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- (71) **Applicant (for all designated States except US):** **GADGET IP, LLC** [US/US]; 7881 Pheasant Wood Dr., Sandy, Utah 84093 (US).
- (72) **Inventors; and**
- (75) **Inventors/Applicants (for US only):** **LEGEIN, Filip** [BE/BE]; De Bruwaan 5D, B-9700 Oudenaarde (BE). **VANLANDEGHEM, Anthony** [BE/BE]; De Bruwaan 5D, B-9700 Oudenaarde (BE). **MARTENS, Peter** [BE/BE]; De Bruwaan 59, B-9700 Oudenaarde (BE).
- (74) **Agent:** **OAKESON, Gary P.**; Thorpe North & Western LLP, 8180 S. 700 E., Suite 350, Sandy, Utah 84070 (US).

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(54) **Title:** COATED ELECTRONIC DEVICES AND ASSOCIATED METHODS

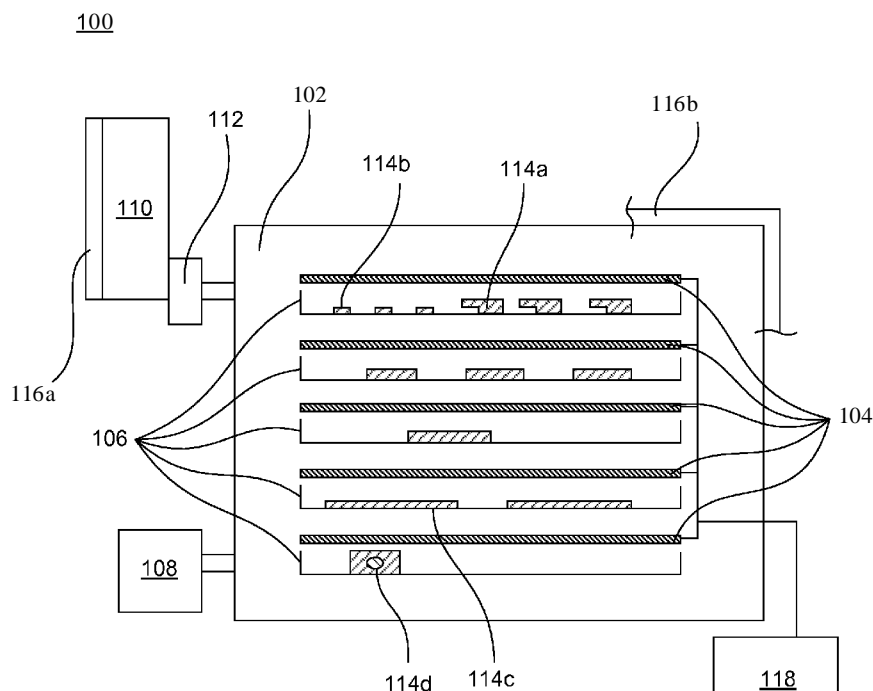


FIG. 1

(57) **Abstract:** The present disclosure provides an electronic device and related method, wherein the device has a polymeric coating with low toxicity. The polymeric coating formed by exposing the electronic device to a plasma, such as a continuous plasma, comprising a compound of $\text{CH}_2 = \text{C}(\text{R}_1)\text{-COO-R}_2$, where R_1 includes $-\text{H}$ or $-\text{CH}_3$; and where R_2 includes $-(\text{CH}_2)_2\text{-(CF}_2\text{)}_m\text{-CF}_3$ and m is 3 or 5.

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5 **COATED ELECTRONIC DEVICES AND ASSOCIATED METHODS**

BACKGROUND

Electronic devices are essentially three dimensional structures of
10 electrically conductive and electrically insulating materials. Such electronic
devices include not only equipment but also sub assemblies, printed circuit
boards (PCBs), both bare and assembled, and individual components such as
integrated circuits and transistors. The electrically conductive parts of such
structures usually consist of metals such as copper, aluminum, silver, gold,
15 conductive polymers, semiconductor materials, etc. The electrically non-
conductive parts or insulators of these structures usually consist of polymers
such as polyimide, polytetrafluoroethylene, silicone, or polyamide, with or without
glass-fiber reinforcement, paper based materials, ceramics, glass, etc.

Throughout the lifetime of assembled electronic devices, they are subject
20 to various forms of contamination. The conductivity of some of the materials may
be reduced by atmospheric corrosion, and pollution can cause conductive paths
to become established between adjacent traces or conductors. Additionally,
electronic devices can often accidentally be submersed in various liquids, such
as water, often destroying the function of the electronic device. As electronic
25 devices are being used increasingly in more and more hostile and polluted

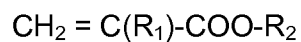
environments, there has become a greater need to protect these items from damage when exposed to those environments.

SUMMARY

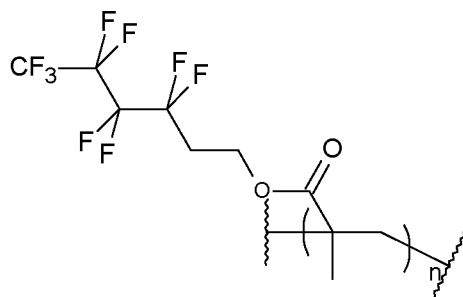
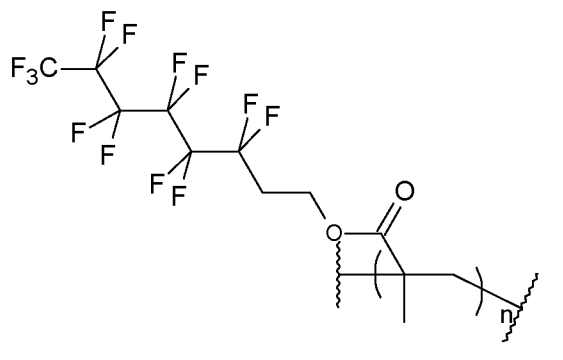
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Accordingly, it has been recognized that there is need for coated electronic devices and methods that allow for protection of electronic devices from water or other moisture exposure, pollutants, and/or other contamination. As such, the present disclosure provides an electronic device having a polymeric coating with low toxicity. The polymeric coating can provide protection to the electronic device from the elements, and do so in a way that is safe to the user and the environment.

The polymeric coating can be formed by exposing the electronic device to a plasma, such as a continuous plasma, of a monomer vapor with following structure:



where R_1 includes $-\text{H}$ or $-\text{CH}_3$; and where R_2 includes $-(\text{CH}_2)_2-(\text{CF}_2)_m-\text{CF}_3$ and m is 3 or 5. As such, the polymerized coating can comprise a compound selected from the group consisting of:



, and mixtures thereof, wherein n is

from 2 to 100,000.

