US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12390811
Kind Code	B1
Date of Patent	August 19, 2025
Inventor(s)	Fedick; Patrick W. et al.

Sampling platform apparatus

Abstract

The embodiments are directed to both sampling apparatuses and systems. Apparatus embodiments are directed to a sample collection apparatus having several receptacles configured to removably-hold sample collection devices. The sample collection devices are configured to hold a sample including solid media and analyte. System embodiments include the sample collection apparatus and several receptacles for removably-holding sample collection devices. The system embodiments also include additional components to perform analysis of the sample.

Inventors: **Fedick; Patrick W. (Ridgecrest, CA), Brown; Hilary M. (Chicago, IL), Mulligan; Christopher C. (Bloomington, IL), McDaniel; Trevor J. (Philadelphia, IL)**

Applicant: **The United States of America, as represented by the Secretary of the Navy** (Arlington, VA); **The Board of Trustees of Illinois State University** (Normal, IL)

Family ID: **1000007025889**

Assignee: **The United States of America, as represented by the Secretary of the Navy (Washington, DC)**

Appl. No.: **18/121336**

Filed: **March 14, 2023**

Related U.S. Application Data

continuation-in-part parent-doc US 16903647 20200617 US 11635353 child-doc US 18121336 us-provisional-application US 63419126 20221025

Publication Classification

Int. Cl.: **B01L3/00** (20060101)

U.S. Cl.:

CPC **B01L3/5085** (20130101);

Field of Classification Search

CPC: B01L (3/5085); B01L (9/52); G01N (1/08)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2321639	12/1942	Zarbo	141/331	B01D 29/085
2456912	12/1947	Burrows	229/4.5	B01D 35/28
2633410	12/1952	Beckley	422/534	G01N 33/528
2671715	12/1953	Beckley	422/534	G01N 33/68
5051584	12/1990	Gray	250/281	H01J 49/105
5078189	12/1991	Ronsonet	141/331	B67C 11/02
5480072	12/1995	Ripley	141/334	B67C 11/02
5793039	12/1997	Oishi	250/288	H01J 49/067
6803568	12/2003	Bousse	250/281	H01J 49/0018
8460782	12/2012	Ivanov	428/297.4	C04B 35/16
9346045	12/2015	Blumentritt	N/A	G01F 23/02
10545073	12/2019	Pawliszyn	N/A	B01J 20/327
10559455	12/2019	Cooks	N/A	H05K 1/18
10578579	12/2019	Alonso Chamarro	N/A	G01N 27/4161
11635353	12/2022	Fedick	73/863	G01N 33/24
11667992	12/2022	Dellis	420/467	C22C 5/04
2007/0084996	12/2006	Li	250/282	H01J 49/167
2011/0009774	12/2010	Calasso	600/583	A61B 5/150427
2011/0263005	12/2010	Chang	435/283.1	C12M 33/04
2013/0136672	12/2012	Blumentritt	422/524	B01L 3/0275
2013/0181010	12/2012	Ouyang	222/209	H01J 49/0009
2014/0001415	12/2013	Sheng	264/105	H01B 1/04
2014/0241956	12/2013	Page	422/534	G01N 1/4077
2017/0053788	12/2016	Cha	N/A	H01J 49/167
2017/0071710	12/2016	Deturmeny	N/A	A61C 17/02
2017/0105707	12/2016	Senior	N/A	A61B 10/0038
2017/0322179	12/2016	Alonso Chamarro	N/A	G01N 27/4035

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
104392886	12/2014	CN	H01J 49/26
762473	12/1994	EP	N/A

OTHER PUBLICATIONS

Fedick et al. “A Low-Cost, Simplified Platform of Interchangeable, Ambient Ionization Sources for Rapid, Forensic Evidence Screening on Portable Mass Spectrometric Instrumentation,” Instruments 2018, 2, 5 (Year: 2018). cited by examiner
H. Brown, et al, Characterization and optimization of a rapid, automated 3D-printed cone spray ionization-mass spectrometry (3D-PCSI-MS) methodology, International Journal of Mass Spectrometry 474 (2022) 116781 (received Oct. 31, 2021, received revised form Dec. 20, 2021, available online Dec. 21, 2021 (9 pages). cited by applicant

---

Primary Examiner: Fitzgerald; John

Attorney, Agent or Firm: Naval Air Warfare Center Weapons Division

---

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a nonprovisional application claiming the benefit of U.S. provisional application No. 63/419,126, filed on Oct. 25, 2022, the contents of which are hereby expressly incorporated by reference in its entirety and which priority is claimed. This application is also a continuation-in-part application claiming the benefit of U.S. nonprovisional application Ser. No. 16/903,647 filed on Jun. 17, 2020 now U.S. Pat. No. 11,635,353, the contents of which are hereby expressly incorporated by reference in its entirety and which priority is claimed.

FIELD
(1) Embodiments generally relate to sampling platforms.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** illustrates an isometric view of a sample collection device, according to some embodiments.
(2) FIG. **2**A illustrates a plan view of a sample collection apparatus having a plurality of receptacles, according to some embodiments.
(3) FIG. **2**B illustrates a plan view of another sample collection apparatus having a plurality of receptacles, according to some embodiments.
(4) FIG. **2**C illustrates a plan view of yet another sample collection apparatus having a plurality of receptacles, according to some embodiments.
(5) FIG. **3** illustrates a close-up view showing the geometry of a single receptacle, according to some embodiments.
(6) FIG. **4** illustrates a plan view of a sampling system, according to some embodiments.
(7) FIG. **5** illustrates an isometric view of the sampling system in FIG. **4**.
(8) FIG. **6** illustrates a close-up plan view of the sample collection device in the sampling system in FIG. **4**, including a solvent fill position and a high voltage application position.
(9) FIG. **7** illustrates a close-up isometric view of a portion of the sampling system in FIG. **4**, including a close-up view of the solvent fill position and the high voltage application position, and the location of a connection to an internal power source in a mass spectrometer.
(10) FIG. **8** illustrates an isometric view of the sampling system in FIG. **4** including a view of the underside of the sample collection apparatus.
(11) FIG. **9** illustrates a close-up side view of a portion of the sampling system in FIG. **4**,

illustrating the positioning and orientation of the sample collection apparatus and the distal end of the sample collection device in relation to the inlet of the mass spectrometer.
(12) It is to be understood that the foregoing general description and the following detailed description are exemplary and explanatory only and are not to be viewed as being restrictive, as claimed. Further advantages will be apparent after a review of the following detailed description of the disclosed embodiments, which are illustrated schematically in the accompanying drawings and in the appended claims.

