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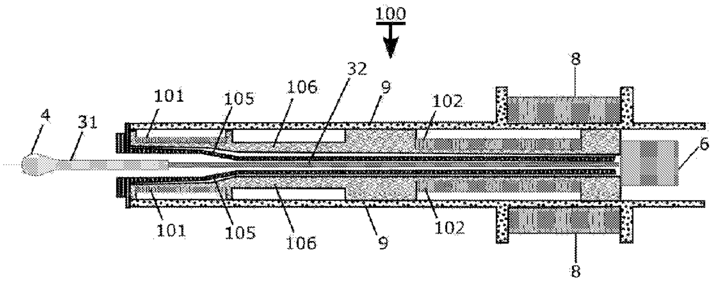

Figure 1 C

(57) Abstract: The apparatus of the invention for measuring intraocular pressure comprises a functional part (100) with a tubular probe base (105) and a probe (3) contactable with a surface of an eye to derive an intraocular pressure in the eye from variations in a velocity of the probe (3). The probe (3) is inside the tubular probe base (105). The probe (3) is partly formed of magnetic material. An induction coil (101, 102) gives the probe (3) a specific velocity. The apparatus also has means for measuring the variations in a velocity of the probe (3), means for processing and displaying the measurement data, and controlling operations. The apparatus is mainly characterized by means (6) for holding the probe (3) inside the tubular probe base (105), and means for releasing the probe (3) for the measurement.

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APPARATUS FOR MEASURING INTRAOCULAR PRESSURE

TECHNICAL FIELD

The invention is concerned with an apparatus for measuring intraocular pressure. It comprises a functional part with a tubular probe base and a probe contactable with a surface of an eye to derive an intraocular pressure in the eye from variations in a velocity of the probe, which is inside the tubular probe base. The probe is partly of magnetic material. An induction coil gives the probe a specific velocity. The apparatus also has means for measuring the variations in a velocity of the probe, means for processing and displaying the measurement data, controlling operations, means for holding the probe (3) inside the tubular probe base, and means for releasing the probe for the measurement.

BACKGROUND

Tonometry is a method for measuring intraocular pressure and the apparatus used for the measurements is called tonometer. Various types of tonometers exist. In contact tonometry, there is a physical contact with the cornea during measurement. A probe is directed against the surface of the cornea, the elasticity of which is measured using various methods. The Goldmann tonometer and the Schiótz tonometer are examples of tonometers.

Two of the most commonly used principles are the measurement of the force required to applanate a certain area of the surface of the eye, or the measurement of the diameter of the area that is applanated by a known force. These methods require the patient's co-operation and cannot be applied without general anaesthesia.

Methods, such as those presented in US patent publications, 5148807, 5279300, and 5299573, in which the surface of the cornea is not touched, the intraocular pressure is instead measured with the aid of a water or air jet, or various kinds of waves, have also been developed. These methods are technically complex and thus expensive. Meters operating on the air-jet principle are widely used by opticians, but their cost has prevented them from being more extensively used by general practitioners.

Rebound tonometry is a type of contact tonometry, wherein a probe, which is partly of magnetic material is accelerated towards an eye by means of an inductive coil system. Upon contact with the cornea of the eye, the probe starts to decelerate and rebounds from the eye. As a result, a voltage is induced in an other coil and the intraocular pressure is calculated from measurement data of parameters of the moving.

US patent 6, 093,147 is mentioned as prior art for such a tonometer. It comprises a probe, which is propelled at a constant velocity in the horizontal direction to impact the eye and includes a device for continuously determining the velocity of the probe. The tonometer disclosed is suitable for horizontal measurements.

The problem with the rebound tonometers of prior art is that measurements, in which the probe in the tonometer apparatus moves in an inclined direction, are not possible to make securely since the probe tend to fall from the apparatus when it is inclined. This means that the measurements have to be done with the patient in upright position if the probe is not prevented from falling by e.g. mechanical means and/or by regulating the driving current and using a wide probe holder, which prevents the probe from falling from the device.

However, in some situations, it is necessary to perform intraocular pressure measurements when the patient is in a non-vertical position, such as during eye surgery. Consequently, an inclined measurement, especially a vertical measurement, is a very useful and desired feature in tonometry.

US patent publication 5176139 discloses a method based on rebound technology, in which a freely-falling ball is dropped onto the eyelid and the height of the ball's rebound is measured. The amount of the ball rebound varies depending on the amount of intraocular pressure and the latter is judged against the amount of the ball rebound. The method solves the above problem mechanically by having a spring lock to prevent the ball from falling and keep it in the top most position. Upon depressing the spring lock, the ball is released for the measurement. The patient can be either recumbent (by leaning back) or sitting during the measurement.

CN patent publication 104274153A is mentioned as prior art for a soft touch intraocular pressure horizontal or vertical measuring device and method, the device comprising a small magnetic needle pressure measuring probe, a front end device, and a driving

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adjusting circuit. The device has a magnetic induction coil connected with an electric solenoid skeleton that is provided with a permanent magnet and an iron core. When the power is on, the probe can be prevented from falling during a vertical measurement by introducing currents in the coils.

There is, however, need for a tonometer device, wherein the probe stays inside the tonometer whether the power is on or off. Also, there is need for a tonometer device, wherein the movement of a rebound type probe can be more easily controlled in all kind of measurements.

A reference herein to a patent document or any other matter identified as prior art, is not to be taken as an admission that the document or other matter was known or that the information it contains was part of the common general knowledge as at the priority date of any of the claims.

Where any or all of the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other features, integers, steps or components.

