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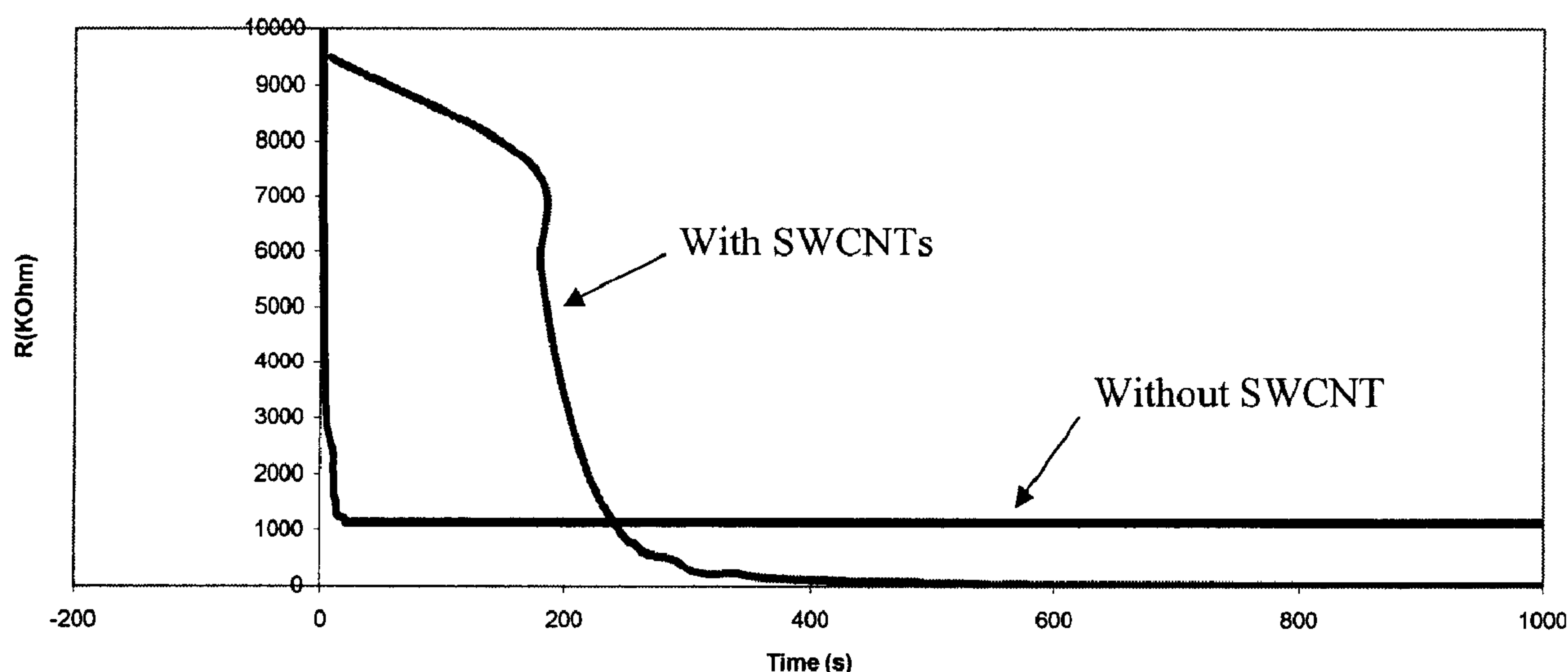
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(54) Titre : PROCEDE ET APPAREIL DE RECUPERATION DE STRUCTURES FILAMENTEUSES DE CARBONE
(54) Title: METHOD AND APPARATUS FOR RECOVERING CARBON FILAMENTARY STRUCTURES



(57) **Abrégé/Abstract:**

The invention relates to a method for depositing carbon filamentary structures on electrodes, comprising the steps of: (a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween; (b) applying a potential difference between the electrodes so as to generate an electric field; and (c) passing a gaseous phase comprising the carbon filamentary structures through the space, thereby depositing the carbon filamentary structures on at least one of the electrodes. An apparatus for carrying out the method according to the invention is also disclosed.

ABSTRACT

The invention relates to a method for depositing carbon filamentary structures on electrodes, comprising the steps of: (a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween; (b) applying a potential difference between the electrodes so as to generate an electric field; and (c) passing a gaseous phase comprising the carbon filamentary structures through the space, thereby depositing the carbon filamentary structures on at least one of the electrodes. An apparatus for carrying out the method according to the invention is also disclosed.

METHOD AND APPARATUS FOR RECOVERING CARBON FILAMENTARY STRUCTURES

FIELD OF THE INVENTION

[0001] The present invention relates to improvements in the field of carbon filamentary structures production. More particularly, the invention relates to an improved method and apparatus for recovering carbon filamentary structures such as carbon fibres and single-wall or multi-wall carbon nanotubes.

BACKGROUND OF THE INVENTION

[0002] Carbon nanotubes are available either as multi-wall or single-wall nanotubes. Multi-wall carbon nanotubes have exceptional properties such as excellent electrical and thermal conductivities. They have applications in numerous fields such as storage of hydrogen (C. Liu, Y.Y. Fan, M. Liu, H. T. Cong, H.M. Cheng, M.S. Dresselhaus, Science 286 (1999), 1127; M.S. Dresselhaus, K.A Williams, P.C. Eklund, MRS Bull. (1999), 45) or other gases, adsorption heat pumps, materials reinforcement or nanoelectronics (M. Menon, D. Srivastava, Phy. Rev. Lett. 79 (1997), 4453). Single-wall carbon nanotubes, on the other hand, possess properties that are significantly superior to those of multi-wall nanotubes. However, single-wall carbon nanotubes are available only in small quantities since known methods of production do not produce more than few grams per day of these nanotubes. For any industrial application such as storage or material reinforcement, the amount of single-wall carbon nanotubes produced must be at least a few kilograms per day. Another difficulty encountered with the synthesis of single-wall carbon nanotubes is that they are very volatile and they can be lost during the synthesis. By using the known methods of producing single-wall nanotubes, an important portion of the produced nanotubes are lost since carried and exited within the carrier gas used. Moreover, they must be purified since they often

contain impurities such as metallic particles or amorphous carbon which can considerably diminish their properties.

[0003] Another major drawback in the synthesis of carbon nanotubes is that the methods that have been proposed so far are not continuous. In fact, to obtain a continuous method of producing carbon nanotubes, both the synthesis and the recovery and/or purification must be carried out in a continuous manner.

SUMMARY OF THE INVENTION

[0004] It is therefore an object of the present invention to overcome the above drawbacks and to provide a method and apparatus for recovering carbon filamentary structures which permit to recover a satisfying proportion of these structures prepared during a synthesis.

[0005] It is another object of the present invention to overcome the above drawbacks and to provide a continuous method and apparatus for recovering carbon filamentary structures.

[0006] According to one aspect of the invention, there is provided a method for depositing carbon filamentary structures on electrodes, comprising the steps of:

- a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween;
- b) applying a potential difference between the electrodes in order to generate an electric field; and
- c) passing a gaseous phase comprising the carbon filamentary structures through the space, thereby depositing the carbon filamentary structures on at least one of the electrodes.

[0007] Applicant has found quite surprisingly that by using the latter method, it is possible to deposit the carbon filamentary structures on electrodes

thereby recovering a satisfying portion of the carbon filamentary structures produced during a gas-phase synthesis.

[0008] According to another aspect of the invention, there is provided a continuous method for depositing carbon filamentary structures on electrodes, comprising the steps of:

a) providing a device comprising:

- an inlet;

- at least two recovering units,

a first recovering unit comprising a set (A) of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a first space therebetween, the first space being in fluid flow communication with the inlet and being dimensioned to receive a gaseous phase comprising the carbon filamentary structures, and

a second recovering unit comprising a set (B) of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a second space therebetween, the second space being in fluid flow communication with the inlet and being dimensioned to receive a gaseous phase comprising the carbon filamentary structures ;

- a valve permitting to selectively feed the first space or the second space with the gaseous;

b) passing the gaseous phase through the inlet;

c) applying a potential difference between the electrodes of the set (A) in order to generate an electric field, and selectively feeding the first space with the gaseous phase, thereby depositing the carbon filamentary structures on at least one electrodes of the set (A);

d) applying a potential difference between the electrodes of the set (B) in order to generate an electric field, and selectively feeding the second space with the gaseous phase, thereby depositing the carbon filamentary structures on at least one electrodes of the set (B),

steps (c) and (d) are repeated until a desired quantity of the carbon filamentary structures is obtained;

while step (d) is carried out, the potential difference between the electrodes of the set (A) is turned off and the carbon filamentary structures deposited in step (c) are recovered; and

while step (c) is carried out for at least the second time, the potential difference between the electrodes of the set (B) is turned off and the carbon filamentary structures deposited in step (d) are recovered.

[0009] According to still another aspect of the invention, there is provided a continuous method for depositing carbon filamentary structures on electrodes, comprising the steps of :

a) providing a device comprising:

- an inlet;

- a valve comprising an inlet and at least two outlets, the outlets being adapted to be selectively put in fluid flow communication with the inlet of the valve, the inlet of the valve being in fluid flow communication with the inlet of the device;

- recovering units each comprising a set at least two electrodes, a first electrode and a second electrode defining a space therebetween, the space being in fluid flow communications with one outlet of the valve and being dimensioned to receive a gaseous phase comprising the carbon filamentary structures;

b) passing the gaseous phase through the inlet of the device, the valve and a selected recovering unit; and applying a potential difference between the electrodes of the selected recovering unit to thereby deposit carbon filamentary structures on at least one electrode; and

c) selecting another recovering unit and repeating step (b).

[0010] Applicant has found quite surprisingly that by using the latter two methods, it is possible to recover, in a continuous manner, the carbon

filamentary structures produced during a gas-phase synthesis. By using such methods it is possible to carry out the recovery of the deposited carbon filamentary structures without stopping their production or without turning off the apparatus used to produce them in a gas-phase synthesis.

[0011] According to yet another aspect of the invention, there is provided a method of detecting carbon filamentary structures in a gas, comprising the steps of:

- a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween;
- b) applying a potential difference between said electrodes in order to generate an electric field;
- c) passing a gaseous phase comprising the carbon filamentary structures through the space, thereby depositing the carbon filamentary structures on at least one of the electrodes and therefore generating an increase of current between the electrodes; and
- d) analyzing behavior of the current over a predetermined period of time.

[0012] Applicant has found quite surprisingly that by using the latter method, it is possible to monitor in real time and detect the presence of the carbon filamentary structures in the gaseous phase.

[0013] According to a further aspect of the invention, there is provided an apparatus for recovering carbon filamentary structures comprising:

- a housing which is preferably an elongated member, the elongated member having an internal bore, an inlet and an outlet, the inlet and the outlet being in fluid flow communication with the bore, and

- a first electrode and a second electrode disposed in the internal bore, the first and second electrodes defining therebetween a space dimensioned to receive a gaseous phase comprising the carbon filamentary

structures, the first electrode being connected to the elongated member and the second electrode being connected to a supporting member adjacent to the elongated member, the electrodes being adapted to generate an electric field for depositing the carbon filamentary structures on at least one of them.

[0014] Applicant has found quite surprisingly that by using the latter apparatus, it is possible to recover a satisfying portion of the carbon filamentary structures produced during a gas-phase synthesis.

