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(54) DEVICE FOR THE CONTINUOUS SUPPLY OF A LIQUID COMPOUND AND RELATED METHOD

(57) A device for continuous supply of a liquid compound comprises a feed port (2) configured for connection to a discontinuous supply (3) of the liquid compound, a compound vessel (4) comprising a compound inlet (5) and a compound outlet (6), a first supply line (7) connecting the feed port (2) to the compound inlet (5), a closure member (8) configured to open and close the first supply line (7), an outlet port (11) for connection to the processing unit, and a second supply line (12) connecting the compound outlet (6) to the outlet port (11). The second supply line (12) comprises a flow controller (13) for measuring and controlling a flow of liquid compound through the second supply line. The flow controller allows to provide a very stable, continuous supply of liquid compound to the outlet port, and avoids the need to use moving parts, such as pumps, for the supply of the liquid compound.

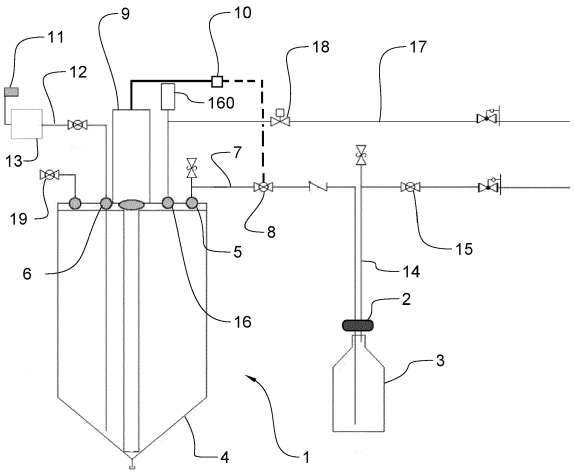

FIG 1

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Description

Technical field

[0001] The present invention is related to a device for the continuous supply of a liquid compound to a processing unit, in particular the supply to an atomizer, for example an atomizer configured for atomizing the liquid compound, for example into an aerosol. The invention is further related to a processing apparatus comprising the device, the processing unit and a processing chamber, for example an atmospheric pressure plasma discharge chamber. The invention further discloses a method for the continuous supply of a liquid compound to a processing unit, using the device of the invention.

Background art

[0002] Many processes require the supply of a chemical compound, e.g. a precursor, to a processing unit, where the chemical compound is consumed. For example, coating processes require the supply of a chemical compound, preferably a precursor, for formation and deposition of a coating. Depending on the nature of the compound and the processing unit, the compound may be supplied as a liquid, i.e. the compound may be a liquid or may be supplied as a solution, an emulsion, a dispersion, or a suspension. Other processes require the supply of the compound to the processing unit in a solid state, such as a powder or particles, as a sol-gel, or as a gas or vapour of an evaporated liquid. The compound supply may be continuous or discontinuous.

[0003] Various devices for the supply of a liquid compounds to a processing unit are known in the state of the art.

[0004] EP 0 549 733 discloses a plurality of feed vessels, each filled with a liquid compound, wherein the feed vessels are connected to a compound vessel. The compound vessel is connected to a processing unit. The plurality of feed vessels allow a continuous supply of liquid compound wherein when a first feed vessel is empty, the liquid compound can be supplied from a second feed vessel, whilst replenishing the first feed vessel.

[0005] US 5,950,693 discloses a compound vessel, which is at a pressure higher than atmospheric pressure, connected by a supply line to valves. There is a possibility to store a limited quantity of liquid compound downstream of the valves to allow replacement of the compound vessel when empty. The supply to a processing unit is controlled and regulated by means of a pressure measurement gauge, and a recirculation back to the compound vessel. The pressure measurement gauge regulates the pressure to the processing unit by opening and closing the valve of the recirculation circuit to increase or decrease the amount of liquid compound recirculated to the compound vessel.

[0006] US 2017/0058400 discloses a feed vessel connected to a compound vessel via a valve. The compound vessel is connected to a pump, which is connected to a processing unit via a supply line. The compound vessel comprises means to control the level of liquid compound, and when the level is below a set minimal level, the valve is opened to allow flow from the feed vessel to the compound vessel. Liquid compound is supplied to the processing unit by means of the pump, and is controlled by a pressure control means measuring the hydrostatic pressure in the supply line from the pump to the processing unit. When the pressure is higher than a preset upper value, the pressure is reduced by opening a throttle valve of a recirculation circuit, so that liquid compound flows back to the compound vessel and reduces the pressure. When the pressure is sufficiently reduced, the throttle valve is closed to stop the flow of liquid compound in the recirculation circuit. Alternatively to the recirculation system with a throttle valve, a flow restrictor or an overflow system can be used.

