following is claimed:

1. A chemical extraction apparatus, comprising:

a support element configured to secure the chemical extraction apparatus to at least one tooth of a user; and

a sampling element coupled to the support element, the sampling element composed of an absorbent material for absorbing or adsorbing volatile chemicals from an oral cavity of the user.

2. The chemical extraction apparatus of claim 1, further comprising an arm for coupling the sampling element to the support element.

3. The chemical extraction apparatus of claim 1, wherein the support element is configured such that the chemical extraction apparatus is secured to the at least one tooth when the at least one tooth is positioned between the support element and the sampling element such that the support element and the support element press against the at least one tooth.

4. The chemical extraction apparatus of claim 1, wherein the support element is configured to wrap around the at least one tooth to secure the chemical extraction apparatus to the at least one tooth.

5. The chemical extraction apparatus of claim 1, wherein the absorbent material is hydrophobic.

6. The chemical extraction apparatus of claim 1, wherein the absorbent material is composed of polydimethylsiloxane.

7. The chemical extraction apparatus of claim 1, wherein the sampling element is positioned behind a front tooth of the user when the chemical extraction apparatus is secured to the at least one tooth.

8. The chemical extraction apparatus of claim 1, wherein the support element comprises an elastic band.

9. The chemical extraction apparatus of claim 8, wherein the elastic band is configured to wrap around the at least one tooth to secure the chemical extraction apparatus to the at least one tooth.

10. The chemical extraction apparatus of claim 1, wherein the sampling element has a length less than .4 inches and a width less than .08 inches.

11. A method, comprising the steps of:  
inserting a chemical extraction apparatus into an oral cavity of a user, the chemical extraction apparatus having an absorbent material;  
securing the chemical extraction apparatus to at least one tooth of the user; and  
absorbing volatile compounds from breaths of the user into the absorbent material.

12. The method of claim 11, further comprising the steps of:  
analyzing the absorbent material; and  
identifying at least one of the volatile compounds based on the analyzing step.

13. The method of claim 12, further comprising the step of determining a concentration of the at least one volatile compound based on the analyzing step.

14. The method of claim 11, further comprising the step of cutting the absorbent material from the chemical extraction apparatus.

15. The method of claim 11, wherein the chemical extraction apparatus comprises a support element, an arm, and a sampling element, wherein the sampling element is composed of the absorbent material, wherein the sampling element is coupled to the support element via the arm, and wherein the method further comprises the step of cutting the arm thereby separating the sampling element from the support element.

16. The method of claim 15, wherein the sampling element has a length less than .4 inches and a width less than .08 inches.

17. The method of claim 11, wherein the securing step comprises the step of positioning the chemical extraction apparatus such that the at least one tooth is positioned between portions of the chemical extraction apparatus.

18. The method of claim 17, wherein each of the portions presses against the at least one tooth.

19. The method of claim 11, wherein the securing step comprises the step of wrapping a portion of the chemical extraction apparatus around the at least one tooth.

20. The method of claim 11, further comprising the step of removing the absorbent material from the portion.

21. The method of claim 11, further comprising the step of positioning the absorbent material behind a front tooth of the user.

22. The method of claim 11, wherein the chemical extraction apparatus comprises an elastic band, and wherein the securing step comprises the step of inserting the at least one tooth into the elastic band.