[0015] According to a still a further aspect of the invention, there is provided an apparatus for recovering carbon filamentary structures comprising:

- at least two recovering units, each unit having a housing which is preferably an elongated member, the elongated member comprising:

- an internal bore, an inlet and an outlet, the inlet and the outlet being in fluid flow communication with the bore;

- a first electrode and a second electrode disposed in the internal bore, the first and second electrodes defining therebetween a space dimensioned to receive a gaseous phase comprising the carbon filamentary structures, the first electrode being connected to the elongated member and the second electrode being connected to a supporting member adjacent to the elongated member, the electrodes being adapted to generate an electric field for depositing the carbon filamentary structures on at least one of the electrodes;

- a distributing device comprising:

- a housing having an internal bore, an inlet dimensioned to receive the gaseous phase, at least two outlets, the inlet and each outlet being in fluid flow communication with the inlet of each elongated member;

- a selecting device connected to the housing permitting to selectively feed any one of the elongated members with the gaseous phase,

thereby permitting to deposit carbon filamentary structures in the selected elongated member while recovering deposited carbon filamentary structures in the non-selected elongated member.

[0016] According to a yet further aspect of the invention there is provided an apparatus for recovering carbon filamentary structures comprising:

- an inlet dimensioned to receive a gaseous phase comprising the carbon filamentary structures;

- a valve comprising an inlet and at least two outlets, the outlets being adapted to be selectively put in fluid flow communication with the inlet of the valve, the inlet of the valve being in fluid flow communication with the inlet of the device; and

- recovering units each comprising a set at least two electrodes, a first electrode and a second electrode defining therebetween a space dimensioned to receive the gaseous phase, the space being in fluid flow communications with one outlet of the valve, the electrodes being adapted to generate an electric field for depositing the carbon filamentary structures on at least one of them.

[0017] Applicant has found quite surprisingly that by using the latter two apparatuses, it is possible to recover, in a continuous manner, the carbon filamentary structures produced during a gas-phase synthesis. By using such apparatuses, it is possible to carry out the recovery of the deposited carbon filamentary structures without stopping their production or without turning off the apparatus used to produce them in a gas-phase synthesis.

DETAILED DESCRIPTION OF THE INVENTION

[0018] In the methods of the invention for depositing carbon filamentary structures, the second electrode can be rotated at a predetermined speed, thereby preventing the deposit from bridging the electrodes. Preferably, the second electrode is rotated at a speed of about 10^{-2} to about 500 rpm and more

preferably at a speed of about 0.1 to about 200 rpm. The deposit can be rolled-up around the second electrode.

[0019] In the method of the invention for detecting carbon filamentary structures in a gas, step (d) is preferably carried out on real time while passing the gaseous phase through the space by using an oscilloscope showing change of the current or of resistance over time. More preferably, step (d) is carried out by monitoring in real time change of current or of resistance over time. This analysis is preferably compared with a standard graph in order to determine the presence or absence of carbon filamentary structures.

[0020] In the methods of the invention, the deposit of carbon filamentary structures can comprise a plurality of filaments of the carbon filamentary structures forming together a web-like structure. Preferably, the first electrode comprises an elongated member defining an internal bore dimensioned to receive the second electrode. The second electrode can longitudinally be aligned with the first electrode. Preferably, the first and second electrodes are parallel and more preferably, the second electrode is disposed in a substantially coaxial alignment into the internal bore. Alternatively, the second electrode can be disposed into the internal bore in a substantially perpendicular manner to the elongated member.

[0021] The electrodes in the methods of the invention can be cylindrical electrodes. A current density having an intensity of about 0 to about $500 \mu\text{A}/\text{cm}^2$ can be collected to the electrodes. An intensity of about 0.1 to about $80 \mu\text{A}/\text{cm}^2$ is preferred. The electric field can have a value of about $1 \times 10^3 \text{V}/\text{m}$ to about $1 \times 10^7 \text{V}/\text{m}$ and preferably of about $1 \times 10^5 \text{V}/\text{m}$ to about $1 \times 10^6 \text{V}/\text{m}$. The potential difference can be about 0.1 to about 50000 V. The potential difference applied between the electrodes can be a Direct Current potential or an Alternative Current potential. A Direct Current potential is preferred.

[0022] In the methods of the invention, the gaseous phase can further comprise a carrier gas. The carrier gas can be selected from the group consisting of be helium, argon, hydrogen or hydrogen sulfide or a mixture thereof. Argon is preferred. The gaseous phase can have a density of about 1×10^2 to about 1×10^{12} and preferably of about 1×10^7 to about 1×10^{10} carbon filamentary structures per cm^3 . A density of about 1×10^9 carbon filamentary structures per cm^3 is particularly preferred. An other gas can be injected through the space so as to slow down the carbon filamentary structures passing through the space. The other gas can be injected in a counter-current manner to the gaseous phase. The other gas is preferably helium.

[0023] In the apparatuses of the invention, the elongated member is preferably the first electrode. The second electrode can be longitudinally aligned with the elongated member. The second electrode is preferably parallel to the first electrode. More preferably, the second electrode is disposed in a substantially coaxial alignment with the elongated member. Alternatively, the second electrode can be disposed into the internal bore in a substantially perpendicular alignment to the elongated member. The second electrode is preferably rotatably mounted on the supporting member. The supporting member can comprise a motor for rotating the second electrodes. Preferably, the first and second electrodes are cylindrical electrodes. The elongated member can further comprise observation windows. Preferably, the outlet comprises a filter.

[0024] In the methods or apparatus of the invention, the carbon filamentary structures can selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, carbon fibres and mixtures thereof.

[0025] In the methods or apparatuses of the invention, the carbon filamentary structures can selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, carbon fibres and mixtures

thereof. Preferably, the carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, and a mixture thereof. More preferably, the carbon filamentary structures are single-wall carbon nanotubes

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Further features and advantages of the invention will become more readily apparent from the following description of preferred embodiments as illustrated by way of examples in the appended drawings wherein:

[0027] Fig. 1 is a schematic sectional elevation view of a system comprising an apparatus for producing carbon nanotubes and an apparatus for recovering carbon filamentary structures according to a preferred embodiment of the invention;

[0028] Fig. 2 is a schematic sectional elevation view of another system comprising an apparatus for producing carbon nanotubes and an apparatus for recovering carbon filamentary structures according to another preferred embodiment of the invention;

[0029] Fig. 3 is a schematic sectional elevation view of another system comprising an apparatus for producing carbon nanotubes and an apparatus for recovering carbon filamentary structures according to still another preferred embodiment of the invention;

[0030] Fig. 4 is a schematic sectional elevation view of an apparatus for recovering carbon filamentary structures according to yet another preferred embodiment of the invention;

[0031] Fig. 5 is a schematic sectional elevation view of an electrode according to another preferred embodiment of the invention;

[0032] Fig. 6 is an elevation view picture of an apparatus for recovering carbon filamentary structures according to a still further preferred embodiment of the invention;

[0033] Fig. 7 is a side view picture of the apparatus of Fig. 6;

[0034] Fig. 8 is a picture of a web single-wall carbon nanotubes obtained using a method according to a preferred embodiment of the invention;

[0035] Fig. 9 is a picture of a web single-wall carbon nanotubes obtained using a method according to another preferred embodiment of the invention;

[0036] Fig. 10 is closer view of the web single-wall carbon nanotubes of Fig. 9;

[0037] Fig. 11 is a picture of web single-wall carbon nanotubes obtained using a method according to still another preferred embodiment of the invention;

[0038] Fig. 12 is graph showing change of current over time obtained by using method of detecting carbon filamentary structures according to a preferred embodiment of the invention;

[0039] Fig. 13 is a graph showing change of the total resistance over time, obtained from the graph of Fig. 12; and

[0040] Fig. 14 is a graph showing the comparison between the evolution of the total resistance over time, in the presence or absence of single-wall carbon nanotubes; and

[0041] Fig. 15 is a schematic representation of a system for producing and recovering single-wall carbon nanotubes, comprising a plasma torch and an apparatus for recovering carbon filamentary structures according to a preferred embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0042] Referring first to Fig. 1, there is shown a system 9 for producing and recovering carbon filamentary structures, which comprises a plasma torch 12 having a plasma tube 14 with a plasma-discharging end 16, the plasma torch generating a plasma 18 comprising ionized atoms of an inert gas, a

carbon-containing substance and a metal catalyst. The system also comprises a quartz tube 20 in fluid flow communication with the plasma-discharging end 16 is disposed in an oven 22. An apparatus 24 (or recovering unit) for recovering carbon filamentary structures is disposed downstream of the tube 20 and is in fluid flow communication with the latter. The ionized particles contained in the plasma 18 enter the oven 22. In the oven 22, the atoms or molecules of carbon and atoms of metal catalyst are condensed to form a gaseous phase comprising carbon filamentary particles such as single-wall carbon nanotubes, multi-wall carbon nanotubes or a mixture thereof. Single-wall nanotubes are preferred. The gaseous phase is then introduced in the apparatus 24 where the carbon filamentary particles are deposited and further recovered.

[0043] As it can be seen from Figs. 2 and 3, systems 10 and 11 for producing and recovering carbon filamentary structures are similar to the system 9 with the exception that systems 10 and 11 each comprise two apparatuses 24 (or recovering units) for recovering carbon filamentary structures. Moreover, systems 10 and 11 each comprise a distributing device 26. The difference between system 10 and system 11 reside in their valve, 28 and 29, respectively. Both systems 10 and 11 permit to selectively feed any one of their two apparatuses 24 by means of their distributing device.

[0044] The apparatus 24, detailed in Fig. 4, comprises an elongated member 30 having an inlet 32 and an outlet 34. The elongated member 30 acts as a first electrode and a second electrode 36 is inserted through the elongated member 30. The electrodes 30 and 36 are spaced-apart and a space 38 is defined therebetween. Electrodes 30 and 36 are in substantially parallel relationship and preferably in parallel relationship. More preferably, they are substantially coaxially aligned. A potential difference is applied between electrode 30 and 36. The electrode is rotatably mounted on a support member 38 which comprises a motor 40.

[0045] In system 9 (Fig. 1), the gaseous phase comprising carbon filamentary structures is first introduced in the inlet 32 of the apparatus 24 (Fig. 4) before passing through space 38. An electric field is generated in space 38 by the electric potential difference applied between electrodes 30 and 36. The carbon filamentary structures, when submitted to such an electric field, will be deposited on the electrode having a polarity opposed to their charge polarity, preferably on the inner electrode (electrode 36) by applying a negative voltage. At the beginning of the process the current is almost non-existent since no ionized particles are suspended in the gaseous phase. The carbon filamentary structures and preferably single-wall carbon nanotubes can be ionized when submitted to the electrical field. Then these ionized particles will be attracted to the electrode of opposed polarity. Since carbon filamentary structures, especially single-wall carbon nanotubes and multi-wall carbon nanotubes have nanometric dimensions which permit to increase the local electric field at the tip or the surface of the structure, they can thus emit electrons because of the field emission effect. When the carbon filamentary particles are gradually deposited on electrode 36, the electric field and electron flow increase in view of the field emission effect. Therefore, an avalanche occurs and leads to the formation of a web comprising carbon filamentary structures which are tangled up and linked together by electrostatic forces. The web of single-wall carbon nanotubes can be seen as the result of the electrical discharge between electrodes, it will have thus the same structure than the electrical streamers of the discharge. Such a web (Fig. 8) configuration indicates the presence of carbon nanotubes since amorphous carbon does not form a web configuration. The particles comprised in the gaseous flow which are not deposited will be exited from the apparatus 24 by means of the outlet 34. Such an outlet also comprises a filter (not shown) which prevents emissions of dangerous particles.