[0007] A first issue with the devices of EP 0 549 733, and US 5,950,693 is that the quantity of liquid compound supplied to the processing unit can fluctuate, which may result in a non-uniform processing in the processing unit. When the processing unit is an atomizer, a fluctuating supply of the liquid compound may result in non-uniform and inhomogeneous formation of droplets (aerosol). An impact on the droplet formation and/or the coating quality is especially an issue when processes have to be performed for long durations, for example to treat products wherein inadequately coated lengths cannot be removed, resulting the whole product to scrap. An example is the treatment of continuous substrates such as wound on a roll or a bobbin, for example continuous filaments, where zones of inadequate quality mean that the entire bobbin of wire has to be thrown away. This significantly reduces the production yield and involves economical losses.

[0008] When the processing unit is an atomizer, a second problem, that is known in the technical field of atomizers, is that the atomizer comprises itself a reservoir for storing liquid compound, which however is limited in volume. Hence, continuous processing for very long times, e.g. 12 hours, 24 hours, 36 hours or even 48 hours or more, which are typical processing durations for very long, continuous substrates, is impossible without the need to interrupt the process to refill reservoir of the atomizer. As explained above, when continuous substrates are processed, an interruption of the liquid supply means a local fluctuation in the coating structure and/or quality, leading to scrapping the entire product.

[0009] A third issue with the known systems, in particular with US 2017/0058400, is that the systems for ensuring continuous supply of the liquid compound are often complex, requiring a recirculation circuit, and/or one or more pumps, which require maintenance and are often not suitable for hazardous, reactive chemicals and compounds.

Aim of the invention

[0010] The present invention aims to solve one or more of the problems of the devices and methods of the state of the art. It is an aim of the invention to provide an improved device and processing apparatus for the continuous supply of a liquid compound to a processing unit, which is of simpler construction, involves a limited number of moving parts, and requires less maintenance.

[0011] The invention further aims to provide an improved method for the continuous supply of a liquid compound to a processing unit.

Summary of the invention

[0012] According to the invention, there is provided a device for the continuous supply of a liquid compound to a processing unit, as set out in the appended claims. Devices according to the invention comprise a feed port configured for connection to a (discontinuous) supply of the liquid compound, a compound vessel comprising a compound inlet and a compound outlet, a first supply line connecting the feed port to the compound inlet, a closure member - in particular a valve - configured to open and close the first supply line, an outlet port configured for connection to the processing unit, and a second supply line connecting the compound outlet to the outlet port. The compound vessel is advantageously a closed vessel, i.e. capable of pressurizing the liquid compound contained therein. The supply of the liquid compound can be provided as a vessel, flask or bottle, and the feed port is arranged for connecting or interfacing with the supply.

[0013] According to an aspect, the second supply line comprises a flow controller for measuring and controlling a flow of liquid compound through the second supply line from the compound outlet towards the outlet port. The flow controller advantageously comprises a mass flow meter. The mass flow meter is advantageously a Coriolis mass flow meter. A flow controller including a mass flow meter allows to dose very accurately small flow rates to the processing unit coupled to the outlet port. Furthermore, at such small flow rates a very stable and continuous supply of liquid compound can be provided to the outlet port. Flow controllers in devices according to the present invention are particularly configured to control flow rates between 100 g/h and 1000 g/h through the outlet port. At such small flow rates it has been observed that prior art solutions cannot guarantee a sufficient stability of the flow. This is particularly the case when the liquid compound is supplied to an atomizer in the processing unit. Flow controllers in devices according to the invention may be configured to control even higher flow rates, e.g. up to 600 kg/h. The flow controller further advantageously avoids the need to use moving parts, such as pumps, for the supply of the liquid compound.

[0014] Advantageously, the device comprises means for measuring a level of the liquid compound in the compound vessel, a supply controller connected to the means for measuring the level of the liquid compound and operably connected to the closure member.

[0015] Advantageously, the device of the present invention further comprises a first gas supply line connected to the feed port. The first gas supply line is advantageously configured for bringing the feed port, or at least the vessel for supplying the liquid compound connected to the feed port at an elevated pressure (higher than atmospheric pressure).

[0016] Advantageously, the compound vessel is preferably a closed vessel and comprises a gas inlet. The device can comprise a second gas supply line connected to the gas inlet. The second gas supply line is configured for bringing the compound vessel at a pressure higher than atmospheric pressure.

[0017] Advantageously, the first gas supply line comprises a first pressure control valve configured to supply a gas at a first pressure. In addition or alternatively, the second gas supply line comprises a second pressure control valve configured to supply a gas at a second pressure. Advantageously, the first pressure is higher than the second pressure. This allows for, when the device is in use, transferring a flow of liquid compound from the feed port at a first, higher, pressure, to the compound inlet of the compound vessel at a second, lower pressure, by means of a difference in pressure only, excluding the need for rotating components such as pumps to transfer the liquid compound.

[0018] Advantageously, the device comprises a pressure relief valve connected to the compound vessel and configured to open when the pressure inside the compound vessel is higher than a predetermined upper threshold.

[0019] Advantageously, the device includes the processing unit. The processing unit is coupled to the outlet port. The processing unit advantageously comprises an atomizer configured for atomizing the liquid compound and/or configured for generating an aerosol.