- 5 Additionally, a method for protecting an electronic device against pollution and/or contamination (including water or other moisture exposure) using a polymeric coating with low toxicity can comprise: placing the electronic device in a plasma chamber; forming a plasma, such as a continuous plasma, in the plasma chamber; vaporizing a compound comprising $\text{CH}_2 = \text{C}(\text{R}_1)\text{-COO-R}_2$,
- 10 where R_1 is -H or $-\text{CH}_3$, and where R_2 is $-(\text{CH}_2)_2-(\text{CF}_2)_m-\text{CF}_3$ and m is 3 or 5; and contacting the vaporized compound with the plasma in the plasma chamber.

With the electronic device in the chamber, the vaporized compound can polymerize on a surface of the electronic device, thereby forming the polymeric coating on the surface of the electronic device.

Additional features and advantages of the invention will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a coating apparatus in accordance with an example of the present disclosure; and

10 FIG. 2 is a flow chart of a method in accordance with an example of the present disclosure.

DETAILED DESCRIPTION

15 Reference will now be made to the exemplary embodiments illustrated in the drawings, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Alterations and further modifications of the inventive features illustrated herein, and additional applications of the principles of the inventions as
20 illustrated herein, which would occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the invention.

It is noted that, as used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the context
25 clearly dictates otherwise.

As used herein, "oleophobicity" refers to the physical property of a molecule or compound that is repelled from oil as measured by ISO 14419:2010 by the International Organization for Standardization at the date of filing the present disclosure.

5 As used herein, "low toxicity" refers to having a perfluorooctane sulfonate (PFOS) level of less than 0.2 parts per billion (ppb) and perfluorooctanoic acid (PFOA) level of less than 0.4 parts per billion (ppb), unless otherwise stated.

As used herein, "free from PFOS and PFOA" refers to a material or polymeric coating having PFOS and PFOA below detectable limits.

10 "Substantially free from PFOS and PFOA" refers to a material or polymeric coating having low levels of PFOS and/or low levels of PFOA so that the coating would be considered to have "low toxicity."

As used herein, "electronic device" refers to any device having an electronic component that is used by an end user or consumer. "Electronic
15 device" does not mean individual electronics components *per se* used to make up an electronic device, such as circuits and circuit boards, etc., prior to assembly in the electronic device. Rather, an electronic device comprises individual components assembled together to form a finished consumer product (with or without the battery), such as a cellular phones, personal digital assistants (PDA),
20 computers, tablet computers, music players, cameras, video recorders, e readers, radio devices, and gaming devices, including batteries thereof.

As used herein, "electronic component" refers to any physical entity in an electronic device used to affect the electrons or their associated fields in a desired manner consistent with the intended function of an electronic device.

As used herein, the term "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
5 determine based on experience and the associated description herein.

As used herein, the term "substantially" or "substantial" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed
10 or nearly completely enclosed. 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.

Concentrations, amounts, and other numerical data may be expressed or
15 presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is
20 explicitly recited. As an illustration, a numerical range of "about 10 to about 50" should be interpreted to include not only the explicitly recited values of about 10 to about 50, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 20, 30, and 40 and sub-ranges such as from 10-30, from 20-40, and from
25 30-50, etc. This same principle applies to ranges reciting only one numerical

value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

It has been discovered that certain coatings, such as conformal nan-coatings, can be used on electronic devices, providing protection of such devices from pollutants and contamination including water or moisture, or other liquid contamination. It has also been discovered that these coatings can be applied in a manner that is safe and effective for end users, and which are also generally environmentally friendly. The conformal coatings can provide an effective barrier between the device and the environment and the coating also be electrically insulating. The coating will typically prevent physical contamination, which may, for example, result in conductive growths across the non-conductive parts of the structure or installation, which can, in time, cause electric defects including, for example, short circuits. Other examples of contamination are dendrites that grow across surfaces under certain conditions and "whiskers" that can grow through the air between component leads. The coatings can also provide protection such that the metal does not oxidize in air or corrode in other environmental gasses. Other desirable conditions that the coating may protect from include high humidity, high temperature, and high pollution including dust, salts, acids, solvents, etc. Furthermore, the coatings of the present disclosure can also protect against accidental immersion or contact with water, e.g., dropping in body of water, exposure to rain, etc.

Traditional conformal coatings typically provide a coating that is on the order of micron in thickness and are generally removed prior to repairs or replacement of parts. In contrast, a conformal nano-coating produced by a plasma process using materials that are environmentally friendly can provide

advantages over these systems. The present disclosure provides a plasma polymerization process where a thin polymeric film can be deposited on any surface that comes in contact with the plasma of an organic monomer, which can be created in the plasma chamber. Depending upon the deposition conditions, or
5 plasma parameters, including power, pressure, temperature, flow, etc., the properties of the film may be adapted to the requirements of the applications of the electronic devices.

With this in mind, an electronic device can have a polymeric coating applied thereto, wherein the coating has low toxicity. The polymeric coating can
10 be formed by exposing the electronic device to plasma, such as a continuous plasma, including the monomers described herein. Generally, for the present electronic devices, a conformal nano-coating can be applied by a low pressure plasma process, e.g., less than about 1000 mTorr. The typical layer of thickness for the coating can be from 5 nm to 500 nm. In one aspect, the coating can be
15 from 25 nm to 250 nm. Notably, such coatings are fundamentally thinner than conformal coatings applied by some other processes. The present conformal nano-coating can provide a uniform coating, and can be especially useful for coating electronic devices, as the thickness can allow for penetration and coverage in small confinements at the surface of the electronic device, thereby
20 preventing water, moisture, or other contamination to enter therein in many circumstances.

Generally the plasma process can be used in a vacuum plasma chamber where the parameters for controlling the plasma process include power, pressure, temperature, type of monomer, flow, frequency of the plasma
25 generator, and process time. The frequency of the plasma generator can be in

the kHz, MHz, and GHz range. Generally, the plasma frequency is continuous.

In one embodiment, the frequency can range from about 20 kHz to about 2.45

GHz. In another aspect, the frequency can be from about 40 KHz to about 20

MHz. In another aspect, the frequency can be from about 12 MHz to about 15

5 MHz. In one specific aspect, the frequency can be about 13.5 to 13.6 MHz, e.g.,
13.56 MHz.

Generally the pressure for the plasma process can be from about 10

mTorr to about 1000 mTorr. In one aspect, the pressure can be from about 10

mTorr to about 100 mTorr. In another aspect, the pressure can be from about 20

10 mTorr to about 60 mTorr.