[0046] Since the deposited carbon filamentary structures have tendency to bridge electrodes 30 and 36 and eventually, over a certain period of time, clog the passage therebetween (space 38), the electrode 36 is preferably rotated to insure a continuous operation. The rotation of electrode 36 will cause the structures to be rolled up around electrode 36, thus preventing the deposit to bridge the electrodes and eventually clog the space 38. Such a rolled up configuration is similar to the configuration of a cotton candy and is clearly showed in Figs. 9 and 10. Fig. 5 represents an electrode 37 with a preferred configuration which optimizes the rolling up of the deposit around the electrode. The webs obtained by using such a method are as long as the inner electrode 37 is. Moreover, the filaments of the web are highly aligned and they have a high specific area which constitutes an interesting characteristic. Such a high specific area is particularly interesting when using these webs to prepare conductive materials. The deposit can also be carried out with a non-rotating electrode 36 or 37, but the space 38 will be more easily clogged over long periods of time.

[0047] A synthesis of carbon filamentary structures can be carried out in a continuous manner by using system 10 or 11 showed in Fig. 3 and 4, respectively. When the gaseous phase exits the tube 20 and is introduced in the distributing device 26, it can be selectively directed in any one of the apparatus 24 by mean of the valve 28 or 29. As example, when the gaseous phase is fed into one of the apparatus 24 for depositing carbon filamentary structures therein, the electrical potential difference in the other apparatus 24 is turned off and the carbon filamentary structures deposited on its electrode 36 or 37 can be recovered. In such a case, the motor 40 and electrode 36 can be removed from the apparatus 24. When this step is completed, this apparatus 24 can be used again for depositing carbon filamentary structures. The deposit is thus performed in each apparatus 24 alternatively.

[0048] The methods and apparatuses of the invention can thus also be used as an online monitor for detecting the presence of nanotubes or carbon fibers in a gas since the graph representing the change of current over time will have a characteristic pattern or signature if carbon filamentary nanotubes and (preferably single-wall carbon nanotubes) are formed (Fig. 12). If such structures are present, the current will increase but, if there is a saturation or decrease of the current, it will indicate that no more carbon filamentary structures are formed. In fact, the presence of filamentary carbon structures is monitored real time and the graph representing the change of current over time can be compared with a standard graph. As example, the graph of Fig. 12 constitutes a standard or a reference which can be used in order to determine if single-wall carbon nanotubes are generated during a synthesis. In Fig. 12, the current collected between the electrodes was monitored in real-time. As it can be seen from Fig. 12, the current is increases with the presence of single-wall nanotubes in the gas. Moreover, a graph as illustrated in Fig. 13 can be further obtained from a graph as illustrated in Fig. 12 according to the Ohm's law : $R = V/I$. A graph as illustrated in Fig. 13 can also be obtained on real time when using an oscilloscope. The results obtained from such a graph can also be compared with two standards or references illustrated in Fig. 14. From Fig. 14, it can be seen that when single-wall carbon nanotubes are present, the current increase rapidly and when there is no single-wall carbon nanotubes in the gas, the current is stabilized to a low value and the resistance remains relatively high. The user can thus optimize the conditions of the synthesis of carbon filamentary structures i.e. by modifying the experimental conditions of the plasma torch. This method of monitoring can be applied to a plurality of synthesis methods of carbon nanotubes such as plasma torch, HiPco, laser vaporization, chemical vapor deposition and electric arc. In fact, such a monitoring technique can be applied to any gas-phase synthesis techniques.

[0049] Figs. 6 and 7 represent pictures of an apparatus 109 which is similar to the apparatus 24 schematized in Fig. 4. The major difference between apparatus 24 and 109 is that the latter apparatus comprises observation windows 42, 44 and 46 which permit a user to observe the deposit of carbon filamentary structures on electrode 37.

[0050] Fig. 15 represent a system 110 for producing and recovering single-wall carbon nanotubes, which comprises an apparatus 111 for producing single-wall carbon nanotubes and an apparatus (or electrostatic trap or recovering unit) 135. The apparatus 111 has been previously described in U.S. Patent Application Ser. No 10/434181 filed on May 5, 2003, which is hereby incorporated by reference. The apparatus 111 comprises a plasma torch 112 having a plasma tube 114 with a plasma-discharging end 116, and an oven 118 disposed downstream of the plasma tube 114 in spaced relation thereto. The plasma tube 114 is adapted to receive an inert gas for activation by electromagnetic radiation generated from a source (not shown) so as to form a primary plasma 120. The electromagnetic radiations are propagated on the plasma tube 114 so as to maintain the primary plasma 120. The primary plasma 120 comprises ionized atoms of the inert gas. A feed conduit 122 having a discharge end 124 is arranged inside the plasma tube 114 and extends substantially coaxially thereof. The discharge end 124 of the feed conduit 122 is disposed adjacent the plasma discharging end 116 of the plasma tube 114. The feed conduit 122 serves to direct a carbon-containing substance, such as a carbon-containing gas, and a metal catalyst towards the primary plasma 120 so that the carbon-containing substance and the metal catalyst contact the primary plasma 120 at the plasma-discharging end 116 of the plasma tube 114, whereby to form a secondary plasma 126 containing atoms or molecules of carbon and the atoms of metal catalyst. The carbon-containing gas is preferably ethylene or methane.

[0051] The oven 118 serves to condense the atoms or molecules of carbon and atoms of metal catalyst to form single-wall carbon nanotubes 128. A heat source 130 is provided for heating the oven 118 to generate a temperature gradient permitting rapid condensation of the atoms or molecules of carbon and the atoms of metal catalyst. A heat-resistant tubular member 132 having a plasma-receiving end 134 extends through the oven 118, the plasma-receiving end 134 being disposed upstream of the plasma-discharging end 116 of the plasma tube 114. The apparatus (or recovering unit or electrostatic trap) 135 comprises an elongated member 139, a filter 136 and a rod 37. The apparatus 111 is extending downstream of oven 118. The elongated member 139 acts as a first electrode while the rod 137 acts as a second electrode. The deposit of single-wall carbon nanotubes 128 occurs mainly inside of the apparatus 135 and more particularly on electrode or rod 137. In fact, the deposit of single-wall carbon nanotubes bridges the rod 137 and the elongated member 139. The filter 136 traps some of the fine particles (not shown) generated during the formation of single-wall carbon nanotubes 128 and reduces the emission of fine particles outside of the apparatus. The apparatus further includes a gas injector 138 for injecting a cooling inert gas into the tubular member 132, downstream of the secondary plasma 126. The cooling inert gas assists in providing the temperature gradient. Another heat-resistant tubular member 140 is disposed about the plasma tube 114 and extends substantially coaxially thereof, the tubular member 140 being fixed to the tubular member 132 and supporting same. Another gas injector 142 is provided for injecting a further inert gas between the plasma tube 114 and the tubular member 140 to prevent undesirable formation of carbon deposit adjacent the plasma-discharging end 116 of the plasma tube 114. The plasma tube 114 is also provided with a cooling system (not shown), which preferably uses water. The apparatus 111 further comprises a Faraday shield (not shown) made of a conductive material, preferably aluminium.

[0052] The inert gas flows through the plasma tube 114 along a helical path represented by the arrow 144. Similarly, the carbon-containing gas and the metal catalyst, optionally in admixture with a carrier gas, flow through the feed conduit 122 along a helical path represented by the arrow 146. The metal catalyst which is fed through the conduit 122 can be either an organometallic complex such as ferrocene, or an inorganic metal catalyst such as iron in metallic form.

EXAMPLE 1

[0053] The production and recovery of single-wall carbon nanotubes has been performed by using a plasma torch as illustrated in Fig. 15 and according to the method described in US. Patent Application Ser. No 10/434181. The following experiment has been carried out by the inventors by providing the plasma torch with a cooling system and a Faraday shield. The cooling system prevents the plasma torch from over-heating and being damaged. The Faraday shield comprising a conductive material, preferably aluminium, prevents the electromagnetic radiations from escaping from the apparatus, thereby protecting users of the plasma torch. All the parameters related to the plasma torch are controlled by a computer using the LABVIEW[®] software. The parameters can also be manually controlled. The inert gas used for generating the primary plasma was argon, the metal catalyst was ferrocene, the carbon-containing gas was ethylene and the cooling gas was helium. Helium was also injected toward the plasma discharging end so as to prevent carbon deposit. Ferrocene was heated to 100°C prior to be injected. The argon flow varied was about 3200 sccm (standard cubic centimeters per minute). The helium flows were both stabilized at about 3250 sccm, and the methane flow varied between 50 and 100 sccm. The temperature of the oven was kept at 900°C and measured with a pyrometer. The power of the source generating the electromagnetic radiations (microwaves) was 1500 W and the reflected power was about 200 W. The heat-resistant tubular members were made of

quartz. The plasma tube was made of brass. The feed conduit, on the other hand, was made of stainless steel. The metal catalyst (ferrocene) and the carbon-containing substance (methane) were used in an atomic ratio metal atoms / carbon atoms of 0.02. The software controlled the flow of the carrier gas, argon, so as to maintain the atomic ratio at such a value. The experiment was carried out at atmospheric pressure under inert conditions (helium and argon). However, it should be noted that such an experiment could also be performed at a lesser or greater pressure.

[0054] In this experiment, an apparatus (or electrostatic trap) having a non-rotatable inner electrode (as schematized in Fig. 15) was used for recovering the single-wall nanotubes. A DC voltage polarity of 1200 V (negative or positive) was applied on the central electrode. The central electrode was made of a conductive material and had a diameter of about 10 mm and a length of about 50 cm. The elongated member of the apparatus which was used as an electrode was also made of a conductive material and had a diameter of 10 cm and a length of about 50 cm. A DC voltage polarity of 0 V was applied on the elongated member.

[0055] Helium (1500 sccm) was injected (counter-current to the gaseous phase comprising the single-wall carbon nanotubes) at the top of the apparatus for recovering the nanotubes in order to slow down the particles in the gaseous phase. At the beginning of the experiment, the current was almost 0 mA since no nanotubes were deposited. The electric field around the central electrode was about $E = 1200\text{V}/(1\text{mm}) \approx 10^6 \text{ V/m}$. The resistance between the two electrodes at the end of the experiment was about $50\text{K}\Omega$. The experiment was carried out over a period of 60 minutes and an amount of about 500 mg of single-wall nanotubes was deposited. The single-wall nanotubes thus deposited had a web configuration and are showed in Fig. 8. The purity of the single-wall nanotubes thus obtained was about 30% by weight.

EXAMPLE 2

[0056] Another experiment has been carried out by using an apparatus for recovering single-wall carbon nanotubes which had a rotating inner (or second) electrode. In this example, a similar plasma torch to example 1 was used under the same conditions but with ethylene as carbon-containing gas. The apparatus used for recovering the single-wall nanotubes is showed in Figs. 6 and 7. This apparatus uses an electrode 37 having three branches. Each of the three branches of the electrode (see Fig. 5) had a diameter of about 3 mm. The inner electrode was rotated at a speed ranging from 3 to 200 rpm. The polarity of the inner electrode was between -1000 and -2000 V. The electric field around the central electrode was about 5×10^5 V/m. The flow of helium injected counter-current was about 1500 sccm. By using such a recovering unit having a rotating electrode, a formation of a web was observed and the rotation of the electrode prevented the single-wall carbon nanotubes to bridge the two electrodes. Thus, the current remained at a relatively low value of about 1 to about 10 mA. During this experiment, the behaviour of the current has been monitored on real time and the results are showed in Fig. 12. Moreover, Fig. 13 has been obtained from the results of Fig. 12 by calculating the resistance by using the Ohm's law. It should be noted that such a graph (Fig. 13) can also be obtained in real time. A comparison between the graph of Fig. 13 and a graph obtained when no single-wall nanotubes are obtained is showed in Fig. 14. The web obtained in this experiment is showed in Fig. 9 to 11. An amount of about 500 mg of single-wall was obtained in one hour and the purity was about 40 to 50% weight.

[0057] While the invention has been described with particular reference to the illustrated embodiment, it will be understood that numerous modifications thereto will appear to those skilled in the art. Accordingly, the above description and accompanying drawings should be taken as illustrative of the invention and not in a limiting sense.

