



(51) International Patent Classification:

H05H 1/24 (2006.01) A61B 18/04 (2006.01)
H05H 1/48 (2006.01) A61L 2/14 (2006.01)

(21) International Application Number:

PCT/GB2015/053294

(22) International Filing Date:

2 November 2015 (02.11.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1419636.4 4 November 2014 (04.11.2014) GB

(71) Applicant: **FOURTH STATE MEDICINE LTD** [GB/GB]; Surrey Technology Centre, Unit 56-57, 40 Occam Road, Surrey GU2 7YG (GB).

(72) Inventors: **KNOLL, Aaron**; 1 Cromwell Way, Farnborough, Hampshire GU14 8LN (GB). **HARLE, Thomas**; 90 Marlborough Road, Southend on Sea, Essex SS1 2UD (GB). **SHAW, Peter**; 4 Cooks Mead, Rusper, Horsham, Sussex RH12 4PU (GB). **FRAME, Thomas**; 3 Poinsettia Close, Titchfield Park, Hampshire PO15 5DW (GB). **WANTOCK, Tom**; 21a Chequers Road, Basingstoke, Hampshire RG21 7PU (GB).

(74) Agent: **CASSIE, Matthew**; 140 London Wall, London, Greater London EC2Y 5DN (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: PLASMA GENERATION

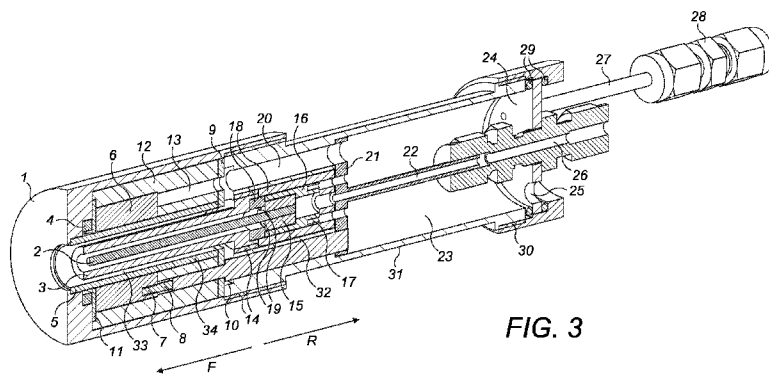


FIG. 3

(57) Abstract: A plasma torch having an open end from which a plasma plume is emitted in use is disclosed. The plasma torch includes a central cathode rod, a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form a first cylindrical cavity open at one end; and a high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof and being arranged around the grounded conductive tube and spaced apart therefrom to form a second annular cylindrical cavity open at one end. A constant direct current (DC) electrical power plus a high voltage pulsed electrical power is provided to the cathode producing an arc discharge in the first cavity between the cathode and grounded tube to generate a central thermal plasma emitted at an open end of the first cylindrical cavity. A high voltage alternating current electrical power or pulsed electrical power is provided to the high voltage electrode producing a dielectric barrier discharge in the second annular cylindrical cavity to generate a non-thermal plasma emitted from an open end of the second cavity as a halo around the central thermal plasma.



PLASMA GENERATION

FIELD OF THE TECHNOLOGY

[0001] The present invention relates generally to plasma generation. In particular, the present invention relates to plasma torches, electrical power generator unit, control modules and methods of operation thereof for producing a cooperative plasma plume having a central thermal plasma blade and a non-thermal plasma halo. The plasma plume finds particular utility in cosmetic treatment of skin, in surgical treatment of wounds and in sterilization of objects in industrial processes.

BACKGROUND

[0002] Surface ablation of biological tissue is a process used in a variety of medical procedures. An ablation process may be used to remove unwanted tissue and can also be used, in certain tissues, to stimulate or induce regeneration and renewal.

[0003] Various cosmetic treatments are known and widely used that attempt to reduce the effects of ageing through surface ablation or other minor trauma of the skin to induce regeneration thereof. The skin is made up of two main layers, the dermis and the epidermis which provides the exposed surface. The epidermis comprises layers of maturing skin cells one on top of the other, with the outermost layer being a layer of dead cells that is shed and replaced by layers underneath as they reproduce. These cosmetic procedures aim to improve the appearance of patient's skin with the intention of, for example, reducing visible fine lines and wrinkles, 'rejuvenating' the skin to remove pigment spots and providing a smoother finish, and improving the appearance of scar tissue, such as scars resulting from acne.

[0004] These cosmetic procedures typically fall into three categories: mechanical procedures, chemical procedures and laser procedures.

[0005] 'Mechanical' procedures achieve the resurfacing of the skin by removing unwanted skin by mechanical abrasion. Microdermabrasion is a light, non-invasive non-surgical cosmetic procedure that works to achieve the removal of dead skin cells in the topmost layer of the epidermis by action small abrasive granular crystals of, for example, aluminium oxide. Microdermabrasion is useful for cosmetically treating fine irregularities in the texture of the skin, fine wrinkles and superficial scarring, but it is temporary in its

effect and it is typically not capable of improving the appearance of the skin by deep resurfacing and rejuvenation to remove more significant wrinkles and scarring.

[0006] Dermabrasion, on the other hand, is a more significant, surgical procedure for effectively removing the top to mid-layers of the skin (the epidermis and even the dermis) using abrasive wheels, brushes and sandpaper to mechanically attack and remove unwanted skin. As deep layers of skin tissue are removed, significant bleeding can often result and so a local or even general anesthetic is required and dermabrasion is typically performed by a medical professional in a medical or surgical setting. The deep ablation and resurfacing of skin by dermabrasion can, following recovery, achieve an improved skin appearance by removing deeper scarring, fine wrinkles and skin irregularities. However, with dermabrasion there is no fine depth control, and the abrasives have to be applied to a wide area of the skin in order to 'blend' the finish, preventing effective treatment of localized irregularities. The traumatic effect on the skin and required recovery time of dermabrasion is significant.

[0007] Chemical peel procedures use a variety of chemical types which when applied directly to the skin, change the skin composition and cause unwanted skin to slough off the surface. Lighter peels can be applied in non-medical settings in cosmetic skincare treatment centres and these can achieve moderate, longer term improvement in the appearance of fine wrinkles and minor skin irregularities. However, medium and higher strength peels that remove skin to deeper layers are surgical treatments that require the expertise of medical practitioners to understand the effect of the chemical peel mixture, but can achieve improved skin appearance of more significant wrinkles and irregularities. However, there is no fine depth control available in any chemical peels, and the peel treatment must be applied to the whole area of the skin – e.g. the face, preventing localized treatment. Chemical peels can often require long recovery periods and also side effects on the skin such as photosensitivity. Repeat peels may also be needed to achieve a desired effect for a longer term.

[0008] Laser skin resurfacing, however, has addressed a number of shortcomings of dermabrasion and chemical peels and is capable of achieving skin resurfacing and rejuvenation to significantly improve skin appearance, and can even reduce the appearance of deeper wrinkles including frown lines and crows feet. Here, a CO₂ or

Er:YAG laser light is used to act to rejuvenate the skin by dissociating the molecular bonds in the surface and subsurface layers of the skin to induce trauma and cause the skin (in particular the layers of the epidermis) to rejuvenate. In addition, the deep heating of the lower layers of the skin by the laser is understood to stimulate fibroblasts in the dermis to form new collagen and elastin to increase the turgor (elasticity) and thickness of the skin, helping to reduce the appearance of deep wrinkles and aging skin. Rather than laser treating the entire surface of the skin, laser treatments typically are delivered to a fraction of the skin in a pattern of pinpoints (or Microscopic Treatment Zones, MTZ) spread over an area of the skin, between which healthy skin remains, which reduces healing time and recovery. Compared to dermabrasion and chemical peels, laser treatment does allow a degree of localized control based on the requirements of the skin area by area. However, this pinpoint patterning of the ablated skin can leave a visible patterned finish even after recovery that is emphasized should further treatment (such as a facelift) be undertaken. As a result of this finish, laser skin resurfacing is not suitable for using in treating small 'zones' of skin, as the pattern of pin pricks cannot be blended.

[0009] A metric useful for assessing energy sources for ablation is fluence, defined for pulsed laser ablation energy sources as the energy of the laser pulse (Joules, J) divided by the area of the incident laser spot (in cm²). Generally, the greater the fluence of the laser, the greater the depth of penetration and rejuvenation of the dermis. For a typical comparison, energy levels achieved using one, well-known system marketed under the trade name Fraxel™ re:pair™ available from Fraxel range from 5-70mJ/MTZ, giving a high level of equivalent fluence in the order of a hundred Joules per cm². Thus a high, concentrated energy transfer is achievable with pulsed fractionated laser systems to a low level of the dermis. For the Fraxel™ re:pair™ system, the penetration depth achievable is from 200-1500 microns. As such, laser treatment is capable of achieving improved deep wrinkle reduction and skin resurfacing with significantly reduced bleeding, side effects and recovery time compared to dermabrasion and strong chemical peels. As a result, laser skin resurfacing can be provided as a cosmetic non-surgical treatment in a non-medicalised setting, administered by a trained operator who is not necessarily a medical professional.

[0010] It has been suggested that plasma, the fourth state of matter, formed by, for example, ionizing a gas, could be used to rejuvenate skin. One such system using a gas plasma for ablative tissue rejuvenation was developed by Rhytec Ltd in the United Kingdom and is now marketed under the brand name of NeoGen™ by Energist Ltd. of United Kingdom, for which more information is currently available from the following URL: <http://www.energistgroup.com/>.

[0011] Rhytec Ltd's International patent application publication no. WO 2001/62169 A2 discloses the technology underlying the development of the NeoGen™ system. The Rhytec Ltd published patent application discloses a handheld surgical instrument having a conduit carrying nitrogen gas and an electrode structure and radio frequency pulsed power source arranged to produce a dielectric barrier discharge inside the conduit that weakly ionizes the nitrogen gas to produce a low energy, non-thermal plasma to be emitted at a nozzle of the conduit. The plasma produced at the nozzle is used in the cosmetic treatment of fine wrinkles and skin irregularities and operates to rapidly transfer heat to the dermis to stimulate collagen production and increase skin elasticity and thickness. However, unlike with laser treatments, this dermal heating and rejuvenation does not occur at the same time as direct ablation (e.g. by vapourisation) of the upper layers of the epidermis. Thus the side effects and down time of this treatment are less significant than for laser treatment. However, the energy levels transferrable by the NeoGen™ system are only 2-6 Joules per pulse across the size of the plasma plume, are relatively low and unconcentrated compared to laser skin resurfacing, being spread over a spot size of over a square centimetre, giving a low equivalent fluence value on the order of 1 J/cm². While, unlike for laser light, absorption of the plasma energy is not dependent on the presence of a particular chromophore (e.g. water present in cells for CO₂ lasers) leading to more uniform absorption across cell types, skin types and structures, the low equivalent fluence of the NeoGen™ plasma system means that its ability to reliably and effectively treat deep wrinkles and achieve significant skin resurfacing is questionable. The lack of any direct skin ablation, combined with the low fluence, means that the usefulness of the NeoGen™ system for skin resurfacing and removal of significant skin irregularities and wrinkles is very limited. Indeed a large number of repeat procedures

may be needed to achieve any noticeable benefit for anything more significant than fine wrinkles and minor skin imperfections.

[0012] Non-ablative treatments to improve the appearance of ageing skin include the use of dermal fillers, botox and collagen which are injected into the skin. However, these are invasive interventions that have significant side effects on the appearance of the individual by bulking out skin and paralyzing muscles. These treatments do not themselves fundamentally rejuvenate the skin, but rather they seek to achieve improved appearance by 'sculpting' the skin and 'filling out' wrinkles, which can appear unnatural.

[0013] Another non-ablative treatment is radio frequency, infrared or ultrasound skin tightening therapy in which radio frequency, infrared light or ultrasound waves are used to heat the skin to attempt to promote collagen formation to tighten the skin. However, the effect of these treatments is not significant and is only short term in benefit, requiring a large number of repeat sessions.

[0014] In view of the above, there is an interest in new treatments for promoting skin rejuvenation and reducing the appearance of wrinkles and skin irregularities. In addition, the ablation and trauma principle is also used for other surgical purposes, notably wound debridement and tissue regeneration.

[0015] It is in this context that the present invention is devised.

SUMMARY OF THE INVENTION

[0016] Viewed from one aspect, the present invention provides a method of generating a plasma plume from an open end of a plasma torch. The method comprises ionizing a feed gas using an arc discharge in a first cylindrical cavity in the plasma torch to produce a central thermal plasma emitted at an open end of the first cylindrical cavity. The method further comprises ionizing a feed gas using a dielectric barrier discharge in a second annular cylindrical cavity arranged around the first cylindrical cavity in the plasma torch to produce at an open end of the second annular cylindrical cavity a non-thermal plasma halo surrounding the central thermal plasma.

[0017] In accordance with the present invention, a high power plasma treatment is provided that has a wide range of utility. For example, a plasma procedure having the power to cosmetically treat deep wrinkles and significant skin irregularities is provided.

The higher energy, two-stage plasma having a thermal central plasma blade and non-thermal plasma halo has a greater effect on patient outcomes than the prior art, low energy, non-thermal plasma-only devices. In addition, a low recovery period is achieved such that the procedure can be carried out by trained, non-medical personnel in a non-surgical setting. Indeed, cosmetic treatments may be carried out using the present invention in which no anaesthetic is required.

[0018] The two stages of the plasma may be operated incrementally such that the user may initiate only the halo non-thermal plasma to treat some areas of the skin at a lower energy level, whereas the central, thermal plasma may be selectively initiated in addition to the halo plasma to treat selected areas of the skin at a higher energy level. In this way, the energy range achievable, and range of utility of the device, is extremely wide. Thus the plasma treatment system can be used to treat deep wrinkles and significant skin irregularities in a similar way to fractionated laser treatments (albeit with fewer side effects and on a more zonal basis as blending is easier), and also used to treat other areas of the skin for fine lines and wrinkles at lower energy levels.

[0019] The fluence achievable with the two stage plasma is in the region of 10-100 J/cm², which is comparable to the Fraxel™ laser systems, whereas the fluence achievable using only the halo non-thermal plasma is in the order of <1-10 J/cm², which is comparable to the NeoGen™ system.

[0020] While the high energy central thermal plasma is used to ablate tissue (e.g. layers of the epidermis, in a delayed fashion, to encourage rejuvenation and regeneration of the surface layers of the skin) and to thermally stimulate tissue (e.g. lower layers of the dermis to stimulate collagen formation), the non-thermal plasma halo has an effect of sterilizing the tissue surrounding the traumatized tissue, to facilitate healing thereof. In skin, the surface layer is ablated by the high energy plasma, but the surrounding tissue is sterilized by the halo and can remain in situ while the underlying and ablated layers heal such that a natural sterile dressing is formed by the plasma treatment itself, facilitating healing of the traumatized tissue. This further reduces recovery times for such a potentially deep wrinkle and rejuvenation treatment. Surface bleeding is in addition minimized, keeping down time low.

[0021] The arrangement of the two-stages of the plasma is such that they are caused to 'co-operate', whereby the highly ionized, energetic central thermal plasma "blade" produced by an arc discharge has a collimating effect on the surrounding non-thermal plasma halo, whereby at least some of the non-thermal plasma halo is entrained or focused by the central plasma. This brings the two types of plasma together into a more concentrated, co-operative plume in which an increased flux of free radicals, generated in the weak ionization of the gas by the dielectric barrier discharge in the non-thermal plasma, is produced at the energetic central tip of the plume. Entraining these free radicals in a high energy plasma blade tip causes the plasma plume to have an increased beneficial interaction with the tissue to promote rejuvenation and healing.

[0022] Thus, in embodiments, the method may further comprise: collimating and optionally entraining and/or focussing, using the central thermal plasma, at least some of the surrounding halo non-thermal plasma.

[0023] In addition, the plume shape enables the torch to be used in cosmetic treatments somewhat like a paintbrush, to treat local areas to a varying depth and effect, providing a flexible finish that is easily blended locally and so usable to treat small areas or zones, particularly deep wrinkle areas such as crow's feet or frown lines, without having to treat a wide area of the skin. This is unlike laser treatment, which is more like a sharp pencil, or leaves a finish like a dot matrix pattern if fractionated, and so cannot be blended easily nor used to treat small zones of the skin alone. Instead, with laser treatment, typically the whole of the face or at least a wide area thereof will need to be treated. The present invention allows targeted local treatment of deep wrinkles and other significant local skin irregularities.

[0024] In embodiments, the spot size and shape of the plume may be adjusted by, in embodiments, providing a plasma torch having an adjustable electrode geometry and adjusting the relative position thereof, increasing or decreasing the feed gas pressure, constricting or dilating the aperture of the open ends of the cavities, or increasing or decreasing or otherwise changing the power supply waveforms to the electrodes to generate the one or both of the two plasma stages. By providing an adjustable spot size and plume shape, the user can readily adapt the output plasma for different regions and

conditions of the skin, like a palette of paintbrushes, allowing blending and bespoke treatments to be applied to small zones of the skin.

[0025] In embodiments, the method further comprises accelerating the thermal plasma towards a focal point in front of the open end of the torch. Focussing the plasma plume in this way gives a higher fluence and a greater effect on the tissue than a more dispersed, non-focussed plume.

[0026] In embodiments, the plasma torch comprises: a central cathode rod; a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form the first cylindrical cavity open at one end; and a high voltage electrode arranged around the grounded conductive tube and spaced apart therefrom to form the second annular cylindrical cavity, the high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof.

[0027] In embodiments, the method further comprises: producing the arc discharge in the first cavity between the cathode and grounded tube by providing to the cathode a constant direct current (DC) electrical power plus a high voltage pulsed electrical power to initiate the arc discharge; producing the dielectric barrier discharge in the second annular cylindrical cavity by providing to the high voltage electrode a high voltage alternating current electrical power or pulsed electrical power to generate the dielectric barrier discharge.