DETAILED DESCRIPTION OF EMBODIMENTS

(13) Embodiments may be understood more readily by reference in the following detailed description in connection with the accompanying figures. It is understood that embodiments are not limited to the specific devices, methods, conditions or parameters described and/or shown herein, and that the terminology used herein is for the purpose of describing particular embodiments by way of example only and is not intended to be limiting of the claimed embodiments.
(14) The embodiments generally relate to sampling platforms and systems. In particular, the apparatus embodiments are configured to removably-hold sample collection devices. System embodiments include the apparatus in addition to components used in high throughput sample analysis. Some embodiments are sometimes referred to as a three-dimensional (3D)-printed cone spray ionization mass spectrometry (3D-PCSI-MS) sources. Other embodiments are simply referred to as apparatuses and systems. All embodiments have performed well in detecting and identifying analytes in bulk solids. In particular, working systems having shown increased throughout both in laboratory-based and in field conditions when components are coupled to a portable mass spectrometer.
(15) Although the embodiments are described in considerable detail, including references to certain versions thereof, other versions are possible. Examples of other versions include varying component orientation or hosting embodiments on different platforms. Therefore, the spirit and scope of the appended claims should not be limited to the description of versions included herein.
(16) Conventions, Parameters, and Terminology
(17) At the outset, it is helpful to describe various conventions, parameters, and terminology associated with the embodiments.
(18) Substantially
(19) As used herein, unless otherwise specified, the term “substantially” refers to the complete, or nearly complete, extent or degree of an action, characteristic, property, state, structure, item, or result. As an arbitrary example, an object that is “substantially” surrounded would mean that the object is either completely surrounded or nearly completely surrounded. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking, the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained.
(20) The use of “substantially” is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. As another arbitrary example, a composition that is “substantially free of” particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is “substantially free of” an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.
(21) About
(22) The use of “about” is used to provide flexibility to a numerical range endpoint by providing that a given value may be “a little above” or “a little below” the endpoint. The degree of flexibility of this term can be dictated by the particular variable and would be within the knowledge of those skilled in the art to determine based on experience and the associated description herein. As such, it is understood that the ranges provided herein include the stated range and any value or sub-range

within the stated range. For example, a range from about 0.15 millimeters to about 0.25 millimeters should be interpreted to include not only the explicitly recited limits from about 0.15 millimeters to about 0.25 millimeters, but also to include individual values, such as 0.18 millimeters, 0.20 millimeters, 0.21 millimeters, etc., and sub-ranges, such as from about 0.17 millimeters to about 0.20 millimeters.

(23) High-Voltage

(24) The term “high-voltage” herein is in the kilovolts (kV) range. In particular, the ranges from about four kV to about seven kV are included. Voltage levels both above and below this range are possible and are based on application-specific conditions, including anticipated sample constituents.

(25) Sample

(26) The embodiments are used to perform analysis using mass spectrometers. The term “sample” is sometimes used. In the embodiments, the sample is a solid media that may or may not contain an analyte. Although the interest is to identify the analyte in the solid media, a person having ordinary skill in the art will recognize that the solid media may not contain analytes.

(27) A person having ordinary skill in the art will recognize that the solid media device **100** can also hold a solid media that does not contain an analyte. Hence, at times, the solid media with or without an analyte can be referred to as a “sample,” herein.

(28) Apparatus and System Embodiments

(29) In the accompanying drawings, like reference numbers indicate like elements. For all embodiments and figures, it is understood that the figures are not to scale and are depicted for ease of viewing. Reference characters **100**, **200**, **250**, and **400** depict various embodiments, sometimes referred to as mechanisms, apparatus, devices, systems, and similar terminology. Several views are presented to depict some, though not all, of the possible orientations of the embodiments.

(30) FIG. **1** depicts an isometric view of a sample collection device **100**. FIGS. **2**A and **2**B depict plan views of a sample collection apparatus **200**. Although not exactly the same, the sample collection apparatuses **200** shown in FIGS. **2**A and **2**B are both disc-shaped and can be referred to as rotary.

(31) Referring to FIG. **2**A a sample collection apparatus **200** is shown. The sample collection apparatus **200** can also be referred to as a sampling platform, a sample collection device holder, an autosampler, an apparatus, a platform, and similar variations. Referring to FIGS. **2**A and **9** simultaneously, the sample collection apparatus **200** is a platform having a first side **202**, a second side **802**, and an outer edge **204**. The first and second sides **202** and **802** can also be referred to as top and bottom sides, or upper and lower sides, respectively. A plurality of receptacles **206** extend through the platform **200** from the first side **202** to the second side **802**. As such, the receptacles **206** perforate through both the first and second sides **202** and **802** and each receptacle in the plurality of receptacles can be referred to as an aperture or similar terminology without detracting from the merits or generalities of the embodiments.

(32) Each receptacle in the plurality of receptacles **206** is configured to removably-hold a sample collection device **100** (shown in FIG. **1**). Similarly, it can be equally said that each receptacle in the plurality of receptacles **206** is configured to receive or cradle the sample collection device **100**. In practice, the number of sample collection devices **100** would match the number of receptacles in the plurality of receptacles **206**. FIG. **3** shows a close-up view of a single receptacle in the plurality of receptacles **206**. Importantly, it is evident that each receptacle in the plurality of receptacles **206** has inner walls **302** cooperating with the geometry of the sample collection device **100**. Although four inner walls **302** are shown, it is understood that fewer or greater than four inner walls can be used without detracting from the merits or generalities of the embodiments. Additionally, the inner walls **302** shaped for quick alignment of the sample collection device **100**. It is understood that the sample collection devices **100** fit in the receptacles **206** and held in place through either lost motion due to the geometry of the inner walls **302** or by friction fit with the inner walls.