23. The method of claim 11, wherein the absorbent material is hydrophobic.

24. The method of claim 11, wherein the absorbent material is composed of polydimethylsiloxane.

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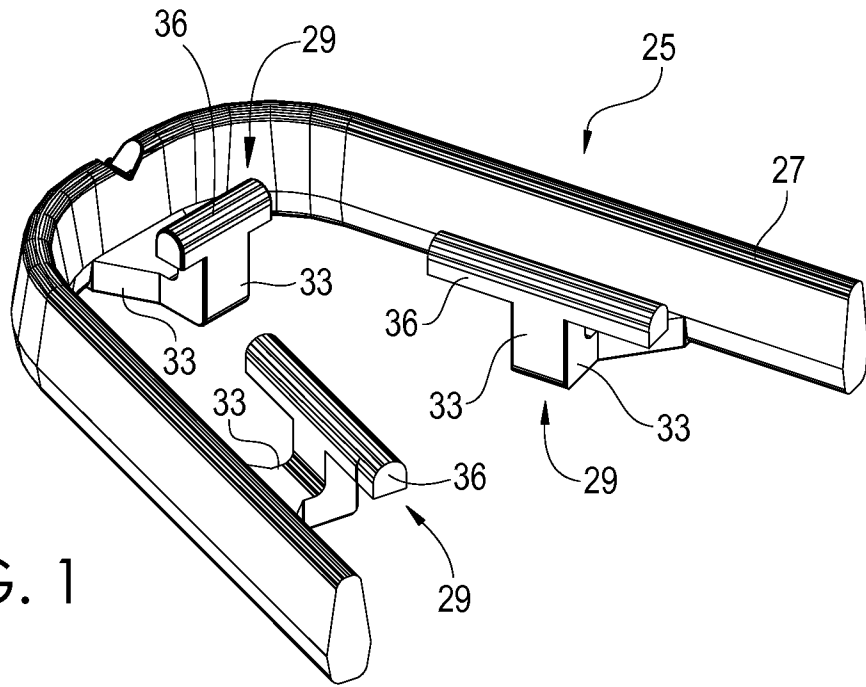