[0028] Viewed from another aspect, the present invention provides a method for the non-surgical cosmetic treatment of skin, comprising: generating a plasma in accordance with any of the methods of the present invention described herein, and directing the generated plasma plume at the skin requiring cosmetic treatment.

[0029] Viewed from another aspect, the present invention provides a method for the sterilization of objects in an industrial process, comprising: generating a plasma in accordance with any of the methods of the present invention described herein, and directing the generated plasma plume at the objects requiring sterilization. The sterilizing and heating effects of the plasma generated by methods of the invention described herein has been found to have particular utility in the sterilization of objects, for example in industrial processes.

[0030] Viewed from one aspect, the present invention provides a plasma torch having an open end from which a plasma plume is emitted in use is disclosed. The plasma torch includes a central cathode rod, a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form a first cylindrical cavity open at one end; and a high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof and being arranged around the grounded conductive tube and spaced apart therefrom to form a second annular cylindrical cavity open at one end. In use, a constant direct current (DC) electrical power plus a high voltage pulsed electrical power is provided to the cathode producing an arc discharge in the first cavity between the cathode and grounded tube to generate a central thermal plasma emitted at an open end of the first cylindrical cavity. Also, in use, a high voltage alternating current electrical power or pulsed electrical power is provided to the high voltage electrode producing a dielectric barrier discharge in the second annular cylindrical cavity to generate a non-thermal plasma emitted from an open end of the second cavity as a halo around the central thermal plasma blade.

[0031] Thus, viewed from another aspect, the present invention provides a plasma torch having an open end from which a plasma plume is emitted in use, comprising: a central cathode rod; a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form a first cylindrical cavity open at one end in which, in use, an arc discharge between the cathode and grounded tube ionizes a feed gas to produce a central thermal plasma emitted from the open end of the first cavity; and a high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof and being arranged around the grounded conductive tube and spaced apart therefrom to form a second annular cylindrical cavity in which, in use, a dielectric barrier discharge between the high voltage electrode and grounded tube ionizes a feed gas to produce at the open end of the second cavity a non-thermal plasma halo surrounding the central thermal plasma. A plasma torch configured in this manner is thus able to produce, in use, a high energy two-stage co-operative plasma having particular utility in cosmetic and surgical treatments.

[0032] In embodiments, the plasma torch may be configured such that, in use, the spot size and shape of the plume may be adjustable by, in embodiments, providing a

handpiece having an adjustable electrode geometry, enabling the feed gas pressure to be increased or decreased, providing one or more means for constricting or dilating the aperture of the open ends of the cavities, or providing a power supply unit operable in use to enable increasing or decreasing or otherwise changing the power supply waveforms to the electrodes to generate the one or both of the two plasma stages.

[0033] In embodiments, the end of the central cathode rod is recessed from an open end of the grounded tube such that, in use, the arc current causes a Lorentz force that accelerates the thermal plasma towards a focal point in front of the open end of the torch. The arrangement of the electrodes in this way causes a magnetic field generated in the first cavity by the current travelling through the grounded tube and the cathode (due to the arc discharge therebetween), with magnetic field lines flowing cylindrically around the cathode. This magnetic field itself has an effect on the charged thermal plasma generated by the arc discharge of producing a Lorentz force on the plasma, which, due to the recess of the cathode compared to the open end of the grounded tube, is directed towards the central common axis of the electrodes in front of the open end of the grounded tube. In this way, the thermal plasma is accelerated towards a focal point in front of the open end of the torch, allowing the plasma to be concentrated, giving a high fluence in the resulting plasma plume. In this respect, the acceleration of the plasma by a magnetic field induced by a current generated by the arc discharge creates a magnetohydrodynamic effect on the plasma, meaning that the accelerated plasma can be considered a magnetohydrodynamic plasma.

[0034] In embodiments, the relative axial extent of the cathode and grounded tube at the open end of the plasma torch is configured such that the resulting plasma plume is concentrated a given focal distance in front of the open end of the torch. In this way, the relative positioning and configuration of the electrodes is set to give a desired plume characteristic. In embodiments, the cathode and grounded tube are relatively axially moveable to allow a user of the torch to adjust a focal distance of the plasma plume. In this way, the relative positioning and configuration of the electrodes is adjustable to allow the operator to adjust the plume shape and intensity, to achieve a desired plume characteristic. This allows the operator a great degree of flexibility and control over the

operation and effect of the plasma torch, and can be considered akin to providing the operator with a variety of paintbrushes with which to rejuvenate different areas of the skin.

[0035] In embodiments, the cathode, grounded tube and high voltage electrode are arranged co-axially.

[0036] In embodiments, the plasma torch further comprises an annular permanent magnet arranged radially outwardly of the grounded tube at the open end thereof and configured to produce a magnetic torque on the arc discharge to cause the arc discharge, in use, to rotate around the cathode. The provision of the annular permanent magnet causes the high energy arc to rotate around the cathode, which allows the heat generated in the cathode and grounded tube at the arc location time to be dissipated. This can extend the lifetime of the 'hot' electrodes as, if the arc were repeatedly incident at the same location on the cathode and grounded tube, these electrodes could overheat and wear out relatively quickly. In accordance with this embodiment, the lifetime of the electrodes is extended, reducing maintenance, and improving the practicality of the two-stage plasma generation system. In other embodiments, however, the permanent magnet can be omitted completely.

[0037] In embodiments, at least the cathode, grounded tube and high voltage electrode are arranged such that, in use, the central thermal plasma collimates, and optionally entrains and/or focusses, at least some of the surrounding halo non-thermal plasma.

[0038] In embodiments, the plasma torch is configured as a handpiece for an end user to hold and manipulate in use. The handpiece may be provided with one or more controls to ignite the outer, non-thermal plasma and also, in addition, the central, thermal plasma.

[0039] In embodiments, the plasma torch further comprises an ergonomic grip coupled to the handpiece to facilitate user operation. In embodiments, the plasma torch comprises interchangeable ergonomic grips detachably coupleable to the handpiece. The interchangeable ergonomic grips may include one or more of: a trigger grip; a tripod grip; a pen grip. By providing the plasma torch as a handheld tool, having ergonomic and selectable grips aids the user in manipulating the plasma plume and allows fine control and comfort in use.

[0040] In embodiments, the cathode is detachably connected to the torch as a or as part of a replaceable modular assembly. Alternatively, or in addition, the high voltage

electrode is detachably connected to the torch as a or as part of a replaceable modular assembly. In embodiments, the cathode and high voltage electrode are separately detachably connected to the torch as parts of separately replaceable modular assemblies. In embodiments, the grounded tube and cathode are together detachably connected to the torch as parts of a replaceable modular assemblies. In embodiments, the plasma torch and each modular assembly have mutually cooperating screw threads to enable the detachable connections therebetween. By providing the plasma torch with a modular construction having readily changeable modular parts for the 'hot' electrode section (including the cathode) and/or the 'cold' electrode section (including the high voltage electrode), if and when the electrodes become worn, they are readily replaceable without the need for disassembly of the torch by a service engineer. Instead, the worn electrode modular components can be removed by the end user, for example by unscrewing them from the torch, and replaced with new or reconditioned modular components.

[0041] Viewed from another aspect, the present invention provides a modular cathode assembly in a plasma torch in accordance with the aspects and embodiments of the invention described herein, the modular cathode assembly comprising a cathode and optionally a grounded tube and being configured to be detachably connectable to the plasma torch to enable the cathode thereof to be replaced.

[0042] Viewed from another aspect, the present invention provides a modular high voltage electrode assembly in a plasma torch in accordance with the aspects and embodiments of the invention described herein, the modular high voltage electrode assembly comprising a high voltage electrode and being configured to be detachably connectable to the plasma torch to enable the high voltage electrode thereof to be replaced.

[0043] In embodiments, the plasma torch further comprises: at least one feed gas inlet opening for each of the first and second cavities; wherein the plasma torch is configured to provide sealed fluid communication between each feed gas inlet and a feed gas connector for connecting to a feed gas supply. In embodiments, separate feed gas connectors are provided for each of the first and second cavities, and wherein the plasma torch is further configured such that fluid communication lines between the feed gas connectors and the feed gas inlets to the first and second cavities are sealed from each other, such that separate feed gases are in use supplied to the first and second cavities.

[0044] Viewed from another aspect, the present invention provides an electrical power generator unit coupled with and providing power in use for a plasma torch in accordance with the aspects and embodiments of the invention described above, the electrical power generator unit comprising: means configured to provide to the cathode in use a constant direct current (DC) electrical power supply plus a high voltage pulsed electrical power supply to initiate the arc discharge in the first cylindrical cavity (the thermal plasma power supply); means configured to provide to the high voltage electrode in use a high voltage alternating current electrical power supply or pulsed electrical power supply to generate the dielectric barrier discharge in the second annular cylindrical cavity (the non-thermal plasma power supply).

[0045] The thermal and non-thermal power supplies may be operated independently, for example in response to user control, such that the two stages of the plasma may be operated incrementally so that, in use, the user may initiate only the halo non-thermal plasma to treat some areas of the skin at a lower energy level, whereas the central, thermal plasma may be selectively initiated in addition to the halo plasma to treat selected areas of the skin at a higher energy level.

[0046] Viewed from another aspect, the present invention provides an apparatus for generating a plasma plume, comprising: a plasma torch in accordance with the aspects and embodiments of the invention described herein; and an electrical power generator unit in accordance with the aspects and embodiments of the invention described herein.

[0047] In embodiments, the apparatus further comprises one or more containers of feed gas connected to the plasma torch, wherein the apparatus is configured such that feed gas is supplied to the first and second cavities to be ionized in use.

[0048] Viewed from another aspect, the present invention provides a method of generating a plasma plume using apparatus for generating a plasma plume torch in accordance with the aspects and embodiments of the invention described herein, the method comprising: providing to the cathode using the electrical power generator unit a constant direct current (DC) electrical power plus a high voltage pulsed electrical power to initiate the arc discharge in the first cylindrical cavity between the cathode and grounded tube to thereby ionize a feed gas supplied thereto to produce a central thermal plasma emitted from the open end of the first cylindrical cavity; and providing to the high

voltage electrode using the electrical power generator unit a high voltage alternating current electrical power or pulsed electrical power to generate the dielectric barrier discharge in the second annular cylindrical cavity between the high voltage electrode and the grounded tube to thereby ionizes a feed gas supplied thereto to produce at the open end of the second cavity a non-thermal plasma halo surrounding the central thermal plasma.

[0049] A control module configured in use to cause the apparatus to perform the above method may be provided as part of the apparatus. The control module may be implemented using hardware or hardware and software. There may be provided a data processing module and computer readable medium, optionally non-transitory, comprising instructions which when carried out by the data processing module configure the apparatus to implement the control module.

[0050] Viewed from another aspect, the present invention provides use of a plasma torch or an apparatus in accordance with the aspects and embodiments of the invention described herein in the non-surgical cosmetic treatment of skin, optionally for one or more of: wrinkle removal; skin resurfacing; skin ablation; scar removal; hair removal.

[0051] Viewed from another aspect, the present invention provides use of a plasma torch or an apparatus in accordance with the aspects and embodiments of the invention described herein in non-surgical treatment.

[0052] Viewed from another aspect, the present invention provides use of a plasma torch or an apparatus in accordance with the aspects and embodiments of the invention described herein in surgical treatment of live tissue, optionally for one or more of: cauterization; tissue ablation for wound healing; wound or burn sterilization; cavity sterilization.

[0053] Viewed from another aspect, the present invention provides use of a plasma torch or an apparatus in accordance with the aspects and embodiments of the invention described herein in an industrial sterilization process, optionally for sterilizing one or more of: foodstuffs; pharmaceuticals; medical implants; medical instruments; surfaces and industrial components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] Aspects of the invention may best be understood by reference to the following description of certain exemplary embodiments together with the accompanying drawings in which:

[0055] Figure 1 shows a view of an apparatus for generating a plasma plume for cosmetic treatment of skin according to an embodiment of aspects of the invention;

[0056] Figure 2 is a schematic drawing illustrating the apparatus shown in Figure 1 showing components of the system control unit;

[0057] Figure 3 is a cutaway view of a plasma torch according to an embodiment;

[0058] Figure 4 is a diagram illustrating the operation of the 'hot' stage of the plasma torch shown in Figure 3 to generate an arc discharge and thermal plasma;

[0059] Figure 5 is a diagram illustrating the operation of the 'cold' stage of the plasma torch shown in Figure 3 to generate an dielectric barrier discharge and non-thermal plasma;

[0060] Figure 6 illustrates the two stages of the plasma generated by the plasma torch and the cooperative effect to generate a collimated, focused plasma plume; and

[0061] Figure 7 is a photograph of a two-stage plasma plume generated by a plasma torch according to an embodiment of aspects of the invention, wherein edge detection algorithm has been applied to the image to help reveal the structure of the cooperative plume.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0062] The detailed description set forth below in connection with the appended drawings is intended as a description of presently preferred embodiments of the invention, and is not intended to represent the only forms in which the present invention may be practised. It is to be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the invention. Furthermore, terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that apparatuses and method steps that comprises a list of elements or steps does not include only those elements but may include other elements or steps not expressly listed or inherent. An element or step preceded by "comprises ...a" does not, without more constraints,

preclude the existence of additional identical elements or steps that comprises the element or step.

[0063] Referring now to Figures 1 and 2, an apparatus 100 for generating a plasma plume in accordance with an embodiment of aspects of the invention includes a plasma torch 101 connected via a connector hose 130 to a system control unit 150. As will be explained in further detail below, by operating the system control unit 150 by means of controls 151, the controller 52 of the system control unit 150 can be caused to release one or more feed gases from gas supply 53 where they are stored under pressure to ionization cavities inside the plasma torch 101. Once the gas is flowing to the plasma torch 101 through gas supply conduit 133 provided in the hose 130, the controller 52 causes the power supply to generate one or more different electrical power signals that are provided via power supply cabling 131 provided in the hose 130 to one or more electrodes in the plasma torch 101 to cause electrical discharge inside the plasma torch 101. The feed gas inside the plasma torch is then ionised by the discharge and is emitted from the open end 103 of the plasma torch 101 in the form of a two-stage plasma plume, as described in more detail below. The plasma plume may be generated for a sustained period of time or may be caused to be emitted in pulses.

[0064] The operator of the apparatus 100 can, by holding the plasma torch by way of ergonomic grip 105, manipulate the plasma torch to direct the plasma plume emitted from opening 103 onto tissue to carry out cosmetic or surgical procedures. To allow easy user control, the plasma torch 101 may be provided with one or more controls (not shown) such as trigger buttons on grip 105 to ignite the outer, non-thermal plasma and also, in addition, the central, thermal plasma. For example, the plume may be used for the cosmetic treatment of deep wrinkles such as crow's feet and other, significant skin irregularities. The ergonomic grip 105 shown in Figure 1 is a trigger grip, but this is removably attached to the plasma torch 101 such that it can be changed for other ergonomic grips which may be specifically adapted for a given operator's hand. This allows the operator a high degree of comfort and accuracy when holding the plasma torch 101 for extended periods in use.

[0065] The plasma generated by the apparatus 100 is a two-stage cooperative plasma having a higher energy central focused thermal plasma blade surrounded by a lower

energy halo non-thermal plasma. Optionally, only the outer halo stage of the non-thermal plasma may be ignited.

[0066] Figure 3 is a cutaway view of the plasma torch 101 showing the electrode structure that gives rise to the creation of the two-stage cooperative plasma in use. The plasma torch 101 can be conceptually divided into two halves. The front half, indicated by the arrow F in Figure 1, contains the electrodes and cavities to which gas is fed for ionisation and from which the two-stage plasma is emitted in use. The front half of the plasma torch 101 is constructed by two user-replaceable modular components, facilitating servicing of the plasma torch 101 when the electrodes therein become worn. The rear half of the plasma torch 101, indicated by the arrow R in Figure 1, acts to support and retain the components of the front half and to provide a coupling to the hose 130 to enable sealed fluid communication of the gas supply from the gas supply conduit 131 of the hose 130 to the cavities 33, 34 in the front half – and to electrically couple the electrodes 2, 6 in the front half F to the electrical power cabling 131 of the hose 130.

[0067] The components of the plasma torch 101 in the front half F are encased in a grounded stainless steel casing 1. The casing 1 is tubular in form having at its front end an end wall with an axially centralised opening 103 for admitting the plasma plume in use. The back end of the casing 1 has a screw thread 14 provided on a radially inward-facing surface thereof that mutually cooperates with and is retained by a corresponding screw thread 14 provided on a radially outward facing surface of a front end of a grounded stainless steel body 31 forming the rear end R of plasma torch 101. A threaded sleeve (not shown) rotatable relative to the casing 1 may be provided on the casing 1 for threading onto the thread 14 of the stainless steel body 31 to allow the front F and rear R parts of the torch to be mated without relative rotation. The body 31 has towards its front end a solid block machined into a perforated bulkhead 32, described in more detail below, that acts to retain certain other components of the plasma torch 101 and to admit feed gas and electrical coupling wires from the rear to the front of the plasma torch 101.

[0068] A cathode rod 2, formed of either tungsten or thoriated tungsten, is provided in the front half of the plasma torch 101 to extend along the central axis thereof. Arranged coaxially around the cathode rod 2 and spaced apart therefrom, there is provided a grounded stainless steel arc tube 3. A cylindrical annular cavity 33 formed between the

rod 2 and the grounded tube 3 is open at its front end but it is sealed at its back end, except for feed gas inlets. As will be explained in greater detail below, in use, the cathode rod 2 is provided with an electrical power signal sufficient to create an arc between the cathode rod 2 and the grounded tube 3 which is used to generate a 'hot' thermal plasma in the cylindrical annular cavity 33 that is then emitted from the open front end of the cavity 33. It should be noted that the axial extent of the cathode rod 2 at the front end thereof is slightly recessed relative to the open end of the front of the grounded tube 3. This relative positioning causes a Lorentz force to be generated by the current of the arc discharge which causes the charged particles of the central thermal plasma to be accelerated towards the central axis of the plasma torch 101 causing the hot stage of the plasma plume to become focused.