[0020] In a second aspect, the invention provides a processing apparatus comprising a device as described herein and a processing chamber in fluid connection with the processing unit. The processing chamber is advantageously a plasma chamber, preferably an atmospheric pressure plasma discharge chamber.

[0021] In a third aspect, the invention provides a method for the continuous supply of a liquid compound to a processing unit, as set out in the appended claims. The method according to the invention comprises connecting a supply of the liquid compound to the feed port, opening the closure member and feeding the liquid compound to the compound vessel, and measuring and controlling the flow of the liquid compound from the compound outlet to the outlet port by means of the flow controller. The method advantageously comprises one or more of the steps of: measuring a level of the liquid compound in the compound vessel, e.g. by means of the means for measuring the level of the liquid compound in the compound vessel, and opening the closure member when the measured

level of the liquid compound in the compound vessel is below a predetermined lower threshold. The method optionally comprises controlling the level of the liquid compound in the compound vessel, e.g. by means of the supply controller. The supply controller can operate the closure member to open when the measured level of the liquid compound in the compound vessel is below a predetermined lower threshold. Methods according to the invention can be implemented in devices as described herein.

[0022] The method may further comprise the step of controlling the level of the liquid compound in the compound vessel, e.g. by means of the supply controller. The supply controller can operate the closure member to close when the measured level of the liquid compound in the compound vessel is higher than a predetermined upper threshold.

Brief description of the figures

[0023]

Fig. 1 discloses a schematic representation of a device of the present invention.

Fig. 2 discloses a schematic representation of a processing apparatus of the present invention.

Detailed description of embodiments

[0024] The present invention is related to the supply of a compound in the liquid state, e.g. a liquid precursor, to a processing unit. The processing unit can process the liquid compound to a suitable form, for example an aerosol, or can convert the liquid compound into a suitable form, for example into a gas or a vapour. The processing unit can be an atomizer, which transfers the liquid compound in the form of droplets, which can be carried by a gas, e.g. an aerosol. The processing unit may be selected such that an aerosol may be produced with droplets having an average diameter adapted to the intended application or use of the atomized droplets. An atomizer may be used in coating processes, such as an atmospheric pressure plasma coating process, to supply droplets of the liquid compound to the atmospheric pressure plasma discharge area, where the droplets are deposited on a substrate to form a functional compound, e.g. a coating.

[0025] Referring to Fig. 1, a device 1 for the continuous supply of liquid compound to a processing unit is disclosed. The device 1 comprises a feed port 2 configured for connection to a supply 3 of the liquid compound, a compound vessel 4 comprising a compound inlet 5 and a compound outlet 6, a first supply line 7 connecting the feed port 2 to the compound inlet 5, and a closure member 8 configured to open and close the first supply line 8. A preferred closure member is a valve.

[0026] The device 1 advantageously comprises means 9 for measuring the level of the liquid compound in the compound vessel 4 and a supply controller 10 connected to the means 9 for determining the level of the liquid compound. The supply controller 10 is operably connected to the closure member 8.

[0027] The device 1 further comprises an outlet port 11 for connection to the processing unit, and a second supply line 12 connecting the compound outlet 6 to the outlet port 11.

[0028] The compound vessel 4 is preferably a closed vessel. The compound vessel may have an internal volume of at least 200 milliliter (ml), up to 200 liter (l), such as at least 500 ml, at least 1 l, at least 2 l, at least 3 l, at least 4 l, at least 5 l, at least 10 l, at least 20 l, at least 25 l, at least 50 l, at least 75 l, at least 100 l, at least 125 l, at least 150 l, or at least 175 l.

[0029] The liquid compound is advantageously supplied in vessels, bottles or flasks which can be replaced when empty. The feed port 2 is configured to be connected to such a supply 3, preferably in a removable way. The supply 3 of the liquid compound is hence a discontinuous supply, configured for replacement by a new supply 3 of the liquid compound and/or refilling. When the supply 3 is a vessel, it may have an internal volume of at least 100 ml up to 100 l, such as at least 500 ml, at least 1 l, at least 2 l, at least 2.5 l, at least 3 l, at least 4 l, at least 5 l, at least 10 l, at least 20 l, at least 25 l, at least 30 l, at least 40 l, at least 50 l, at least 60 l, at least 70 l, at least 75 l, at least 80 l, or at least 90 l.

[0030] The compound vessel 4 advantageously has an internal volume that is equal to or larger than the internal volume of the supply. Alternatively, the supply may have an internal volume that is larger than the internal volume of the compound vessel.

[0031] A first gas supply line 14 is advantageously connected to the feed port 2. The first gas supply line 14 is configured to maintain the liquid compound of the supply 3 (e.g., vessel) at an elevated pressure (compared to atmospheric pressure). To this end, the first gas supply line 14 advantageously comprises a first pressure control valve 15 configured to supply a gas at a first pressure. The first pressure may be equal to or higher than 0.1 bar, such as at least 0.25 bar, at least 0.5 bar, at least 0.75 bar, at least 1 bar, at least 1.5 bar, or at least 2 bar (differential pressure). The first pressure can be 5 bar or less. The first pressure is advantageously higher than atmospheric pressure to bring the feed port 2 at a so-called 'overpressure'.