FIG. 1

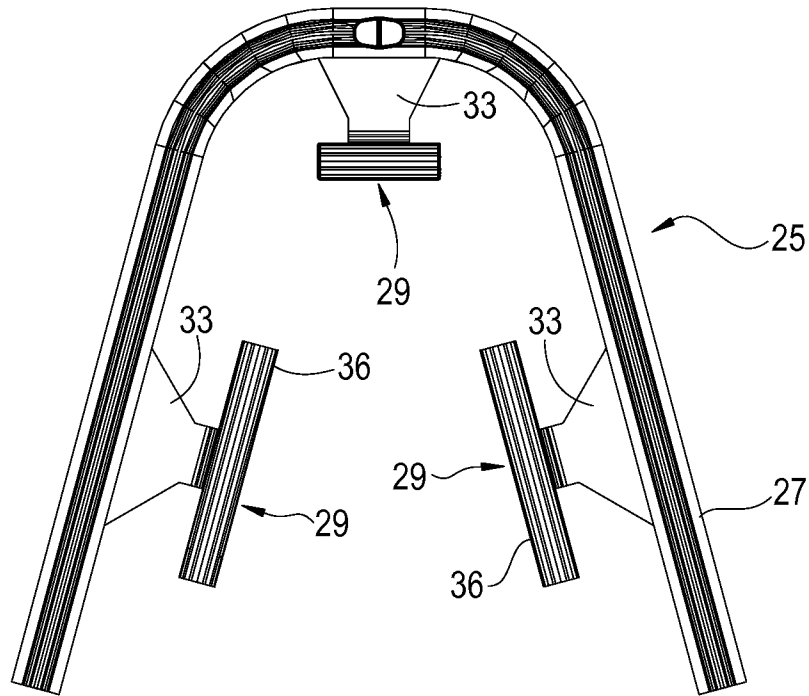


FIG. 2

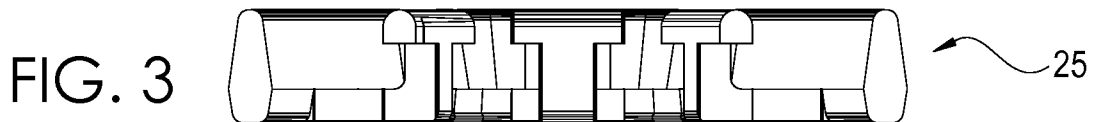


FIG. 3

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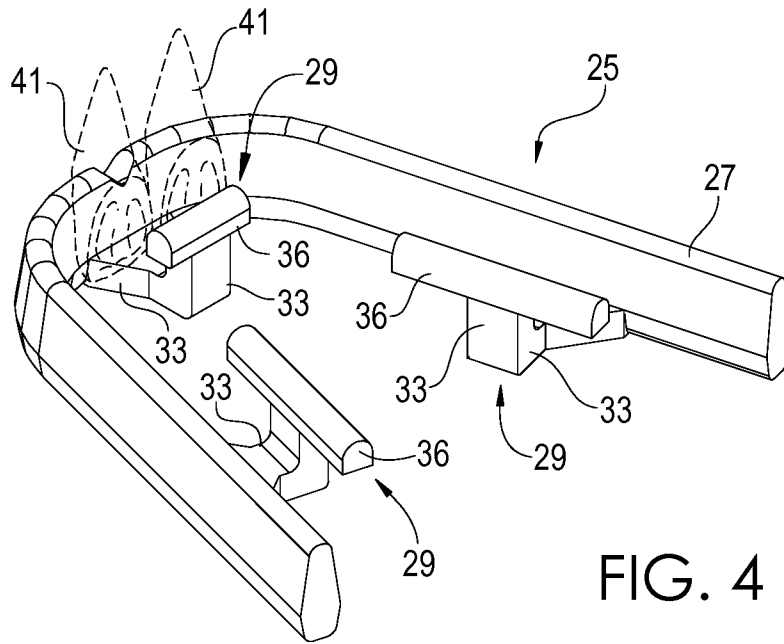


FIG. 4

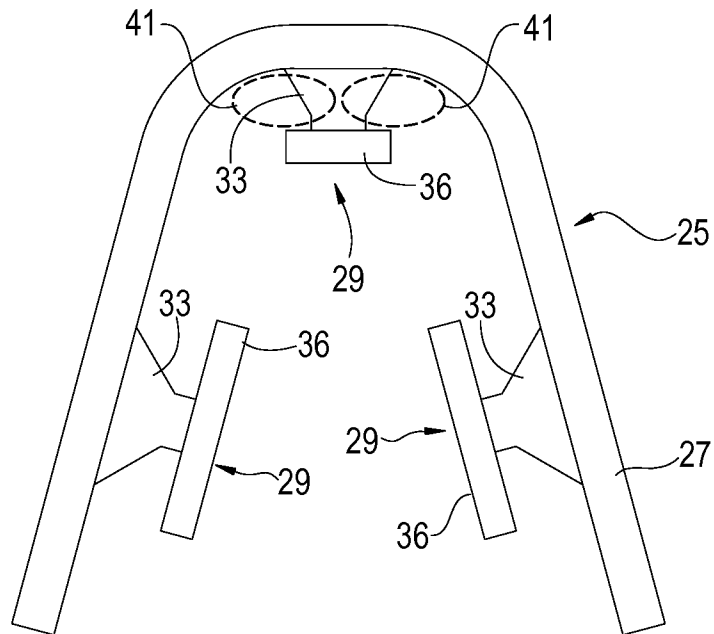


FIG. 5

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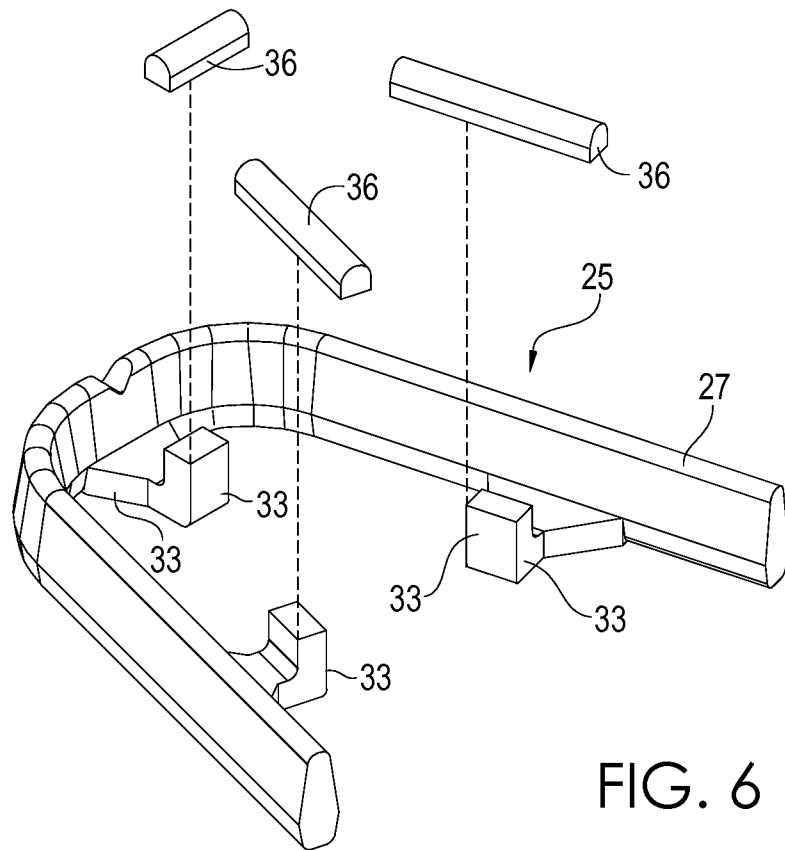