[0069] Arranged radially outside the grounded tube 3 at its front end is an annular NdFeB permanent magnet 4 that creates a magnetic field that provides a stabilising magnetic torque on the arc between the cathode 2 and grounded tube 3 and causes the arc to rotate around the cathode 2 in use. This prevents the arc from being sustained at a single location between the cathode rod 2 and grounded tube 3 which may prevent the cathode 2 from overheating and becoming damaged. This can extend the life of the components of the plasma torch 101 and the conservation of the cathode 2 by the magnet 4 allows the use of an arc discharge to become more practical. In alternative embodiments, however, the permanent magnet may be omitted.

[0070] Arranged coaxially around the grounded tube 3 and spaced apart therefrom is a Borosilicate glass or ceramic (Boron Nitride/Alumina) tube 5 that has a dielectric constant of 4.6 and that acts as a dielectric barrier to a high-voltage copper electrode 6 arranged radially outwardly thereof. A second cylindrical cavity 34 is formed between the grounded tube 3 and the dielectric barrier tube 5 that is open at its front end but is sealed at its back end by bulkhead 32, except for inlets formed by bores 20 in the bulkhead 32 that enable the passage of feed gas, a thermocouple 13 and a coaxial power supply cable 8 from the rear R to the front F of the plasma torch 101. As will be explained in greater detail below, in use, the high-voltage electrode 6 is provided with an electrical power signal sufficient to create a dielectric barrier discharge between the dielectric barrier tube 5 and the

grounded tube 3 which is used to generate a 'cold' non-thermal plasma in the cylindrical annular cavity 34 that is then emitted from the open front end of the cavity 34.

[0071] The high-voltage electrode 6 is connected to a brass threaded rod 7 acting as high voltage connector and having a conductive core of a coaxial cable 8 soldered to it. In use, the coaxial cable 8 conducts the high-voltage electric power signal generated by the power supply 51 via the electrical power cabling 131 to the high-voltage electrode 6.

[0072] A grounded brass plate 9 is provided in the front part of the plasma torch 101 surrounding the grounded tube 3 in front of the bulkhead 32 but slightly spaced therefrom. The grounded shielding 10 of the coaxial cable 8 is soldered to the brass plate 9 to provide the ground reference. The brass plate 9 is in contact with the casing 1 and body 31 and acts as the ground reference for the grounded components of the plasma torch 101.

[0073] A ceramic (Boron Nitride/Alumina) disc 11 is arranged between the magnet 4 and the high-voltage electrode 6 to electrically and thermally insulate them from each other. A further ceramic (Boron Nitride/Alumina) block 12 is arranged to extend around the high-voltage electrode 6 to electrically and thermally insulate the high-voltage electrode 6 from all other grounded metal surfaces. A bore 13 is formed in the block 12 to receive a thermocouple (not shown) arranged to monitor temperature of the high-voltage electrode 6 in use to ensure that it does not overheat. A further bore is formed on the block 12 to receive the coaxial cable core 8 for connection to the high-voltage electrode 6 via the high-voltage connector 7. Holes are provided through the brass plate 9 and the bulkhead 32 registered to the bores provided in the block 12 for passing the thermocouple and coaxial cable from the rear to the front of the plasma torch 101.

[0074] The bulkhead 32 is also perforated centrally by a large central bore that contains a brass cathode connector 16 surrounded by ceramic (Boron Nitride/Alumina) components 18 provided radially outwardly and to the rear of the cathode connector 16 to electrically and thermally insulate the cathode connector 16 from all other grounded metal surfaces. A bore in the brass cathode connector 16 forms a cavity sized to receive a stainless steel cathode base 15 with an interference fit therein. The cathode 2 is supported by and extends from the cathode base 15 to the front of the plasma torch 101.

A ceramic insulator 18 to the front of the cathode connector 16 insulates the cathode 2, cathode base 15 and cathode connector 16 from the grounded steel tube 3.

[0075] The grounded tube 3 has an enlarged cylindrical base having, on its radially outward facing surface a screw thread 14 that mutually co-operates with a screw thread 14 provided on a radially inner surface of the central bore of the bulkhead 32, such that the grounded tube 3 is releasably engageable with the grounded steel body 31 and is grounded thereby in use.

[0076] In the embodiment, a replaceable “cold tip” module is provided by the grounded casing 1 and contains the permanent magnet 4, dielectric tube 5, ceramic insulators 11, 13 and brass plate 9. These components are provided together in a single assembly that is releasably engageable with the steel body 31 of the rear of the plasma torch 101 by means of screw thread 14 provided on the radially outer surface of the steel body 31.

[0077] In the embodiment, a replaceable “hot tip” module is provided by the cathode 2, grounded tube 3, cathode base 15 and the ceramic insulator component 18 sandwiched between the cathode base 15 and the enlarged cylindrical base of grounded tube 3. These components are provided together in a single assembly that is releasably engageable with the steel body 31 of the rear of the plasma torch 101 by means of screw thread provided on the radially inner surface of the bulkhead 32 of the steel body 31. The interference fit between the cathode base 15 and the cathode connector 16 form a mateable and the demateable male – female connector, in which the cathode base 15 forms the male part then the cathode connector 16 forms the female part.

[0078] The cold tip and hot tip modules can be easily replaced by the user to service the plasma torch 101 when the electrodes thereof become worn. In other embodiments, the cold tip, which includes the high-voltage electrode at least, and the hot tip, which includes the cathode at least, may be constructed differently and have different components in the assembly to that shown for the embodiment described in detail in Figure 3. For example, a fastening mechanism other than a screw thread may be usable to connect the hot tip and cold tip modules to the body of the plasma torch 101.

[0079] To the rear of the bulkhead 32, the wall of the body 31 of the plasma torch 101 forms a cylindrical chamber 23 closed at the rear end by an end cap 30 having a radially extending feed through plate 24 having holes there through and connectors for interfacing

with the power supply 51 and gas supply 53 via the gas supply conduit 133. The end cap 30 is joined to the body 31 by means of a screw thread.

[0080] Abutting against the rear facing surface of the bulkhead 32, a stainless steel retainer plate 21 retains the cathode connection assembly 16 in place by being screwed into the rear facing ceramic insulators 18 and bulkhead 32. Extending from the axial centre of the retainer plate 21 is an integral stainless steel spindle 22 having a bore extending centrally there through open at both ends. The rear of the spindle 22 is joined to a swage lock connector 26 that penetrates through feed through plate 24 that closes off and seals the chamber 23 formed by cylindrical body 31. In use, the feed gas supply for the central, thermal plasma to be ionised in the hot tip is connected to the swage lock connector 26. A fluid communication channel is thereby provided between the swage lock connector 26 and the cavity 33 via the central bore of the spindle 22, through holes penetrated through the centre of the ceramic insulator 18 provided at the rear end of the cathode connector 16 through the cathode connector 16 itself, and also through grooves provided through the stainless steel cathode base 15 that allow the feed gas to pass around the interference fit between the cathode base 15 and cathode connector 16 and through into the cavity 33 formed in the space between the cathode rod 2 and the grounded tube 3.

[0081] A second swage lock connector 28 is connected to the feed through plate 24 and provides a fluid communication channel into the chamber 23 formed inside the rear of the body 31 closed by the feed through plate 24. In use, the cold feed gas supply is connected to the swage lock 28 such that the chamber 23 in the rear of the body 31 is filled with cold feed gas. Nitrile O-rings 29 arranged between the feed through plate 24 and the body 31 to provide a seal between the external atmosphere and the interior of the device when under compression. Four bores 20 provided extending through the retainer 21 and bulkhead 32 provide fluid communication paths for the cold feed gas from the chamber 23 at the rear R of the plasma torch 101 to the front of the plasma torch 101. A radially extending gap formed between the front F of the bulkhead 32 and the brass plate 9 allows cold plasma feed gas from the bores 20 to pass into the cavity 34 in which the cold plasma is formed in use by an annular gap between the brass plate 9 and the grounded tube 3.

[0082] One of the bores 20 performs the alternative function of providing a passageway for the high-voltage coaxial cable 8 that extends from a hole in the feed through plate 24 at the rear of the plasma torch 101, through the cold plasma chamber 23, through a hole in the retainer plate 21, through the bore 20 in the bulkhead 32, through a hole in the brass plate 9, and through a bore in the ceramic insulator 12. At the front of the bore in the ceramic insulator 12 the conductive core of the coaxial cable 8 is connected to the high-voltage electrode 6 by a high-voltage connector 7. In this way, a conductive connection is formed between from the high-voltage electrode 6 and power supply 51 via electrical power cabling 131.

[0083] To connect the power supply 51 to the cathode 2, holes are provided in the retainer 21, ceramic insulator 18 to the rear of the cathode connector 16 opening into bores in the cathode connector 16 itself. Single core wires extending into the plasma torch via holes in the feed through plate 24 extend through the chamber 23 and through the holes in the retainer 21 and ceramic insulator 18 whereby the wire core is soldered to the cathode connector 16. In this way, a conductive connection is formed between the cathode 2 and power supply 51 via electrical power cabling 131.

[0084] In the embodiment shown in Figure 3, the first cavity 33 and second cavity 34 are sealed from each other such that they are not in fluid communication (except via the open front ends) and separate gas supplies are connected through the hose 130 to feed the first 33 and second 34 cavities separately. Noble gases such as nitrogen or argon or mixtures thereof may be used as feed gases and different types or compositions of these gases may be fed separately to the first 33 and second 34 cavities. Alternatively, the same type or composition of gases may be fed separately to both the first 33 and second 34 cavities. Alternatively, in other embodiments, the fluid passages for communicating feed gas from the rear R to the front F of the plasma torch 101 may be unified/in fluid communication such that a single gas supply may be used to feed gas of the same type to the first 33 and second 34 cavities.

[0085] Operation of the apparatus 100 to generate the two-stage cooperative plasma plume will now be described with reference to Figures 2, 4 and 5.

[0086] In order to begin production of the two-stage plasma, the gas supply 51 in the system control unit 150 is caused by the controller 52 in response to user operation of the

controls 151 to begin releasing feed gas under pressure to the first 33 and second 34 cavities via the gas supply conduit 133.

[0087] Then the controller 52 causes the power supply 51 to generate electrical power signals which are provided to the cathode 2 and high-voltage electrode 6 via the electrical power cabling 131.

[0088] As shown in Figure 4, to generate the hot stage of the plasma, the cathode 2 is connected to a DC power supply provided by power supply 51. The DC power supply consists of a constant supply at ~25V, ~4.2A DC plus a ballast/ignitor high-voltage pulse circuit to initiate the arc discharge. This DC power supply generates and sustains a voltage and current vs time waveform as shown in Figure 8 in which an initial voltage pulse of 100-200V is applied by the ballast/igniter circuit which, as the electrical field breaks down and an electrical arc is initiated between the cathode 2 and the grounded tube 3 through the feed gas then settles down to around 20-60V DC steady state. The electrical arc provides the heating and ionisation mechanism for generating from the feed gas the highly ionised, high-energy thermal plasma that provides the “hot” component of the device’s plasma plume. The current j generated in the grounded tube 6 and cathode 2 by the sustained arc discharge has a current flow which can be varied between 2-6A. This current flow causes the generation of an azimuthal magnetic field B around the cathode as illustrated in Figure 4. As can be shown at the open end of the cavity 33, the interaction of this azimuthal magnetic field B and the electrical arc j generates a Lorentz force F that acts on the generated ions to accelerate the hot plasma in the direction shown by the arrow in Figure 4 towards the axial centre of the plasma torch 101 to focus the thermal plasma towards a focal point P a distance in front of the open end of the cavity 33. In this way, the interaction of the plasma and the magnetic field B generates a magnetohydrodynamic (MHD) thermal plasma ‘blade’ 601 shaped as shown in Figure 6. The high-energy of this highly ionised, focused thermal plasma produces a high fluence at the focal point which enables the apparatus 100 to have a significantly greater and more penetrative effect on the tissue, such as skin, to which it may be directed in use. As a result, the apparatus 100 achieves a significantly improved tissue resurfacing, regenerating and rejuvenating effect compared to known plasma tissue resurfacing devices, improving patient outcomes in both cosmetic and surgical tissue treatments.

Indeed, the patient outcomes achieved by the apparatus 100 are comparable in order to the known laser systems, described above, without any of the attendant disadvantages like the pin-prick patterning on the skin. Instead, the finish on skin for cosmetic treatments using the two-stage plasma is smoother and more easily blended such that cosmetic treatment of smaller “zones” of the skin is enabled while still providing a homogeneous surface finish.

[0089] The magnetic torque produced by the magnet 4 on the arc causes the arc discharge to rotate around the cathode 2 minimising the heating damage and wear of the discharge on the cathode 2 and grounded tube 3, lengthening the operational lifetime of the “hot tip” components.

[0090] The plasma generation system 100 may be, in other embodiments, be configured such that, in use, the spot size and shape of the plume may be adjustable. While not shown in the embodiment of Figure 3, a user-controllable electrode geometry alteration mechanism may be provided in the plasma torch to allow the operator to adjust the spot size and shape of the plume. For example, a mechanism may be provided to allow the user to adjust the relative axial positioning of the front ends of the cathode 2 and grounded tube 3 so as to adjust the directionality of the focusing Lorentz force that acts on the thermal plasma, and so also the focal distance, spot size, and spot energy/fluence of the resulting plasma plume. This may be manipulatable directly on the plasma torch, for example by means of a mechanical scroll wheel, or by means of controls 151. Alternatively, the electrode geometry may be adjusted by providing interchangeable electrode tips or other structural adaptations. Further controls may be provided in the plasma control system operable, for example, from control panel 151 which may allow the user to adjust the spot size or plume geometry by causing the feed gas pressure to be increased or decreased, providing one or more means for constricting or dilating the aperture of the open ends of the cavities, or providing a power supply unit operable in use to enable increasing or decreasing or otherwise changing the power supply waveforms to the electrodes to generate the one or both of the two plasma stages. Finely adjusting these parameters individually or in combination allows a variety of spot sizes and plume geometries to be achievable, allowing the plasma generation device to provide a palette of plasma plumes usable in a variety of different ways to facilitate treatment of different

wrinkles and skin irregularities, and to facilitate blending. For example, a higher-energy, smaller size spot may be used to treat deep laughter line wrinkles formed around the mouth, whereas a lower-energy, larger size spot may be used to blend the treated laughter lines and to treat wider areas of fine wrinkles, such as crow's feet around the eyes.

[0091] As shown in Figure 5, to generate the cold stage of the plasma, the high-voltage electrode 6 is connected to a high-voltage pulse width modulated (PWM) power supply provided by power supply 51 (in other embodiments, an AC power supply may be used rather than a PWM, but a PWM is more efficient and effective in this context). The high-voltage PWM power supply consists of a variable frequency PWM power supply providing a PWM voltage signal to high voltage electrode 6 as shown in Figure 9 of ~2-8 kV, ~25mA at a frequency of 23 kHz up to RF for the duration of the cold stage discharge (two discharge pulses are shown in Figure 9). This powers a dielectric barrier discharge between the grounded tube 3 and the dielectric barrier layer tube 5, providing the plasma production mechanism that weakly ionises the feed gas in cavity 34 that is convected downstream under pressure to provide an emission of annular, relatively low energy, non-thermal plasma as a cold stage shaped as a halo 603 surrounding the central high-energy, thermal plasma blade 601. The dielectric barrier discharge produces in the cold halo plasma a relatively high proportion of free radicals, which have a sterilising effect when incident on the tissue.

[0092] As shown in Figure 6, the accelerated, high-energy MHD central thermal plasma blade 601 has a collimating and focusing effect on the surrounding convected relatively low energy dielectric barrier halo plasma 603 which, due to a shear induced turbulent flux from the thermal plasma blade 601, becomes entrained with the thermal plasma blade 601 to produce a cooperative, focused plasma plume 610. The plume 610 has a high-energy central plasma spot with a relatively high degree of free radicals that is used to ablate tissue and heat subsurface dermal layers. This is surrounded by an entrained sterilizing, relatively low energy, non-thermal plasma halo, which is the source of the free radicals, which acts to sterilise the trauma induced in the tissue in situ and to promote healing thereof.

[0093] When the cooperative plasma plume 610 is used to rejuvenate skin tissue and to treat deep wrinkles and other significant skin irregularities, the ablated surface layers of the tissue are not immediately vaporised and are instead caused to disintegrate and slough off over the course of a few hours to days. In the meantime, the heating and trauma caused to the subsurface epidermal and dermal layers that encourage collagen and elastin production and rejuvenation are sterilised by the plume and protected by the remaining surface epidermal layers such that the traumatised subsurface layers are provided with an in situ sterile dressing that significantly promotes healing and improves the recovery time while minimising the side-effects and downtime of the rejuvenating skin treatment.

[0094] Figure 7 shows a photograph of a two-stage plasma plume generated by a plasma torch 101 built according to the embodiment shown in Figure 3. The photograph has been processed using edge detection algorithm which reveals the structure of the cooperative plume showing the focused, central thermal MHD blade 601 and the entrainment of the sterilising DBD non-thermal halo 603 to produce a collimated, cooperative two-stage plasma plume 610.