[0032] The compound vessel 4 advantageously comprises a gas inlet 16. Gas inlet 16 is configured to maintain the liquid compound of the compound vessel 4 at an elevated pressure (compared to atmospheric pressure). To this end, device 1 comprises a second gas supply line 17 connected to the gas inlet 16. The second gas supply line 17 advantageously comprises a second pressure control valve 18 configured to supply a gas at a second pressure. The second pressure may be equal to or higher than 0.05 bar, such as at least 0.1 bar, at least 0.15 bar,

at least 0.2 bar, at least 0.25 bar, at least 0.3 bar, at least 0.4 bar, or at least 0.5 bar (differential pressure). The second pressure can be 3 bar or less. The second pressure is advantageously higher than atmospheric pressure, to bring the compound vessel 4 at a so-called 'overpressure'.

[0033] The first pressure is advantageously higher than the second pressure. The difference in pressure between the feed port 2, at the first pressure, and the gas inlet 16 of the compound vessel 4, at the second pressure, allows for the transport of the liquid compound from the feed port 2 to the compound vessel 4 without the need for rotating components such as pumps. The pressure difference between the first pressure and the second pressure may be at least 0.05 bar, at least 0.1 bar, at least 0.2 bar, at least 0.25 bar, at least 0.5 bar, at least 0.75 bar, at least 1 bar, at least 1.25 bar, at least 1.5 bar, at least 1.75 bar, or at least 2 bar. The pressure difference can be 3 bar or less.

[0034] The optimal first pressure, the optimal second pressure and the optimal difference between the first pressure and the second pressure depends on, without being limited thereto, the internal volume of the compound vessel and the composition and properties of the liquid compound, e.g. the viscosity, the vapour pressure, and/or the density. When the device is in use, the optimal first and second pressure and the optimal difference between the first and the second pressure may depend on the flow of liquid compound to be delivered to the processing unit. The optimal pressures must be high enough to allow for a continuous flow of liquid compound to the processing unit, without being too high, which may lead to damage of the device.

[0035] The gas supplied by the first 14 and the second 17 gas supply line may be an inert gas, such as argon (Ar), helium (He), carbon dioxide (CO_2) or nitrogen (N_2). Alternatively, the gas may be a reactive gas, such as oxygen (O_2), hydrogen (H_2), air, or methane (CH_4). Alternatively, the gas may be a mixture of two or more inert gasses, two or more reactive gases, or two or more inert gasses and reactive gasses.

[0036] The gas atmosphere allows to largely reduce and possibly inhibit the reaction of a reactive liquid compound in the device of the invention. A gas atmosphere further allows to protect the material of which the device is made against hazardous reactions and damage by the liquid compound. Depending on the type of liquid compound, reaction inhibition and protection of the device of the invention may be obtained by using a reactive atmosphere or an inert atmosphere. For most liquid compounds the gas is advantageously an inert gas, even more preferably argon. The use of an inert gas allows to supply liquid compounds under an inert atmosphere. The advantage of an inert gas is that even reactive or hazardous liquid compounds can be supplied to a processing unit in a safe way. Alternatively, some liquid compounds require a reactive atmosphere to provide a protective atmosphere. For example, when the liquid compound is acrylic acid, a reactive atmosphere such as air is advantageously used.

[0037] The gas supplied by means of the first 14 and the second 17 gas supply line may be the same or may be different. Preferably, it is the same.

[0038] The device may further comprise a pressure relief valve 19 connected to the compound vessel 4. The pressure relief valve 19 is configured to open when the pressure inside the compound vessel 4 is higher than a predetermined upper threshold.

[0039] According to the invention, the second supply line 12 comprises a flow controller 13 for measuring and controlling a flow of liquid compound through the second supply line 12. The flow controller advantageously comprises a mass flow meter. The mass flow meter is advantageously a Coriolis mass flow meter.

[0040] The flow controller 13 according to the invention allows to supply a flow of liquid compound from the compound outlet 6 of the compound vessel 4 to the outlet port 11 in a controlled way. The flow controller 13 advantageously comprises a flow sensor, a controller and a flow control valve. The sensor is configured to measure a flow rate, in particular a mass flow rate. The flow control valve is advantageously configured to adjust the flow of the liquid compound based on comparing the measured flow with a predetermined value of the flow. The flow control valve can be a pressure actuated control valve

[0041] The mass flow sensor is advantageously a Coriolis type mass flow sensor. The mass flow sensor advantageously uses a direct mass flow measurement. A Coriolis type flow controller advantageously comprises two parallel tube loops, forming part of an oscillating system. When a fluid flows through the tubes, Coriolis forces cause a variable phase shift between the loops. The sensor is configured to detect the phase shift, which is representative of a mass flow value.