(33) As the shapes and dimensions of the sample collection device **100** can vary, so too can the shapes and dimensions of the receptacles **206**. The receptacle **206** shown in FIG. **3** is typical of the receptacles in some embodiments. However, it is understood that dimensions and shapes in all embodiments for all components can be varied based on application-specific conditions. The receptacle **206** shown in FIG. **3** resembles a trapezoidal shape at both the first and second surfaces **202** and **802** of the sample collection apparatus **200**. At opposing sides of the receptacle **206** at the first side **202**, at least one dimension is two centimeters (shown as a1 in FIG. **3**) and at least one dimension is three centimeters (shown as a2 in FIG. **3**), with the respective sides parallel to each other. Similarly, at opposing sides of the receptacle **206** at the second side **902**, at least one dimension is 0.6 centimeters (shown as b1 in FIG. **3**) and at least one dimension is one centimeter (shown as b2 in FIG. **3**), with the respective sides parallel to each other.
(34) The inner wall nearest the outer edge **204** is vertical, i.e. perpendicular to the first and second sides **202** and **802**, and has a dimension of 1.4 centimeters (shown as c1 in FIG. **3**). The inner wall nearest the central longitudinal axis **208**, i.e. farthest from the outer edge **204** is slanted at about 37 degrees from the first side **202** to second side **802** to accommodate proper fit for the sample collection devices **100** in the receptacles **206** for sample analysis. The intersection of at least two interior walls **302** forms creates an intersection distance of 2.5 centimeters (shown as c2 in FIG. **3**) from the first side **202** to the second side **802**. It should be noted that the dimensions and geometry shown is not to be construed as limiting, but is only for illustrative purposes.
(35) Referring to FIG. **1**, the sample collection device **100** has a proximal end **114** and a distal end **116**. The distal end **116**, which can also be referred to as a tip, has a hole **102** with a diameter range of about 0.15 millimeters to about 0.25 millimeters. The sample collection device **100** also includes a hollow interior **112** that forms a cavity, which can hold a solid media sample. The sample collection device **100** can be any hollow shape that terminates at a point and that can hold a solid media sample while allowing solvent extraction from the device during ambient ionization for mass spectrometer analysis. This diameter of the hole **102** has proven to be small enough to retain a solid media sample, but is large enough to allow solvent to exit during mass spectrometric analysis. The hole **102** allows for analysis via ambient ionization after the solvent has passed through the solid media and solvent extraction of analyte has occurred.
(36) The sample collection device **100** also has a height and a width, shown as h and w, respectively, in FIG. **1**. The height h and width w can be any height and width that is large enough to hold a solid media sample, but small enough to remain portable while using the least amount of material as possible. The height h is defined as the vertical distance from the hole **102** at the distal end **116** of the sample collection device **100** to the proximal end **114**. The width w is defined as the furthest distance from the inner side of a wall to the opposite inner side of a wall of the sample collection device **100**. In an embodiment, the sample collection device **100** may have a height h and a width w ranging from about 12.5 millimeters to about 40 millimeters.
(37) The sample collection device **100** also has a thickness that is large enough to hold a solid media sample, but small enough to retain the device's original shape while using the least amount of material as possible. The sample collection device's **100** thickness is defined as the distance from the inner side of a wall to the outer side of a wall. In an embodiment, the sample collection device **100** has a thickness ranging from about 0.6 millimeters to about 3 millimeters. The sample collection device **100** can be made using any known methods to produce a conductive polymer device, including 3D printing. Once produced, the sample collection device **100** can be used immediately to collect samples for mass spectrometer analysis.
(38) The sample collection device **100** is made of a conductive polymer. The conductive polymer includes a mixture of carbon nanotubes and a polymer. Alternatives to the carbon nanotubes include metal-infused polymers such as, for example, copper and conductive resins. The polymer may be any polymer that can be subjected to a voltage and is immiscible with the extraction and spray solvent. For example, the polymer may be polyethylene terephthalate, acrylonitrile butadiene

styrene, polylactic acid, polyetherketoneketone, polyether ether ketone, polycarbonate, polyphenylene sulfide, polyvinylidene fluoride, and combinations thereof. The carbon nanotubes may be any carbon nanotubes that conduct electricity. An example of the carbon nanotubes is multi-wall carbon nanotubes.
(39) The platform **200** has a central longitudinal axis **208**. The plurality of receptacles **206** are axially-spaced at equal distance about the central longitudinal axis **208**. The platform **200** is, in several embodiments, generally a disc and is sometimes referred to as disc-shaped, rotary-shaped, or substantially-circular. The platform **200** can also be referred to as rotary, a rotary disc, or rotary platform. It is evident when viewing FIGS. **2**A, **2**B, and **4** through **8** that the sample collection apparatus **200** is polygonal in plan view, i.e. is a polygonal shape, while still maintaining a rotary or substantially-circular, disc shape. FIG. **2**A depicts the outer edge **204** as having twenty sides. Whereas, FIGS. **2**B and **4** through **8** show the platform **200** having its outer edge **204** defined by eight sides, i.e. being octagonal in plan view or having an octagonal shape. In all instances, it is evident that all of the above shapes are applicable without detracting from the merits or generalities of the embodiments. Likewise, the sample collection apparatus **200** is not specifically limited to the number of sides forming its outer edge **204**.
(40) The rotary, disc-shaped platforms in FIGS. **2**A and **2**B are about 16 centimeters in diameter. The distance between diametrically-opposed receptacles **206**, i.e. receptacles 180 degrees apart is about 10 centimeters. The platform **200** thickness, measured parallel to the central longitudinal axis **208** and perpendicular to the first and second sides **202** and **802** is about 1.4 to about 1.5 centimeters, however it can range from about one centimeter to about ten centimeters, depending on application-specific conditions. It is understood that the dimensions can be varied to accommodate larger or smaller platforms **200**, as well as different receptacle **206** geometries and dimensions.
(41) FIG. **2**C illustrates another embodiment, depicted with reference character **250**, of the sample collection apparatus shown in a linear rail orientation. The sample collection apparatus **250** in FIG. **2**C is a platform and is rectangular in shape and also has a plurality of receptacles **206** through both sides of the platform. As before, the first side is depicted with reference character **202**. The second side is not viewable in FIG. **2**C, but a person having ordinary skill in the art will recognize that the linear rail orientation platform **250** includes the second side. The outer edge **204** forms the rectangular shape of the sample collection apparatus **250** in FIG. **2**C. As before, the receptacles **206** in the sample collection apparatus **250** in FIG. **2**C are configured to accommodate sample collection devices **100**, both in number and the previously discussed dimensions and geometries. The sample collection apparatus **250** in FIG. **2**C has thickness is about 1.4 to about 1.5 centimeters, however it can range from about one centimeter to about ten centimeters, depending on application-specific conditions.
(42) In some embodiments, the number of receptacles in the plurality of receptacles **206** is a range of about four to about twelve receptacles and, hence, the number of sample collection devices **100** would also be a range of about four to about twelve devices. In other embodiments, the range can be greater such as, for example, three to twenty receptacles **206** and sample collection devices **100**. As such, any number of receptacles **206** and sample collection devices **100** can be used, based on the dimensions of the sample collection apparatuses **200** and **250**, without detracting from the merits or generalities of the embodiments.
(43) In the disc-shaped, rotary-shaped, or substantially-circular embodiments in FIGS. **2**A, **2**B, and **4** through **8**, the axial spacing is a range of about 30 degrees to about 90 degrees. The plurality of receptacles **206** in the linear rail orientation (**250** in FIG. **2**C) are in a series arrangement with equal spacing between adjacent receptacles. The figures, for ease of viewing, depict the plurality of receptacles **206** has being eight receptacles, but it is understood that any number can be used based on application-specific conditions. For instance, in other disc-shaped, rotary-shaped, or substantially-circular embodiments, the axial spacing can be a range of about 18 degrees to about