SUMMARY

The apparatus of the invention for measuring intraocular pressure comprises a functional part with a tubular probe base and a probe contactable with a surface of an eye to derive an intraocular pressure in the eye from variations in a velocity of the probe. The probe is inside the tubular probe base. The probe is partly of magnetic material. An induction coil gives the probe a specific velocity. The apparatus also has means for measuring the variations in a velocity of the probe, means for processing and displaying the measurement data, controlling operations, means for holding the probe inside the tubular probe base, and means for releasing the probe for the measurement. The apparatus is mainly characterized in that the means for holding the probe is a magnetic circuit and the means for releasing the probe is a magnetic coil.

The preferable embodiments of the invention have the features of the subclaims.

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With inclined measurements is meant measurements in which the measurements are performed with the tonometer in such a position that the probe is during measurement moving in a direction forming an angle compared to the horizontal plane. Vertical measurements, wherein this angle is 90°, is to be seen as a special case of an inclined measurement, in which the measurements are performed with the tonometer in such a position that the probe is moving vertically during measurement (i.e. perpendicularly to the horizontal plane).

Currently, in the rebound tonometer apparatuses of prior art, the probe does not fall from the tonometer when the power is on even if the apparatus is inclined because the measuring coil is pulling the probe back. However, the clinicians performing the measurement might not remember to switch the power on before inclining the apparatus for the measurement, which is a risk for the patient to get the probe in the eye if there is no additional means to prevent the probe from falling.

In the apparatus of the present invention, vertical and other inclined measurements are risk-free thanks to the inventive means for holding the probe inside the tonometer in a probe base. The probe stays inside the probe base of the tonometer independently of whether the power is on or off.

The means for holding the probe inside the probe base can e.g. be a magnetic circuit like in the invention, or it can be a mechanical lock, or a friction brake.

In the developing of the apparatus of the invention, the focus has been in the control of the influence of gravity on the probe. With the apparatus of the invention, an inclined/vertical measurement can be performed by decreasing the driving current as a function of the inclination degree because the influence of gravity on the probe also changes as a function of the inclination degree.

The intraocular pressure is determined from the movement parameters, which are examined from the induced voltage in the measuring coil.

The improvement of the invention of holding the probe inside the probe base during inclined/vertical measurement also when the power is off improves the usability of the device. Yet, the invention retains the apparatus' as a simple, economical, and precise measuring basic construction by means of which intraocular pressure also can be

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measured in patients incapable of co-operating. In addition, the apparatus of the invention is also suitable for extensive screening campaigns, as the measurements are rapid and require neither local anaesthesia nor specially trained operators. The position of the apparatus during the measurements is now more flexible including the possibility for both horizontal and inclined/vertical measurements in a secure way.

Next, the invention will be described by means of some example embodiments and accompanying figures to which the invention is not restricted.

FIGURES

Figure 1A presents a first type of a probe that can be used in the embodiments of a tonometer of the invention

Figure 1B presents a second type of a probe that can be used in the embodiments of a tonometer of the invention

Figure 1C presents a first embodiment of a tonometer of the invention, wherein the holding mechanism is a magnet and the releasing actuator is a magnetic coil

Figure 2 presents a second embodiment of a tonometer of the invention, wherein the holding mechanism is a magnet and the releasing actuator is a magnetic coil

Figure 3 presents a third embodiment of a tonometer of the invention, wherein the holding mechanism is a magnet and the releasing actuator is a magnetic coil

Figure 4 presents a fourth embodiment of a tonometer of the invention, wherein the holding mechanism is a magnet and the releasing actuator is a magnetic coil

Figure 4B is a cross-sectional view of the magnet and the releasing actuator of figure 4

Figure 5 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnet and the releasing actuator is a magnetic coil

Figure 6 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnet and the releasing actuator is a magnetic coil

Figure 7 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnet and the releasing actuator is a magnetic coil

Figure 8 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnet and the releasing actuator is a magnetic coil

Figure 9 presents a tonometer, wherein the holding mechanism is a friction brake caused by a solid object and the releasing actuator is a piezoelectric element, a pneumatic membrane, a hydraulic membrane or a magnetic coil

Figure 10 presents a tonometer, wherein the holding mechanism is a mechanical catch and the releasing actuator is a piezoelectric element, a pneumatic membrane, a hydraulic membrane or a magnetic coil

DETAILED DESCRIPTION

Figure 1A presents a probe 3 that can be used in the embodiments of an apparatus of the invention for measuring intraocular pressure, i.e. in a tonometer. The probe 3 is formed of a rear part 32 of magnetic material, such as steel, and a front part 31 of non-magnetic material, such as a plastic material. The front part 31 of the probe 3 has a tip 4, which impacts the eye in the measurement of the intraocular pressure.

Figure 1B presents a probe 3 that can be used in the embodiments of an apparatus of the invention for measuring intraocular pressure, i.e. in a tonometer. The probe 3 is partly of magnetic material and the probe 3 has a tip 4, which impacts the eye in the measurement of the intraocular pressure.

Figure 1C presents a first embodiment of a functional part 100 of the tonometer of the invention, wherein the probe 3 of figure 1A and figure 1B can be used.

The functional part 100 together with other components belonging to a tonometer are inside a tonometer case. Examples of other components in the tonometer are means for adjusting the distance from which the probe is launched for impacting the eye, batteries, from which the apparatus gets its operating power, a circuit board on which the electronics of the apparatus are assembled, a display, a processing unit, and a socket, to which an external recharging device can be connected. The means for adjusting the distance can be an adjustable forehead support. Only the functional part 100 of the tonometer is presented in the figures. The above components of a tonometer are closer presented in WO publication 03/105681.

The functional part 100 has a frame pipe 9, inside which there is an inner tube around the probe 3, which is partly of magnetic material. The inner tube is hereafter referred to as the probe base 105.