WHAT IS CLAIMED IS:

1. A method for depositing carbon filamentary structures on electrodes, comprising the steps of:
 - a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween;
 - b) applying a potential difference between said electrodes in order to generate an electric field;
 - c) passing a gaseous phase comprising said carbon filamentary structures through said space, thereby depositing said carbon filamentary structures on at least one of said electrodes.
2. The method of claim 1, wherein said deposit of carbon filamentary structures comprises a plurality of filaments of said carbon filamentary structures forming together a web-like structure.
3. The method of claim 1 or 2, wherein said first electrode comprises an elongated member defining an internal bore dimensioned to receive said second electrode.
4. The method of claim 3, wherein said second electrode is longitudinally aligned with said first electrode.
5. The method of claim 3 or 4, wherein said first and second electrodes are parallel.
6. The method of any one of claims 3 to 5, wherein said second electrode is disposed in a substantially coaxial alignment into said internal bore.

7. The method of claim 3, wherein said second electrode is disposed into said internal bore in a substantially perpendicular manner to said elongated member.
8. The method of any one of claims 1 to 7, wherein said second electrode is rotated at a predetermined speed, thereby preventing said deposit from bridging said electrodes.
9. The method of claim 8, wherein said second electrode is rotated at a speed of about 10^{-2} to about 500 rpm.
10. The method of claim 9, wherein said second electrode is rotated at a speed of about 0.1 to about 200 rpm.
11. The method of any one of claims 8 to 10, wherein said deposit is rolled-up around said second electrode.
12. The method of any one of claims 1 to 11, wherein said first and second electrodes are cylindrical electrodes.
13. The method of any one of claims 1 to 12, wherein a current density having an intensity of about 0 to about $500 \mu\text{A}/\text{cm}^2$ is collected to said electrodes.
14. The method of claim 13, wherein said current density has an intensity of about 0.1 to about $80 \mu\text{A}/\text{cm}^2$.
15. The method of any one of claims 1 to 14, wherein said electric field has a value of about $1 \times 10^3 \text{V}/\text{m}$ to about $1 \times 10^7 \text{V}/\text{m}$.

16. The method of claim 15, wherein said electric field has a value of about 1×10^5 V/m to about 1×10^6 V/m.
17. The method of any one of claims 1 to 16, wherein said potential difference is about 0.1 to about 50000 V.
18. The method of any one of claims 1 to 17, wherein said gaseous phase further comprises a carrier gas.
19. The method of claim 18, wherein said carrier gas is selected from the group consisting of helium, argon, hydrogen or hydrogen sulfide or a mixture thereof.
20. The method of claim 19, wherein said gas is argon.
21. The method of any one of claims 1 to 20, wherein said gaseous phase has a density of about 1×10^2 to about 1×10^{12} carbon filamentary structures per cm^3 .
22. The method of claim 21, wherein said gaseous phase has a density of about 1×10^7 to about 1×10^{10} carbon filamentary structures per cm^3 .
23. The method of any one of claims 1 to 22, wherein another gas is injected through said space so as to slow down said carbon filamentary structures passing through said space.

24. The method of claim 23, wherein said other gas is injected in a counter-current manner to said gaseous phase.
25. The method of claim 23 or 24, wherein said gas is helium.
26. The method of any one of claims 1 to 25, wherein said potential difference applied between said electrodes is a Direct Current potential.
27. The method of any one of claims 1 to 25, wherein said potential difference applied between said electrodes is an Alternative Current potential.
28. A continuous method for depositing carbon filamentary structures on electrodes, comprising the steps of:
- a) providing a device comprising:
 - an inlet;
 - at least two recovering units,
 - a first recovering unit comprising a set (A) of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a first space therebetween, said first space being in fluid flow communication with said inlet and being dimensioned in order to receive a gaseous phase comprising said carbon filamentary structures, and
 - a second recovering unit comprising a set (B) of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a second space therebetween, said second space being in fluid flow communication with said inlet and being dimensioned in order to receive a gaseous phase comprising said carbon filamentary structures ;
 - a valve permitting to selectively feed said first space or said second space with said gaseous phase;
 - b) passing said gaseous through said inlet;

c) applying a potential difference between the electrodes of said set (A) in order to generate an electric field, and selectively feeding said first space with said gaseous phase, thereby depositing carbon said filamentary structures on at least one electrodes of said set (A);

d) applying a potential difference between the electrodes of said set (B) in order to generate an electric field, and selectively feeding said second space with said gaseous phase, thereby depositing said carbon filamentary structures on at least one electrodes of said set (B),

steps (c) and (d) are repeated until a desired quantity of said carbon filamentary structures is obtained;

while step (d) is carried out, the potential difference between the electrodes of said set (A) is turned off and the carbon filamentary structures deposited in step (c) are recovered; and

while step (c) is carried out for at least the second time, the potential difference between the electrodes of said set (B) is turned off and the carbon filamentary structures deposited in step (d) are recovered.

29. The method of claim 28, wherein said deposit of carbon filamentary structures comprises a plurality of filaments of said carbon filamentary structures forming together a web-like structure.

30. The method of claim 28 or 29, wherein said first electrode in set (A) and/or (B) comprises an elongated member defining an internal bore dimensioned to receive said second electrode.

31. The method of claim 30, wherein in set (A) and/or (B) said second electrode is longitudinally aligned with said first electrode.

32. The method of claim 30 or 31, wherein said first and second electrodes in set (A) and/or (B) are parallel.

33. The method of any one of claims 30 to 32, wherein said second electrode in set (A) and/or (B) is disposed in a substantially coaxial alignment into said internal bore.

34. The method of claim 30, wherein said second electrode in set (A) and/or (B) is disposed into said internal bore in a substantially perpendicular manner to said elongated member.

35. The method of any one of claims 28 to 34, wherein said second electrode in set (A) and/or (B) is rotated at a predetermined speed, thereby preventing said deposit from bridging said first and second electrodes in set (A) and/or (B).

36. The method of claim 35, wherein said second electrode in set (A) and/or (B) is rotated at a speed of about 10^{-2} to about 500 rpm.

37. The method of claim 36, wherein said second electrode in set (A) and/or (B) is rotated at a speed of about 0.1 to about 200 rpm.

38. The method of any one of claims 35 to 37, wherein said deposit is rolled-up around said second electrode in set (A) and/or (B).

39. The method of any one of claims 28 to 38, wherein said first and second electrodes in set (A) and/or (B) are cylindrical electrodes.

40. The method of any one of claims 28 to 39, wherein a current density having an intensity of about 0 to about $500 \mu\text{A}/\text{cm}^2$ is collected to said electrodes in set (A) and/or (B).
41. The method of claim 40, wherein said current density has an intensity of about 0.1 to about $80 \mu\text{A}/\text{cm}^2$.
42. The method of any one of claims 28 to 41, wherein said electric field has a value of about $1 \times 10^3 \text{V}/\text{m}$ to about $1 \times 10^7 \text{V}/\text{m}$.
43. The method of claim 42, wherein said electric field has a value of about $1 \times 10^5 \text{V}/\text{m}$ to about $1 \times 10^6 \text{V}/\text{m}$.
44. The method of any one of claims 28 to 43, wherein said potential difference is about 0.1 to about 50000 V.
45. The method of any one of claims 28 to 44, wherein said gaseous phase further comprises a carrier gas.
46. The method of claim 45, wherein said carrier gas is selected from the group consisting of be helium, argon, hydrogen or hydrogen sulfide or a mixture thereof.
47. The method of claim 46, wherein said gas is argon.
48. The method of any one of claims 28 to 47, wherein said gaseous phase has a density of about 1×10^2 to about 1×10^{12} carbon filamentary structures per cm^3 .

49. The method of claim 48, wherein said gaseous phase has a density of about 1×10^7 to about 1×10^{10} carbon filamentary structures per cm^3 .
50. The method of any one of claims 28 to 49, wherein another gas is injected through said space so as to slow down said carbon filamentary structures passing through said first space and/or said second space.
51. The method of claim 50, wherein said other gas is injected in a counter-current manner to said gaseous phase.
52. The method of claim 50 or 51, wherein said gas is helium.
53. The method of any one of claims 28 to 52, wherein said potential difference applied between said electrodes is a Direct Current potential.
54. The method of any one of claims 28 to 52, wherein said potential difference applied between said electrodes is an Alternative Current potential.
55. The method of any one of claims 1 to 54, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, carbon fibres and mixtures thereof.
56. The method of any one of claims 1 to 54, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, and a mixture thereof.

57. The method of claim 56, wherein said carbon filamentary structures are single-wall carbon nanotubes.

58. A method for monitoring the production of carbon filamentary structures in a gas, comprising the steps of:

a) providing a set of electrodes comprising at least two electrodes, a first electrode and a second electrode defining a space therebetween;

b) applying a potential difference between said electrodes in order to generate an electric field;

c) passing a gaseous phase comprising said carbon filamentary structures through said space, thereby depositing carbon filamentary structures on at least one of said electrodes and therefore generating an increase of current between said electrodes; and

d) analyzing behavior of said current over a predetermined period of time.

59. The method of claim 58, wherein the analysis of step (d) is carried out on real time while passing said gaseous phase through said space by using an oscilloscope showing change of said current or of a resistance over time.

60. The method of claim 59, wherein said analysis is compared with a standard graph in order to determine the presence or absence of said carbon filamentary structures.

61. The method of any one of claims 58 to 60, wherein said deposit of carbon filamentary structures comprises a plurality of filaments of said carbon filamentary structures forming together a web-like structure.
62. The method of claim 58 to 61, wherein said first electrode comprises an elongated member defining an internal bore dimensioned to receive said second electrode.
63. The method of claim 62, wherein said second electrode is longitudinally aligned with said first electrode.
64. The method of any one of claims 58 to 63, wherein said first and second electrodes are parallel.
65. The method of any one of claims 58 to 64, wherein said second electrode is disposed in a substantially coaxial alignment into said internal bore.
66. The method of any one of claims 58 to 62, wherein said second electrode is disposed into said internal bore in a substantially perpendicular manner to said elongated member.
67. The method of any one of claims 58 to 66, wherein said first and second electrodes are cylindrical electrodes.
68. The method of any one of claims 58 to 67, wherein a current density having an intensity of about 0 to about $500 \mu\text{A}/\text{cm}^2$ is collected to said electrodes.

69. The method of claim 68, wherein said current density has an intensity of about 0.1 to about 80 $\mu\text{A}/\text{cm}^2$.

70. The method of any one of claims 58 to 69, wherein said electric field has a value of about $1 \times 10^3 \text{ V/m}$ to about $1 \times 10^7 \text{ V/m}$.

71. The method of claim 70, wherein said electric field has a value of about $1 \times 10^5 \text{ V/m}$ to about $1 \times 10^6 \text{ V/m}$.

72. The method of any one of claims 58 to 71, wherein said potential difference is about 0.1 to about 50000 V.

73. The method of any one of claims 58 to 72, wherein said gaseous phase further comprises a carrier gas.

74. The method of claim 73, wherein said carrier gas is selected from the group consisting of be helium, argon, hydrogen or hydrogen sulfide or a mixture thereof.

75. The method of claim 74, wherein said gas is argon.

76. The method of any one of claims 58 to 75, wherein said gaseous phase has a density of about 1×10^2 to about 1×10^{12} carbon filamentary structures per cm^3 .

77. The method of claim 76, wherein said gaseous phase has a density of about 1×10^7 to about 1×10^{10} carbon filamentary structures per cm^3 .

78. The method of any one of claims 58 to 77, wherein another gas is injected through said space so as to slow down said carbon filamentary structures passing through said space.