[0042] An example of a direct mass flow measurement system using the Coriolis principle is the Cori-flow™ (Bronckhorst®, The Netherlands). Some models are suitable for measuring and controlling a flow of 200 g/h up and higher, while up to full industrial scale models are suitable for regulating flows up to 600 kg/h. In the light of the present invention, mass flow meters configured for measuring and controlling a flow rate between 100 g/h and 1500 g/h are advantageously used, such as mass flow meters configured for measuring and controlling a flow rate between 125 g/h and 1250 g/h, such as 150 g/h and 1000 g/h, between 175 g/h and 750 g/h, or between 200 g/h and 500 g/h, such as around 400 g/h.

[0043] Alternatively, other types of flow controller may be used, for example flow controllers comprising a Peltier element for flow measurement and control by means of a cooling method (Horiba, Japan).

[0044] Referring to Fig. 2, a processing unit 102 is or can be coupled to the outlet port 11. The processing unit 102 advantageously comprises an atomizer. The atomizer is advantageously configured for atomizing the liquid compound. Preferably, the atomizer is configured for

generating an aerosol.

[0045] Any type of atomizer can be used. An atomizer preferably comprises a compound inlet, a gas inlet, and an aerosol outlet. A gas supply line is advantageously connected to the gas inlet. The outlet port 11 is advantageously connected to the compound inlet. The gas supply line is configured to supply a carrier gas to the atomizer. Preferably, when in use, the gas is made to flow through an orifice, e.g. a Venturi orifice, to form a high velocity jet. The atomizer uses the Venturi-effect created by the carrier gas flow passing through the orifice to suck the liquid compound out of the compound inlet, into the atomizing section. The mixture of carrier gas and droplets of liquid compound is a so-called aerosol. Optionally, a dilution gas may be added to the atomizer to decrease the concentration of the aerosol.

[0046] The optimal average diameter of the droplets forming the aerosol depends on the application wherein the aerosol is used. For example, when the aerosol is introduced in a processing chamber to deposit a coating on a substrate by means of atmospheric pressure plasma discharge, the average diameter of the droplets is advantageously equal to or lower than 2 μm, because larger droplets having an average diameter higher than 2 μm can result in significant condensation of the droplets in the aerosol and in droplet wise deposition.

[0047] The diameter of the droplets obtained depends on, without being limited thereto, the liquid compound, the flow of liquid compound, the gas, the flow of gas, and the atomizer itself (orifice, Venturi effect). For example, when smaller droplets are required, for example having an average diameter of 2 μm or less, large droplets can be removed from the aerosol prior to leaving the atomizer, e.g. by using an impactor. Removed droplets can be collected and disposed of, or recirculated back to the supply container of the liquid compound, the compound vessel, the first supply line, or the second supply line upstream of the flow controller. Other embodiments are also possible. The recirculation of the removed liquid compound to the device at a position upstream of the mass flow controller has the advantage that no liquid compound is lost while further the steady and continuous supply of liquid compound is not negatively impacted.

[0048] Atomizers suitable for use as processing units in devices of the present invention are sold by Vito, Belgium. Other atomizers suitable for use as processing unit in devices of the present invention are for example sold by TSI, United Kingdom. One type of atomizer that is particularly suitable is model 3076 by TSI.

[0049] The flow controller advantageously provides a well-controlled and stable flow of liquid compound to the atomizer. A controlled and stable flow contributes to an improvement of the functioning of the atomizer, leading to a more homogeneous and uniform aerosol. A more uniform and homogeneous aerosol contributes to a better quality of the process wherein the aerosol is consumed or used.

[0050] Alternatively, the processing unit can be a vaporizer, transferring the flow of liquid compound into a flow of compound vapour. The processing unit preferably comprises a compound inlet, a vapour outlet, and means to convert the liquid compound into the compound vapour. The conversion means may comprise one or more heating means. Alternatively, the conversion means may comprise one or more means to reduce the pressure in the processing unit, thereby reducing the temperature at which the liquid compound will evaporate. Alternatively, the conversion means may comprise both one or more heating means and one or more means to reduce the pressure in the processing unit. A combination of heating means and means to reduce the pressure in the processing unit is advantageous for liquid compounds having a low vapour pressure and/or a high boiling temperature. Examples are halogenated organic monomers, such as acrylates and methacrylates. When the conversion means comprise heating means, the optimal heating conditions depend on, without being limited thereto, the stability and composition of the liquid compound, the presence of any additives, the purity and the vapour pressure of the liquid compound.

[0051] Alternatively, the processing unit can be a bubbler. The bubbler advantageously comprises a bubbler compound inlet, a bubbler gas inlet, and a bubbler outlet. A gas supply line is advantageously connected to the bubbler gas inlet and is configured to supply a gas to the bubbler. The bubbler compound inlet is advantageously configured to be fluidly connected to the outlet port of the device of the present invention to allow the supply of a liquid compound to the bubbler compound inlet. The advantage of the use of the device of the present invention for the supply of a liquid compound to the bubbler is that a constant level of liquid compound in the bubbler can be ensured. Upon operation of the processing unit, the gas bubbles through the liquid compound in the bubbler, and a gas flow comprising droplets of liquid compound is obtained and advantageously leaves the bubbler at the bubbler outlet.