The probe 3 is accelerated towards an eye by means of a driving inductive coil system 101 in the front end of the probe base 105. The force pushing the probe 3 is generated in the coil 101 by a voltage fed to the coil 101. So power is supplied to the front coil 101 causing the probe 3 to start moving and to impact the eye. Upon contact with the cornea of the eye, the probe 3 starts to decelerate and rebounds from the eye.

As a result, a voltage, which is dependent on the intraocular pressure, is induced in another coil 102. The coils 101 and 102 are mounted on a coil frame 106.

This voltage and other parameters, such as the speed of the probe 3, are detected by the rear coil 102 and recorded and processed with a data processing unit (not shown). The intraocular pressure is calculated by means of an algorithm from the measurement data of parameters of the moving probe 3 and the result is presented on a display of the tonometer.

The tonometer of the invention might also comprise means for correcting the measurement results in proportion to how much kinetic energy is lost or gained in the impact and rebound of the probe.

Instead of the front coil 101 giving the probe 3 the launching power, it is possible to use the rear coil 102.

One of the coils 101 and 102 are intended to operate also as a retainer for holding the probe 3 in place when the power is switched on in the tonometer.

After the impact has occurred and the measurement result has been obtained, there is a risk that the probe 3 detaches due to movements of the tonometer or for other reasons. This is prevented in the embodiment of figure 1C of the invention by using a magnetic circuit 6 (such as a magnet), which magnetic circuit 6 can be located behind the rear part of the probe base 105 (in the opposite end of the apparatus than the tip 4 of the probe 3).

The magnetic circuit 6 holds the probe 3 inside the probe base 105 in any position of the apparatus once the probe 3 is loaded into the probe base 105.

The magnetic circuit 6 can consist of a permanent magnet. Means for releasing the probe, such as a releasing coil 8, is placed around the frame pipe 9 in order to cancel the effect of the magnetic circuit 6 during measurement. Consequently, the probe 3 can move. The frame pipe 9 works as a case in the functional part 100 of the apparatus.

When current is flown into the releasing coil 8 during measurement, the resulting magnetic field compensates the effect of the magnetic field of the magnetic circuit 6 and the probe 3 can move.

The control functions of the releasing coil 8 is integrated into the electric circuit board of the tonometer. The releasing coil 8 gets its power from the power supply and the currents flow in the releasing coil 8 and the driving coil 101 flow during a measurement.

The position, shape, dimensions, material, layers and turns of the magnetic coil are not fixed and can be adapted suitable case by case. Similarly, the position, shape, dimensions, material and grade of the magnet 6 are not fixed and can be adapted suitable case by case.

Figure 2 presents a second embodiment of a tonometer of the invention. In this embodiment, the releasing coil 8 is wrapped around the frame pipe 9 like in the first embodiment of figure 1B but the frame pipe is split into two parts, i.e. a rear frame part 9A and a front frame part 9B.

Figure 3 presents a third embodiment of a tonometer of the invention. The frame pipe 9 is in one part like that in figure 1C. A centralizing part 10 between the frame pipe 9 and the magnetic circuit 6 facilitates the mounting and keeping of the magnet 6 in place.

The embodiment of figure 4 otherwise corresponds to that of figure 1C but the releasing coil 8 is directly wound around the magnet 6, whereby the means 6 for holding the probe 3 inside the probe base 105 are integrated with the means 8 for releasing the probe 3.

Figure 4B is a cross-sectional view of the magnet 6 around which the releasing coil 8 has been wound.

Figure 5 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnet and the releasing actuator is a magnetic coil.

A magnet 6 generates a magnetic field and the probe 3 turns parallel to the field. Because of the turning, the probe touches the probe base 105, which causes friction between the contact areas of the probe 3 and the probe base 105. The friction prevents the probe 3 from moving and falling out from the device. During a measurement, current flows into the releasing coil 8 and the produced magnetic field compensates the effect of the magnetic circuit 6. Consequently, the probe can move.

Figure 6 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnetic circuit 6 and the releasing actuator is a magnetic coil 8. Here the magnetic circuit 6 is on the frame pipe 9 of the functional part 100 and the releasing coil 8 is inside the frame pipe 9. The releasing coil 8 is outside the rear part of the coil frame 106.

Figure 7 presents a tonometer, wherein the holding mechanism is a friction brake caused by a magnetic circuit 6 and the releasing actuator is a magnetic coil 8. Here the position of the magnetic circuit 6 is like in figure 6 around the releasing coil 8 with the frame pipe 9 there between, but the magnetic circuit 6 and the releasing coil 8 are in the front part of the functional part 100 between the driving coil 101 and the measuring coil 102.

Figure 8 presents a tonometer, wherein the holding mechanism is a friction brake caused by a holding magnet and the releasing actuator is a magnetic coil. The releasing coil 8, which is around the magnet 6 is outside the rear part of the functional part 100, the combination being mounted on the frame pipe 9.

A magnet 6 generates a magnetic field which is guided via a magnetic material 11 placed in the vicinity of the magnet 6. The magnetic field affects the probe 3 and it tries to turn parallel to the field. Because of the turning, the probe 3 touches the probe base 105, which causes friction between the contact areas of the probe base 105 and the probe 3. The friction prevents the probe 3 from moving and falling out from the device. During a measurement, current flows in the releasing coil 8 and a produced magnetic field compensates the effect of the magnet 6. Consequently, the probe 3 can move.

Figure 9 presents a tonometer, wherein the holding mechanism is a friction brake caused by a solid object and the releasing actuator is a piezoelectric element, a pneumatic membrane, a hydraulic membrane or a magnetic coil.