79. The method of claim 78, wherein said other gas is injected in a counter-current manner to said gaseous phase.

80. The method of claim 78 or 79, wherein said gas is helium.

81. The method of any one of claims 58 to 80, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, carbon fibres and mixtures thereof.

82. The method of any one of claims 58 to 80, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, and a mixture thereof.

83. The method of claim 82, wherein said carbon filamentary structures are single-wall carbon nanotubes.

84. An apparatus for recovering carbon filamentary structures comprising:

a housing which is preferably an elongated member, said elongated member having an internal bore, an inlet and an outlet, said inlet and said outlet being in fluid flow communication with said bore, and

a first electrode and a second electrode disposed in said internal bore, said first and second electrodes defining therebetween a space dimensioned to receive a gaseous phase comprising said carbon filamentary

structures, said first electrode being connected to said elongated member and said second electrode being connected to a supporting member adjacent to said elongated member, said electrodes being adapted to generate an electric field for depositing said carbon filamentary structures on at least one of said electrodes.

85. The apparatus of claim 84, wherein said elongated member is said first electrode.

86. The apparatus of claim 84 or 85, wherein said second electrode is longitudinally aligned with said elongated member.

87. The apparatus of any one of claims 84 to 86, wherein said second electrode is parallel to said first electrode.

88. The apparatus of claim 87, wherein said second electrode is disposed in a substantially coaxial alignment with said elongated member.

89. The apparatus of claim 84 or 85, wherein said second electrode is disposed into said internal bore in a substantially perpendicular alignment to said elongated member.

90. The apparatus of any one of claims 84 to 89, wherein said second electrode is rotatably mounted on said supporting member.

91. The apparatus of claim 90, wherein said supporting member comprises a motor for rotating said second electrodes.

92. The apparatus of any one of claims 84 to 91, wherein said first and second electrodes are cylindrical electrodes.

93. The apparatus of any one of claims 84 to 92, wherein said elongated member further comprises observation windows.

94. The apparatus of any one of claims 84 to 93, wherein said outlet comprises a filter.

95. An apparatus for recovering carbon filamentary structures comprising:

- at least two recovering units, each unit having a housing which is preferably an elongated member, said elongated member comprising:

- an internal bore, an inlet and an outlet, said inlet and said outlet being in fluid flow communication with said bore;

- a first electrode and a second electrode disposed in said internal bore, said first and second electrodes defining therebetween a space dimensioned to receive a gaseous phase comprising said carbon filamentary structures, said first electrode being connected to said elongated member and said second electrode being connected to a supporting member adjacent to said elongated member, said electrodes being adapted to generate an electric field for depositing said carbon filamentary structures on at least one of said electrodes;

- a distributing device comprising:

- a housing having an internal bore, an inlet dimensioned to receive said gaseous phase, at least two outlets, said inlet and each outlet being in fluid flow communication with the inlet of each elongated member;

a selecting device connected to said housing permitting to selectively feed any one of the elongated members with said gaseous phase, thereby permitting to deposit carbon filamentary structures in said selected elongated member while recovering deposited carbon filamentary structures in the non-selected elongated member.

96. The apparatus of claim 95, wherein said elongated member is said first electrode.

97. The apparatus of claim 95 or 96, wherein said second electrode is longitudinally aligned with said elongated member.

98. The apparatus of any one of claims 95 to 97, wherein said second electrode is parallel to said first electrode.

99. The apparatus of claim 98, wherein said second electrode is disposed in a substantially coaxial alignment with said elongated member.

100. The apparatus of claim 95 or 96, wherein said second electrode is disposed into said internal bore in a substantially perpendicular alignment to said elongated member.

101. The apparatus of any one of claims 95 to 100, wherein said second electrode is rotatably mounted on said supporting member.

102. The apparatus of claim 101, wherein said supporting member comprises a motor for rotating said second electrodes.

103. The apparatus of any one of claims 95 to 102, wherein said first and second electrodes are cylindrical electrodes.

104. The apparatus of any one of claims 95 to 103, wherein said elongated member further comprises observation windows.

105. The apparatus of any one of claims 95 to 104, wherein said outlet comprises a filter.

106. An apparatus for recovering carbon filamentary structures comprising:

an elongated member having an internal bore, an inlet and an outlet, said inlet and said outlet being in fluid flow communication with said bore; and

a first electrode and a second electrode disposed in said internal bore and connected to said elongated member, said first and second electrodes defining therebetween a space dimensioned to receive a gaseous phase comprising carbon filamentary structures, said electrodes being adapted to generate an electric field for depositing said carbon filamentary structures on at least one of said electrodes.

107. The apparatus of any one of claims 84 to 106, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, carbon fibres and a mixture thereof.

108. The apparatus of any one of claims 84 to 107, wherein said carbon filamentary structures are selected from the group consisting of single-wall carbon nanotubes, multi-wall carbon nanotubes, and a mixture thereof.

109. The apparatus of claim 108, wherein said carbon filamentary structures are single-wall carbon nanotubes.

110. A continuous method for depositing carbon filamentary structures on electrodes, comprising the steps of :

a) providing a device comprising:

- an inlet;

- a valve comprising an inlet and at least two outlets, said outlets being adapted to be selectively put in fluid flow communication with the inlet of the valve, said inlet of the valve being in fluid flow communication with the inlet of the device;

- recovering units each comprising a set at least two electrodes, a first electrode and a second electrode defining a space therebetween, said space being in fluid flow communications with one outlet of the valve and being dimensioned to receive a gaseous phase comprising said carbon filamentary structures;

b) passing said gaseous phase through said inlet of the device, said valve and a selected recovering unit; and applying a potential difference between the electrodes of the selected recovering unit to thereby deposit carbon filamentary structures on at least one electrode; and

c) selecting another recovering unit and repeating step (b).

111. An apparatus for recovering carbon filamentary structures comprising:

- an inlet dimensioned to receive a gaseous phase comprising said carbon filamentary structures;

- a valve comprising an inlet and at least two outlets, said outlets being adapted to be selectively put in fluid flow communication with the inlet

of the valve, said inlet of the valve being in fluid flow communication with the inlet of the device; and

- recovering units each comprising a set at least two electrodes, a first electrode and a second electrode defining therebetween a space dimensioned to receive said gaseous phase, said space being in fluid flow communications with one outlet of the valve, said electrodes being adapted to generate an electric field for depositing said carbon filamentary structures on at least one of them.

Application number / Numéro de demande: 2748064

Figures: 8-9-10-11

Pages: _____

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des dossiers au 10ième étage)