[0095] In order to use the plasma plume 610 for cosmetic or surgical treatment, the operator would initiate the plasma plume and move the tip of the plasma torch 101 along the treatment area of the tissue at a fixed distance, in a “paintbrush” fashion, to achieve the desired effect and outcome. This distance is controlled using disposable “patient interface tubes” that allow the user to see the area and the plume of the device. For cosmetic, non-surgical use of the plasma to reduce wrinkles and rejuvenate skin, the cosmetic treatments may be performed by appropriately trained, non-medical personnel (such as a cosmetic technician) in a non-medical setting as the treatment is non-invasive and poses minimal health risks and side effects as the plasma plume itself provides a sterile dressing. For purely cosmetic treatments, the operator need not be a skilled medical professional. However, for wound debridement and for stimulating regeneration of tissue for medically curative purposes, or for cauterisation in a surgical setting or as part of a wider surgical intervention, the two-stage plasma plume will need to be operated by a medical professional.

[0096] A trigger control (not shown) may be provided on the plasma torch to initiate the release of the feed gas and the activation of the power supply by the system control unit in order to produce the co-operative plume on-demand (or just the non-thermal plasma) by the operator. The apparatus may be configured such that the trigger mechanism may cause the plasma plume to be constantly generated for as long as the trigger is depressed. Alternatively, the apparatus may be configured such that a short blast or pulse of plasma is generated in response to depressing of the trigger. Repeated operation of the trigger may then be necessary in order to produce plasma pulses for use in cosmetic and surgical treatments. The energy to be delivered to the surface will be controlled on the base unit.

[0097] The description of the preferred embodiments of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or to limit the invention to the forms disclosed. It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiment disclosed, but covers modifications within the scope of the present invention as defined by the appended claims.

CLAIMS

1. A method of generating a plasma plume from an open end of a plasma torch, comprising:
 - ionizing a feed gas using an arc discharge in a first cylindrical cavity in the plasma torch to produce a central thermal plasma emitted at an open end of the first cylindrical cavity;
 - ionizing a feed gas using a dielectric barrier discharge in a second annular cylindrical cavity arranged around the first cylindrical cavity in the plasma torch to produce at an open end of the second annular cylindrical cavity a non-thermal plasma halo surrounding the central thermal plasma.
2. A method as claimed in claim 1, further comprising:
 - accelerating the thermal plasma towards a focal point in front of the open end of the torch.
3. A method as claimed in claim 1 or 2, further comprising:
 - collimating and optionally entraining and/or focusing, using the central thermal plasma, at least some of the surrounding halo non-thermal plasma.
4. A method as claimed in claim 1, 2 or 3, wherein the plasma torch comprises:
 - a central cathode rod;
 - a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form the first cylindrical cavity open at one end; and
 - a high voltage electrode arranged around the grounded conductive tube and spaced apart therefrom to form the second annular cylindrical cavity open at one end, the high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof.
5. A method as claimed in claim 4, further comprising:
 - producing the arc discharge in the first cavity between the cathode and grounded tube by providing to the cathode a constant direct current (DC) electrical power plus a high voltage pulsed electrical power to initiate the arc discharge;
 - producing the dielectric barrier discharge in the second annular cylindrical cavity by providing to the high voltage electrode a high voltage alternating current

electrical power or pulsed electrical power to generate the dielectric barrier discharge.

6. A method for the non-surgical cosmetic treatment of skin, comprising:
generating a plasma in accordance with the method of any of claims 1 to 5,
and
directing the generated plasma plume at the skin requiring cosmetic treatment.

7. A method for the surgical treatment of tissue, comprising:
generating a plasma in accordance with the method of any of claims 1 to 5,
and
directing the generated plasma plume at the tissue requiring surgical treatment.

8. A method for the sterilization of objects in an industrial process, comprising:
generating a plasma in accordance with the method of any of claims 1 to 5,
and
directing the generated plasma plume at the objects requiring sterilization.

9. A plasma torch having an open end from which a plasma plume is emitted in use, comprising:

a central cathode rod;

a grounded conductive tube having an open end and being arranged around the cathode and spaced therefrom to form a first cylindrical cavity open at one end in which, in use, an arc discharge between the cathode and grounded tube ionizes a feed gas to produce a central thermal plasma emitted from the open end of the first cavity; and

a high voltage electrode having a dielectric barrier material at a radially inward-facing surface thereof and being arranged around the grounded conductive tube and spaced apart therefrom to form a second annular cylindrical cavity open at one end in which, in use, a dielectric barrier discharge between the high voltage electrode and grounded tube ionizes a feed gas to produce at the open end of the second cavity a non-thermal plasma halo surrounding the central thermal plasma.

10. A plasma torch as claimed in claim 9, wherein the end of the central cathode rod is recessed from an open end of the grounded tube such that, in use, the arc current causes a Lorentz force that accelerates the thermal plasma towards a focal point in front of the open end of the torch.

11. A plasma torch as claimed in claim 9 or 10, wherein the relative axial extent of the cathode and grounded tube at the open end of the plasma torch is configured such that the resulting plasma plume is concentrated a given focal distance in front of the open end of the torch.

12. A plasma torch as claimed in claim 9, 10 or 11, wherein the cathode and grounded tube are relatively axially moveable to allow a user of the torch to adjust a focal distance of the plasma plume.

13. A plasma torch as claimed in any of claims 9 to 12, wherein the cathode, grounded tube and high voltage electrode are arranged co-axially.

14. A plasma torch as claimed in any of claims 9 to 13, further comprising an annular permanent magnet arranged radially outwardly of the grounded tube at the open end thereof and configured to produce a magnetic torque on the arc discharge to cause the arc discharge, in use, to rotate around the cathode.

15. A plasma torch as claimed in any of claims 9 to 14, wherein at least the cathode, grounded tube and high voltage electrode are arranged such that, in use, the central thermal plasma collimates, and optionally entrains and/or focusses, at least some of the surrounding halo non-thermal plasma.

16. A plasma torch as claimed in any of claims 9 to 15, wherein the plasma torch is configured as a handpiece for an end user to hold and manipulate in use.

17. A plasma torch as claimed in claim 16, further comprising an ergonomic grip coupled to the handpiece to facilitate user operation.

18. A plasma torch as claimed in claim 17, comprising interchangeable ergonomic grips detachably coupleable to the handpiece, wherein optionally the interchangeable ergonomic grips include one or more of: a trigger grip; a tripod grip; a pen grip.

19. A plasma torch as claimed in any of claims 9 to 18, wherein the cathode is detachably connected to the torch as a or as part of a replaceable modular assembly;

and/or wherein the high voltage electrode is detachably connected to the torch as a or as part of a replaceable modular assembly.

20. A plasma torch as claimed in claim 19, wherein the cathode and high voltage electrode are separately detachably connected to the torch as parts of separately replaceable modular assemblies.

21. A plasma torch as claimed in claim 19 or 20, wherein the grounded tube and cathode are together detachably connected to the torch as parts of a replaceable modular assemblies.

22. A plasma torch as claimed in claim 19, 20 or 21, wherein the plasma torch and each modular assembly have mutually cooperating screw threads to enable the detachable connections therebetween.

23. A plasma torch as claimed in any of claims 9 to 22, further comprising:
at least one feed gas inlet opening for each of the first and second cavities;
wherein the plasma torch is configured to provide sealed fluid communication between each feed gas inlet and a feed gas connector for connecting to a feed gas supply.

24. A plasma torch as claimed in claim 23, wherein separate feed gas connectors are provided for each of the first and second cavities, and wherein the plasma torch is further configured such that fluid communication lines between the feed gas connectors and the feed gas inlets to the first and second cavities are sealed from each other, such that separate feed gases are in use supplied to the first and second cavities.

25. An electrical power generator unit coupled with and providing power in use to a plasma torch as claimed in any of claims 9 to 24, comprising:

means configured to provide to the cathode in use a constant direct current (DC) electrical power supply plus a high voltage pulsed electrical power supply to initiate the arc discharge in the first cylindrical cavity;

means configured to provide to the high voltage electrode in use a high voltage alternating current electrical power supply or pulsed electrical power supply to generate the dielectric barrier discharge in the second annular cylindrical cavity.

26. Apparatus for generating a plasma plume, comprising:

a plasma torch as claimed in any of claims 9 to 24; and
an electrical power generator unit as claimed in claim 25 coupled to the plasma torch.

27. Apparatus for generating a plasma plume as claimed in claim 26, further comprising one or more containers of feed gas connected to the plasma torch, wherein the apparatus is configured such that feed gas is supplied to the first and second cavities to be ionized in use.

28. A method of generating a plasma plume using apparatus as claimed in claim 26 or 27, comprising:

providing to the cathode using the electrical power generator unit a constant direct current (DC) electrical power plus a high voltage pulsed electrical power to initiate the arc discharge in the first cylindrical cavity between the cathode and grounded tube to thereby ionize a feed gas supplied thereto to produce a central thermal plasma emitted from the open end of the first cylindrical cavity;

providing to the high voltage electrode using the electrical power generator unit a high voltage alternating current electrical power or pulsed electrical power to generate the dielectric barrier discharge in the second annular cylindrical cavity between the high voltage electrode and the grounded tube to thereby ionizes a feed gas supplied thereto to produce at the open end of the second cavity a non-thermal plasma halo surrounding the central thermal plasma.

29. Apparatus for generating a plasma plume as claimed in claim 26 or 27 further comprising:

a control module configured in use to cause the apparatus to perform the method of claim 28.

30. Apparatus for generating a plasma plume as claimed in claim 29, further comprising a data processing module and computer readable medium, optionally non-transitory, comprising instructions which when carried out by the data processing module configure the apparatus to implement the control module.

31. A modular cathode assembly in a plasma torch as claimed in any of claims 19 to 22, comprising a cathode and optionally a grounded tube and being configured to

be detachably connectable to the plasma torch to enable the cathode thereof to be replaced.

32. A modular high voltage electrode assembly in a plasma torch as claimed in any of claims 19 to 22, comprising a high voltage electrode and being configured to be detachably connectable to the plasma torch to enable the high voltage electrode thereof to be replaced.

33. Use of a plasma torch as claimed in any of claims 9 to 24 or an apparatus as claimed in claim 26 or 27 in the non-surgical cosmetic treatment of skin, optionally for one or more of: wrinkle removal; skin resurfacing; skin ablation; scar removal; hair removal; treatment of Rosacea; treatment of acne.

34. Use of a plasma torch as claimed in any of claims 9 to 24 or an apparatus as claimed in claim 26 or 27 in non-surgical treatment.

35. Use of a plasma torch as claimed in any of claims 9 to 24 or an apparatus as claimed in claim 26 or 27 in surgical treatment of live tissue, optionally for one or more of: cauterization; tissue ablation for wound healing; wound or burn sterilization; cavity sterilization.

36. Use of a plasma torch as claimed in any of claims 7 to 24 or an apparatus as claimed in claim 26 or 27 in an industrial sterilization process, optionally for sterilizing one or more of: foodstuffs; pharmaceuticals; medical implants; medical instruments; surfaces; industrial components.

37. A method of generating a plasma plume substantially as hereinbefore described, with reference to the accompanying drawings.

38. A plasma torch substantially as hereinbefore described, with reference to the accompanying drawings.

39. Apparatus for generating a plasma plume substantially as hereinbefore described, with reference to the accompanying drawings.