The power used in the plasma process can dependent, in some degree,

upon the monomer used. In one embodiment, the power can be from about 5 W

to about 5000 W. In another aspect, the power can range from about 0.017 to

0.023 W per cm² of electrode. Generally, if the monomer is large and/or less

15 stable, it may be too easily decomposed by high power and lower power may be
more appropriate for use in the plasma process.

Generally, the plasma can be formed at any temperature that allows for

reactivity of the plasma with the monomer but does not destroy the monomer. In

one embodiment, the plasma can be formed at a temperature from about 5°C to

20 about 200°C. In one aspect, the temperature can be from about 20°C to about

100°C. In addition to the temperature of the plasma, the walls of the plasma

chamber can controlled such that the monomer does not condense thereon.

Such control can include the heating the walls to a specific temperature. In one

embodiment, the walls of the chamber can have a temperature from about 20°C

25 to about 200°C. In another aspect, the temperature can be from about 40°C to

about 50°C. Further, the monomer can be heated to a specific temperature to allow the monomer to vaporize into a gaseous state before inducing it into the plasma chamber or as it enters the plasma chamber. In one embodiment, the temperature of the monomer can be from 120°C to about 200°C. In another aspect, the temperature can be from about 140°C to about 150°C. These temperatures can apply to the monomer in the liquid state prior to vaporization, to the vapor state, or even the gaseous state. In addition to temperature, it is understood that pressure can be also used to transform the liquid monomer into a gaseous state prior to or during contact with the plasma. Also, monomers used in accordance with the present disclosure may be gaseous in general or, as outlined herein, may be made gaseous through the use of temperature and/or pressure.

The monomers can comprise a compound having the following structure:



where R_1 includes -H or -CH₃; and where R_2 includes -(CH₂)₂-(CF₂)_m-CF₃ and m is 3 or 5.

Such monomers and resulting the coatings of the present disclosure are generally friendlier to humans and the environment (e.g., lower toxicity) as compared to longer fluorinated monomers. Additionally, in one embodiment, such low toxicity can include having a perfluorooctane sulfonate (PFOS) level of less than 0.2 parts per billion (ppb) and perfluorooctanoic acid (PFOA) level of less than 0.4 parts per billion (ppb). In another embodiment, the levels of PFOS can be less than 0.1 parts per billion (ppb) and the levels of PFOA can be less than 0.2 parts per billion (ppb). In still another embodiment, the levels can be low

enough that they are undetectable or absent, e.g., free from PFOS and PFOA which is defined to include being free from their precursors and/or related higher homologues (having carbon and/or fluorine from 1-100).

The coatings described herein can provide an oleophobicity level of at least 5. In one aspect the oleophobicity level can be at least 6. Additionally, the coating can provide a water contact angle of at least 100°. In one aspect, the coating can provide a water contact angle of at least 110°. Such characteristics of the coating can help protect against pollutants and contamination, including water or moisture contamination. In one embodiment, the coating can protect against liquid damage. In another aspect, the contamination or liquid damage can be water.

As discussed herein, the coating can be applied to any electronic device. In one embodiment, the electronic device can include cellular phones, personal digital assistants (PDA), music players, cameras, video recorders, computers, tablet computers, batteries, e readers, radio devices, and gaming devices. In one particular aspect the electronic device can be a cellular phone.

Turning now to FIG. 1, a coating apparatus 100 can include a plasma chamber 102 comprising electrodes 104 and trays 106 for holding various electronic devices, e.g., cell phones 114a, batteries 114b, tablet computers 114c, cameras 114d, etc. The plasma chamber can have a vacuum pump 108 connected thereto for controlling the pressure inside the plasma chamber. The electrodes can be connected to a power source 118 for controlling the power. The monomer can be present in a canister 110, either in gaseous, vapor, or liquid form. The monomer can then be introduced into the plasma chamber through control mechanism 112. In one embodiment, the control mechanism can be a

control valve. The control mechanism generally controls the flow of the monomer into the plasma chamber. In one specific embodiment, the flow rate can be about 30 standard cubic centimeter per minute (seem) to about 50 seem for a plasma chamber having a volume of about 450 liter to about 550 liter with a pump

5 capacity of about 500 m³/h, though this can be varied for achieving modified results as would be apparent to one skilled in the art after considering the present disclosure. As discussed herein also, the monomer can be heated with a heating unit 116a at the canister, additional heating can occur at the plasma chamber 116b. The specific device used for heating can be any heating device known in

10 the art that would be functional for providing heating parameters described herein in practicing the principles of the present disclosure.

The plasma chamber generally defines a volume of space sufficient to house an electronic device for coating. In one embodiment, the plasma chamber can have a volume of about 0.1 ft³ to about 50 ft³. In another aspect, the volume

15 can be about 15 ft³ to about 20 ft³. Even though the plasma chamber of FIG. 1 provides for a plurality of trays with electrodes in close proximity, other configurations are considered to be with the present scope. For example, the plasma chamber may comprise a single tray for placement of an electronic device with a single electrode for generation of the plasma, where the electrode

20 is spaced substantially apart from the tray. It is understood that plasma can be generated to partially fill the plasma chamber or may fill the entire volume, or substantially entire volume, of the plasma chamber. Additionally, the electrodes can be orientated in varying configurations such that plasma can be generated over an area or volume as desired. FIG. 1 provides several trays each having

25 electrodes capable of generating plasma sufficient to encompass the contents of

each tray; however, as discussed above, other configurations are contemplated herein.