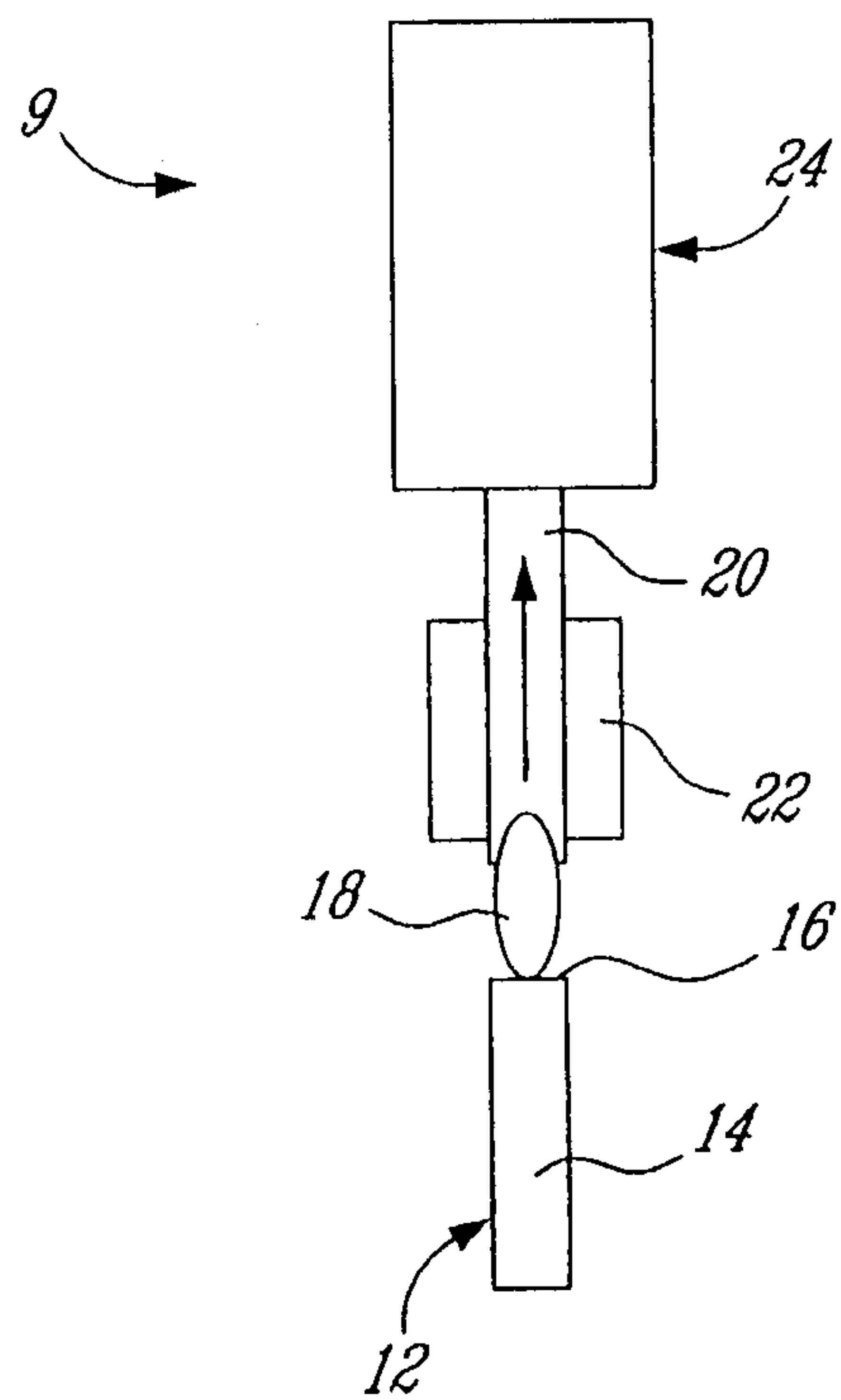


FIG. 1

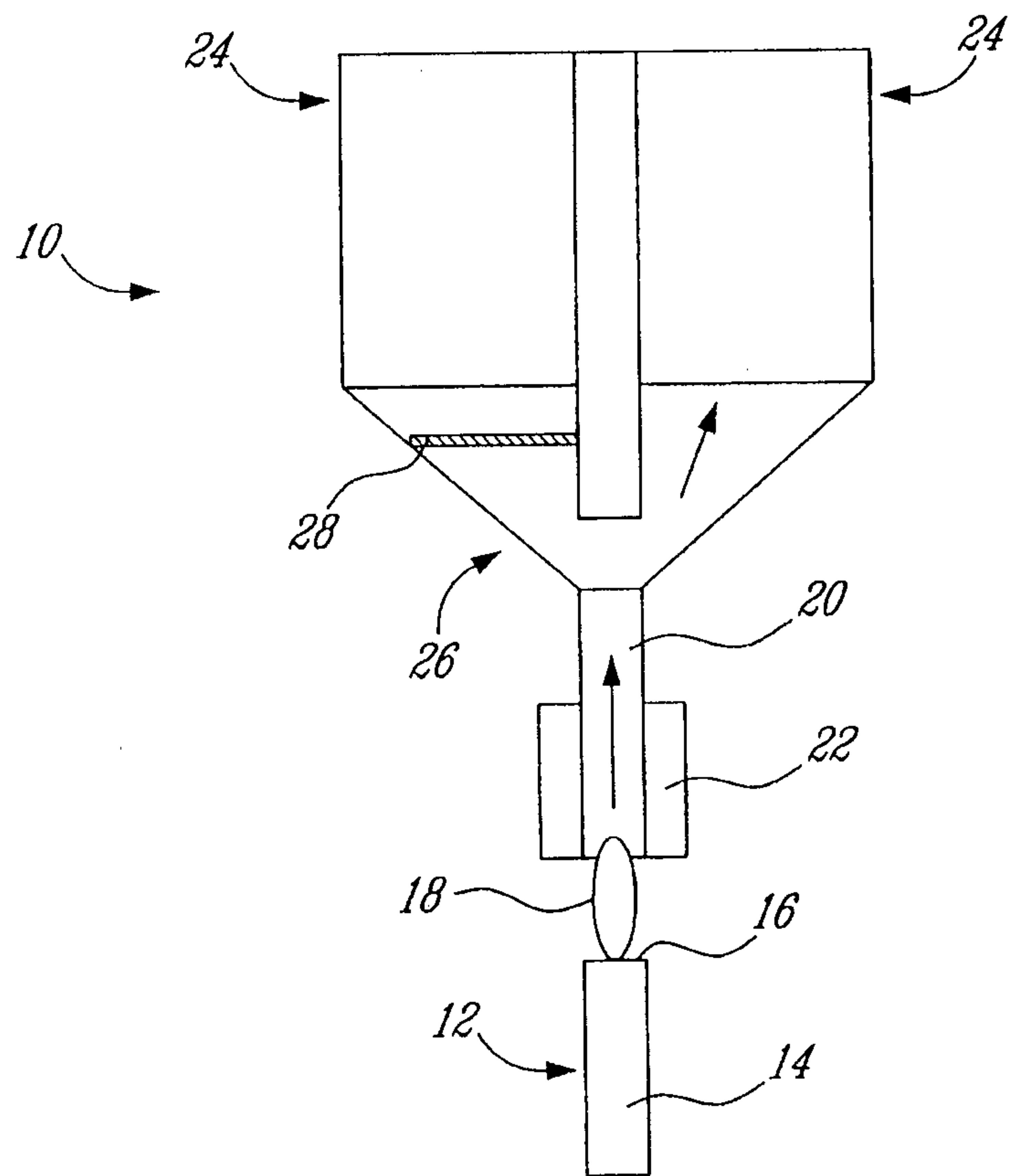


FIG. 2

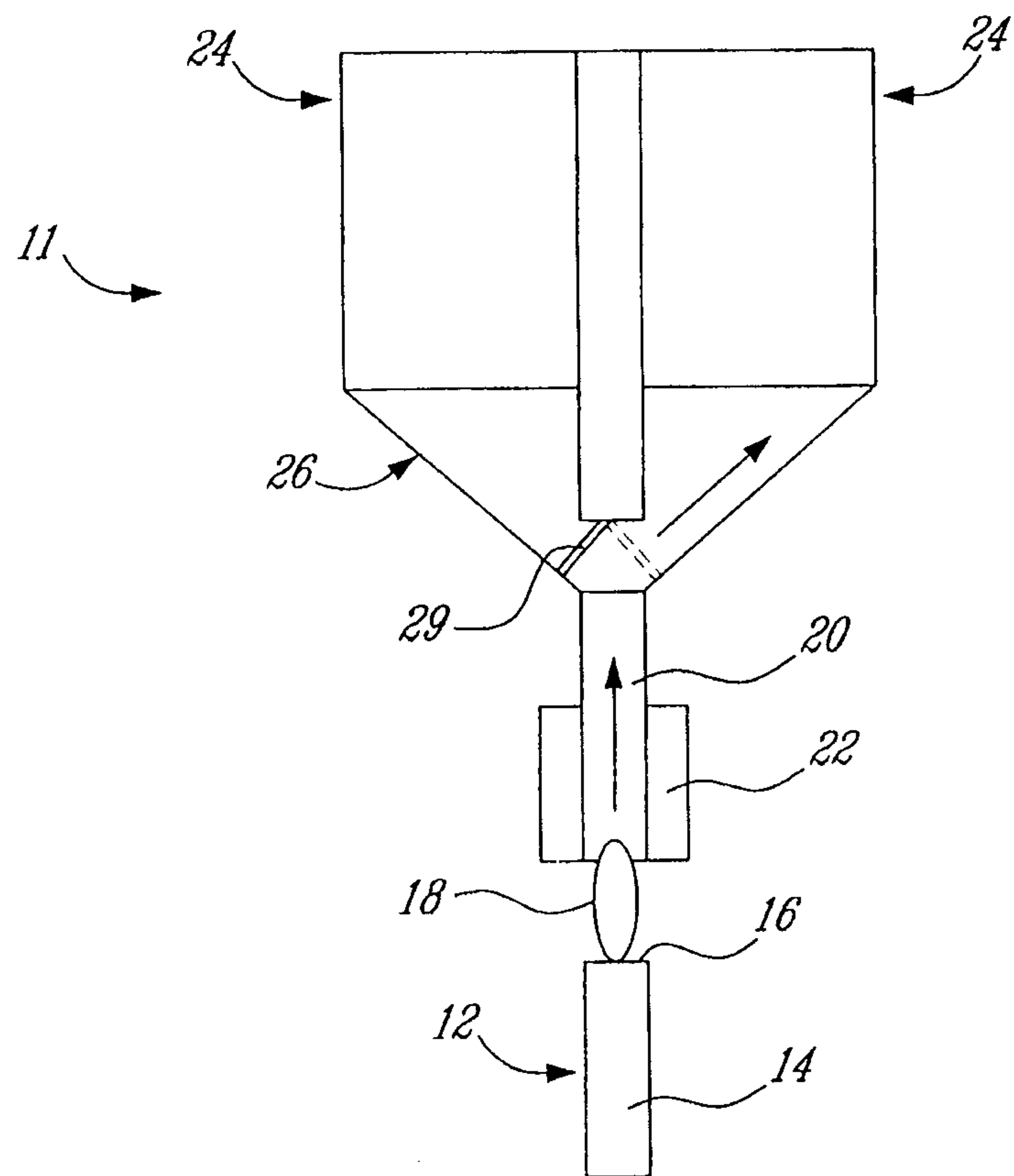


FIG. 3

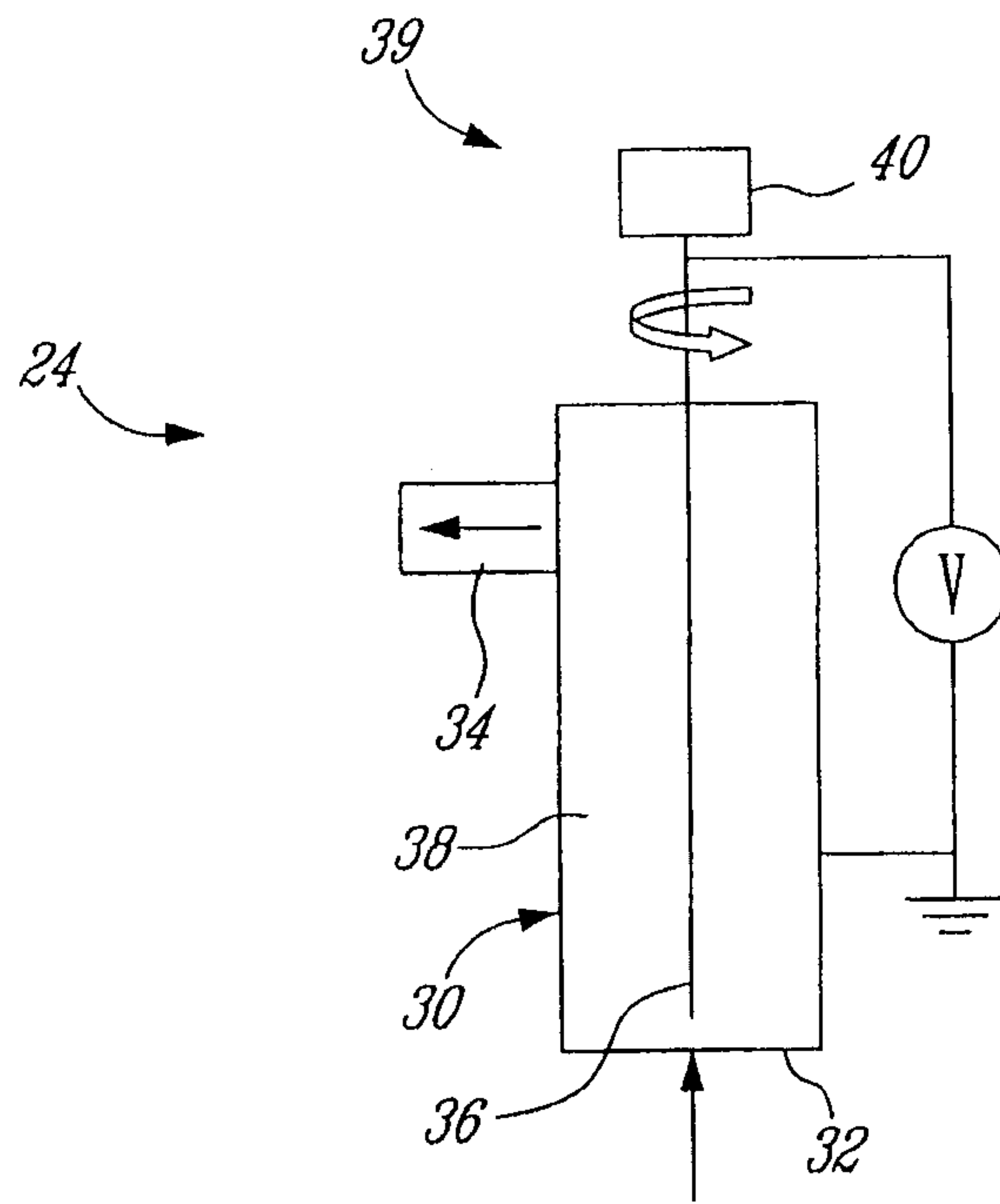