A solid object 12 is in contact with the probe 3 and causes friction between the contact areas of the probe 3 and the solid object 12. The friction holds the probe 3 so that it can not move or fall out from the device. During the measurement, the releasing actuator 8' shifts the solid object 12 so that it does not touch the probe 3 anymore. Consequently, there is no friction and the probe 3 can move.

The releasing actuator 8' is on the frame pipe 9 at the rear part of the functional part 100 and the solid object touches the rear end of the probe 3, which is partly inside the releasing actuator 8'.

Figure 10 presents a tonometer, wherein the holding mechanism is a mechanical catch and the releasing actuator is a piezoelectric element, a pneumatic membrane, a hydraulic membrane or a magnetic coil.

There is a notch 13 in the rear part of the probe 3. A solid object 12' is placed on the notch 13 and these work together as a mechanical catch. The catch prevents the probe

3 from moving and falling out from the device. During the measurement, the releasing actuator 8’ lifts the solid object 12’ and the probe 3 can move.

The releasing actuator 8’ is on the frame pipe 9 at the rear part of the functional part 100 and the mechanical catch is at the rear end of the probe 3.

CLAIMS

1. An apparatus for measuring intraocular pressure, which comprises a functional part with
   a tubular probe base,
   a probe contactable with a surface of an eye to derive an intraocular pressure in the eye from variations in a velocity of the probe, the probe being inside the tubular probe base, and the probe being partly of magnetic material,
   an induction coil for giving the probe a specific velocity,
   means for measuring the variations in a velocity of the probe,
   means for processing and displaying the measurement data,
   controlling operations,
   means for holding the probe inside the tubular probe base, and
   means for releasing the probe for the measurement,
   wherein the means for holding the probe is a magnetic circuit, which is located behind the rear part of the probe base in the opposite end of the apparatus than the tip of the probe, and the means for releasing the probe is a magnetic coil.

2. An apparatus according to Claim 1, wherein the means for releasing the probe is located at the rear part of the probe base.

3. An apparatus according to Claim 1, wherein the means for releasing the probe are located at the rear part of the probe base, and include a centralized part between a frame pipe and the magnetic circuit, which centralized part keeps the magnetic circuit in place.

4. An apparatus according to Claim 1, wherein the means for holding the probe inside the tubular probe base and the means for releasing the probe are integrated, whereby the means for releasing the probe are wound in the form of a releasing coil around the means for holding the probe inside the tubular probe base.

5. An apparatus according to any one of the preceding claims, wherein the induction coil is intended also to operate, when the power is switched on in the apparatus, as a retainer for holding the probe in place.

6. An apparatus according to any one of the preceding claims, wherein it includes means for correcting the measurement results in proportion to how much kinetic energy is lost or gained in the impact and rebound of the probe.