FIG. 6

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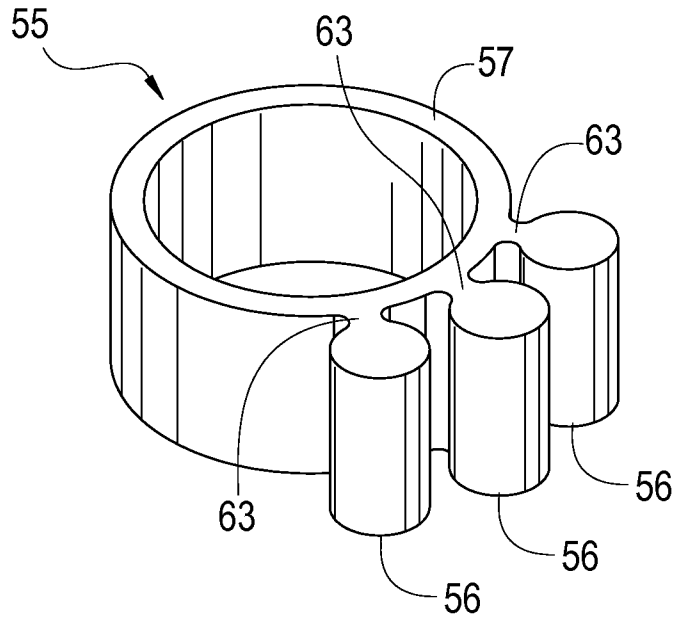


FIG. 7

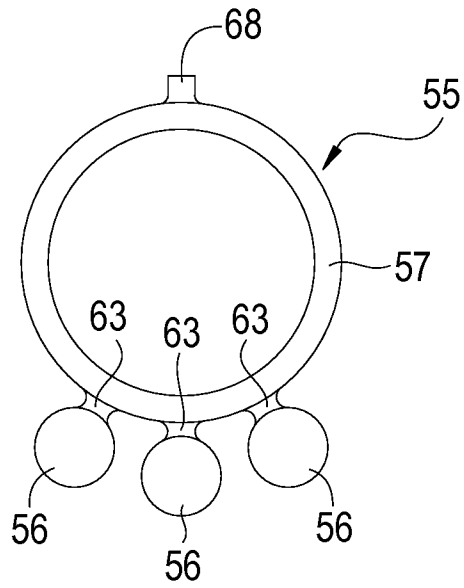


FIG. 8

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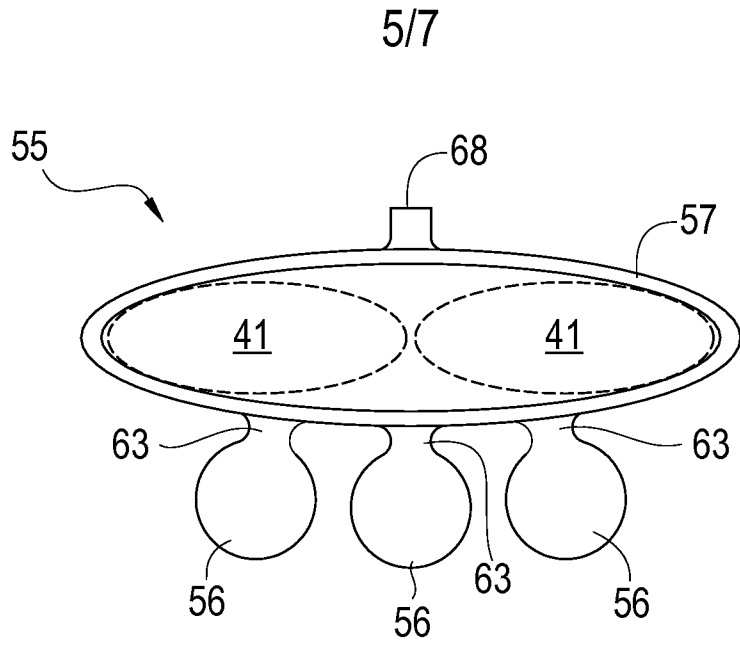