120 degrees, based on the dimensions of the sample collection device **200**.

(44) The sample collection device **100** is hollow and is configured to hold a solid media containing an analyte. In some embodiments, the sample collection device **100** is a hollow multi-faced pyramid. In other embodiments, the sample collection device is a hollow cylindrical cone. The polymer of the sample collection device **100** is selected from the group consisting of polyethylene terephthalate, acrylonitrile butadiene styrene, polylactic acid, polyetherketoneketone, polyether ether ketone, polycarbonate, polyphenylene sulfide, polyvinylidene fluoride, and combinations thereof. The solid media is selected from the group consisting of soil, sand, sediment, waste, pure analytes, and combinations thereof. Toxicology samples and analysis can be included in the embodiments, based on application-specific conditions. The analyte is selected from the group consisting of perfluoroalkyl substances, polyfluoroalkyl substances, energetics, chemical warfare agent simulants, drugs of abuse, pesticides, and combinations thereof. Any perfluoroalkyl substances, polyfluoroalkyl substances, energetics, chemical warfare agent simulant, drugs of abuse, or pesticides known to those skilled in the art may be used as the analyte depending on the purpose of evaluating the solid media. Some specific examples of perfluoroalkyl substances include perfluorodecanoic acid, heptafluorobutyric acid, perfluorotridecanoic acid, perfluoroheptanoic acid, perfluorooctane-sulfonic acid, perfluoroundecanoic acid, perfluorooctance-sulfonamide, tridecafluorooctane-1-sulphonic acid, perfluorooctanoic acid, perfluorononanoic acid, tricosafluorododecanoic acid, or combinations thereof.

(45) The sample collection apparatuses discussed—both rotary or disc-shaped **200** and rectangular or linear rail **250** versions, are made from non-conductive, chemically-inert plastics. Suitable materials for the sample collection apparatuses **200** and **250** include plastics such as polylactic acid (PLA), polyethylene terephthalate glycol (PETG), and acrylonitrile butadiene styrene (ABS). Fabrication techniques of the sample collection apparatuses **200** and **250** include 3-D printing and machining techniques such as computerized numerical control (CNC) and injection molding.

(46) Samples in the sample collection devices **100** are not shown for ease of viewing, especially due to the vast differences in substances that can be analyzed. Samples, i.e. solid media for analysis, can consist of the analyte in its solid form (powders, pressed powders, tablets, crystals, etc.) or an analyte within, or upon, a solid matrix (i.e. per—and polyfluoroalkyl substances (PFAS) in soil, sediment, or solid waste). The solid samples can be scooped or shoveled into the sample collection device.

(47) The system embodiments in FIGS. **4** through **9** may refer to the platform **200** as rotary disc or rotary platform. FIG. **4** illustrates a plan view of a working sampling system **400**. FIG. **5** illustrates an isometric view of the system **400**. The system **400** includes a motorized platform **502**, which is best viewed in its entirety in FIG. **5**. The motorized platform **502** includes a rotary disc **200**, an electric motor **504**, and controller **506**. The electric motor **504** can also referred to as a motor. A person having ordinary skill in the art will recognize that the apparatuses (i.e. platforms **200** from FIGS. **2**A and **2**B) can be used interchangeably in the system **400** for the rotary disc without detracting from the merits or generalities of the embodiments. The motorized platform **502** is configured with the rotary disc **200** electromechanically-coupled to the electric motor **504** and controller **506**. A person having ordinary skill in the art will recognize that the electric motor **504** and controller **506** can also be a single component, such as a servo-controller or separate components without detracting from the merits or generalities of the embodiments. It is also understood that, should a user wish to do so, the rotary disc **200** could be manually-rotated into specific positions that would allow for analyses, without including or using the electric motor **504** and controller **506**.

(48) The rotary disc **200**, has a first side **202**, a second side **802**, an outer edge **204**, and a central longitudinal axis **208**. Mounting holes **210** are shown in FIGS. **2**A and **2**B, as well in FIG. **2**C. The mounting holes **210** are also used in the system **400** embodiments shown in FIGS. **4**, **5**, **6**, and **8**. The mounting holes **210** are used to secure the rotary disc **200** to the electric motor **504**. The motor

504 used is a rotation stage platform and was the base for the rotary disc **200** for automated control. Eight mini-series adaptors with external M4 threads and internal M3 threads were inserted at equidistant positions in the mounting holes **210**. Two mini-series optical posts, each having with a six millimeters diameter and a length of 75 millimeters, were screwed into each mini-series adapter to create eight posts **510** each about 150 millimeters tall. The posts **510**, which can also be referred to as mounting posts or rods, attach the rotary disc **200** to the electric motor **504**. M3 screws **410**, each having a length of thirty millimeters, were threaded through the mounting holes **210** from the first side **202** to attach the rotary disc **200** to the posts **510** that were inserted through the mounting holes on the second side **802**. The rotary disc **200**, posts **510**, and screws used for secure attachment can be adjusted based on the environment, including height requirements of the mass spectrometer **504** being used. It is understood that a different number of posts **510** can be used and that the sizes can be varied based on user discretion. Additionally, it is understood that various lifts, tables, stands, bars, and clamps are used for height and placement purposes based on environment conditions, i.e. laboratory versus use.