Turning now to FIG. 2, a method 200 for protecting an electronic device against pollution and/or contamination using a polymeric coating with low toxicity can

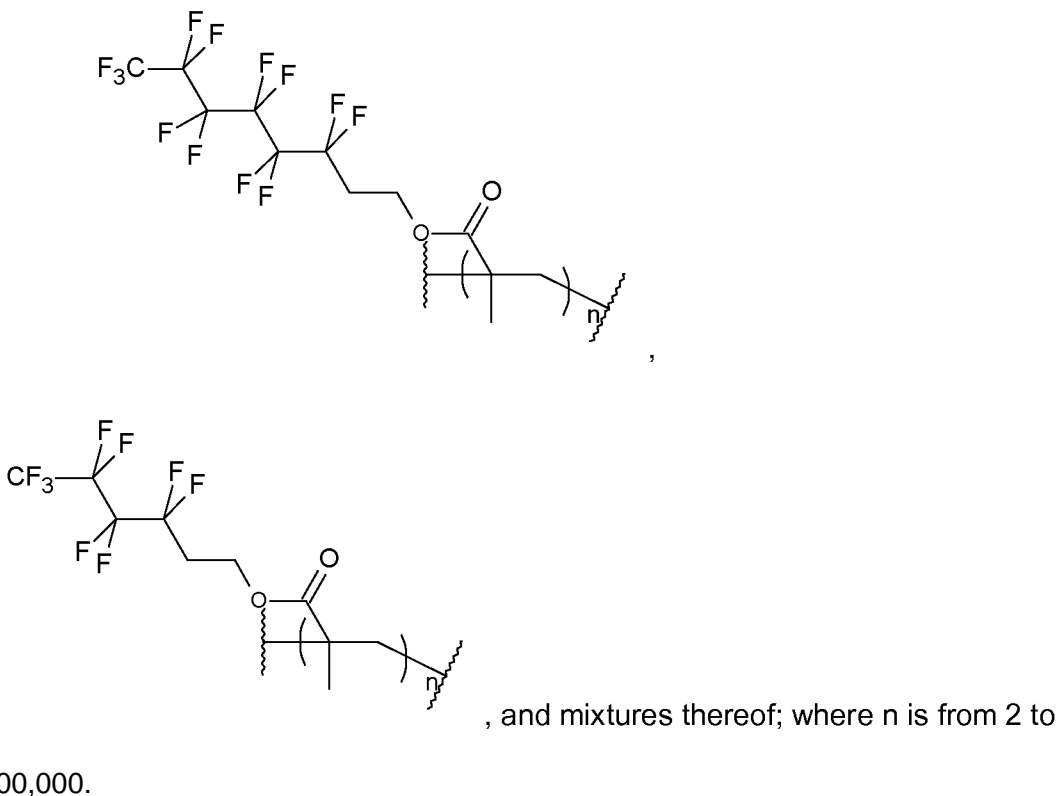
5 comprise: placing 202 the electronic device in a plasma chamber; forming 204 a continuous plasma in the plasma chamber; vaporizing 206 a compound with the following structure:



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where R_1 includes $-\text{H}$ or $-\text{CH}_3$; and where R_2 includes $-(\text{CH}_2)_2-(\text{CF}_2)_m-\text{CF}_3$, and m is 3 or 5; and contacting 208 the vaporized compound with the plasma in the plasma chamber, wherein the vaporized compound polymerizes on a surface of the electronic device, thereby forming the polymeric coating. Additionally, in one
15 embodiment, the method can further include lowering the pressure of the plasma chamber. Further, the method can include opening the device prior to coating the device (the electronic device can be assembled, partially assembled, or disassembled).

Generally, the vaporized compound polymerizes on a surface of the
20 electronic device thereby forming a polymeric coating. In one embodiment, the polymeric coating can have the following structure:



The present coatings can be deposited upon the electronic device at

5 varying rates depending upon the processing parameters. In one embodiment, the polymer forms at a rate of about 25 nm to about 75 nm per minute, or in a more specific embodiment, at a rate of about 50 nm per minute. While the present coatings can be used for any electronic device, in one embodiment, the electronic device can be a cellular phone or other electronic device with a battery,

10 and the battery can be separated from the cellular phone or other device prior to placing the cellular phone in the plasma chamber. Furthermore, many cellular phones and other devices have water damage sensors hidden beneath the battery or elsewhere for manufacturers to determine whether an electronic device has been damaged by water (usually for warranty purposes). In accordance with

15 embodiments of the present disclosure, the water damage sensor can also be

coated with polymer, making water contact now possible without activating the sensor.

The present methods can further include cleaning and/or etching the electronic device prior to contacting the vaporized compound with the plasma.

5 Such etching or cleaning can provide good adhesion between the coating and the component parts of the electronic device. Such adhesion can help maintaining the integrity of the coating throughout the life span of the electronic device.

Generally, etching or cleaning removes organic material from the surfaces of the electronic device. With an electronic device with a viewing window, such as a
10 cell phone, it may not be desirable to etch the surface; however, cleaning the surface may be perfectly appropriate when coating such devices. While cleaning generally involves the removal of organic material and other contaminants from the external and internal surfaces of the electronic device, etching may include partial removal, or roughening, of the surfaces of the electronic device.

15 The present low pressure plasma process can be particularly suitable for electronic devices as the reaction gasses, including the gaseous monomer, can permeate into openings of the three-dimensional structure. Such a process is distinct from liquid conformal coatings that are limited by surface tension.

Additionally, the present process is also a dry process compared to traditional
20 liquid processes.

Typical gases used for plasma cleaning or etching include O_2 , N_2 , CF_4 , Ar, He, and mixtures thereof. The present cleaning or etching step can be performed prior to placing the electronic device in the plasma chamber or can be performed in the plasma chamber prior to coating the electronic device. In one aspect, the
25 cleaning or etching can be performed in the plasma chamber prior to coating the

electronic device, allowing for a more efficient and economical process. As mentioned, in many instances, cleaning will be more appropriate than etching in order to maintain the look of the electronic device, but in some more limited instances, etching may still be appropriate.

5 The present methods can further include activating the surface of the electronic device prior to contacting the vaporized compound with the plasma in the plasma chamber. Such activation can improve the bond between the coating and the surfaces of the electronic device. Activation generally includes the formation of chemical groups on the surfaces of the electronic device, both
10 external and internal, which can increase the affinity of the surfaces for the coating. Typical gases used for activation include O_2 , N_2 , N_2O , NH_3 , H_2 , CH_4 , CF_4 , Ar, He, and mixtures thereof. The present activation step can be performed prior to placing the electronic device in the plasma chamber or can be performed in the plasma chamber prior to coating the electronic device. In one aspect, the
15 activation can be performed in the plasma chamber prior to coating the electronic device allowing for a more efficient and economical process.

 The present methods can further include degassing the electronic device prior to introducing the vaporized compound into the plasma chamber. Degassing can remove trapped gases or liquids allowing for improved bonding
20 between the coating and the surfaces of the electronic device. Such degassing can allow the monomer and reaction gases to penetrate into the electronic device, or at least into openings on the surface of the electronic device (openings that would also be susceptible to leaks when submersed or exposed to water or moisture). The degassing can be performed in a single step or can be performed
25 over a series of degassing cycles. As discussed herein, a vacuum can be used

to reduce the pressure in the plasma chamber during the coating process. The vacuum can also be used in the degassing step. As such, the present degassing step can be performed prior to placing the electronic device in the plasma chamber or can be performed in the plasma chamber prior to coating the electronic device. In one aspect, the degassing can be performed in the plasma chamber prior to coating the electronic device allowing for a more efficient and economical process.