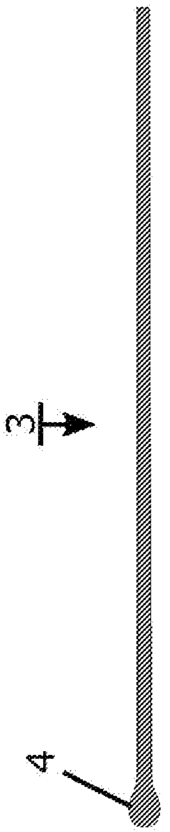

Figure 1 B

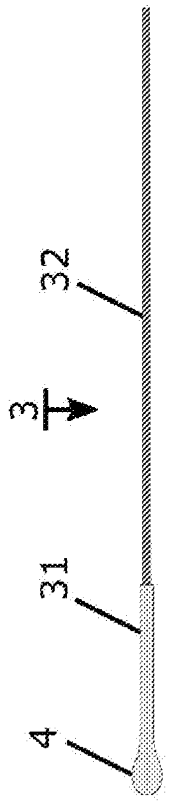

Figure 1 A

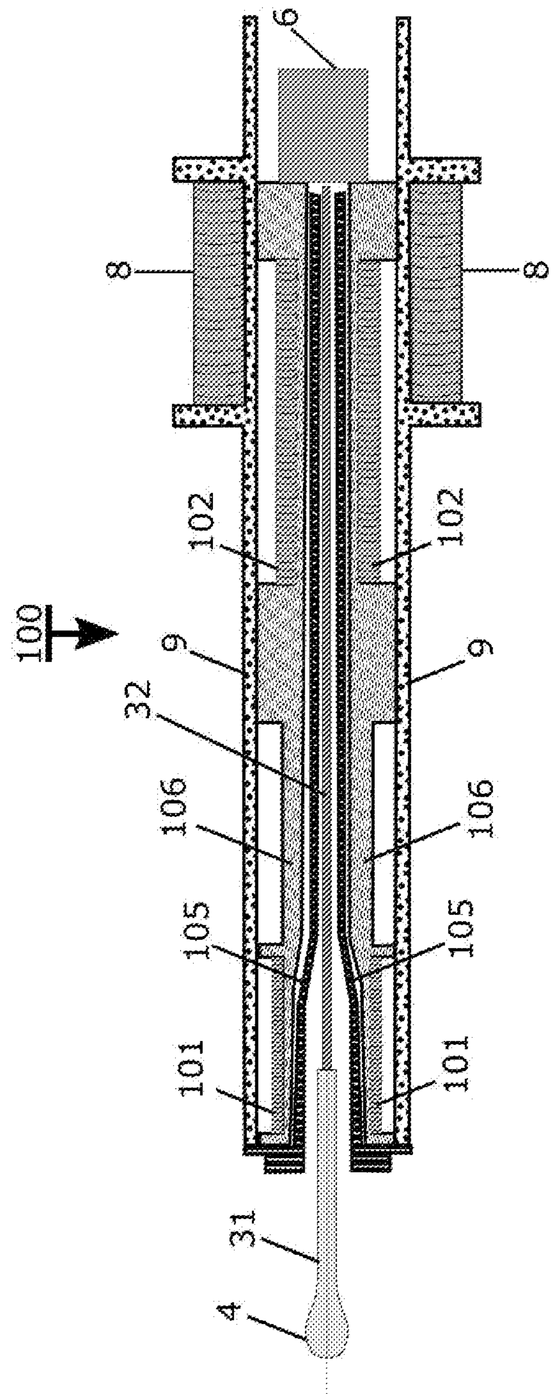

Figure 1 C