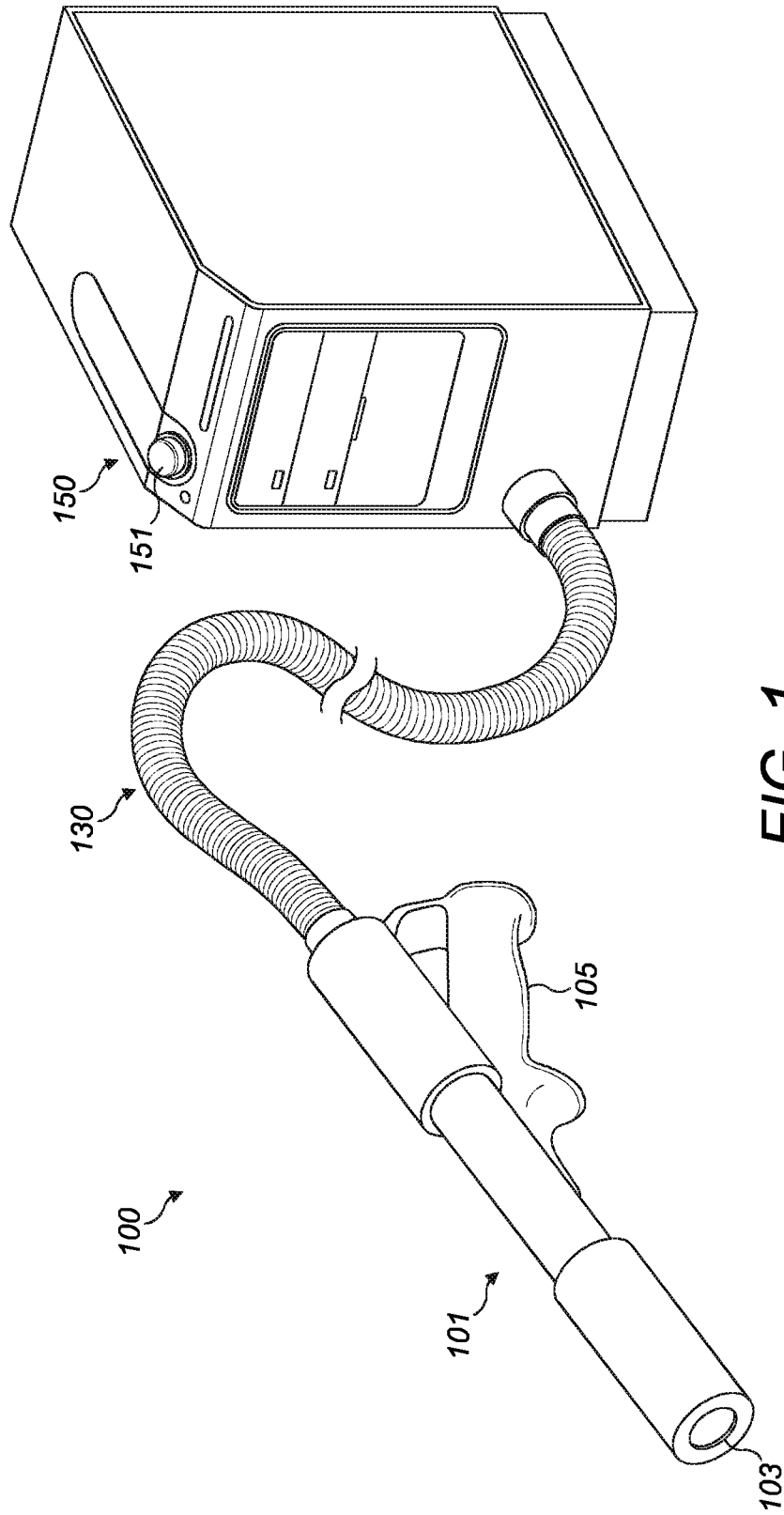


FIG. 1

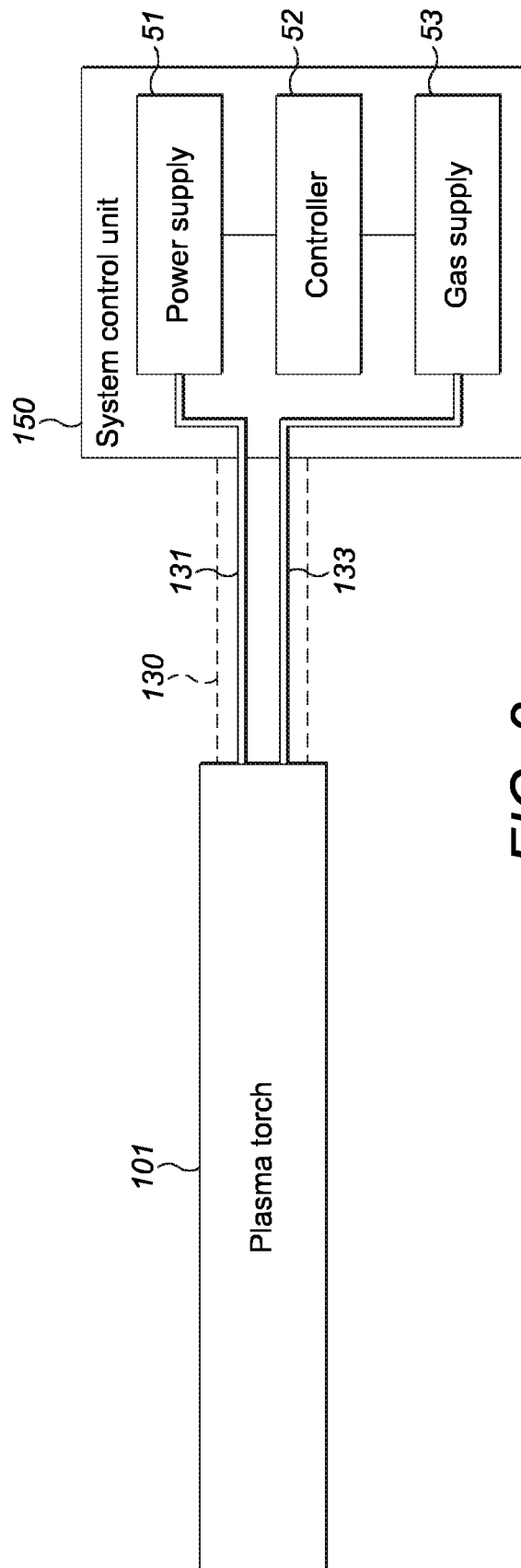
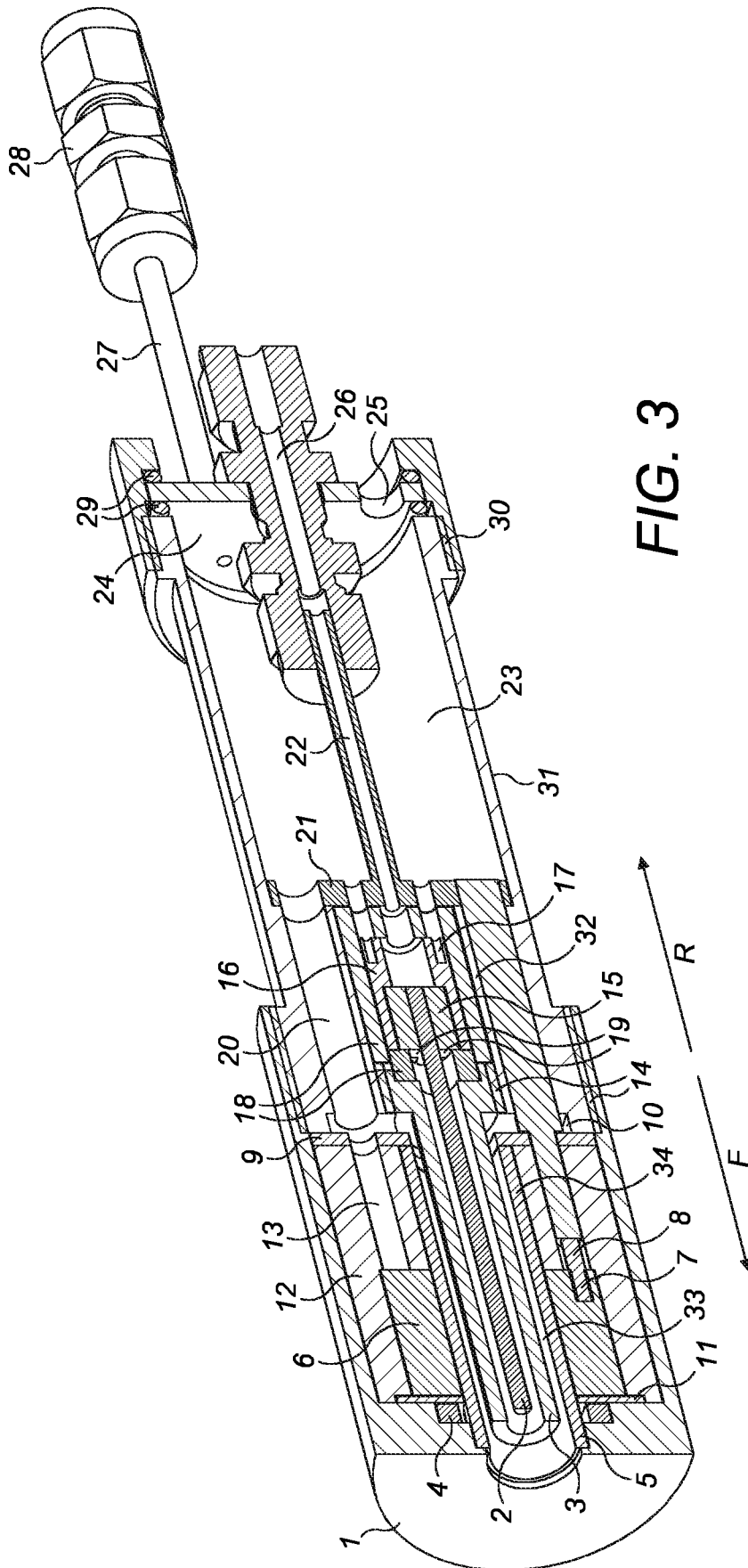


FIG. 2



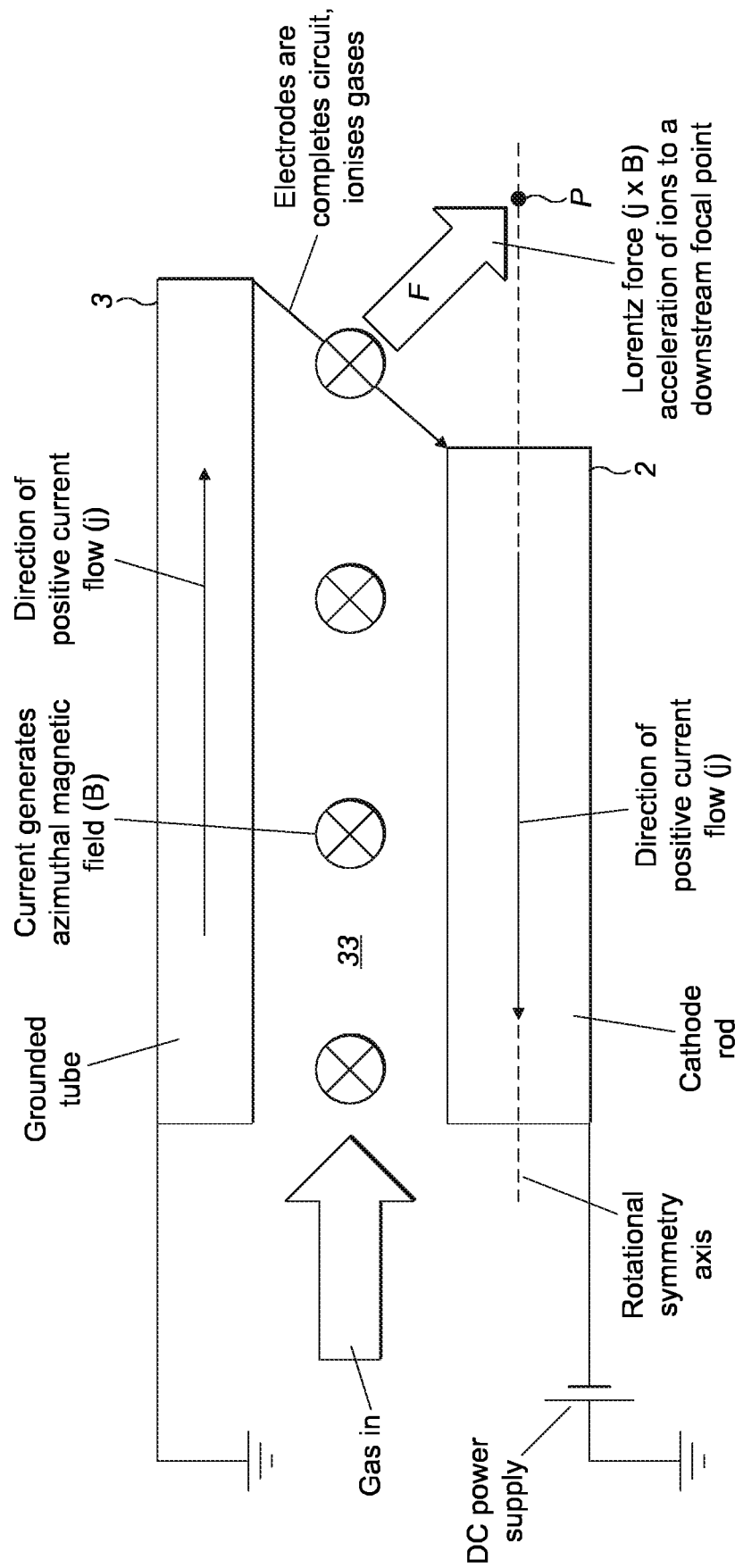


FIG. 4

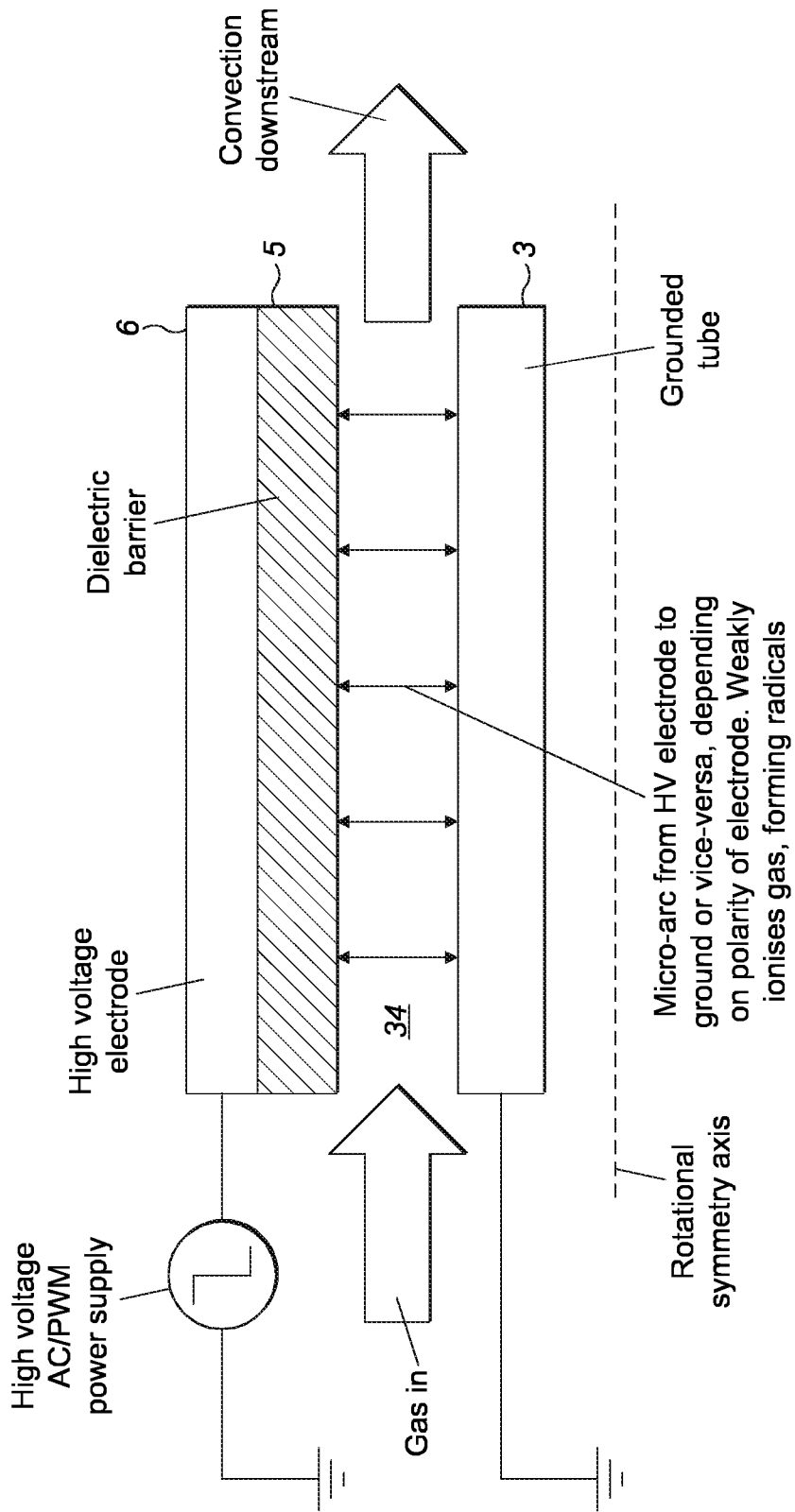


FIG. 5

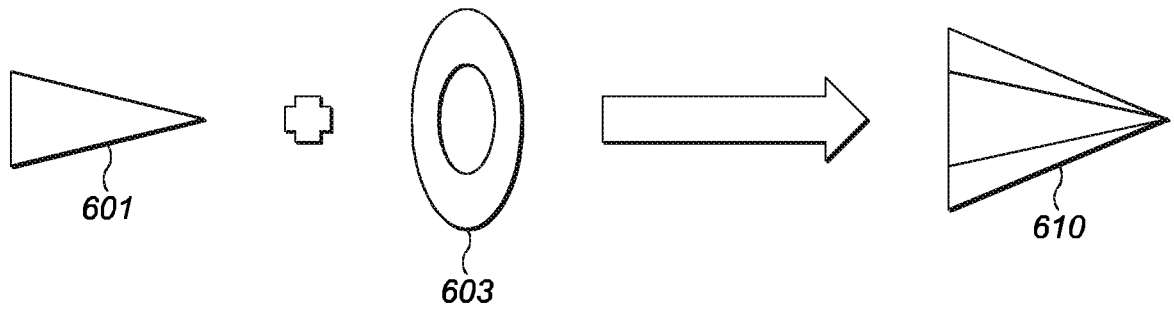


FIG. 6

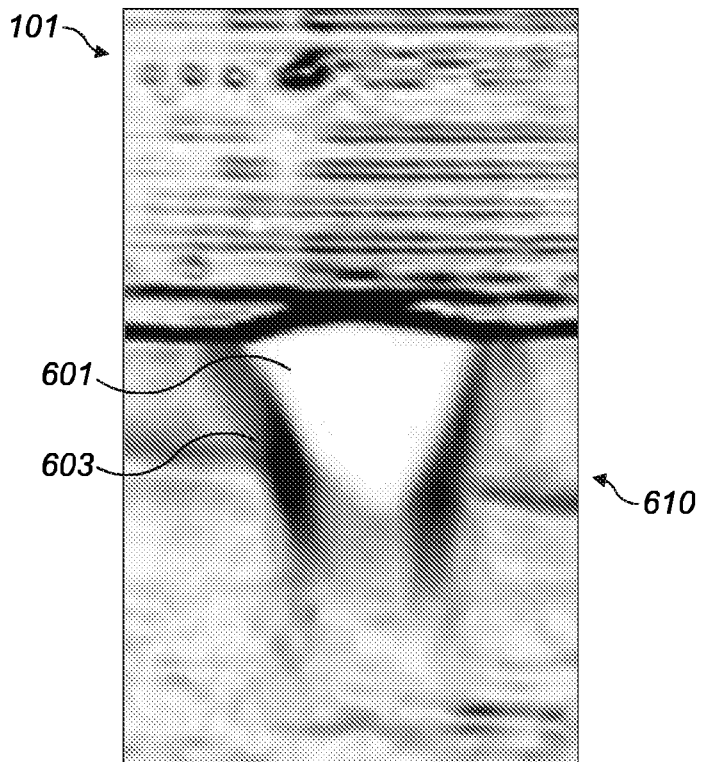


FIG. 7

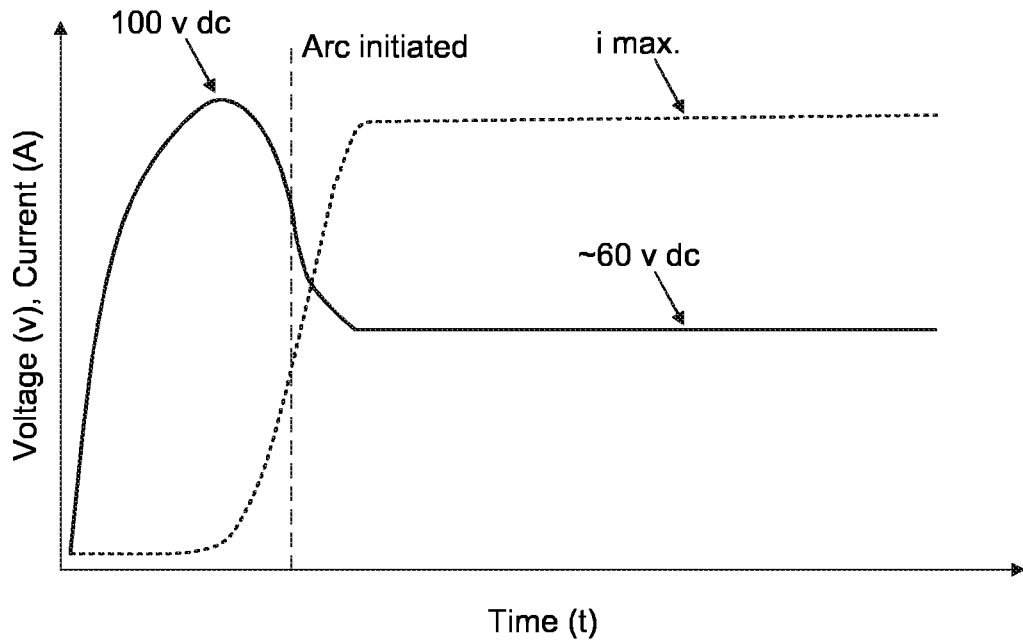


FIG. 8

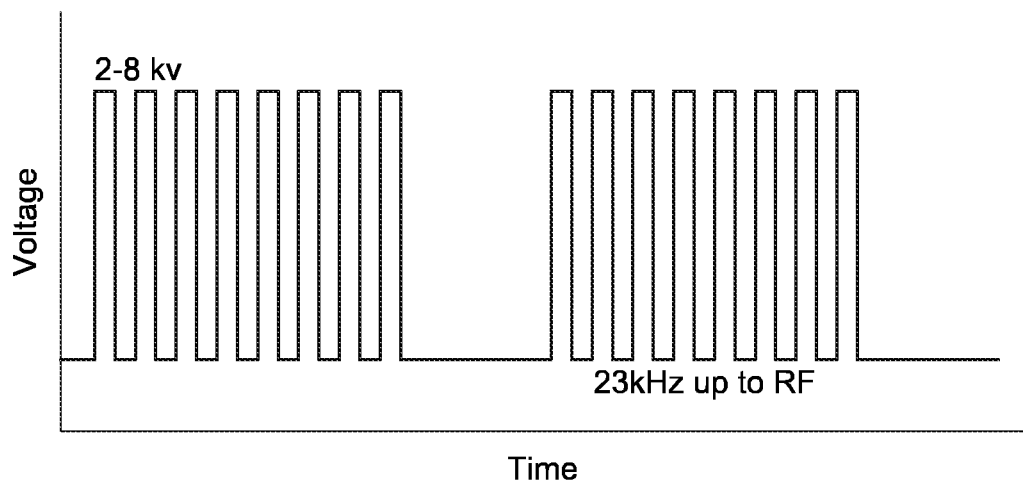


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2015/053294

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05H1/24 H05H1/48 A61B18/04 A61L2/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B A61L H05H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/044342 A1 (MACKAY DALE VICTOR [AU]) 4 March 2004 (2004-03-04) figure 2	31, 32
A	----- WO 2007/006517 A2 (PLASMA SURGICAL SVENSKA AB [SE]; PLASMA SURGICAL INVEST LTD; SUSLOV NI) 18 January 2007 (2007-01-18) paragraph [0028] - paragraph [0035]; figures 1a, 21, 3	1-6, 8-34, 36-39
A	----- US 2007/073287 A1 (GOBLE NIGEL M [GB]) 29 March 2007 (2007-03-29) figure 8 paragraph [0072] - paragraph [0077] ----- -/--	1-6, 8-34, 36-39