FIG. 4

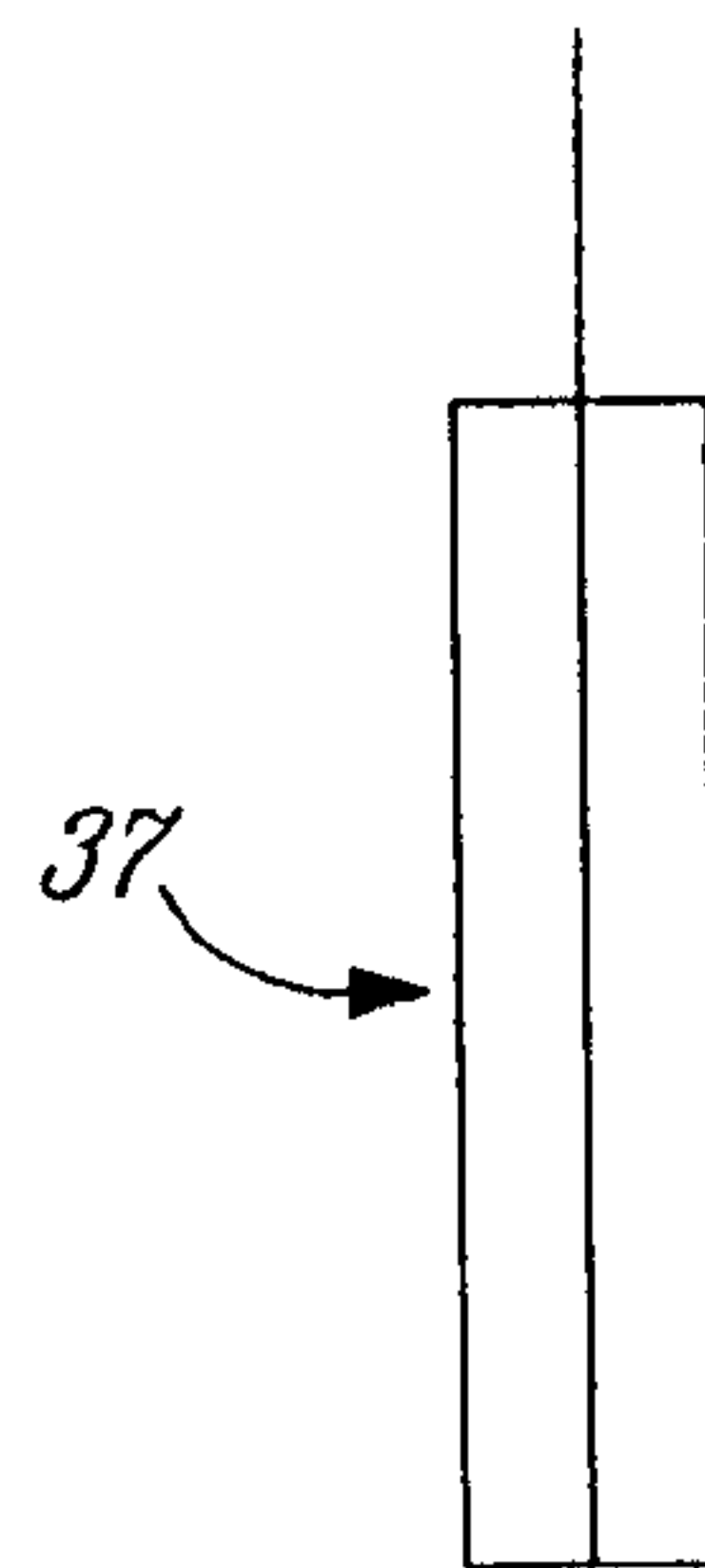


FIG. 5

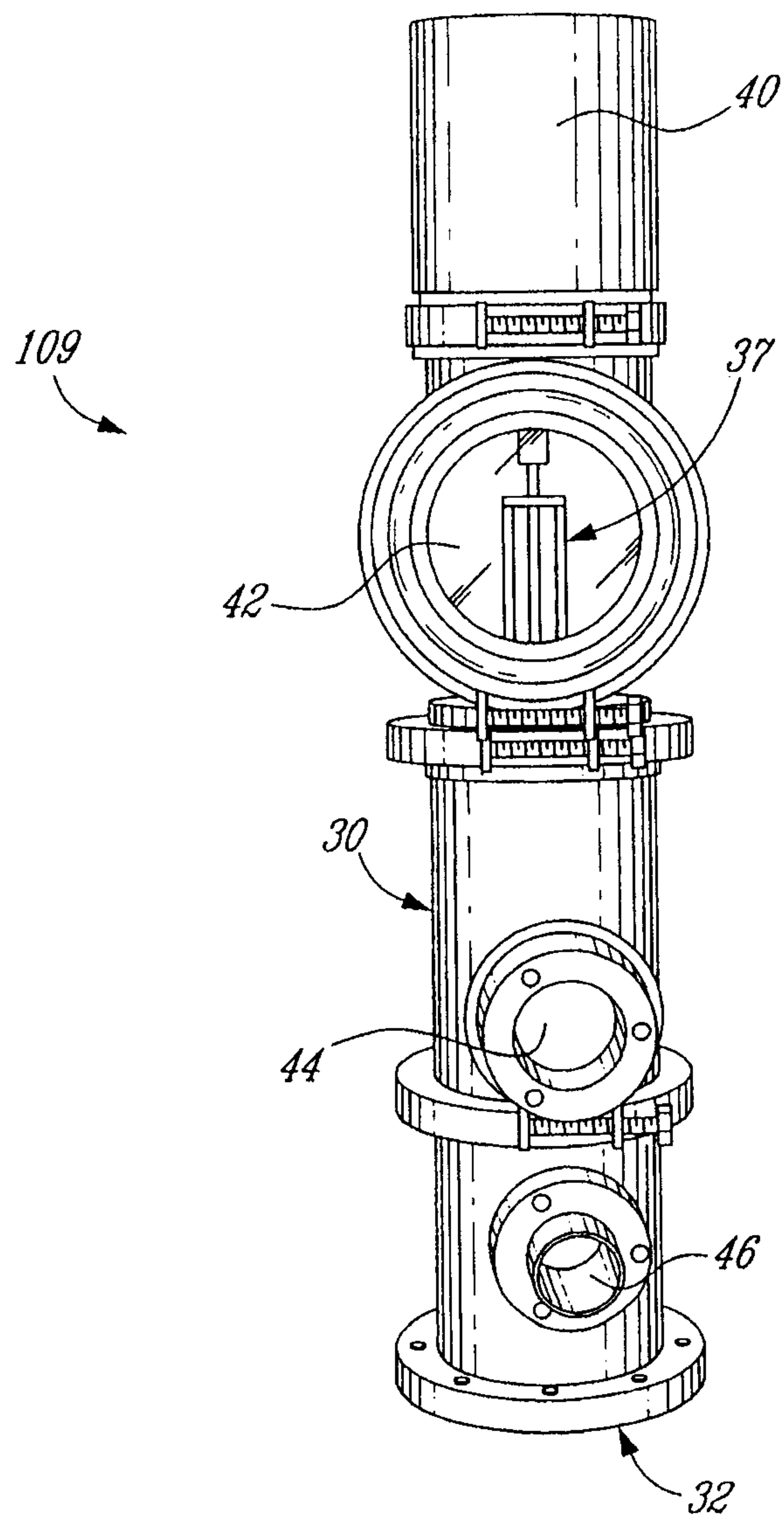


FIG. 6

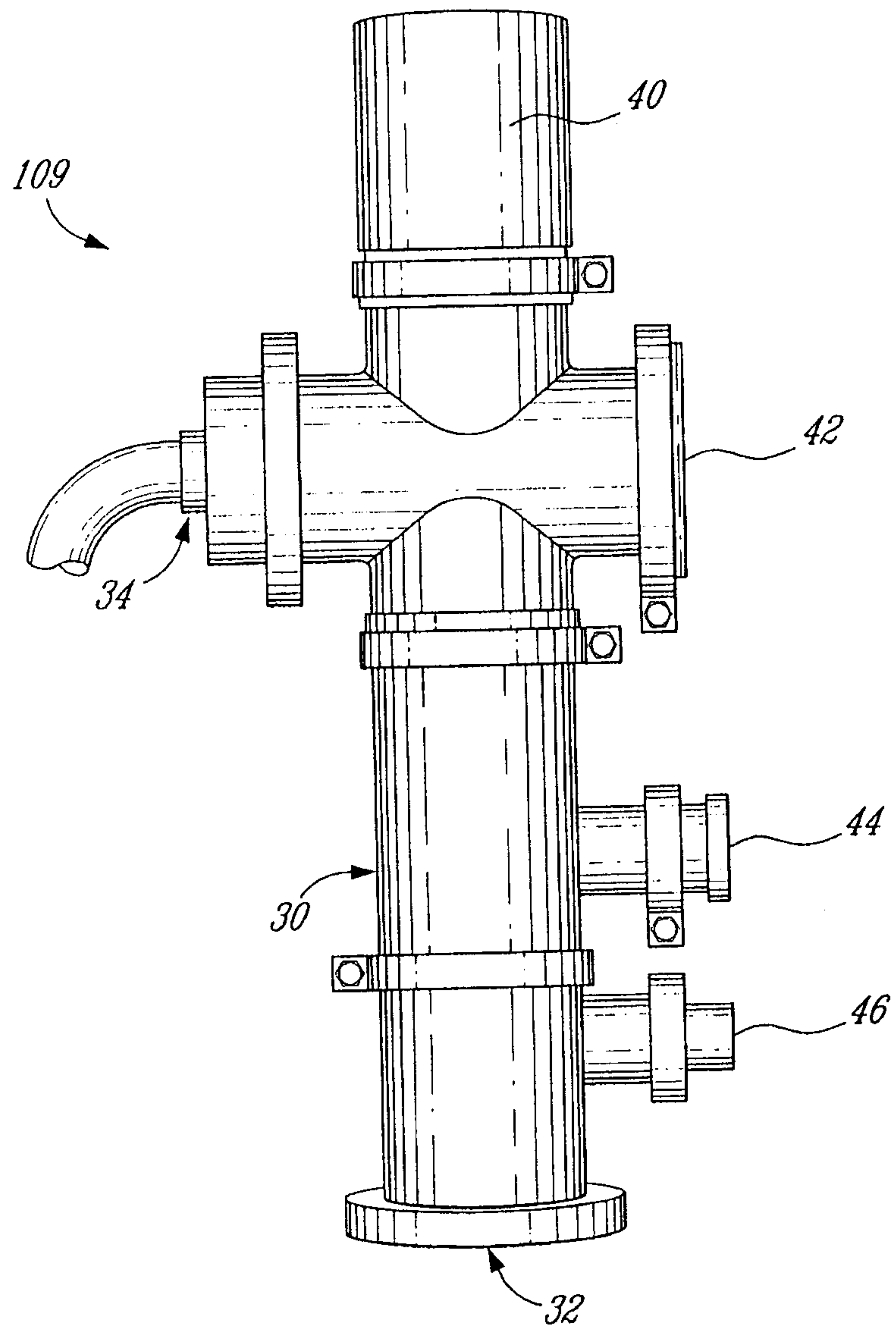


FIG. 7