(49) The system includes a computer **402** used for communicating with components. Communication links throughout the system **400** can be wireless data links, hard-wired, or a combination of the two depending on component capabilities. The communication links are generically shown by jagged lines with arrows. The computer **402** is in communication with the motorized platform **502** and, in particular, the controller **506** to provide instructions to the controller. The controller **506** is configured to prompt the electric motor **504** to actuate, i.e. engage, based on received computer instructions. It should be noted that the computer **402** can be referred to as a non-transitory electronic processor readable medium. Based on this, the computer instructions are electronic processor executable instructions that, when executed by the processor, causes the processor to perform the processes described herein. It is understood that the computer **402** can be a desktop, laptop, tablet, or handheld computer such as, for example, a mobile phone, without detracting from the merits or generalities of the embodiments. It is also understood that a user can start the sample analysis using the system **400** by selecting an icon or executable file on the computer **402** such as, for example running a computer program. Additionally, it is also understood that the computer **402** includes a display screen for user viewing.

(50) The computer **402** is also in communication with a mass spectrometer **404**, via a dedicated internal mass spectrometer computer (not visible for ease of viewing and due to it being internal). The mass spectrometer **404** has a sampling inlet **902**, which is illustrated in a close-up view in FIG. **9**. The sampling inlet **902**, is sometimes referred to as a mass spectrometer inlet or simply as the inlet, provides a vacuum. The system **400** includes a syringe pump **406**, having a dedicated internal syringe pump computer (not visible for ease of viewing and due to it being internal). The computer **402** and syringe pump **406**, via the dedicated internal syringe pump computer, are configured to communicate with each other. Both the dedicated internal syringe pump computer associated with the syringe pump **406** and the dedicated internal mass spectrometer computer associated with the mass spectrometer **404** can also be referred to as a non-transitory electronic processor readable mediums. Based on these aspects, the mass spectrometer **404** and the syringe pump **406** can communicate with each other in some embodiments via their dedicated internal computers, i.e. the dedicated internal syringe pump computer and the dedicated internal mass spectrometer computer. All communication in the system **400** both to and from the computer **402**, both to and from the dedicated internal syringe pump computer, and both to and from the dedicated internal mass spectrometer computer can be referred to as electrical communication or as signal communication, which is strictly non-transitory signal communication.

(51) The mass spectrometer **404** has an internal power source (not visible for ease of viewing and due to it being internal). The power source is configured to apply a high voltage as discussed below and can be referred to as a voltage source or high voltage source. All components in the system **400** such as, for example, the computer **402**, the mass spectrometer **404**, syringe pump **406**, the electric

motor **504**, and controller **506**, can be configured to access multiple power sources, including alternating current (AC) or direct current (DC), solar, wind, and generator power, with any required adaptor or transform techniques included. Additionally, mechanically-driven systems are included such as, for example, internal combustion engines, two and four-cycle engines, and tractor power take off shafts in place of the electric motor **504**, without detracting from the merits or generalities of the embodiments.

(52) Referring to FIGS. **4**, **5**, and **8**, the plurality of receptacles **206** extend through the rotary disc **200** from the first side **202** to the second side **802**, and are axially-spaced at equal distance about the central longitudinal axis **208**. It is evident that the first side **202** can also be referred to as the top side or top surface. Similarly, the second side **802** can also be referred to as the bottom side or bottom surface. The plurality of receptacles **206** are apertures through the rotary disc **200**. Each receptacle in the plurality of receptacles **206** is configured to removably-hold a sample collection device **100**, sometimes referred to as a corresponding sample collection device.

(53) As shown in FIGS. **4**, **5**, and the close-up view in FIG. **6**, each receptacle in the plurality of receptacles **206** has a dedicated sample collection device **100**, which in the system environment **400**, can be referred to as a corresponding sample collection device. The syringe pump **406** is in fluid communication with the each of the sample collection devices **100**, i.e. in fluid communication with each corresponding sample collection device **100**, based on the rotation and advancement of the rotary disc **200**. A syringe hose **407** is connected to the syringe pump **406**, providing the fluid communication from the syringe pump to the sample collection device **100** and enabling solvent to be deposited on the sample in the sample collection device.

(54) Similarly, FIG. **6** depicts a wire **604** in contact with the proximal end **114** of the sample collection device. The wire **604** is electrically-connected to the mass spectrometer's **404** internal power source by an electrical cable **605**. Thus, due to the sample collection device **100** being conductive and its proximal end **114** being in contact with the wire **604**, the sample collection device is electrically-connected to the power source. By virtue of this connection, the mass spectrometer **404**, through its power source, is configured to apply a high voltage to the sample collection device **100** in contact with the wire **604**. One having ordinary skill in the art will understand that alternatives to the wire **604** exist to create a path for high voltage application. Some alternatives include providing a conductive portion such as, for example, using ball bearings embedded into the rotary disc **200** or having a conductive plastic portion or conductive plastic polymer portion in the rotary disc that contacts the sample collection device **100**.

(55) Referring to FIGS. **6** and **9**, the sample in the sample collection device **100** to the left of the inlet **902** is defined as a solvent fill position **606**, sometimes referred to as a first position, which is in fluid communication with the syringe pump **406** via the syringe hose **407**. In the embodiments, the syringe pump **406** pumps solvent for ten seconds at a flow rate of six milliliters per minute to the first sample collection device **100**A, which is positioned in the solvent fill position **606**. Based on this, it is understood that the system **400** depicted will have eight total pulses of solvent, one for each time a sample collection device **100** is positioned in the solvent fill position **606**.