[0052] Alternatively, the processing unit can be a spray generating or a jet generating device fluidly connected to the outlet port of the device of the present invention, wherein the spray or jet generating device is suitable to supply a spray or jet of liquid compound in liquid state to a further unit, for example a coating unit suitable for the deposition of a wet chemical coating on a substrate.

[0053] Still referring to Fig. 2, the device 1 as described hereinabove can form part of a processing apparatus 100. The processing apparatus 100 comprises a processing chamber 101 in fluid connection with the processing unit 102. Preferably, the processing chamber 101 is a plasma chamber, such as an atmospheric pressure plasma discharge chamber, for example an atmospheric pressure plasma discharge chamber for depositing a coating on a substrate 103. The processing chamber 101 advantageously comprises one or more chamber-inlets for a liquid compound 104, for example a chamber-inlet for an aerosol comprising the liquid precursor in

the form of droplets. Alternatively, the plasma chamber can be a low pressure plasma chamber. As a result, a processing unit may be obtained that is suitable to be operated on a continuous basis at industrial scale, for example a processing unit capable of contacting long lengths of fibers (such as bulk continuous filaments (BCFs)), yarns, slivers, wires, tows or cords, films, foils, membranes or sheets with the liquid compound.

[0054] The substrate may be any one of sheets, membranes, foils, films, tows, cords, yarns or fibers, in particular continuous substrates having a long length and requiring longer processing times. The substrate may comprise one or more of the following materials: polymers, ceramics, metals, or composites.

[0055] The device as described hereinabove can be used according to the following method. A supply 3 of liquid compound is attached to the feed port 2. The liquid compound in the supply 3 is brought under pressure by providing gas under pressure through the first gas supply line 14. Gas pressure can be controlled by the first pressure control valve 15. By opening closure member 8, e.g. operated via controller 10, the liquid compound is made to flow over the supply line 7 to the compound vessel 4. Closure member 8 can be closed when the liquid compound in the compound vessel 4 has reached a predetermined level (e.g. full), or when the supply 3 is empty. In the latter case, the supply 3 can be removed from the feed port 2 and replaced by a fresh supply 3.

[0056] A processing unit 102 can be attached to the outlet port 11. A flow of liquid compound from the compound vessel 4 to the processing unit 102 can be obtained as follows. The liquid compound in the compound vessel 4 is brought under pressure by providing gas under pressure through the gas inlet 16. The gas pressure can be controlled by second pressure control valve 18. A pressure sensor 160 is optionally fluidly connected to the gas inlet 16. The pressure in the compound vessel is set such that a flow of the liquid compound is obtained from the compound outlet 6, through the second supply line 12 to the outlet port 11. The flow through the second supply line 12 is controlled by flow controller 13, which adjusts the flow rate according to predetermined settings. It will be convenient to note, that during the supply of liquid compound to outlet port 11, closure member 8 can be operated (closed and opened) one or more times, in order to replenish the compound vessel 4.

[0057] Advantageously, the level of the liquid compound in the compound vessel 4 is measured by liquid level sensing means 9. The liquid level sensing means 9 is operably connected to supply controller controlling the level of the liquid compound in the compound vessel 4, which opens closure member 8 when the measured level of the liquid compound in the compound vessel 4 reaches a predetermined lower threshold. The supply controller 10 closes the closure member 8 when the measured level of the liquid compound in the compound vessel 4 reaches a predetermined upper threshold.

[0058] First gas supply 14 brings the feed port 2 (and the feed vessel 3) at a first pressure and second gas supply 17 brings the compound vessel at a second pressure. As explained above, the first pressure is advantageously higher than the second pressure, at least during replenishment of the compound vessel 4.

[0059] An advantage of the device and method of the present invention is that the compound vessel 4 can be refilled over and over again without jeopardizing a continuous supply of liquid component from the component vessel 4 to the processing unit. Consequently, very long processing times and continuous operation during very long processing times is guaranteed.

[0060] The present invention allows to solve one or more problems of the devices described in the state of the art, by providing a device and a method that allow to provide a continuous supply of liquid compound to the outlet port, by controlling the flow of liquid compound through the second supply line by means of the flow controller, and by allowing to supply a wide range of liquid compounds, even reactive, aggressive and harsh ones, due to the absence of any pumps in the device and the possibility to supply this type of compounds under an inert atmosphere.

[0061] In case an atomizer is used as the processing unit, the combination of a compound vessel 4 and a flow controller 13 leads to an unexpected increase in the uniformity and homogeneity of the aerosol. An improved aerosol quality can lead to an improvement of the quality of the process performed in the processing chamber.