The present cleaning, etching, activation, and/or degassing steps can be achieved individually or in combination by the appropriate choice of process parameters and by use of appropriate materials. Additionally, heating may be used in combination with these steps as appropriate.

As discussed herein, vaporizing the monomer compound can occur in the plasma chamber or can occur outside the plasma chamber. Generally, the steps recited herein are not limited to the order presented but may be combined or reordered, unless otherwise stated. For example, an electronic device can be placed in the plasma chamber where the electronic device undergoes a cleaning step, an etching step, an activation step, and/or a degassing step, or can be placed in the plasma chamber followed by the cleaning/etching/activation/de-gassing step(s).

It is to be understood that the above-referenced arrangements are only illustrative of the application for the principles of the present invention. Numerous modifications and alternative arrangements can be devised without departing from the spirit and scope of the present invention. While the present invention has been shown in the drawings and fully described above with particularity and detail in connection with what is presently deemed to be the most practical and

preferred embodiment(s) of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications can be made without departing from the principles and concepts of the invention as set forth herein.

5

EXAMPLES

The following examples illustrate a number of variations of the present devices and methods that are presently known. However, it is to be understood that the following are only exemplary or illustrative of the application of the principles of the present disclosure. Numerous modifications and alternative devices and/or methods may be devised by those skilled in the art without departing from the spirit and scope of the present disclosure. The appended claims are intended to cover such modifications and arrangements. Thus, while the present electronic devices and methods have been described above with particularity, the following examples provide further detail in connection with what are presently deemed to be acceptable.

Example 1 - Conformal Nano-Coating of Cellular Phone

A cellular phone is separated from its battery, and both are placed in a tray in a plasma chamber having dimensions 700mm x 730mm x 960mm. The temperature walls of the plasma chamber are heated to 40-50 °C. The temperature of the monomer in a canister is held at 150°C prior to introduction to the plasma chamber. An etching gas of Ar is cycled through the plasma chamber followed by a degassing cycle for about 10 minutes. An electrode, having an area of 3416 cm², is powered to 75 W generating a continuous frequency of

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about 13.56 MHz. The plasma chamber is reduced in pressure to 20-50 mTorr prior to introduction of the monomer. The monomer with the following structure:

$\text{CH}_2 = \text{C}(\text{R}_1) - \text{COO} - \text{R}_2$, where R_1 is $-\text{CH}_3$

and where R_2 is $-(\text{CH}_2)_2 - (\text{CF}_2)_m - \text{CF}_3$, with m being 5, is vaporized and introduced

- 5 into the plasma chamber at rate of 50 seem. The cellular phone and the battery are treated for about 2 minutes resulting in a uniform polymeric coating having a thickness of about 100 nm. The battery is re-inserted in the phone making sure the electrical contact between the two is established. The result is a phone and battery combination that is more water resistant than prior to treatment.
- 10 Furthermore, the water damage sensor hidden beneath the battery also becomes coated with polymer, making water contact now possible without activating the sensor.

Example 2 - Conformal Nano-Coating of Tablet Computer

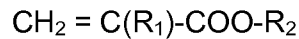
- 15 A tablet computer is opened and placed in a tray in a plasma chamber having dimensions 700mm x 730mm x 960mm. The temperature walls of the plasma chamber are heated to 40-50 °C. The temperature of the monomer in a canister is held at 150°C prior to introduction to the plasma chamber. An etching gas of Ar is cycled through the plasma chamber followed by a degassing cycle for
- 20 about 10 minutes. An electrode, having an area of 3416 cm², is powered to 75 W generating a continuous frequency of about 13.56 MHz. The plasma chamber is reduced in pressure to 20-50 mTorr prior to introduction of the monomer. A monomer with the following structure: $\text{CH}_2 = \text{C}(\text{R}_1) - \text{COO} - \text{R}_2$ where R_1 is $-\text{CH}_3$ and R_2 is $-(\text{CH}_2)_2 - (\text{CF}_2)_m - \text{CF}_3$, with m is 5, is vaporized and introduced into the plasma
- 25 chamber at rate of 50 seem. The tablet computer is treated for about 4 minutes

resulting in a uniform polymeric coating having a thickness of about 200 nm. The result is a tablet computer that is more water resistant than prior to treatment.

CLAIMS

What is claimed is:

- 5 1. A method of coating a surface of an electronic device, comprising:
 exposing the surface of the electronic device to a plasma comprising a
 compound with the following chemical formula:

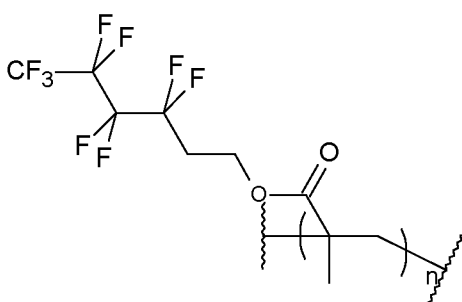
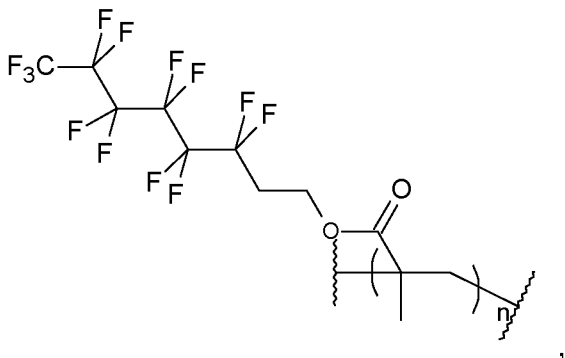


- where R_1 includes -H or $-\text{CH}_3$, R_2 includes $-(\text{CH}_2)_2-(\text{CF}_2)_m-\text{CF}_3$, and m is 3 or 5, so
10 as to form a polymeric coating on the surface, the polymeric coating having an
 oleophobicity level of at least 5.

2. The method of claim 1, wherein the polymeric coating has an
 oleophobicity level of 5 or 6.

- 15 3. The method of claim 1, wherein the polymeric coating has a low toxicity
 level with a perfluorooctane sulfonate (PFOS) level of less than 0.1 parts per
 billion (ppb) and a perfluorooctanoic acid (PFOA) level of less than 0.2 parts per
 billion (ppb).