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

6 January 2016

Date of mailing of the international search report

13/01/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Clemente, Gianluigi

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2015/053294

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/116918 A1 (KONESKY GREGORY A [US]) 17 June 2004 (2004-06-17) figures 2,10-12 claim 1 paragraph [0044] - paragraph [0074] -----	1-6, 8-34, 36-39

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2015/053294

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: 7, 35
because they relate to subject matter not required to be searched by this Authority, namely:
Claims 7 and 35 define methods for the surgical treatment of the human body. Therefore said claims fall within the provisions of Art.17(2)(a)(i) and Rule 39.1(iv) PCT for which the ISA is not required to perform a search.
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2015/053294

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004044342	A1	04-03-2004	NONE

WO 2007006517	A2	18-01-2007	CA 2614375 A1 18-01-2007
			CN 101243732 A 13-08-2008
			EP 1905285 A2 02-04-2008
			HK 1123667 A1 09-11-2012
			JP 5336183 B2 06-11-2013
			JP 2009500799 A 08-01-2009
			US 2007029292 A1 08-02-2007
			WO 2007006517 A2 18-01-2007

US 2007073287	A1	29-03-2007	NONE

US 2004116918	A1	17-06-2004	NONE

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

To:

CASSIE, Matthew
140 London Wall
London
Greater London EC2Y 5DN
ROYAUME-UNI

Date of mailing (day/month/year) 01 May 2017 (01.05.2017)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference P218252WO	
International application No. PCT/GB2015/053294	International filing date (day/month/year) 02 November 2015 (02.11.2015)

1. The following indications appeared on record concerning:

the applicant the inventor the agent the common representative

Name and Address FOURTH STATE MEDICINE LTD Surrey Technology Centre Unit 56-57 40 Occam Road Surrey GU2 7YG United Kingdom	State of Nationality GB	State of Residence GB
	Telephone No.	
	Facsimile No.	
	E-mail address	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

the person the name the address the nationality the residence

Name and Address FOURTH STATE MEDICINE LTD Longfield Midhurst Road Fernhurst Haslemere GU27 3HA United Kingdom	State of Nationality GB	State of Residence GB
	Telephone No.	
	Facsimile No.	
	E-mail address <input type="checkbox"/> Notifications by e-mail authorized	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

<input type="checkbox"/> the receiving Office	<input type="checkbox"/> the International Preliminary Examining Authority
<input checked="" type="checkbox"/> the International Searching Authority	<input checked="" type="checkbox"/> the designated Offices concerned
<input type="checkbox"/> the Authority(ies) specified for supplementary search	<input type="checkbox"/> the elected Offices concerned
	<input type="checkbox"/> other:

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Chahine Leila e-mail pct.team4@wipo.int Telephone No. +41 22 338 74 04
---	--



(12)发明专利申请

(10)申请公布号 CN 107079573 A

(43)申请公布日 2017.08.18

(21)申请号 201580060821.7

(22)申请日 2015.11.02

(30)优先权数据

1419636.4 2014.11.04 GB

(85)PCT国际申请进入国家阶段日

2017.05.03

(86)PCT国际申请的申请数据

PCT/GB2015/053294 2015.11.02

(87)PCT国际申请的公布数据

W02016/071680 EN 2016.05.12

(71)申请人 第四类医疗有限公司

地址 英国萨里

(72)发明人 亚伦·克诺尔 托马斯·哈尔

彼得·肖 托马斯·弗雷姆

汤姆·瓦恩托克

(74)专利代理机构 北京安信方达知识产权代理有限公司 11262

代理人 张瑞 郑霞

(51)Int.Cl.

H05H 1/24(2006.01)

H05H 1/48(2006.01)

A61B 18/04(2006.01)

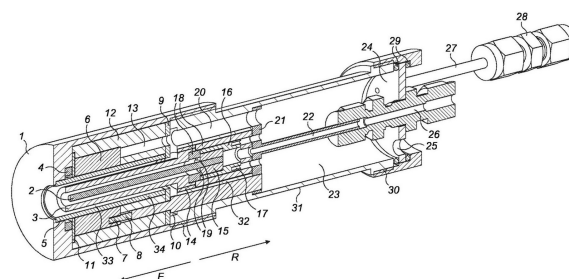
权利要求书4页 说明书14页 附图7页

(54)发明名称

等离子体的生成

(57)摘要

公开了具有开口端的等离子体炬,等离子体羽流在使用中从该开口端被发出。等离子体炬包括中心阴极棒、具有开放端并且被布置在阴极周围且与其间隔开以形成在一端开放的第一圆柱形腔的接地的导电管;以及高压电极,在其径向朝内的表面处具有介质阻挡材料并且被布置在接地的导电管周围且与其间隔开以形成在一端开放的第二环形圆柱形腔。恒定直流(DC)电力加高压脉冲电力被提供到电极,在阴极和接地的管之间的第一腔中产生电弧放电以生成在第一圆柱形腔的开口端处所发出的中心热等离子体。高压交流电力或脉冲电力被提供到高压电极,在第二环形圆柱形腔中产生介质阻挡放电以生成从第二腔的开口端发出的非热等离子体作为中心热等离子体周围的晕。



1. 一种从等离子体炬的开口端生成等离子体羽流的方法,包括:
使用电弧放电在所述等离子体炬中的第一圆柱形腔中电离进料气体,以产生在所述第一圆柱形腔的开口端处发出的中心热等离子体;
使用介质阻挡放电在被布置在所述等离子体炬中的所述第一圆柱形腔周围的第二环形圆柱形腔中电离进料气体,以在所述第二环形圆柱形腔的开口端处产生围绕所述中心热等离子体的非热等离子体晕。
2. 如权利要求1所述的方法,还包括:
使所述热等离子体朝向所述炬的所述开口端前方的焦点加速。
3. 如权利要求1或2所述的方法,还包括:
使用所述中心热等离子体,准直以及可选地夹带和/或聚焦围绕的晕非热等离子体中的至少一些。
4. 如权利要求1、2或3所述的方法,其中,所述等离子体炬包括:
中心阴极棒;
接地的导电管,所述接地的导电管具有开口端并被布置在所述阴极周围且与其间隔开,以形成在一端开放的所述第一圆柱形腔;以及
高压电极,所述高压电极被布置在所述接地的导电管周围并与其间隔开,以形成在一端开放的所述第二环形圆柱形腔,所述高压电极在其径向朝内的表面处具有介质阻挡材料。
5. 如权利要求4所述的方法,还包括:
通过向所述阴极提供恒定的直流(DC)电力加高压脉冲电力以启动所述电弧放电,来在所述阴极和所述接地的管之间在所述第一腔中产生所述电弧放电;
通过向所述高压电极提供高压交流电力或脉冲电力以生成所述介质阻挡放电,来在所述第二环形圆柱形腔中产生所述介质阻挡放电。
6. 一种用于皮肤的非外科手术美容治疗的方法,包括:
根据权利要求1至5中任一项所述的方法生成等离子体,以及
将所生成的等离子体羽流引导到需要美容治疗的皮肤上。
7. 一种用于组织的外科手术治疗的方法,包括:
根据权利要求1至5中任一项所述的方法生成等离子体,以及
将所生成的等离子体羽流引导到需要外科治疗的组织上。
8. 一种用于在工业过程中的对象的灭菌的方法,包括:
根据权利要求1至5中任一项所述的方法生成等离子体,以及
将所生成的等离子体羽流引导到需要灭菌的对象上。
9. 一种具有开口端的等离子体炬,等离子体羽流在使用中被从所述等离子体炬的开口端处发出,所述等离子体炬包括:
中心阴极棒;
接地的导电管,所述接地的导电管具有开口端并被布置在所述阴极周围且与其间隔开,以形成在一端开放的第一圆柱形腔,其中在使用中,所述阴极和所述接地的管之间的电弧放电电离进料气体,以产生从所述第一腔的开口端发出的中心热等离子体;以及
高压电极,所述高压电极在其径向朝内的表面处具有介质阻挡材料,并被布置在所述

接地的导电管周围且与其间隔开,以形成在一端开放的第二环形圆柱形腔,其中在使用中,所述高压电极和所述接地的管之间的介质阻挡放电电离进料气体,以在所述第二腔的开口端处产生围绕所述中心热等离子体的非热等离子体晕。

10.如权利要求9所述的等离子体炬,其中,所述中心阴极棒的端部从所述接地的管的开口端凹入,使得在使用中,所述电弧电流引起使所述热等离子体朝向所述炬的所述开口端前方的焦点加速的洛伦兹力。

11.如权利要求9或10所述的等离子体炬,其中,所述阴极和所述接地的管在所述等离子体炬的开口端处的相对轴向范围被配置成使得所得到的等离子体羽流集中在所述炬的所述开口端前方的给定焦距。

12.如权利要求9、10或11所述的等离子体炬,其中,所述阴极和所述接地的管能够相对地轴向移动,以允许所述炬的用户调整所述等离子体羽流的焦距。

13.如权利要求9至12中任一项所述的等离子体炬,其中,所述阴极、所述接地的管和所述高压电极被同轴地布置。

14.如权利要求9至13中任一项所述的等离子体炬,还包括环形永磁体,所述环形永磁体在其开口端处被布置成相对于所述接地的管径向向外,并且被配置为在所述电弧放电上产生磁矩以引起所述电弧放电在使用中在所述阴极周围旋转。

15.如权利要求9至14中任一项所述的等离子体炬,其中,至少所述阴极、所述接地的管和所述高压电极被布置成使得在使用中,所述中心热等离子体准直并且可选地夹带和/或聚焦围绕的晕非热等离子体中的至少一些。

16.如权利要求9至15中任一项所述的等离子体炬,其中,所述等离子体炬被配置为用于终端用户在使用中保持和操纵的手持件。

17.如权利要求16所述的等离子体炬,还包括符合人体工程学的夹持器,所述符合人体工程学的夹持器联接到所述手持件以便于用户操作。

18.如权利要求17所述的等离子体炬,包括可拆卸地连接到所述手持件的可互换的符合人体工程学的夹持器,其中可选地,所述可互换的符合人体工程学的夹持器包括以下中的一个或多个:触发器夹持器;三脚架夹持器;笔夹持器。

19.如权利要求9至18中任一项所述的等离子体炬,其中,所述阴极作为可替换的模块化配件或其部件可拆卸地连接到所述炬;以及/或者其中,所述高压电极作为可替换的模块化配件或其部件可拆卸地连接到所述炬。

20.如权利要求19所述的等离子体炬,其中,所述阴极和所述高压电极作为单独可替换的模块化配件的部件分别可拆卸地连接到所述炬。

21.如权利要求19或20所述的等离子体炬,其中,所述接地的管和所述阴极共同作为可替换的模块化配件的部件可拆卸地连接到所述炬。

22.如权利要求19、20或21所述的等离子体炬,其中,所述等离子体炬和每个模块化配件具有相互协作的螺纹,以实现它们之间的可拆卸的连接。

23.如权利要求9至22中任意一项所述的等离子体炬,还包括:

对所述第一腔和所述第二腔中的每个开放的至少一个进料气体入口;

其中,所述等离子体炬被配置为在每个进料气体入口和用于连接到进料气体供应的进料气体连接器之间提供密封的流体连通。

24. 如权利要求23所述的等离子体炬,其中,单独的进料气体连接器被提供给所述第一腔和所述第二腔中的每个,以及其中,所述等离子体炬还被配置成使得所述进料气体连接器和至所述第一腔和第二腔的所述进料气体入口之间的流体连通管线彼此被密封,使得单独的进料气体在使用中被供应到所述第一腔和所述第二腔。

25. 一种电力发电机组,所述电力发电机组与如权利要求9至24中任一项所述的等离子体炬连接并在使用中向其提供电力,所述电力发电机组包括:

被配置为在使用中向所述阴极提供恒定的直流(DC)电力加高压脉冲电力以在所述第一圆柱形腔中启动所述电弧放电的装置;

被配置为在使用中向所述高压电极提供高压交流电力或脉冲电力以在所述第二环形圆柱形腔中生成所述介质阻挡放电的装置。

26. 一种用于生成等离子体羽流的装备,包括:

如权利要求9至24中任一项所述的等离子体炬;以及

连接到所述等离子体炬的如权利要求25所述的电力发电机组。

27. 如权利要求26所述的用于生成等离子体羽流的装备,还包括连接到所述等离子体炬的一个或多个进料气体容器,其中,所述装备被配置成使得进料气体在使用中被供应给所述第一腔和第二腔以进行电离。

28. 一种使用如权利要求26或27所述的装备生成等离子体羽流的方法,包括:

使用所述电力发电机组向所述阴极提供恒定的直流(DC)电力加高压脉冲电力,以在所述阴极和所述接地的管之间在所述第一圆柱形腔中启动所述电弧放电,从而电离被供应到其的进料气体,以产生从所述第一圆柱形腔的开口端发出的中心热等离子体;

使用所述电力发电机组向所述高压电极提供高压交流电力或脉冲电力,以在所述高压电极和所述接地的管之间在所述第二环形圆柱形腔中生成所述介质阻挡放电,从而电离被供应到其的进料气体,以在所述第二腔的开口端处产生围绕所述中心热等离子体的非热等离子体晕。

29. 如权利要求26或27所述的用于生成等离子体羽流的装备,还包括:

控制模块,所述控制模块被配置为在使用中使所述装备执行权利要求28所述的方法。

30. 如权利要求29所述的用于生成等离子体羽流的装备,还包括数据处理模块和包括指令的可选地为非暂时性的计算机可读介质,所述指令当由所述数据处理模块执行时对所述装备进行配置以实现所述控制模块。

31. 一种如权利要求19至22中任一项所述的等离子体炬中的模块化阴极配件,包括阴极和可选地包括接地的管,并且被配置为可拆卸地连接到所述等离子体炬以使其阴极能够被替换。

32. 一种如权利要求19至22中任一项所述的等离子体炬中的模块化高压电极配件,包括高压电极并被配置为可拆卸地连接到所述等离子体炬以使其高压电极能够被替换。

33. 如权利要求9至24中任一项所述的等离子体炬或者如权利要求26或27所述的装备在皮肤的非外科手术美容治疗中的用途,可选地用于以下一种或多种:皱纹消除;皮肤表面重塑;皮肤消融;瘢痕消除;毛发消除;红斑痤疮的治疗;痤疮的治疗。

34. 如权利要求9至24中任一项所述的等离子体炬或者如权利要求26或27所述的装备在非外科手术治疗中的用途。

35. 如权利要求9至24中任一项所述的等离子体炬或者如权利要求26或27所述的装备在活体组织的外科手术治疗中的用途, 可选地用于以下一种或多种: 烧灼; 用于伤口愈合的组织消融; 伤口或烧伤的灭菌; 腔体灭菌。

36. 如权利要求7至24中任一项所述的等离子体炬或者如权利要求26或27所述的装备在工业灭菌过程中的用途, 可选地用于以下一种或多种进行灭菌: 食品; 药物; 医疗植入物; 医疗器械; 表面; 工业组件。

37. 一种参照附图生成实质上如前述的等离子体羽流的方法。

38. 一种参照附图实质上如前述的等离子体炬。

39. 一种参照附图用于生成实质上如前述的等离子体羽流的装备。

等离子体的生成

技术领域

[0001] 本发明大体上涉及等离子体的生成。特别地,本发明涉及等离子体炬、电力发电机组、控制模块,以及对它们进行操作以生成具有中心热等离子体刀和非热等离子体晕的协同等离子体羽流(cooperative plasma plume)的方法。等离子体羽流在皮肤的美容治疗、伤口的外科手术治疗和在工业过程中的对象灭菌方面有特殊的用途。

[0002] 背景

[0003] 生物组织的表面消融是用在各种医疗程序中的过程。消融过程可用于去除不想要的组织,并且也可在某些组织中用于刺激或诱导再生和更新。

[0004] 尝试通过表面消融或皮肤的其他微创来诱导其再生以降低老化的作用的各种美容治疗是已知的并被广泛使用的。皮肤由两个主要层组成,真皮和提供暴露的表面的表皮。表皮包括一层在另一层之上成熟的皮肤细胞层,最外层是死的细胞层,当它们再生时会脱落并由下层替换。这些美容程序旨在改善患者皮肤的外观,其目的在于例如减少可见的细线和皱纹,“复原”皮肤以去除色素斑点,并提供更光滑的光洁度,以及改善瘢痕组织(诸如由痤疮引起的疤痕)的外观。

[0005] 这些美容程序通常分为三类:机械程序、化学程序和激光程序。

[0006] “机械”程序通过机械磨损去除不需要的皮肤来实现皮肤的表面重塑。微晶磨皮是一种轻的、非侵入性的、非外科手术的美容程序,其用于通过作用例如氧化铝的小磨料颗粒状晶体来实现表皮最顶层中的死的皮肤细胞的去除。微晶磨皮可用于美容治疗皮肤纹理中的细小的不规则、细纹和浅表性瘢痕,但其效果是暂时的,并且通常不能够通过深层的表面重塑和复原以去除更多显著的皱纹和疤痕来改善皮肤的外观。