Claims

1. Device (1) for the continuous supply of a liquid compound to a processing unit, comprising:

   a feed port (2) configured for connection to a supply of the liquid compound,
   a compound vessel (4) comprising a compound inlet (5) and a compound outlet (6),
   a first supply line (7) connecting the feed port (2) to the compound inlet (5),
   a closure member (8), in particular a valve, configured to open and close the first supply line (7),
   an outlet port (11) configured for connection to the processing unit, and
   a second supply line (12) connecting the compound outlet (6) to the outlet port (11), **characterized in that** the second supply line (12) comprises a flow controller (13) for measuring and controlling a flow of liquid compound through the second supply line (12).

2. Device according to claim 1, wherein the flow controller (13) comprises a mass flow meter.

3. Device according to claim 2, wherein the mass flow meter is a Coriolis-type mass flow meter.

4. Device according to any one of the preceding claims, comprising a first gas supply line (14) connected to the feed port (2).

5. Device according to any one of the preceding claims, wherein the compound vessel (4) is a closed vessel and comprises a gas inlet (16) configured to maintain the liquid compound in the compound vessel under elevated pressure, and wherein the device (1) comprises a second gas supply line (17) connected to the gas inlet (16).

6. Device according to claim 5 in conjunction with claim 4, wherein the first gas supply line (14) comprises a first pressure control valve (15) configured to supply a gas at a first pressure and the second gas supply line (17) comprises a second pressure control valve (18) configured to supply a gas at a second pressure, wherein the first pressure is higher than the second pressure.

7. Device according to any one of the preceding claims, comprising means (9) for measuring a level of the liquid compound in the compound vessel (4), a supply controller (10) connected to the means (9) for measuring the level of the liquid compound and operably connected to the closure member (8).

8. Device according to any preceding claim, comprising a pressure relief valve (19) connected to the compound vessel (4) and configured to open when the pressure inside the compound vessel (4) is higher than a predetermined upper threshold.

9. Device according to any preceding claim, comprising the processing unit coupled to the outlet port (11), wherein the processing unit comprises an atomizer configured for atomizing the liquid compound.

10. Device of claim 9, wherein the atomizer is configured for generating an aerosol.

11. Processing apparatus comprising a device (1) according to claim 9 or 10 and a processing chamber in fluid connection with the processing unit, the processing chamber being preferably a plasma chamber.

12. Processing apparatus according to claim 11, wherein the processing chamber is an atmospheric pressure plasma discharge chamber.

13. Method for the continuous supply of a liquid compound to a processing unit using the device (1) according to any one of claims 1 to 10 or the processing apparatus of claim 11 or 12, comprising the steps of:

connecting a supply of the liquid compound to the feed port,
opening the closure member (8) and feeding the liquid compound to the compound vessel, and
measuring and controlling the flow of the liquid compound from the compound outlet (6) to the outlet port (11) by means of the flow controller (13).

14. Method according to claim 13, comprising measuring a level of the liquid compound in the compound vessel (4), and opening the closure member (8) when the measured level of the liquid compound in the compound vessel (4) is below a predetermined lower threshold.

15. Method according to claim 14, comprising the step of closing the closure member (8) when the measured level of the liquid compound in the compound vessel (4) is higher than a predetermined upper threshold.