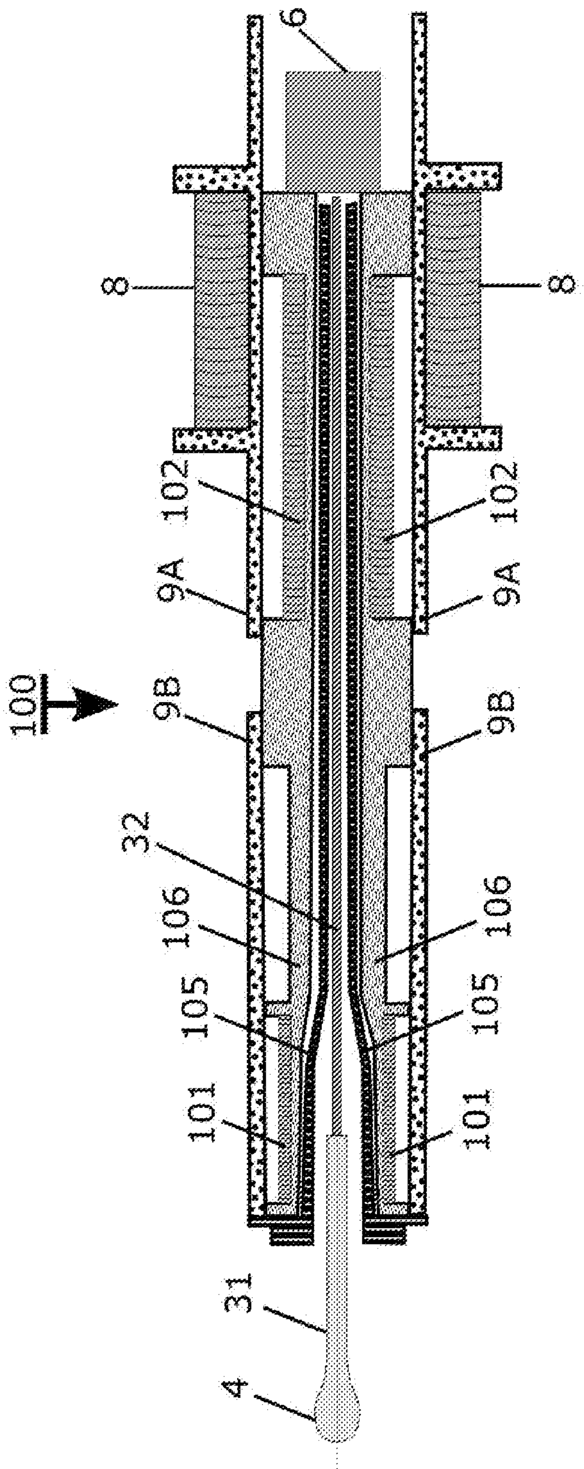

Figure 2

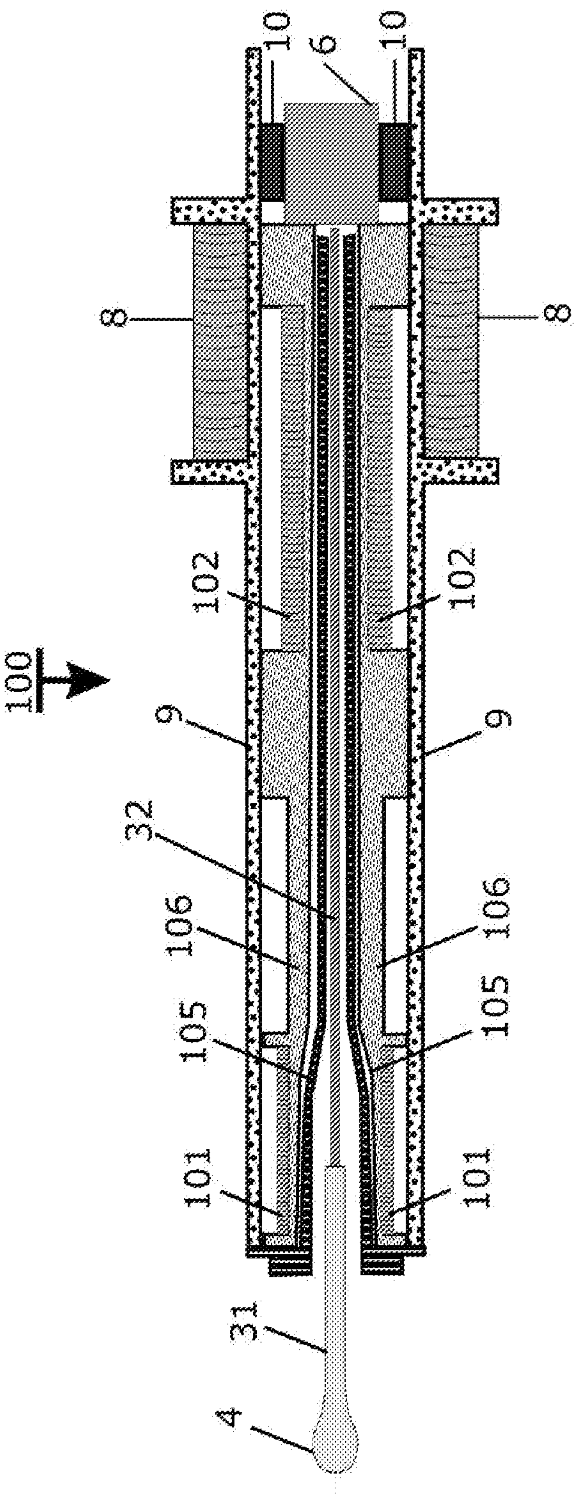

Figure 3

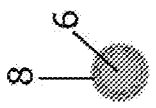

Figure 4B

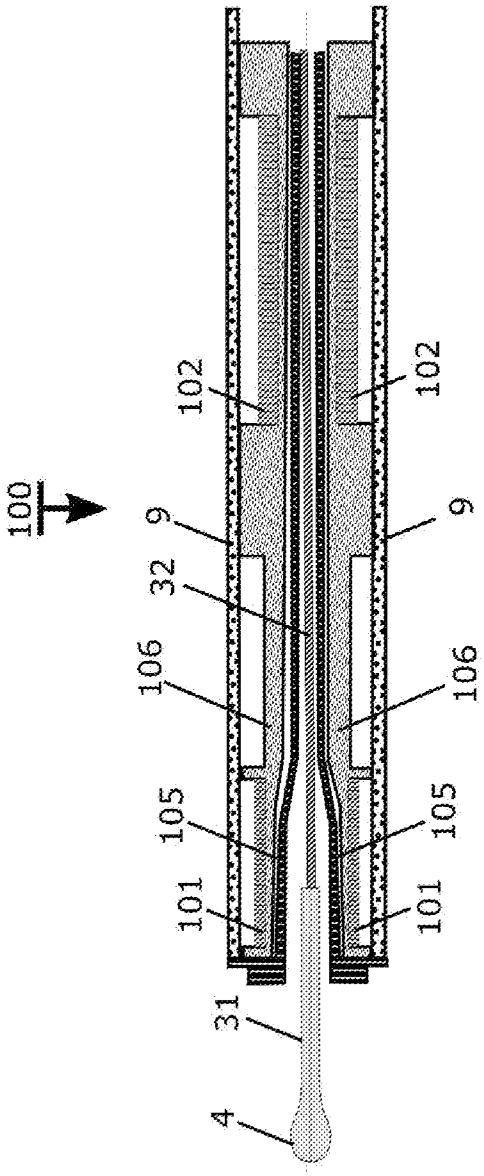