[0007] 另一方面,磨皮是使用磨轮、刷子和砂纸来机械地攻击和去除不需要的皮肤的一种用于有效地去除皮肤(表皮甚至真皮)的顶层到中间层的更显著的外科手术程序。当皮肤组织的深层被去除时,通常会导致显著的出血,因此需要局部甚至是全身的麻醉剂,并且磨皮通常由医疗专业人员在医疗或外科手术环境下来执行。皮肤通过磨皮的深层消融和表面重塑可在恢复之后通过去除更深层的疤痕、细纹和皮肤不规则来实现改善的皮肤外观。然而,在磨皮方面没有精细的深度控制,并且磨料必须施加于大面积的皮肤,以便“混合”光洁度,防止对局部不规则的有效治疗。对皮肤的创伤效果和磨皮所需的恢复时间是显著的。

[0008] 化学剥离程序使用各种化学类型,当其被直接应用到皮肤时,改变皮肤组成并使不需要的皮肤脱离表面。更轻的剥离可应用在美容护肤治疗中心中的非医疗环境中,并且这些可在细纹和轻微的皮肤不规则的外观方面实现适度较长期的改善。然而,对于较深层去除皮肤的中等和较高强度的剥离是外科手术治疗,其需要医学从业者的专业知识来了解化学剥离混合物的效果,但可实现更显著的皱纹和不规则的改善的皮肤外形。然而,在任何化学剥离中没有可用的精细的深度控制,并且剥离治疗必须应用到皮肤的整个区域(例如,面部),防止局部治疗。化学剥离通常可能需要长的恢复时间,并且对皮肤也有副作用,诸如光敏性。也可能需要重复剥离,以实现长期的期望效果。

[0009] 然而,激光皮肤表面重塑已经解决了磨皮和化学剥离的一些缺点,并且能够实现

皮肤的表面重塑和复原,以显著改善皮肤外观,并且甚至可减少较深皱纹(包括皱眉线和鱼尾纹)的外观。本文中,CO₂或Er:YAG激光用于通过分离皮肤的表面和表面下层中的分子键以诱导创伤并使皮肤(特别是表皮层)复原来复原皮肤。另外,通过激光对皮肤下层的深层加热被理解为刺激真皮中的成纤维细胞,以形成新的胶原蛋白和弹性蛋白,从而增加皮肤的饱满(弹性)和厚度,有助于减少深皱纹和老化皮肤的外观。不是激光治疗皮肤的整个表面,而是激光治疗通常以散布于其间保留有健康皮肤的皮肤区域的精确点(或显微处理区MTZ)的图案被递送到皮肤的一小部分,这样减少了愈合时间和恢复。相较于磨皮和化学剥离,激光治疗确实可按面积基于皮肤区域的要求进行一定程度的局部控制。然而,即使在恢复之后,该精确点图案化的消融皮肤也可能留下可见的图案化光洁度,其应着重进行进一步的治疗(诸如整容)。由于该光洁度的结果,激光皮肤表面重塑不适于用在治疗皮肤的小“区”中,因为针刺的图案不能混合。

[0010] 用于评估消融的能量源的度量是能量密度,针对脉冲激光消融能量源定义为激光脉冲的能量(焦耳,J)除以入射激光光斑的面积(cm²)。通常,激光的能量密度越大,真皮的穿透深度和复原深度就越大。对于典型的比较,使用从Fraxel可购的飞梭范围从5-70mJ/MTZ起的以商品名Fraxel™ re:pair™出售的一个众所周知的系统所实现的能量等级,给出了按照每cm²一百焦耳的量级的高等级的等效能量密度。因此,用脉冲分级的激光系统可以实现高浓度能量到低层的真皮的转移。对于Fraxel™ re:pair™系统,穿透深度可达200-1500微米。因此,激光治疗能够用相较于磨皮和强化学剥离显著减少的出血、副作用和恢复时间来实现改善的深层皱纹减少和皮肤表面重塑。因此,激光皮肤表面重塑可作为非医疗化环境中的美容非外科手术治疗来提供,由不必是医疗专业人员的受过训练的操作者管理。

[0011] 已经提出,通过例如电离气体形成的第四状态的物质等离子体可用于复原皮肤。使用气体等离子体用于消融组织复原的一个这样的系统由英国的Rhytec有限责任公司开发,并且现在由英国的Energist有限责任公司以NeoGen™的品牌出售,目前可从以下URL获得关于其更多的信息:<http://www.energistgroup.com/>。

[0012] Rhytec有限责任公司的国际专利申请公开号W0 2001/62169 A2公开了基于NeoGen™系统的开发的技术。Rhytec有限责任公司公布的专利申请公开了一种手持式外科手术器械,其具有携带氮气的导管和电极结构以及射频脉冲电源,其被布置用于在弱电离氮气的导管内产生介质阻挡放电,以产生要在导管的喷嘴处发出的低能量非热等离子体。在喷嘴处产生的等离子体用在细皱纹和皮肤不规则的美容治疗中,并操作以快速地将热量传递到真皮,从而刺激胶原蛋白产生并增加皮肤的弹性和厚度。然而,不同于激光治疗,该真皮加热和复原不会在与表皮的上层的直接消融(例如,通过汽化)同时发生。因此,该治疗的副作用和休整时间不如激光治疗那么显著。然而,由NeoGen™系统可传递的能量等级在等离子体羽流的大小上仅每脉冲2-6焦耳,相较于激光皮肤表面重塑而言相对较低且不集中,散布于超过一平方厘米的光斑大小上,给出约1J/cm²的低等效的能量密度值。然而,不同于激光,等离子体能量的吸收不取决于特定的氯化物(例如,用于CO₂激光的存在于细胞中的水)的存在,导致跨细胞类型、皮肤类型和结构更均匀的吸收,NeoGen™等离子体系统的低等效的能量密度意味着其可靠和有效地治疗深层皱纹并实现显著的皮肤表面重塑的能力是有问题的。缺乏任何直接的皮肤消融连同低能量密度意味着NeoGen™系统对于皮肤表面重

塑以及显著皮肤不规则和皱纹的去除有效性非常有限。实际上,可能需要大量的重复程序来实现任何比细纹和轻微皮肤缺陷更显著的任何明显的益处。

[0013] 用于改善老化皮肤外观的非消融治疗包括被注射到皮肤中的真皮填充剂、肉毒杆菌毒素和胶原蛋白的使用。然而,这些是通过使皮肤膨胀和麻痹肌肉对个体外观具有显著的副作用的侵入性干预。这些治疗本身并没有从根本上复原皮肤,而是通过“雕刻”皮肤和‘填充’皱纹来寻求实现改善的外观,这可能会显得不自然。

[0014] 另一种非消融治疗是射频、红外或超声皮肤收紧疗法,其中射频、红外光或超声波用于加热皮肤以试图促进胶原蛋白形成,从而收紧皮肤。然而,这些治疗的效果并不显著,而只是短期受益,需要大量的重复时间段。

[0015] 以上述角度来看,存在对促进皮肤复原和减少皱纹和皮肤不规则的外观的新治疗的兴趣。另外,消融和创伤原理也用于其他外科手术目的,尤其是伤口清创和组织再生。

[0016] 这正是设想本发明的背景。

[0017] 发明概述

[0018] 从一方面看,本发明提供了从等离子体炬的开口端生成等离子体羽流的方法。方法包括使用电弧放电在等离子体炬的第一圆柱形腔中电离进料气体,以产生在第一圆柱形腔的开口端处发出的中心热等离子体。该方法还包括使用围绕在等离子体炬中的第一圆柱形腔布置的第二环形圆柱形腔中的介质阻挡放电来电离进料气体,以在第二环形圆柱形腔的开口端处产生环绕中心热等离子体的非热等离子体晕。

[0019] 根据本发明,提供了具有广泛用途的高功率等离子体治疗。例如,提供了具有在美容上处理深层皱纹和显著的皮肤不规则的能力的等离子体程序。具有热中心等离子体刀和非热等离子体晕的较高能量的两节段等离子体对患者预后具有比现有技术的低能量仅非热等离子体的设备具有更好的效果。另外,实现了低恢复期,使得程序可在非外科手术的环境中由受过训练的非医疗专业人员进行。实际上,其中不需要麻醉剂的美容治疗可利用本发明来进行。

[0020] 等离子体的两个阶段可递增地操作,使得用户可仅启动晕非热等离子体,以在较低能量等级下处理皮肤的一些区域,而除了晕等离子体之外,中心热等离子体可被选择性地启动,以在较高的能量等级下治疗皮肤的选定区域。通过这种方式,可实现的能量范围和设备的效用范围是非常宽的。因此,等离子体治疗系统能够以与分级激光治疗(尽管副作用较少,并且在更多分区的基础上混合更容易)相似的方式用于治疗深层皱纹和显著的皮肤不规则,并且还用于在较低能量等级下治疗有细线和皱纹的皮肤的其他区域。

[0021] 可用两阶段等离子体实现的能量密度在 $10-100\text{J}/\text{cm}^2$ 的范围内,这与NeoGen™激光系统相当,而仅使用晕非热等离子体可实现的能量密度是 $<1-10\text{J}/\text{cm}^2$ 的量级,这与NeoGen™系统相当。

[0022] 虽然高能量中心热等离子体用于消融组织(例如,以延迟的方式用于促进皮肤表面层的复原和再生的表皮层),并用于热刺激组织(例如,用于刺激胶原蛋白形成的真皮的下层),非热等离子体晕具有对围绕创伤组织的组织进行灭菌以促进其愈合的效果。在皮肤中,表面层由高能量等离子体消融,但是周围的组织由晕灭菌,并且可以保留在原位,同时底层和消融层愈合,使得天然无菌敷料通过等离子体治疗本身形成,促进了创伤组织的愈合。这进一步减少了对于这样的潜在的深层皱纹和复原治疗的恢复时间。表面出血除了被

最小化之外,还保持修整时间低。

[0023] 等离子体的两阶段的布置使得它们“协同操作”,由此,通过电弧放电产生的高电离能量的中心热等离子体“刀”对周围的非热等离子体晕具有准直效应,由此,至少一些非热等离子体晕由中心等离子体夹带或聚焦。这将两种类型的等离子体一起成为更集中的协作的羽流,其中在非热等离子体中通过介质阻挡放电对气体的弱电离中生成的增加的自由基通量在羽流的能量中心尖端处产生。在高能量等离子体刀尖端中夹带这些自由基使等离子体羽流具有与组织增加的有益的相互作用以促进复原和愈合。

[0024] 因此,在实施例中,方法还可以包括:使用中心热等离子体,准直以及可选地夹带和/或聚焦至少一些环绕的晕非热等离子体。

[0025] 另外,羽流形状使炬能够用在某种程度上像漆刷(paintbrush)的美容治疗中,以将局部区域治疗到不同的深度和效果,提供易于局部混合的灵活的光洁度从而可用于治疗小区域或区,特别是深层皱纹的区域,诸如鱼尾纹或皱眉线,而不必治疗广泛的皮肤区域。这不同于激光治疗,激光治疗更像是尖锐的铅笔,或者如果分级留下像点阵图案的光洁度,因此既不能容易地混合,也不能用于单独治疗皮肤的小区。相反,借助激光治疗,通常需要对整个面部或至少其广泛的区域进行治疗。本发明允许对深层皱纹和其他显著的局部皮肤不规则进行有针对性的局部治疗。

[0026] 在实施例中,可通过在实施例中进行以下操作来调整羽流的光斑大小和形状:提供具有可调整电极几何形状的等离子体炬并调整其相对位置,增加或减少进料气体压力,收缩或扩张腔的开口端,或者增加或减少或以其他方式改变电极的电源波形以生成两个等离子体阶段中的一个或两个。通过提供可调整的光斑大小和羽流形状,用户可以容易地将输出的等离子体适应于皮肤的不同区域和状况,像漆刷的调色板一样,允许混合和定制治疗以应用于皮肤的小区。

[0027] 在实施例中,该方法还包括使热等离子体朝向炬的开口端前方的焦点加速。通过这种方式聚焦等离子体羽流对组织给出了相比于比较分散的非聚焦羽流更高的能量密度和更大的效应。

[0028] 在实施例中,等离子体炬包括:中心阴极棒;接地的导电管,该接地的导电管具有开口端并且被布置在阴极周围且与其间隔开,以形成在一端开放的第一圆柱形腔;以及高压电极,该高压电极被布置在接地的导电管周围且与其间隔开,以形成第二环形圆柱形腔,该高压电极在其径向朝内的表面处具有介质阻挡材料。

[0029] 在实施例中,方法还包括:通过向阴极提供恒定的直流(DC)电力加高压脉冲电力以启动电弧放电,在阴极和接地的管之间在第一腔中产生电弧放电;通过向高压电极提供高压交流电力或脉冲电力以生成介质阻挡放电,在第二环形圆柱形腔中产生介质阻挡层放电。

[0030] 从另一方面看,本发明提供了用于皮肤的非外科手术美容治疗的方法,包括:根据本文中所描述的本发明的任何方法生成等离子体,以及在需要美容治疗的皮肤处引导所生成的等离子体羽流。

[0031] 从另一方面看,本发明提供了用于在工业过程中的对象的灭菌的方法,包括:根据本文中所描述的本发明的任何方法生成等离子体,以及在需要灭菌的对象处引导所生成的等离子体羽流。已经发现通过本文中所描述的本发明的方法生成的等离子体的灭菌和加热

的作用在对象的灭菌中(例如,在工业过程中)具有特别的用途。

[0032] 从一个方面看,本发明提供了具有开口端的等离子体炬,公开了等离子体羽流在使用中从该开口端被发出。等离子体炬包括中心阴极棒、接地的导电管,该接地的导电管具有开口端并且被布置在阴极周围且与其间隔开以形成在一端开放的第一圆柱形腔;以及高压电极,该高压电极在其径向朝内的表面处具有介质阻挡材料,并且被布置在接地的导电管周围且与其间隔开以形成在一端开放的第二环形圆柱形腔。在使用中,恒定直流(DC)电力加高压脉冲电力被提供到阴极,在阴极和接地的管之间在第一腔中产生电弧放电,以生成在第一圆柱形腔的开口端处所发出的中心热等离子体。另外,在使用中,高压交流电力或脉冲电力被提供到高压电极,在第二环形圆柱形腔中产生介质阻挡放电,以生成从第二腔的开口端发出的非热等离子体作为中心热等离子体刀周围的晕。

[0033] 因此,从另一方面看,本发明提供了具有开口端的等离子体炬,等离子体羽流在使用中从该开口端被发出,该等离子体炬包括:中心阴极棒;接地的导电管,其具有开口端并且被布置在阴极周围且与其间隔开以形成在一端开放的第一圆柱形腔,其中在使用中,阴极和接地的管之间的电弧放电电离进料气体,以产生从第一腔的开口端发出的中心热等离子体;以及高压电极,在其径向朝内的表面上具有介质阻挡材料,并且被布置在接地的导电管的周围且与其间隔开以形成第二环形圆柱形腔,其中在使用中,高压电极和接地的管之间的介质阻挡放电电离进料气体,以在第二腔的开口端处产生围绕中心热等离子体的非热等离子体晕。因此,通过这种方式配置的等离子体炬能够在使用中产生在美容和外科手术治疗中具有特殊用途的高能量二阶段协作的等离子体。

[0034] 在实施例中,等离子体炬可被配置成使得在使用中羽流的光斑大小和形状可通过在实施例中进行以下操作来进行调整:提供具有可调整的电极几何形状的手持件,使进料气体压力能够增加或减少,提供用于收缩或扩张腔的开口端的孔径的一个或多个装置,或者提供在使用中可操作的电源单元以实现增加或减少或以其他方式改变电极的电源波形从而能够生成两个等离子体阶段中的一个或两个。

[0035] 在实施例中,中心阴极棒的端部从接地的管的开口端凹入,使得在使用中,电弧电流引起使热等离子体朝向炬的开口端前方的焦点加速的洛伦兹力。以这种方式进行的电极的布置通过使电流通过接地的管和阴极(由于它们之间的电弧放电)而引起在第一腔中产生的磁场,其中磁场线在阴极周围圆柱形地流动。该磁场本身对通过在等离子体上产生洛伦兹力的电弧放电所生成的带电热等离子体具有影响,这是由于相较于接地的管的开口端,阴极的凹处指向接地的管的开口端前方的电极的中心公共轴。通过这种方式,热等离子体朝向炬的开口端前方的焦点加速,允许等离子体被集中,在产生的等离子体羽流中给出高的能量密度。在这方面,通过由电弧放电产生的电流所引起的磁场的等离子体加速在等离子体上产生了磁流体动力学效应,这意味着加速的等离子体可被认为是磁流体动力学等离子体。

[0036] 在实施例中,阴极和接地的管在等离子体炬的开口端处的相对轴向范围被配置成使得所得到的等离子体羽流集中在炬的开口端前方的给定焦距。通过这种方式,电极的相对定位和配置被设置为给出期望的羽流特性。在实施例中,阴极和接地的管可相对地轴向移动,以允许炬的用户调整等离子体羽流的焦距。通过这种方式,电极的相对定位和配置是可调整的,以允许操作者调整羽流的形状和强度,从而实现期望的羽流特性。这允许操作者

在等离子体炬的操作和效果上有很程度的灵活性和控制,并且可被认为类似于为操作者提供用其复原皮肤不同区域的各种漆刷。

[0037] 在实施例中,阴极、接地的管和高压电极被同轴地布置。

[0038] 在实施例中,等离子体炬还包括环形永磁体,该环形永磁体在其开口端处被布置成相对于接地的管径向向外,并且被配置为在电弧放电上产生磁矩以引起该电弧放电在使用中在阴极周围旋转。环形永磁体的提供使高能量电弧在阴极周围旋转,这允许在电弧定位时于阴极和接地的管中所生成的热被消散。这可延长“热的”电极的寿命,因为如果电弧重复地入射在阴极和接地的管的相同位置上,则这些电极可能相对快地过热和耗损。根据该实施例,电极的寿命延长,减少了维护并改善了两阶段等离子体生成系统的实用性。然而,在其它实施例中,可以完全省略永磁体。