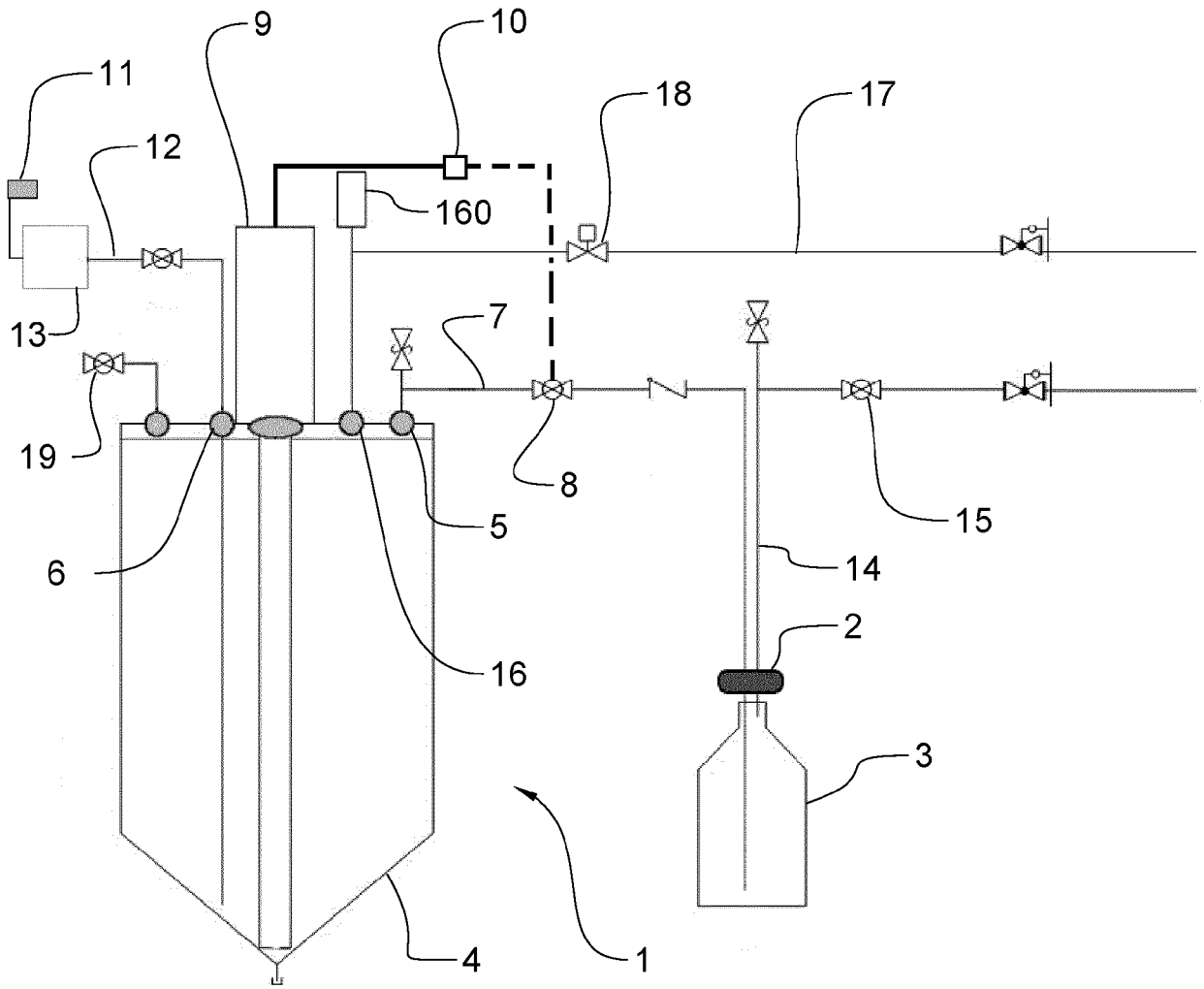

FIG 1

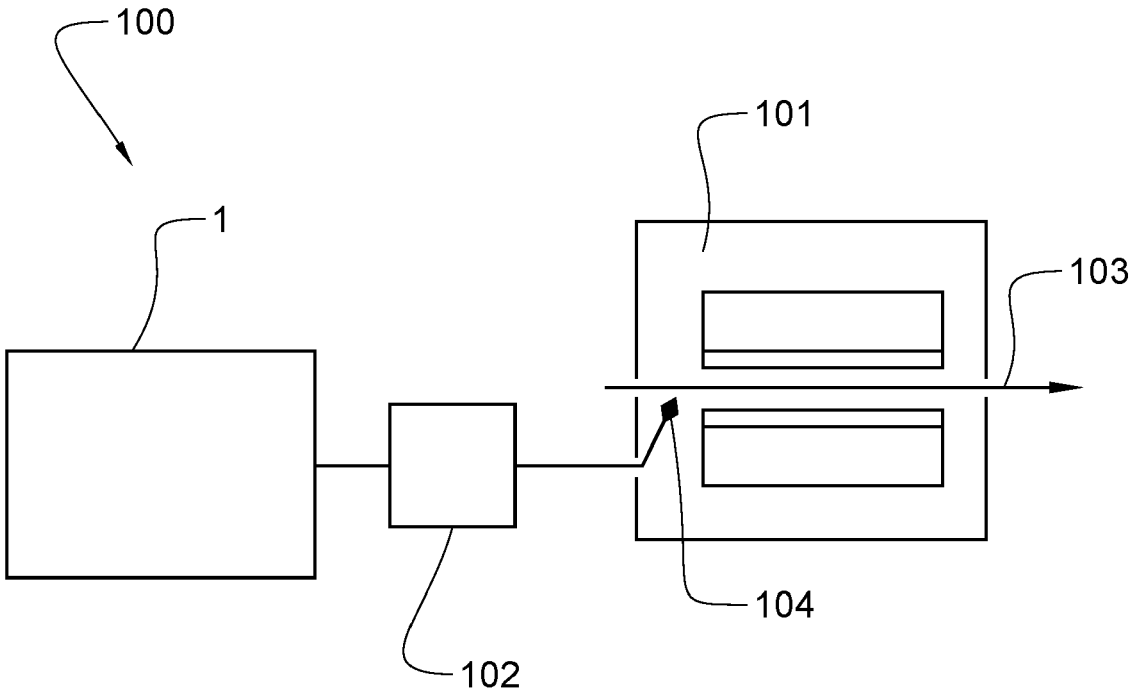

FIG 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 15 6835

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	US 2019/301000 A1 (JORDAN ERIC [US] ET AL) 3 October 2019 (2019-10-03) * abstract; figure 3A * * paragraph [0027] * -----	3	

TECHNICAL FIELDS SEARCHED (IPC)

B05B
B67D
C23C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	28 July 2020	Frego, Maria Chiara

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28-07-2020

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REFERENCES CITED IN THE DESCRIPTION

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