Figure 4

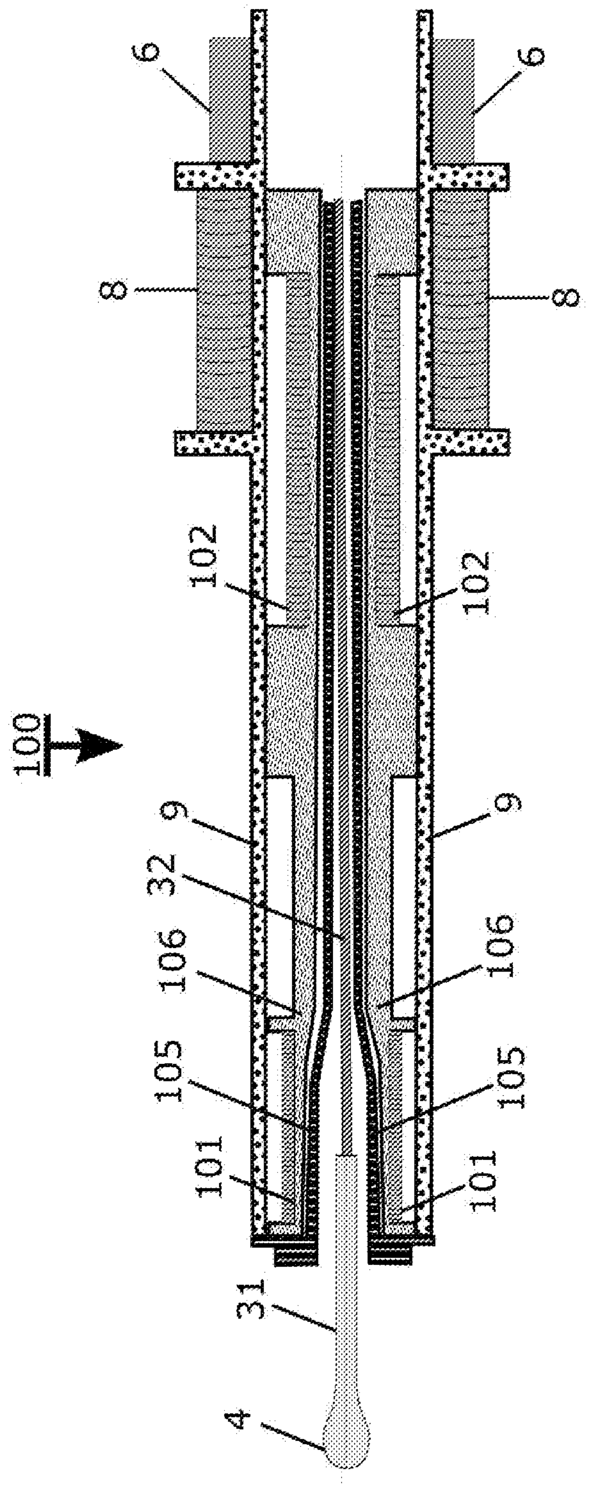

Figure 5

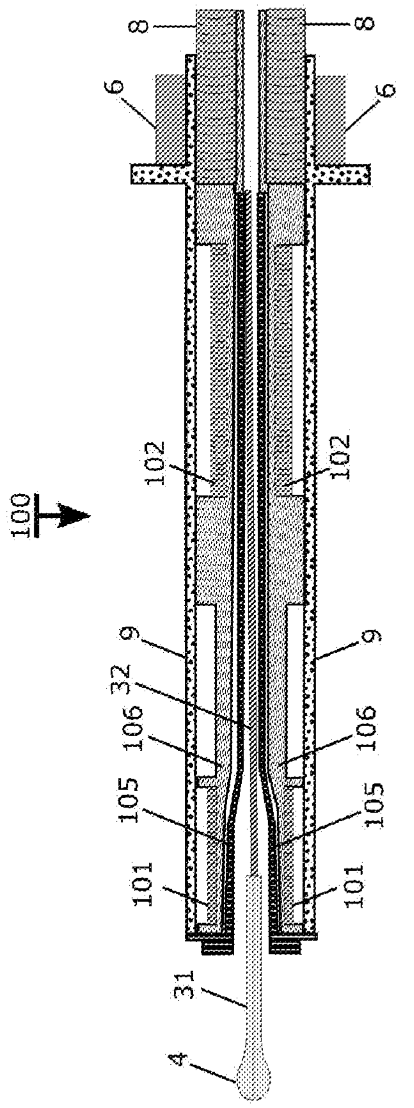

Figure 6

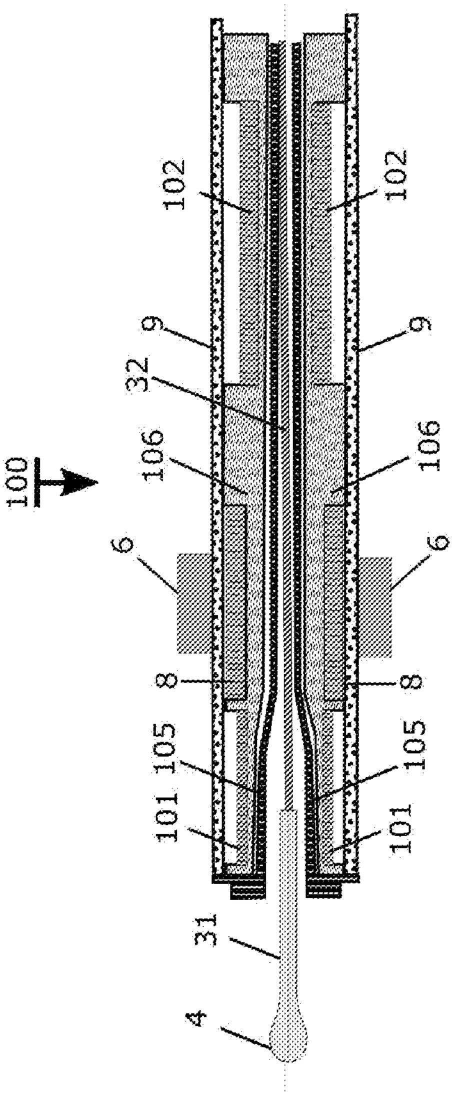