- 20 4. The method of claim 1, wherein the polymeric coating comprises a
 polymer selected from a group consisting of:



, and mixtures thereof, where n is from 2 to

100,000.

5 5. The method of claim 1, further comprising introducing the compound in a plasma chamber at a flow rate from about $30 \text{ cm}^3/\text{min}$ to about $50 \text{ cm}^3/\text{min}$, prior to exposing the surface of the electronic device to the plasma comprising the compound.

10 6. The method of claim 1, wherein the plasma is a low pressure plasma of less than 1000 mTorr.

7. The method of claim 1, wherein at least a portion of the device is opened prior to exposing the surface to the plasma.

8. The method of claim 1, further comprising cleaning, etching, or activating the electronic device prior to exposing the surface to the plasma.

9. The method of claim 1, further comprising degassing the electronic
5 device prior to exposing the surface to the plasma.

10. The method of claim 1, wherein the plasma is formed at a pressure between about 10 mTorr and about 1000mTorr, at a temperature of about 5°C to about 200°C, and at a frequency of about 20 kHz to about 2.45 GHz, and at a
10 power setting from about 5 W and about 5000 W.

11. The method of claim 1, wherein the plasma is formed at a pressure between about 20 mTorr and about 60 mTorr.

12. The method of claim 1, wherein the plasma is formed at a temperature
15 of about 40°C to about 50°C.

13. The method of claim 1, wherein the plasma is formed at a frequency of about 12 MHz to about 15 MHz.

20

14. The method of claim 1, wherein the plasma is formed at a power setting ranging from about 0.017 to 0.023 W per cm² of electrode.

15. The method of claim 1, wherein the polymeric coating is formed at a
25 rate of about 25 to 75 nm of thickness on the electronic device per minute.

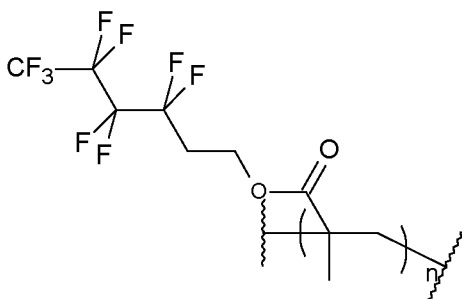
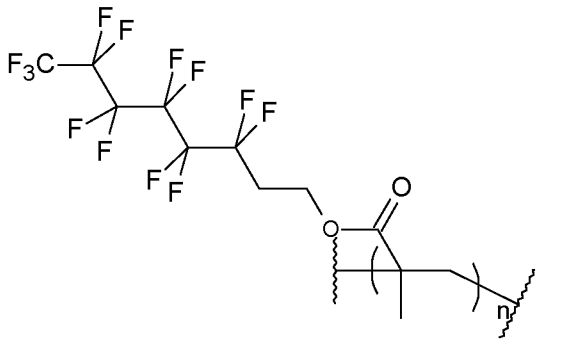
16. The method of claim 1, wherein the electronic device is selected from a group consisting of a cellular phone, a personal digital assistants (PDA), a computer, a tablet computer, a music player, a camera, a video recorder, a battery, an e reader, a radio device, and a gaming device.

17. The method of claim 1, wherein the step of exposing comprises the steps of:

placing the electronic device in a plasma chamber;
forming a continuous plasma in the plasma chamber in the presence of the compound to form a vaporized compound; and
contacting the vaporized compound with the surface of the electronic device, thereby forming the polymeric coating thereon.

18. A method of coating a surface of an electronic device, comprising:
exposing the surface of the electronic device to a plasma to form a polymeric coating comprising a polymer selected from a group consisting of:

25



, and mixtures thereof, where n is from 2 to

- 100,000, and wherein the polymeric coating has a low toxicity level with a perfluorooctane sulfonate (PFOS) level of less than 0.1 parts per billion (ppb) and a perfluorooctanoic acid (PFOA) level of less than 0.2 parts per billion (ppb).

19. The method of claim 18, wherein the polymeric coating has an oleophobicity level of at least 5.

- 10 20. The method of claim 18, wherein the polymeric coating has an oleophobicity level of 5 or 6.

21. The method of claim 18, wherein the polymeric coating is formed at a rate of about 25 to 75 nm of thickness on the electronic device per minute.

22. The method of claim 18, wherein the electronic device is selected from a group consisting of a cellular phone, a personal digital assistants (PDA), a computer, a tablet computer, a music player, a camera, a video recorder, a battery, an e reader, a radio device, and a gaming device.

5

23. The method of claim 18, wherein the plasma is formed at a power setting ranging from about 0.017 to 0.023 W per cm² of electrode.

24. An electronic device having an oil and water repellant coating, formed by exposing a surface of the electronic device to a plasma comprising a compound with the following chemical formula:



where R_1 includes -H or -CH₃, R_2 includes -(CH₂)₂-(CF₂)_m-CF₃, and m is 3 or 5, so as to form the coating on the surface, the coating having an oleophobicity level of at least 5.

15

25. The electronic device of claim 24, wherein the coating has an oleophobicity level of level 5 or level 6.

26. The electronic device of claim 24, wherein the coating has a low toxicity level with a perfluorooctane sulfonate (PFOS) level of less than 0.1 parts per billion (ppb).

20

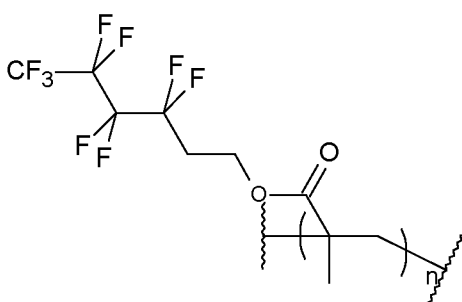
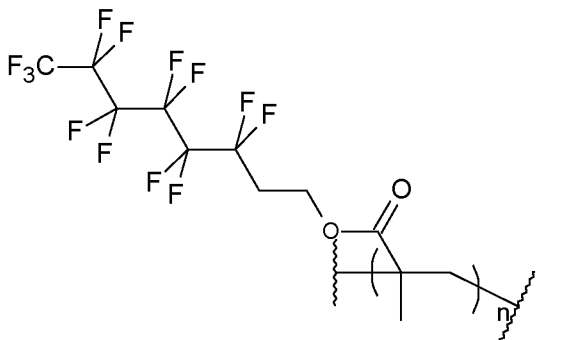
27. The electronic device of claim 24, wherein the coating has a low toxicity level with a perfluorooctanoic acid (PFOA) level of less than 0.2 parts per billion (ppb).