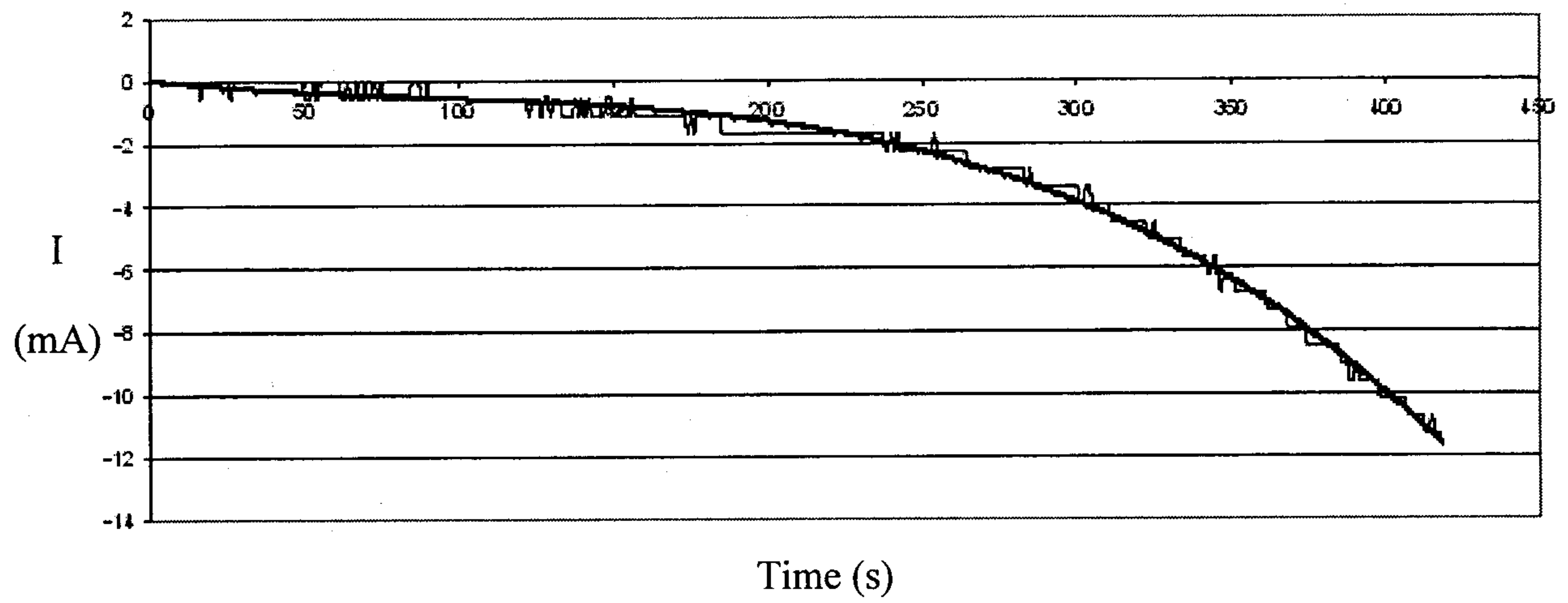


Fig. 12

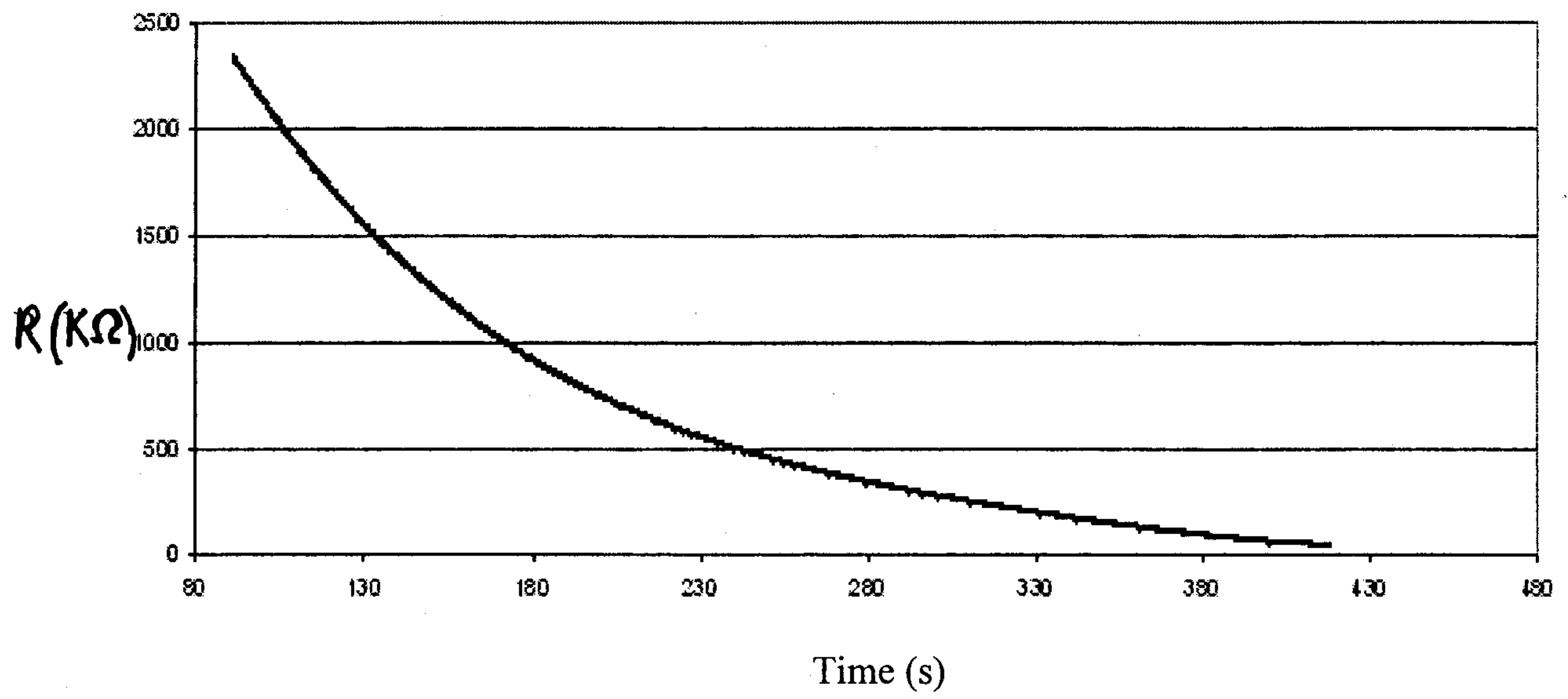


Fig. 13

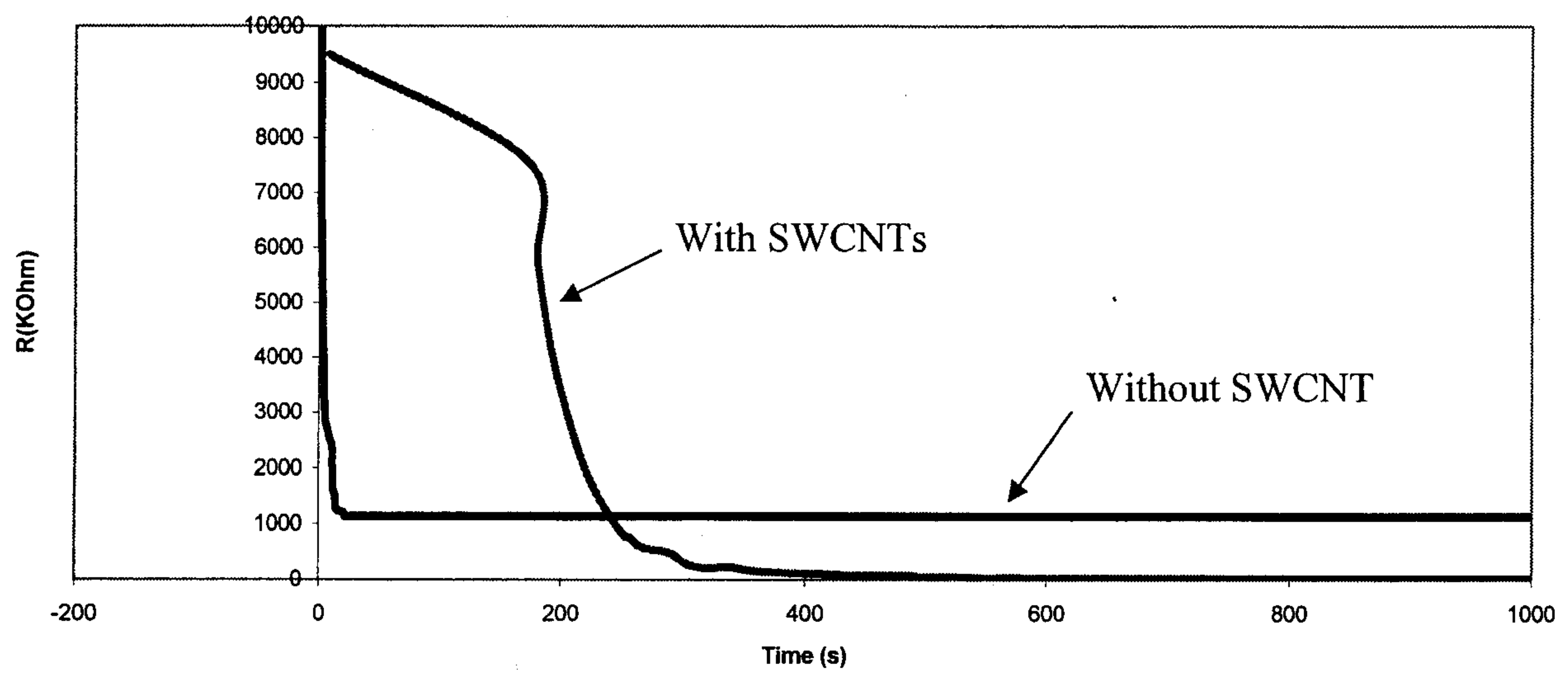


Fig. 14

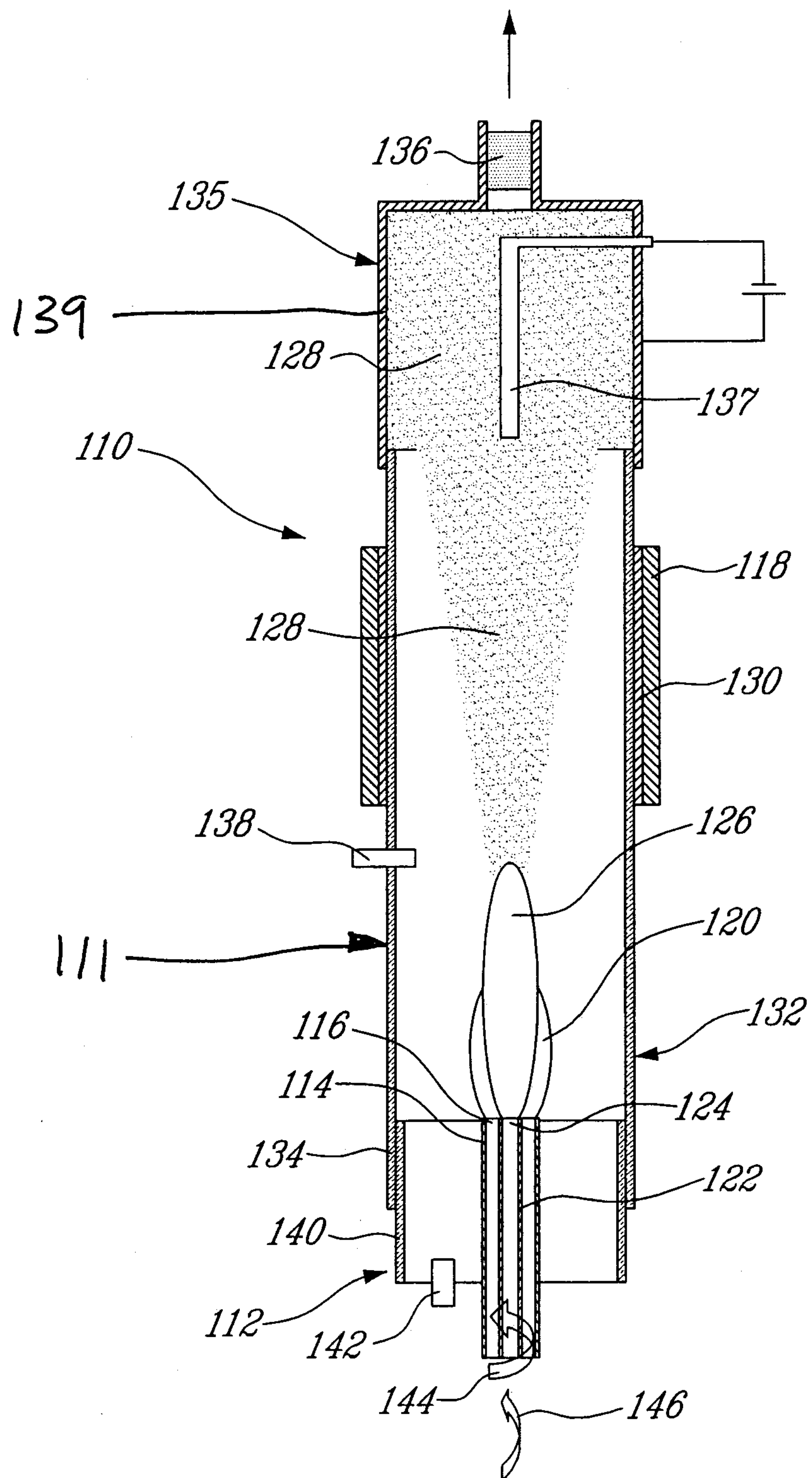


Fig. 15