(56) Based on this, the system **400** shown in FIG. **4**, upon beginning the analysis process, with all sample collection devices **100** in place and holding their respective samples, the rotary disc **200** begins with a first receptacle (the receptacle **206** counterclockwise to the inlet **902**), holding a first sample collection device **100**A, as shown in FIG. **6**. The first receptacle holds the first sample collection device **100**A, which is positioned in the first position **606**, i.e. the solvent fill position. The syringe pump **406** is in fluid communication with the solvent fill position **606** and, at the beginning of the process, in fluid communication with the first sample collection device **100**A.

(57) A last sample collection device **100**N is held in the voltage application position **608**, or simply referred to as a second position, and corresponds with a last receptacle in the plurality of receptacles **206**. The computer **402** instructs the controller **506** to actuate the electric motor **504** causing it to advance the rotary disc **200** about the central longitudinal axis **208**. The advancement

positions a next sample collection device at the first position **606**. The computer **402** then instructs the syringe pump **406** to pump solvent into the next sample collection device. For reference, in FIG. **6**, the next sample collection device is immediately counterclockwise to the first sample collection device **100**A.

(58) This advancement also causes the last sample collection device **100**N to advance clockwise. It should be noted that, at this point, the last sample collection device **100**N has not yet received solvent at the first position **606** and also did not receive high voltage at the second position **608**. The computer instructs high voltage application of a sample collection device **100** only after the sample collection device has been in fluid communication, i.e. received solvent at the first position.

(59) The advancement then positions the first sample collection device **100**A at the second position **608**, i.e. the high voltage application position. The power source is electrically-coupled with the first sample collection device **100**A at the second position **608**. The computer **402** instructs the mass spectrometer **404** to apply a high voltage from its internal power source to the first sample collection device **100**A. The mass spectrometer **404** is always under vacuum and the sampling inlet **902**, which is a metal, such as stainless steel, is exposed to the outside atmosphere. The high voltage application causes a voltage difference, sometimes referred to as a voltage differential between the first sample collection device **100**A, which is at about four kV to about seven kV, and the sampling inlet **902**, which is sometimes grounded and sometimes floated to approximately 100 volts (V) to 200 V. The voltage difference causes the solvent and resulting extracted products and its ions from the solid media containing the analyte to be sprayed into the sampling inlet **902**. The vacuum from the mass spectrometer **404** is applied to the distal end **116** of the first sample collection device and assists with collecting the extracted products and its ions, but much less so than the voltage difference. The mass spectrometer **404** then analyzes the resulting extracted products from the first sample collection device **100**A. The analysis determines the chemical composition and concentration of the resulting extracted products. It should be noted that the resulting extracted products, most importantly extracted analytes, are in liquid phase as they exit the distal **116** end of the first sample collection device **100**A. However, due to the voltage difference, the extracted analytes are gas phase ions by the time they enter the mass spectrometer **404**.

(60) Analysis of samples in the system **400** continue by the advancement of the rotary disc **200** based on computer executable instructions stored on the computer **402**. Thus, the pumping of solvent by the syringe pump **406** into sample collection devices **100** at the first position **606** continues. The high voltage application at the second position **608** continues for sample collection devices **100** that were previously in the first position **606** and received solvent from the syringe pump **406**. The vacuum remains on. Extracted products are sprayed into the sampling inlet **902** and those extracted products are analyzed by the mass spectrometer **404**. The process continues until all sample collection devices **100** have had their respective extracted products analyzed by the mass spectrometer **404**.

(61) Stated more simply, the process continues in such fashion that the rotary disc **200** continues advancing through all sample collection devices **100** from the first sample collection device **100**A to the last sample collection device **100**N, until: 1) the last sample collection device **100**N has advanced to the first position **606** and received solvent from the syringe pump **606**; 2) the last sample collection device **100**N has advanced to the second position **608** and received the high voltage application and had its resulting extracted products sprayed into the sampling inlet **902**; and 3) the mass spectrometer **404** analyzes the last sample collection device's **100**N resulting extracted products.

(62) Data obtained by the analysis can be shown and/or represented to a tangible medium for user verification, such as providing a visual verification to the user which could be useful before taking further action. Examples of the tangible medium include the display screen associated with the computer **402**, hard copy printouts of data, as well as other media using the analysis data such as,

for example, a computer having computer-readable instructions that is configured to use output from the embodiments.

(63) Although eight sample collection devices **100** are depicted in the system **400**, nomenclature for the first and last sample collection devices **100**A and **100**N is chosen to accommodate any number sample collection devices, hence the use of the "N" designation. The assigned number of N is equal to the number of sample collection devices **100**, which is determined by the number of receptacles in the plurality of receptacles **206**. Additionally, it is understood that nomenclature can be adapted upon actuation, i.e. rotation, of the rotary disc **200**, so that the first sample collection device **100**A then moves to the second position **608**. The last sample collection device **100**N then advances to eventually receiving solvent in the solvent fill position **606** and having high voltage applied in the second position **608**.

(64) The syringe pump **406** is configured to pump solvent to the first position **606** and then wait thirty seconds. For the process associated with the system **400** in FIG. **4**, the rotary disc **200** rotates 45 degrees. This is based on the rotary disc **200** having eight receptacles **206** and, therefore, eight sample collection devices **100**. A person having ordinary skill in the art will recognize, however, that the degrees of rotation can vary based on the diameter of the rotary disc **200**, the axial-spacing about the central longitudinal axis **208** of the receptacles **206**, and the number of receptacles. In many embodiments, rotation is a range of about 30 degrees to about 90 degrees. Solvent is then pumped to the first position **606** and high voltage is applied at the second position **608** to the proximal end **114**. Analysis is performed by the mass spectrometer **404** for thirty seconds. Thus, after rotating, a thirty seconds waiting period is observed before the next rotation. It should be noted that the analysis time can vary, depending on application-specific conditions such as, for example, sample constituents and mass spectrometer type. Likewise, thirty seconds is an example and should not be construed as being limiting. As such, times greater than or less than thirty seconds can be used. The rotary disc **200** then rotates and the process continues until all sample collection devices **100** containing samples have been analyzed and their chemical compositions and concentrations determined.