5 28. The electronic device of claim 24, wherein the electronic device is selected from a group consisting of a cellular phone, a personal digital assistants (PDA), a computer, a tablet computer, a music player, a camera, a video recorder, a battery, an e reader, a radio device, and a gaming device.

10 29. The electronic device of claim 24, wherein the electronic device includes a battery, the battery coated separately from the electronic device.

30. The electronic device of claims 24, wherein the coating comprises a polymer selected from a group consisting of:

28



, and mixtures thereof; where n is from 2 to

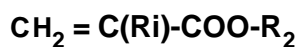
100,000.

5 31. The electronic device of claim 24, wherein the polymeric coating has a water contact angle of at least 100°.

32. The electronic device of claim 24, wherein the polymeric coating has a water contact angle of at least 110°.

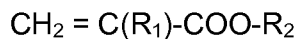
10

33. An electronic device having a water repellant coating, formed by exposing a surface of the electronic device to a plasma comprising a compound with the following chemical formula:



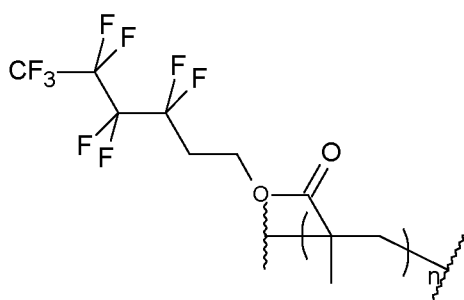
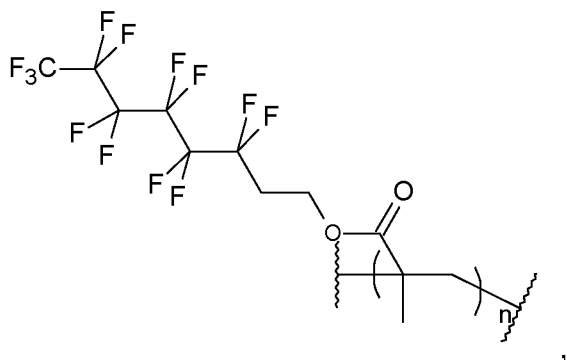
where R_1 includes -H or $-CH_3$, R_2 includes $-(CH_2)_2-(CF_2)_m-CF_3$, and m is 3 or 5, so as to form the coating on the surface, the coating having a low toxicity level with a perfluorooctane sulfonate (PFOS) level of less than 0.2 parts per billion (ppb).

- 5 34. An electronic device having a water repellent coating, formed by exposing a surface of the electronic device to a plasma comprising a compound with the following chemical formula:



- 10 where R_1 includes -H or $-CH_3$; R_2 includes $-(CH_2)_2-(CF_2)_m-CF_3$, and m is 3 or 5, so as to form the coating on the surface, the coating having a low toxicity level with a perfluorooctanoic acid (PFOA) level of less than 0.1 parts per billion (ppb).

35. An electronic device having an oil and water repellent coating, the coating comprising a polymer selected from a group consisting of:

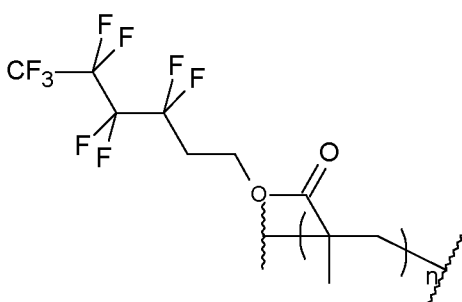
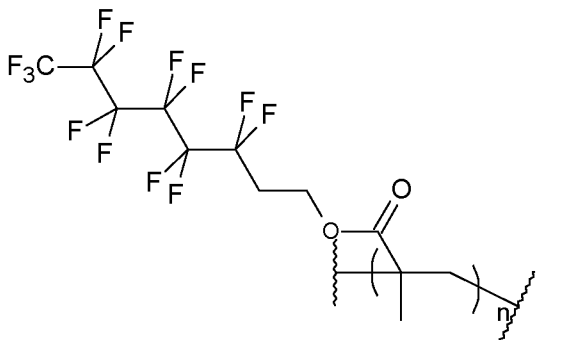


, and mixtures thereof, where n is from 2 to

100,000, and wherein the coating has an oleophobicity level of at least 5.

- 5 36. An electronic device having a water repellant coating, the coating comprising a polymer selected from a group consisting of:

31

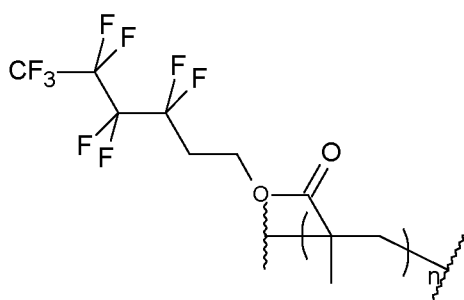
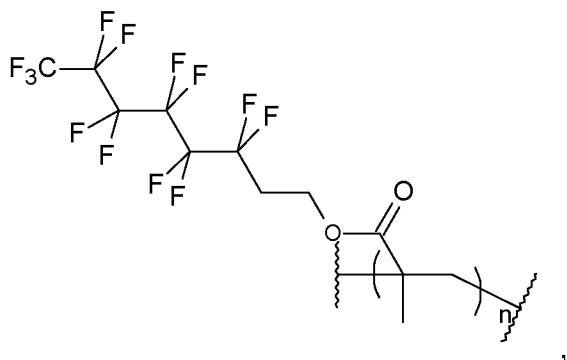


, and mixtures thereof; where n is from 2 to

100,000, and wherein the coating has a low toxicity level with a perfluorooctane sulfonate (PFOS) level of less than 0.2 parts per billion (ppb).

5

37. An electronic device having a water repellant coating, the coating comprising a polymer selected from a group consisting of:



, and mixtures thereof, where n is from 2 to

100,000, and wherein the coating has a low toxicity level with a perfluorooctanoic acid (PFOA) level of less than 0.1 parts per billion (ppb).