Figure 7

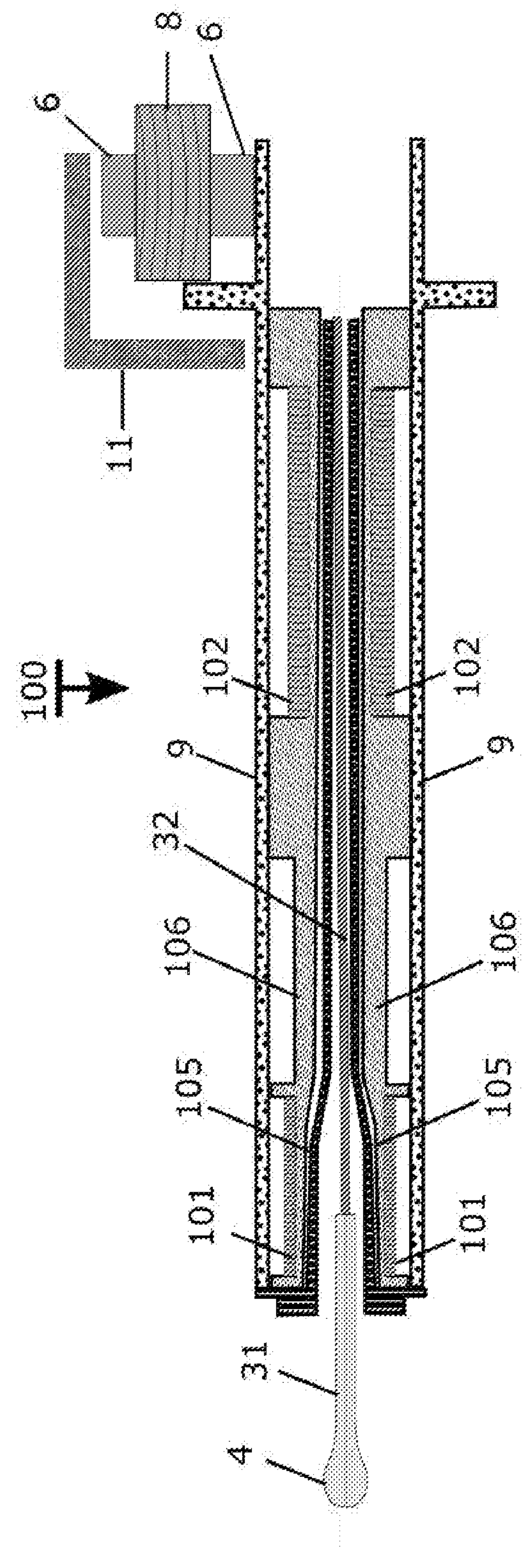

Figure 8

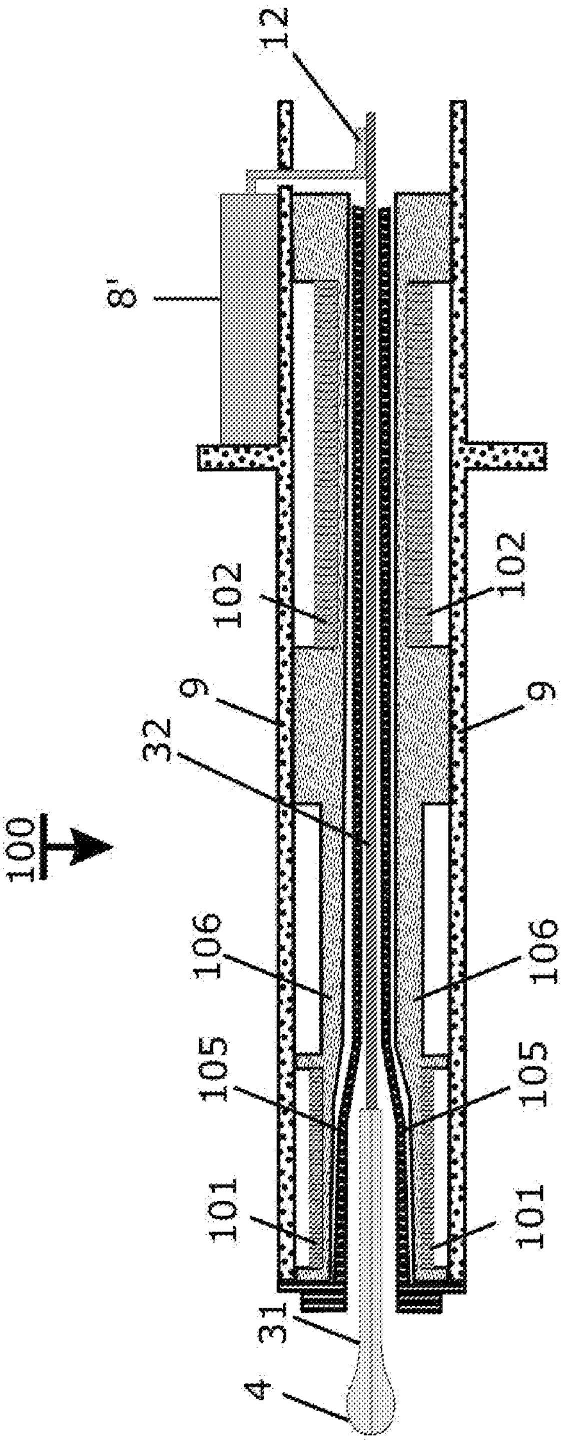

Figure 9

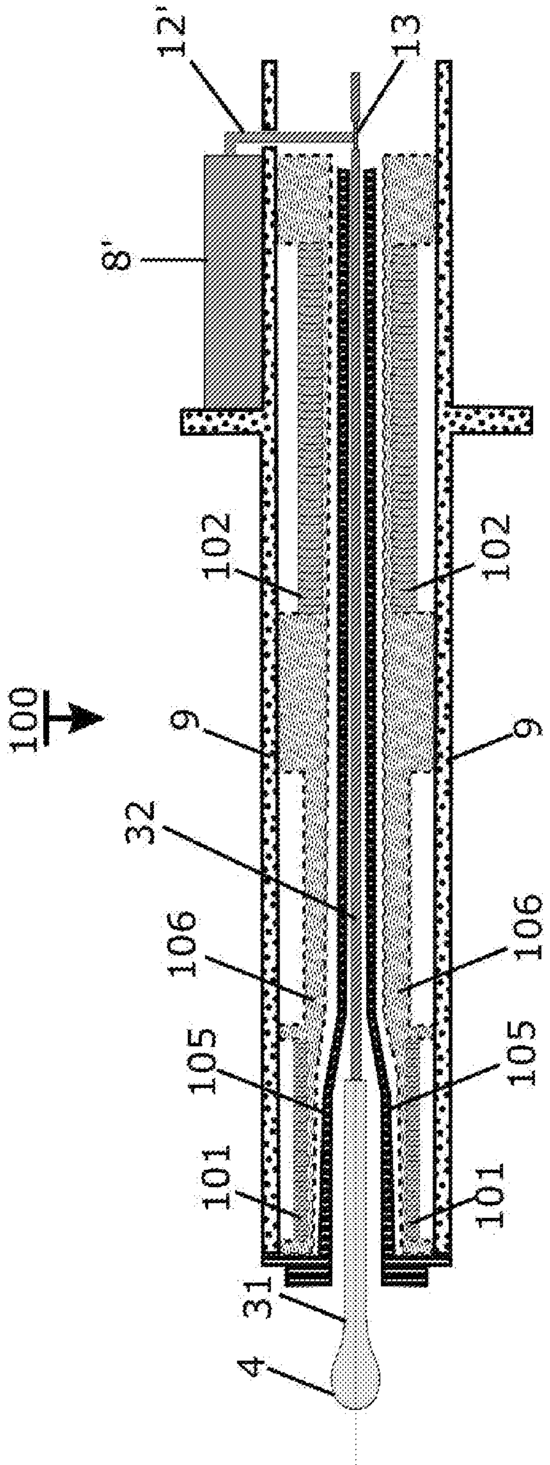

Figure 10