(65) The electric cable **605** can be referred to as a high voltage cable. The wire **604** can also be referred to as a high voltage wire. Various conductive clips, such as copper, can be used to connect the high voltage cable **605** to the wire **604**. As the rotary disc **200** rotates to the next position, the sample collection device **100** that was in front of the inlet **902** comes in contact with the high voltage wire **604** and the high voltage is applied to the proximal end **114**. The high voltage can be either positive or negative polarity depending on the analyte of interest, which is sprayed with the solvent into the inlet **902**. This creates a Taylor cone. After all samples in the sample collection devices **100** have been analyzed, an analyst simply needs to replace used sample collection devices with new, unused sample collection devices. Should the sampling system **400** be operating continuously, the analyst would change the sample collection devices **100** before the mass spectrometer **404** completes its analysis of the sample in the last sample collection device **100**N.

(66) As shown in FIG. **6**, the first sample collection device **100**A is in a first position **606**, which is often referred to as a solvent fill position. The syringe **406** then pumps solvent to the first sample collection device **100**A and its associated solid media, i.e. the sample in the first sample collection device **100**A. The rotary disc **200** when coupled to the electric motor **504** and controller **506**, is configured to advance about the central longitudinal axis **208** upon instructions from the computer **402** sending computer executable instructions to the controller **506** and electric motor **504**.

(67) The advancement positions the first sample collection device **100**A to the second position **608**. The advancement causes the computer **402** to send computer executable instructions to the mass spectrometer **404** to apply a high voltage from the mass spectrometer's power source. The high voltage is applied to the proximal end **114** of the first sample collection device **100**A after it advances to the second position **608**. The mass spectrometer **404** applies a vacuum at its inlet **902**. The amount of vacuum depends on the type of mass spectrometer **404** used and application-specific

embodiments. In some embodiments, the high voltage applied is a range of 4 to 5 kV. In other embodiments, the high voltage applied is a range of 4 to 7 kV. While in other embodiments, the high voltage applied is a specific voltage such as, for example, 7 kV. Specific voltage levels and ranges are based on application-specific conditions and, as such, can be greater or less than that above voltage ranges.

(68) FIG. **9** and reference character **900** depict the positioning of the first sample collection device **100**A and the rotary disc **200** in relation to the mass spectrometer's inlet **902** after the rotary disc has rotated and placed the first sample collection device at the second position **608**. For ease of viewing in FIG. **9**, application of the high voltage to the proximal end **114** of the first sample collection device **100**A is not shown. Positioning is such that as high voltage is applied, solvent and any resulting extracted products from the solid media sample are pulled through the hole **102** (not visible in the side view of FIG. **9**) at the distal end **116** into the inlet **902**, so that the mass spectrometer **404** can perform analysis.

(69) Additionally, positioning assures unimpeded motion of the rotary disc **200** and sample collection devices **100** with objects such as, for example the mass spectrometer **404**, while still allowing for a Taylor cone into the inlet **902**. Appropriate positioning is controlled by the distal end **116** in relation to the inlet **902**. In the embodiments, in the second position **608**, the distal end **116** is five millimeters vertically (depicted as d1) above and five millimeters horizontally (depicted as d3) from the inlet **902**, which is approximately a 45 degree angle. When properly positioned, the second side **802** of the rotary disc **200** is nine millimeters vertically (depicted as d2) above the inlet **902**. As shown in FIG. **9**, the outer edge **204**, the second side **802**, and the distal end **116** are unimpeded.

(70) The positioning and spacing dimensions can be varied based on application-specific conditions. For instance, the depth that the sample collection devices **100** sit within the rotary disc **200** can be varied to control ion signal or concentration of analytes reaching the inlet **902**. Based on this, the receptacles **206** can be optimized for trace and concentrated analytes by modifying the shape and dimensions of the inner walls **302**.

(71) Theory of Operation and Working System

(72) Using the embodiments includes preparing the sample collection devices **100** and inserting the sample collection devices into the receptacles **206**. The sample collection devices **100** are filled with the sample, i.e. the solid media and any analyte contained in the solid media. Filling of the sample collection devices **100** can be done either before or after inserting the sample collection devices into the receptacles **206**. Solvent is applied to the sample at the first position **606** and voltage is applied at the second position **608**. Analysis of the sample is then performed at the second position **608** by the mass spectrometer **404** to determine whether an analyte is present or not present, i.e. whether an analyte is detected or not detected in the sample. When an analyte is detected, the mass spectrometer **404** determines the analyte's chemical composition and concentration.

(73) The rotary disc **200** can move clockwise or counterclockwise, depending on the electric motor **504** configuration and application-specific conditions. For simplicity, however, rotational movement herein is described as clockwise. The rotary disc **200** moves in a clockwise manner, rotating 45 degrees after each sample is analyzed. Computer executable instructions stored on a nontransitory computer readable medium such as, for example, the computer **402**, provide instructions for a thirty seconds mass spectrometer **404** analysis time.

(74) The embodiments enable solvent to be applied prior to analysis in the “prep,” i.e. the first position **606**, and when the sample collection device **100** moves into the “spray,” i.e. the second position **608**, high voltage is applied to initiate the electrospray. The high voltage line is held above the sample collection device **100** that is aligned with the inlet **902** and makes contact with the proximal end **114** only when in the second position **608**. Depending on the mass spectrometer **404**, the solvent and the high voltage can either be applied by the mass spectrometer or the external

syringe pump **406** and an external power supply (not shown in the figures). The duty cycle of the system **400**, via the computer **402** or mass spectrometer **404**, can be changed to allow additional extraction time (after solvent deposition) in the sample collection device **100** prior to analysis as needed.

(75) The solvent is applied to the solid media and the high voltage is applied to the proximal end **114** of the sample collection device **100**. The solvent extracts the analyte and separates the analyte from the solid media to the solvent within the sample. High voltage is applied to the sample collection device **100** to form a spray plume at the distal end **116** where the hole **102** is located. Voltage is applied based on application-specific conditions, which can be for up to thirty seconds. The analyte is ionized and its chemical composition and concentration are then determined by the mass spectrometer **404**.