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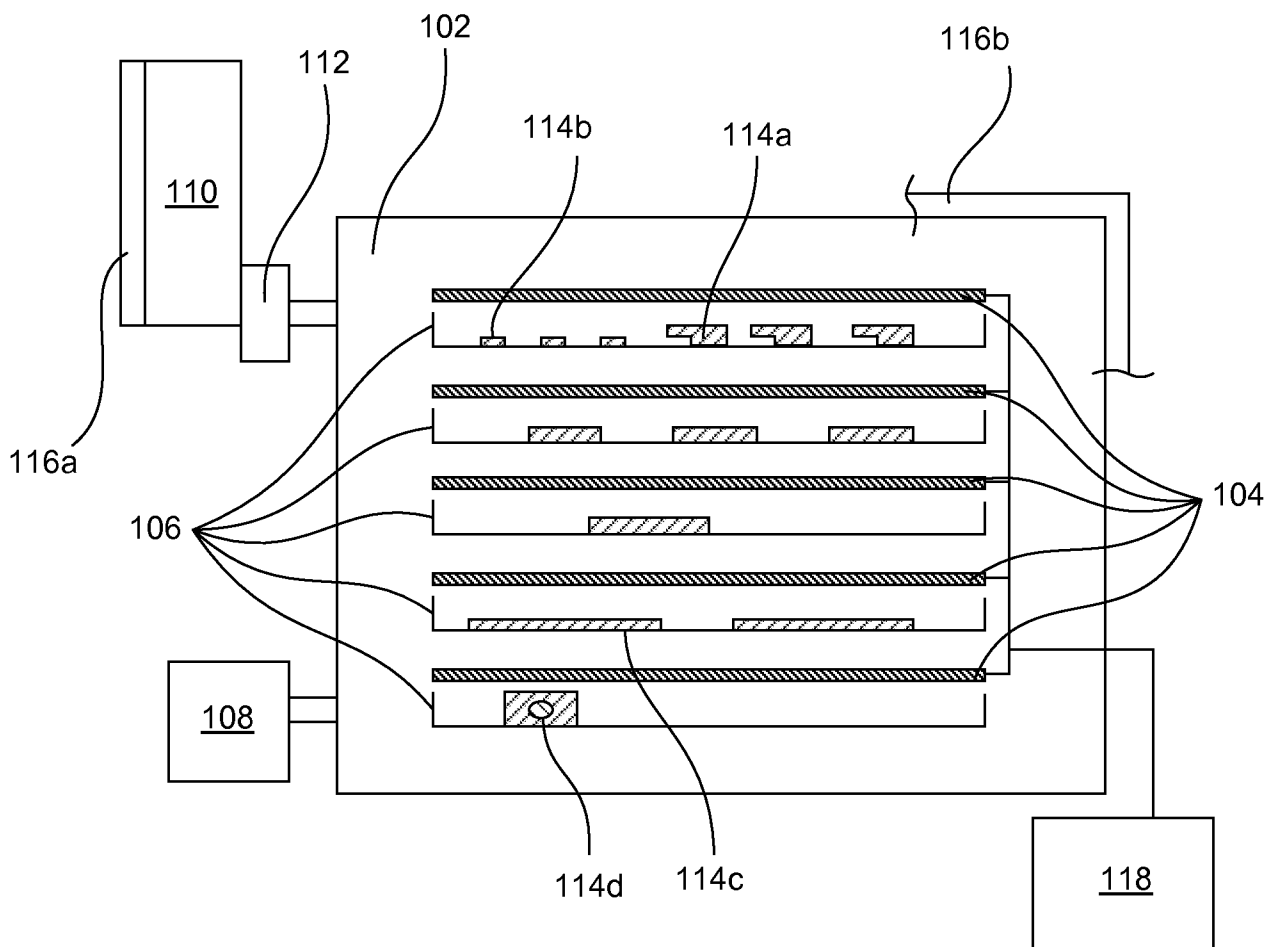


FIG. 1

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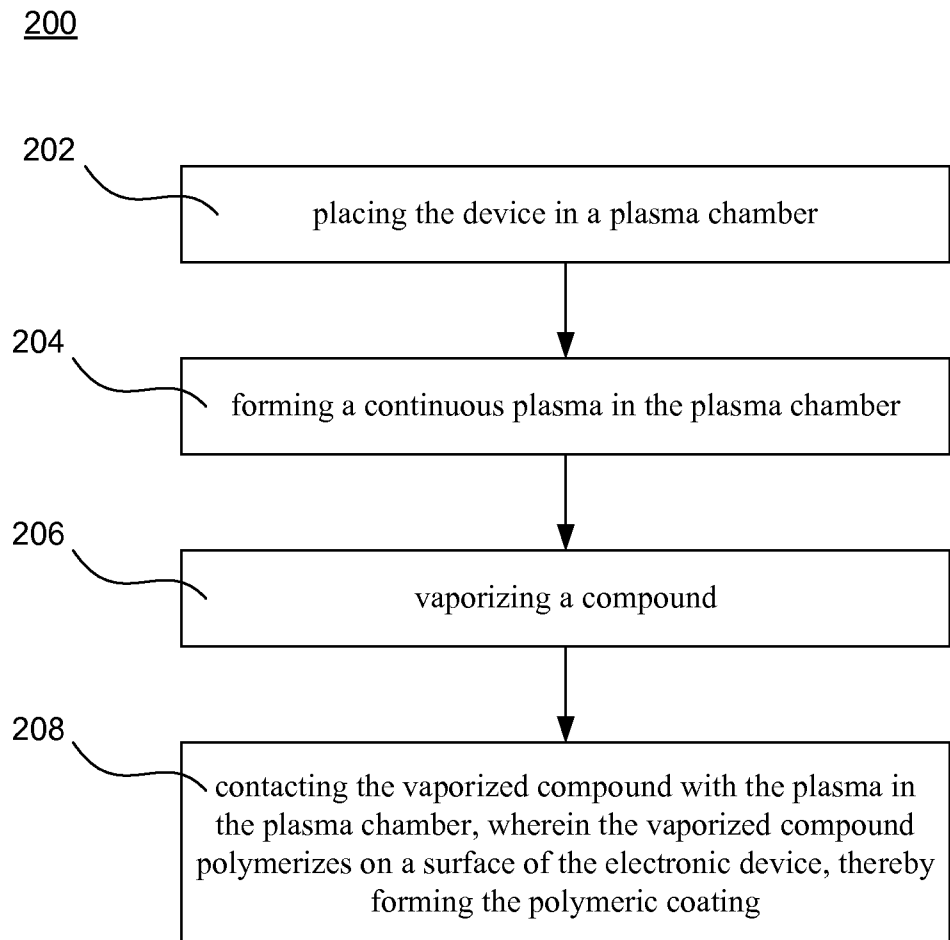


FIG. 2