FIG. 9

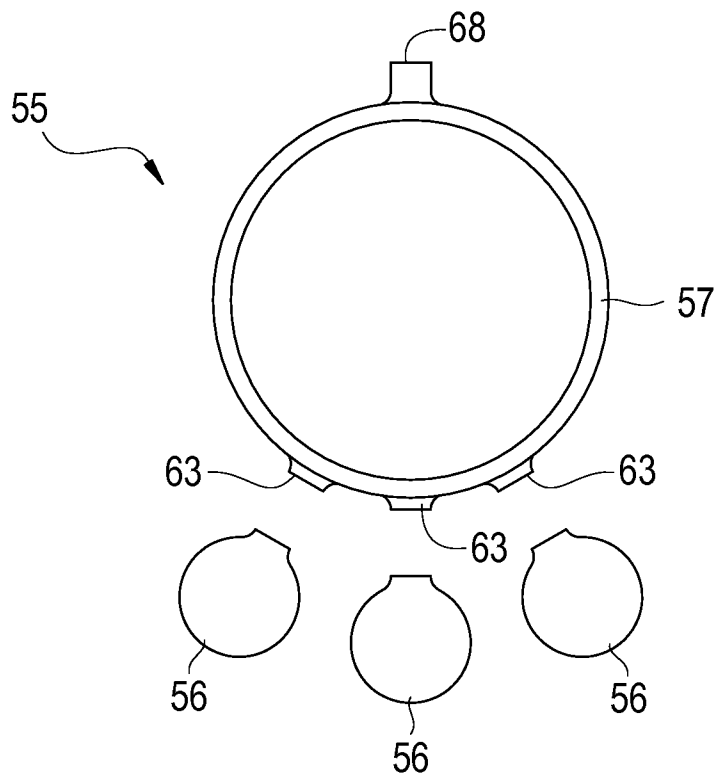


FIG. 10

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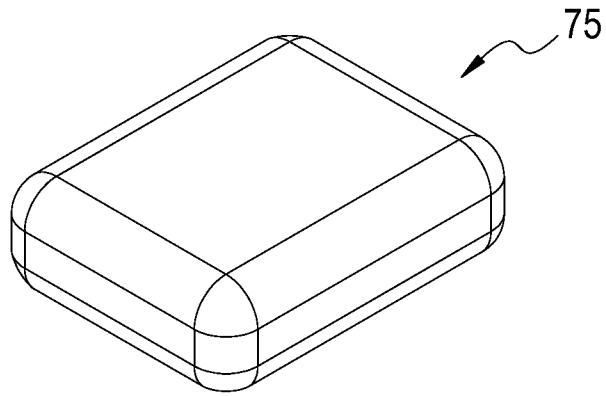