(76) The solvent extracts the analyte within the solid media sample. Some examples of the solvent include methanol, ethanol, propanol, isopropanol, acetonitrile, water, water mixed with organic solvents, and combinations thereof. The amount of solvent varies depending on the size of the sample collection device **100** and the solid matrix. The amount solvent is directly proportional to the size of the sample collection device **100** (i.e., as the size of the sample collection device increases, so does the amount of solvent used). Similarly, to increase the amount of time a spray plume is being produced, more solvent may be added. In some embodiments, the solvent may be added sequentially (e.g., three 2 milliliters aliquots) or all at once (e.g., one 6 milliliters portion). In other embodiments, the solvent is added in aliquots ranging from about one milliliter to about two milliliters.

(77) In some embodiments, an additive is used in conjunction with the solvent. The additive assists with the extraction of the analyte of the solid media. The additive is added to the solvent prior to adding the solvent to the solid media within the sample collection device to form a mixture of the solvent and additive. Some examples of the additive that may be used with the solvent include acetic acid, formic acid, ammonium acetate, and combinations thereof. The amount of additive differs based on the additive and solvent that is used. For example, a mixture of methanol as the solvent and one percent formic acid as the additive may be used.

(78) Sample analysis includes determining a sample analysis, thereby determining whether an analyte is present in the solid media and, when present, the chemical composition and concentration of the analyte. Additionally, if multiple analytes are detected, the chemical composition and concentration of each analyte is determined. When no analyte is detected, it is reported as no analyte detected or similar designation. Analyte presence, chemical composition, and concentration are determined by analyte standards of the molecule of interest. For example, if the data from the sample matches the standard, the target analyte is present. The mass spectrometer **404** performs the analysis using known techniques. The embodiments result in about sixty samples being examined in the same time as one sample is examined for liquid chromatography mass spectrometry (LC-MS).

(79) After sampling the sample in a sample collection device **100**, the rotary disc **200** advances to the next position where the used sample collection device is removed and a new sample collection device is now aligned with the inlet **902**. The new sample collection device **100**, i.e. solvent has been applied to the first sample collection device **100**A, which is now in the second position **608** and in contact with the wire **604** providing high voltage, which initiates an electrospray (the Taylor cone) into the inlet **902** for sample analysis. Rotation occurs and the next sample collection device **100** is moved into the first position **606**, i.e. the “prep” position and has solvent applied. Rotation is continuous and customizable to the number of samples needing analysis. The sample collection devices **100** that have already been analyzed do not need to be removed right away but should be replaced if the system **400** is set to continuously sample. For the system **400** shown in FIG. **4**, eight sample collection devices **100** are used, which means that the sample collection devices would need to be replaced at least every six analyses to ensure no repetitive analyses. Increasing the

diameter of the rotary disc **200** and ultimately the number of receptacles **206** can add to the amount of samples run during each cycle and increase the time in between sample removal and loading.
(80) Rotation of the rotary disc **200** can be controlled by a timer and be on a continuous loop based on instruction from the computer **402**, or be triggered by a contact closure signal from the mass spectrometer **404**. Similarly, once positioned the start-up of the sequence of solvent and high voltage application can be controlled by the computer **402** using a timer or be triggered by a contact closure signal from the mass spectrometer **404**.
(81) In some embodiments, the sample collection device **100** may be cleaned and reused in the field or at the laboratory to obtain another solid media sample. In other embodiments, the sample collection device **100** is discarded after sample collection. When the sample collection device **100** is cleaned and reused, the solid media is removed from the sample collection device and the sample collection device is submerged and sonicated in a solvent. The submerging and sonication step is repeated until the sample collection device **100** is cleaned (i.e., a clean standard sample is run with the sample collection device **100**, which shows no chemicals present). In some examples, different solvents are used to clean the sample collection device **100** each time the sample collection device **100** is submerged and sonicated.
(82) While the embodiments have been described, disclosed, illustrated and shown in various terms of certain embodiments or modifications which it has presumed in practice, the scope is not intended to be, nor should it be deemed to be, limited thereby and such other modifications or embodiments as may be suggested by the teachings herein are particularly reserved especially as they fall within the breadth and scope of the claims here appended.

Claims

1. A sample collection apparatus, comprising: a platform having a first side, a second side, and an outer edge; and a plurality of receptacles extending through said platform from said first side to said second side, wherein each receptacle in said plurality of receptacles is configured to removably-hold a sample collection device, said sample collection device, comprising: a proximal end and a distal end, said distal end having a hole; wherein said sample collection device is constructed of a conductive polymer, said conductive polymer including a mixture of carbon nanotubes and a polymer.
2. The apparatus according to claim 1, wherein said platform is a disc.
3. The apparatus according to claim 1, wherein said platform is rectangular.
4. The apparatus according to claim 1, wherein each receptacle in said plurality of receptacles is an aperture through said platform.
5. The apparatus according to claim 1, wherein said plurality of receptacles is a range of about four to about twelve receptacles.
6. The apparatus according to claim 1, wherein said sample collection device is a multi-faced pyramid.
7. The apparatus according to claim 1, wherein said sample collection device is a cylindrical cone.
8. The apparatus according to claim 1, wherein said polymer is selected from the group consisting of polyethylene terephthalate, acrylonitrile butadiene styrene, polylactic acid, polyetherketoneketone, polyether ether ketone, polycarbonate, polyphenylene sulfide, polyvinylidene fluoride, and combinations thereof.
9. The apparatus according to claim 1, wherein said platform is constructed of a non-conductive, chemically-inert plastic.
10. The apparatus according to claim 1, said platform having a central longitudinal axis, wherein said plurality of receptacles are axially-spaced at equal distance about said central longitudinal axis.
11. The apparatus according to claim 10, wherein said spacing of said plurality of receptacles is a range of about 30 degrees to about 90 degrees.

12. The apparatus according to claim 1, wherein said sample collection device is configured to hold a solid media containing an analyte.
13. The apparatus according to claim 12, wherein said solid media is selected from the group consisting of soil, sand, sediment, waste, pure analytes, and combinations thereof.
14. The apparatus according to claim 12, wherein said analyte is selected from the group consisting of perfluoroalkyl substances, polyfluoroalkyl substances, energetics, chemical warfare agent simulants, drugs of abuse, pesticides, and combinations thereof.