FIG. 11

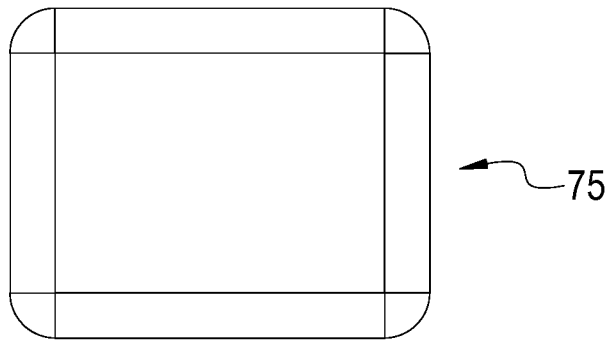


FIG. 12

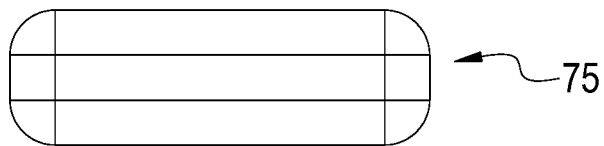


FIG. 13

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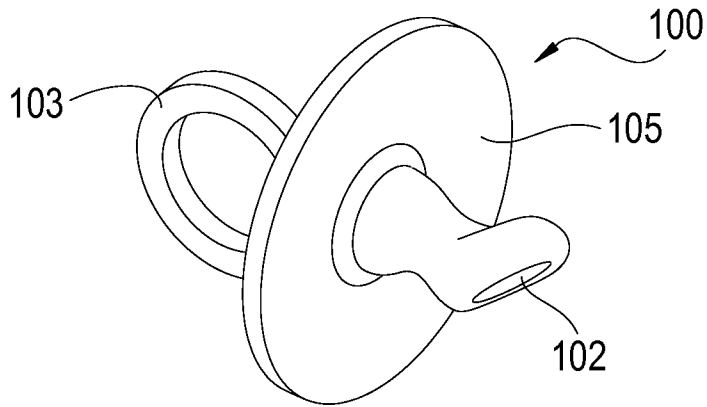


FIG. 14

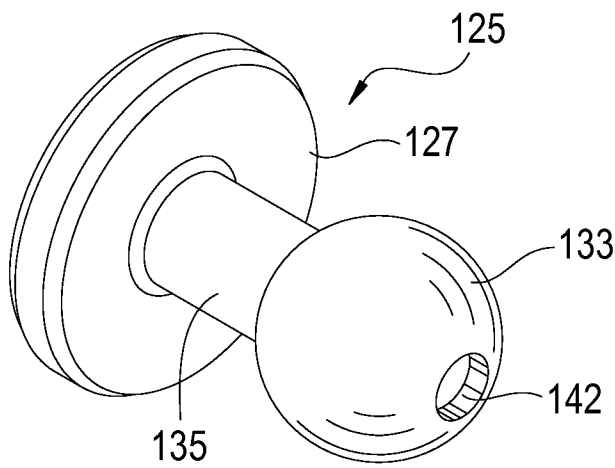


FIG. 15

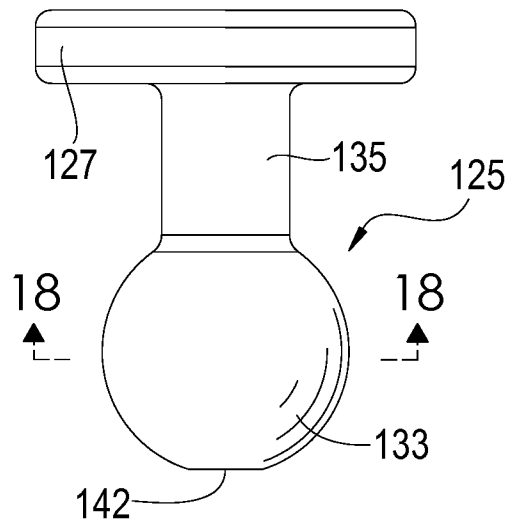


FIG. 16

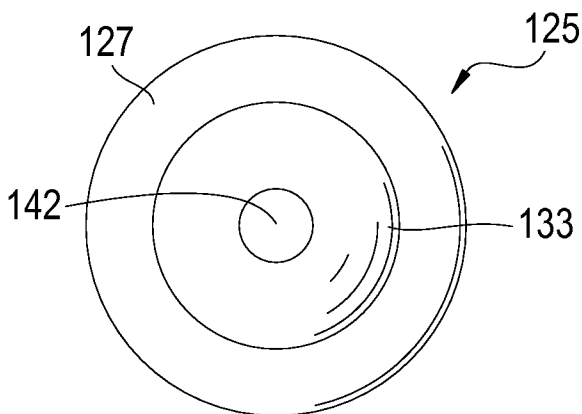


FIG. 17

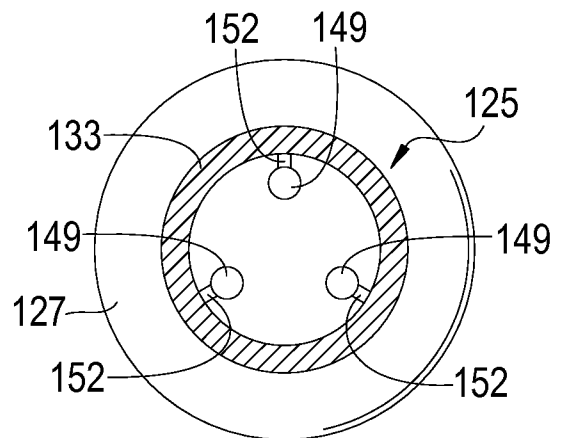


FIG. 18

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