[0039] 在实施例中,至少阴极、接地的管和高压电极被布置成使得在使用中,中心热等离子体准直并且可选地夹带和/或聚焦至少一些周围的晕非热等离子体。

[0040] 在实施例中,等离子体炬被配置为用于终端用户在使用中保持和操纵的手持件。手持件可被设置有一个或多个控制装置以点燃外部非热等离子体以及除此之外的中心热等离子体。

[0041] 在实施例中,等离子体炬还包括联接到手持件以便于用户操作的符合人体工程学的夹持器。在实施例中,等离子体炬包括可拆卸地联接到手持件的可互换的符合人体工程学的夹持器。可互换的符合人体工程学的夹持器可包括以下中的一个或多个:触发器夹持器;三脚架夹持器;笔夹持器。通过提供等离子体炬作为手持式工具,具有了符合人体工程学和可选择的夹持器辅助用户操纵等离子体羽流,并允许使用中的精细控制和舒适性。

[0042] 在实施例中,阴极作为可替换的模块化配件或其部件可拆卸地连接到炬。可替代地或附加地,高电压电极作为可替换的模块化配件或其部件可拆卸地连接到炬。在实施例中,阴极和高压电极分别作为单独可替换的模块化配件的部件可单独地可拆卸地连接到炬。在实施例中,接地的管和阴极一起作为可替换模块化配件的部件可拆卸地连接到炬。在实施例中,等离子体炬和每个模块化配件具有相互协作的螺纹,以实现它们之间的可拆卸连接。通过为等离子体炬提供具有用于“热的”电极节段(包括阴极)和/或“冷的”电极节段(包括高压电极)的可容易改变的模块化部件的模块化结构,如果和当电极耗损时,它们是可容易替换的,而无需由服务工程师拆卸炬。相反,耗损的电极模块化组件可由终端用户去除,例如通过将它们从炬中拧下来,并用新的或重新调整的模块化组件来替换。

[0043] 从另一方面看,本发明提供了根据本文中所描述的本发明的方面和实施例的等离子体炬中的模块化阴极配件,该模块化阴极配件包括阴极和可选的接地的管,并且被配置为可拆卸地连接到该等离子体炬,使其阴极能够被替换。

[0044] 从另一方面看,本发明提供了根据本文中所描述的本发明的方面和实施例的等离子体炬中的模块化高压电极配件,该模块化高压电极配件包括高压电极并且被配置为可拆卸地连接到等离子体炬,以使其高压电极能够被替换。

[0045] 在实施例中,等离子体炬还包括:为第一腔和第二腔中的每个开放的至少一个进料气体入口;其中,等离子体炬被配置为在每个进料气体入口和用于连接到进料气体供应的进料气体连接器之间提供密封的流体连通。在实施例中,单独的进料气体连接器被提供给第一腔和第二腔中的每个,以及其中,等离子体炬还被配置成使得进料气体连接器和至

第一腔和第二腔的进料气体入口之间的流体连通管线彼此被密封,使得该单独的进料气体在使用中被供应到第一腔和第二腔。

[0046] 从另一方面看,本发明提供了与根据上述本发明的方面和实施例的与等离子体炬连接并在使用中向其提供电力的电力发电机组,该电力发电机组包括:被配置成在使用中向阴极提供恒定的直流(DC)电力加高压脉冲电力以在第一圆柱形腔(热等离子体炬)中启动电弧放电的装置;被配置为在使用中向高压电极提供高压交流电力或脉冲电力以在第二环形圆柱形腔(非热等离子体炬)中生成介质阻挡放电的装置。

[0047] 热电力和非热电力可以独立地操作,例如响应于用户控制,使得等离子体的两个阶段可以逐步操作,从而在使用中用户可仅启动非热等离子体,以在较低能量等级下处理皮肤的一些区域,而除了非热等离子体之外,中心热等离子体可被选择性地启动,以在较高的能量等级下治疗皮肤的选定区域。

[0048] 从另一方面看,本发明提供了用于生成等离子体羽流的装备,该装备包括:根据本文中所述的本发明的方面和实施例的等离子体炬;以及根据本文中所述的本发明的方面和实施例的电力发电机组。

[0049] 在实施例中,装备还包括连接到等离子体炬的一个或多个进料气体容器,其中,该装备被配置成使得在使用中进料气体被供应到第一腔和第二腔以进行电离。

[0050] 从另一方面看,本发明提供了使用用于生成根据本文中所述的本发明的方面和实施例的等离子体羽流炬的装备生成等离子体羽流的方法,该方法包括:使用电力发电机组向阴极提供恒定的直流(DC)电力加高压脉冲电力,以在阴极和接地的管之间在第一圆柱形腔中启动电弧放电,从而电离供应给其的进料气体,以产生从第一圆柱形腔的开口端发出的中心热等离子体;以及使用电力发电机组向高压电极提供高压交流电力或脉冲电力,以在高电压电极和接地的管之间在第二环形圆柱形腔中生成介质阻挡放电,从而电离供应给其的进料气体,以在第二腔的开口端处产生围绕中心热等离子体的非热等离子体晕。

[0051] 被配置为在使用中使装备执行以上方法的控制模块可被设置为该装备的部件。控制模块可使用硬件或硬件和软件来实现。可提供数据处理模块和可选地是非暂时性的包括指令的计算机可读介质,该指令当由数据处理模块执行时对装备进行配置以实现控制模块。

[0052] 从另一方面看,本发明提供了根据本文中所述的本发明的方面和实施例的等离子体炬或装备在皮肤的非外科手术美容治疗中的用途,可选地用于以下一种或多种:皱纹消除;皮肤表面重塑;皮肤消融;疤痕消除;毛发消除。

[0053] 从另一方面看,本发明提供了根据本文中所述的本发明的方面和实施例的等离子体炬或装备在非外科手术治疗中的用途。

[0054] 从另一方面看,本发明提供了根据本文中所述的本发明的方面和实施例的等离子体炬或装备在活体组织的外科手术治疗中的用途,可选地用于以下一种或多种:烧灼;用于伤口愈合的组织消融;伤口或烧伤的灭菌;腔体灭菌。

[0055] 从另一方面看,本发明提供了根据本文中所述的本发明的方面和实施例的等离子体炬或装备在工业灭菌过程中的用途,可选地用于对以下中的一种或多种进行灭菌:食品;药物;医疗植入物;医疗器械;表面和工业组件。

[0056] 附图简述

[0057] 本发明的方面可通过参照以下结合附图进行的特定示例性实施例的描述来理解，其中：

[0058] 图1示出了用于生成根据本发明方面的实施例的用于皮肤的美容治疗的等离子体羽流的装备的视图；

[0059] 图2是图1所示出的系统控制单元的组件的图1中所示出的装备的示意图；

[0060] 图3是根据实施例的等离子体炬的剖视图；

[0061] 图4是图3所示出的等离子体炬的“热的”阶段的操作以生成电弧放电和热等离子体的图；

[0062] 图5是图3所示出的等离子体炬的“冷”阶段的操作以生成介质阻挡放电和非热等离子体的图；

[0063] 图6图示了由等离子体炬生成的等离子体的两个阶段和用于生成准直聚焦的等离子体羽流的协作效应；以及

[0064] 图7是由根据本发明方面的实施例的等离子体炬生成的两阶段等离子体羽流的图片，其中边缘检测算法已经应用于图像以帮助揭示出协作羽流的结构。

[0065] 优选实施例的详细描述

[0066] 以下结合附图所阐述的详细描述旨在作为本发明的当前优选实施例的描述，而不旨在表示可以实践本发明的唯一形式。应当理解，相同或等同的功能可以通过旨在包含在本发明的精神和范围内的不同实施例来实现。此外，术语“包括 (comprises)”，“包括 (comprising)”或其任何其它变体旨在涵盖非排他性包含，使得包括元素或步骤的列表的装备和方法步骤不仅包括那些元件，而且可以包括未明确列出或固有的其他要素或步骤。由“包括...”进行的元素或步骤在没有更多约束的情况下不排除包括元素或步骤的附加相同的元素或步骤的存在。

[0067] 现在参照图1和图2，用于生成根据本发明方面的实施例的等离子体羽流的装备100包括经由连接器软管130连接到系统控制单元150的等离子体炬101。如以下将进一步详细解释的，通过借助于控制装置151操作系统控制单元150，可使系统控制单元150的控制器52释放来自气体供应53的一个或多个进料气体，其中该进料气体在压力下被储存到等离子体炬101内的电离腔。一旦气体通过设置在软管130中的气体供应导管133流到等离子体炬101，控制器52就让电源生成一个或多个不同的电力信号，该一个或多个不同的电力信号经由设置在软管130中的电源电缆131被提供到等离子体炬101中的一个或多个电极，以在等离子体炬101内引起放电。如以下更详细描述，随后，等离子体炬内的进料气体通过放电被电离，并且以两阶段等离子体羽流的形式被从等离子体炬101的开口端103发出。等离子体羽流可在持续的时间段内被生成，或者可以以脉冲形式被发出。

[0068] 装备100的操作者可通过用符合人体工程学的夹持器105保持等离子体炬来操纵等离子体炬，以将从开口103发出的等离子体羽流引导到组织上，从而执行美容或外科手术程序。为了允许容易的用户控制，等离子体炬101可被设置有一个或多个控制装置(未示出)，诸如夹持器105上用于点燃外部非热等离子体和除此之外的中心热等离子体的触发器按钮。例如，羽流可用于诸如鱼尾纹和其他显著的皮肤不规则的深层皱纹的美容治疗。图1中所示的符合人体工程学的夹持器105是触发器夹持器，但其可移除地附接到等离子体炬101，使得其可被改变成可特别适于给定操作者的手的其他符合人体工程学夹持器。这允许

操作者在使用中当长期保持等离子体炬101时有高度的舒适性和精度。

[0069] 由装备100生成的等离子体是两阶段协作的等离子体,其具有由较低能量的晕非热等离子体包围的较高能量中心聚焦的热等离子体刀。可选地,只有非热等离子体的外晕阶段可被点燃。

[0070] 图3是等离子体炬101的剖视图,其示出了在使用中引起两阶段协作等离子体的产生的电极结构。等离子体炬101在概念上可分为两半。由图1中的箭头F指示的前半部分包含电极和腔,气体被馈入到该腔以用于电离,并且两阶段等离子体在使用中被从该腔中发出。等离子体炬101的前半部分由两个用户可替换的模块化组件构成,当其中的电极损耗时便于等离子体炬101的维修。由图1中的箭头R指示的等离子体炬101的后半部分用于支撑并保持前半部分的组件,并提供与软管130的连接,以实现气体供应从软管130的气体供应导管131到前半部分中的腔33、34的密封的流体连通,以及将前半部分F中的电极2、6电连接到软管130的电力电缆131。

[0071] 等离子体炬101在前半部分F中的组件被封装在接地的不锈钢外壳1中。外壳1是在其前端具有端壁的形式管状的,该端臂具有用于在使用中接纳等离子体羽流的轴向集中的开口103。外壳1的后端具有被设置在其径向朝内的表面上的螺纹14,其与被设置在形成等离子体炬101的后端R的接地的不锈钢主体31前端的径向朝外的表面上的相应螺纹14相互协作并由其保持。可相对于外壳1旋转的螺纹套(未示出)可被设置在外壳1上,以用于穿到不锈钢主体31的螺纹14上,从而使炬的前部F和后部R配对而不会相对旋转。如下更详细描述,主体31朝向其前端具有被加工成多孔隔板32的实心块,其用于保持等离子体炬101的某些其他组件,并且接纳进料气体和电连接线从等离子体炬101的后部到其前部。

[0072] 钨或钨钨形成的阴极棒2被设置在等离子体炬101的前半部分中,以沿着其中心轴线延伸。设置有接地的不锈钢电弧管3,其被同轴地布置在阴极棒2周围且与其间隔开。在棒2和接地的管3之间形成的圆柱形环形腔33在其前端是开放的,但是除了进料气体入口之外,它在其后端被密封。如以下将更详细解释的,在使用中,阴极棒2被设置有足以在阴极棒2和接地的管3之间产生电弧的电力信号,该电弧用于在圆柱形环形腔33中生成“热的”热等离子体,该热等离子体随后被从腔33的开放前端发出。应当注意,阴极棒2在其前端处的轴向范围相对于接地的管3的前方的开口端稍微凹入。该相对定位引起待由电弧放电的电流生成的洛仑兹力,这使中心热等离子体的带电粒子朝向等离子体炬101的中心轴加速,使等离子体羽流的热阶段变得聚焦。

[0073] 在其前端被径向地布置在接地的管3外的是产生磁场的环形NdFeB永磁体4,其在阴极2和接地的管3之间的电弧上提供稳定的磁矩,并使电弧在使用中围绕阴极2旋转。这防止了电弧维持在阴极棒2和接地的管3之间的单一位置处,这样可防止阴极2过热并被损坏。这可以延长等离子体炬101的组件的寿命,并且阴极2通过磁体4的保护使电弧放电的使用变得更实用。然而,在可替代实施例中,可以省略永磁体。

[0074] 被同轴地布置在接地的管3周围并与其间隔开的是硼硅酸盐玻璃或陶瓷(氮化硼/氧化铝)管5,其具有4.6的介电常数,并且用作对径向向外布置的高压铜电极6的介质阻挡。第二圆柱形腔34在接地的管3和介质阻挡管5之间形成,该介质阻挡管5在其前端处是开放的,但是在其后端处通过隔板32密封,除了由隔板32中的钻孔20形成的入口,该入口实现了进料气体、热电偶13和同轴电源电缆8从等离子体炬101的后部R到前部F的通道。如以下将

更详细解释的,在使用中,高压电极6被设置有足以在介质阻挡管5和接地的管3之间产生介质阻挡放电的电力信号,该介质阻挡放电用于在圆柱形环形腔34中生成“冷的”非热等离子体,该“冷的”非热等离子体随后被从腔34的开放前端发出。

[0075] 高压电极6连接到黄铜螺纹杆7,该黄铜螺纹杆用作高压连接器并且具有焊接到其的同轴电缆8的导电芯。在使用中,同轴电缆8经由电力电缆131将由电源51生成的高电压电力信号传导到高电压电极6。

[0076] 接地的黄铜板9被设置在围绕隔板32前方的接地的管3的等离子炬101的前部中,但稍微与其间隔开。同轴电缆8的接地屏蔽10被焊接到黄铜板9,以提供接地参考。黄铜板9与外壳1和主体31接触,并且用作等离子体炬101的接地组件的接地参考。

[0077] 陶瓷(氮化硼/氧化铝)盘11被布置在磁铁4和高电压电极6之间,以使它们彼此电绝缘和热绝缘。另外的陶瓷(氮化硼/氧化铝)块12被布置成在高电压电极6周围延伸,以使高压电极6与所有其它接地的金属表面电绝缘和热绝缘。钻孔13在块12中形成,以接收被布置成在使用中监测高压电极6的温度的以确保其不会过热的热电偶(未示出)。另一孔在块12上形成,以接收用于经由高压连接器7连接到高压电极6的同轴电缆芯8。孔被设置为通过黄铜板9和对齐(registered)到块12中设置的孔的隔板32,以将热电偶和同轴电缆从等离子体炬101的后部传递到其前部。

[0078] 隔板32还由大的中心钻孔在中心穿孔,该中心钻孔包含黄铜阴极连接器16,该黄铜阴极连接器16由被设置为径向向外并且到阴极连接器16的后部的陶瓷(氮化硼/氧化铝)组件18围绕,以使阴极连接器16与所有其他接地的金属表面电绝缘和热绝缘。黄铜阴极连接器16中的钻孔形成被定尺以接收其中具有干涉配合(interference fit)的不锈钢阴极基座15。阴极2由阴极基座15支撑并从中延伸到等离子体炬101的前部。到阴极连接器16前部的陶瓷绝缘体18将阴极2、阴极基座15和阴极连接器16与接地的钢管3绝缘。

[0079] 接地的管3具有扩大的圆柱形基座,该扩大的圆柱形基座在其径向朝外的表面上具有螺纹14,该螺纹14与被设置在隔板32的中心钻孔的径向内表面上的螺纹14相互协作,使得接地的管3可与接地钢主体31松开啮合,并从而在使用中接地。

[0080] 在实施例中,可替换的“冷尖端”模块由接地外壳1提供,并且包含永磁体4、介质管5、陶瓷绝缘体11、13和黄铜板9。这些组件被共同设置在单一配件中,该单一配件可借助于被设置在钢主体31的径向外表面上的螺纹14与等离子体炬101的后部的钢主体31松开啮合。

[0081] 在实施例中,可替换“热尖端”模块由阴极2、接地的管3、阴极基座15以及夹在阴极基座15和接地的管3的扩大的圆柱形基座之间的陶瓷绝缘体组件18提供。这些组件被共同设置在单一配件中,该单一配件可借助于被设置在钢主体31的隔板32的径向内表面上的螺纹与等离子体炬101的后部的钢主体31松开啮合。阴极基座15和阴极连接器16之间的干涉配合形成可配对和可去配对的阳-阴连接器,其中阴极基座15形成阳部,阴极连接器16形成阴部。

[0082] 当冷尖端和热尖端模块的电极损耗时,该冷尖端和热尖端模块可由用户容易地替换以维修等离子体炬101。在其他实施例中,至少包括高压电极的冷尖端和至少包括阴极的热尖端可被不同地构造,并且在配件中具有与图3中所详细描述的实施例所示的配件不同的组件。例如,除了螺纹之外的紧固机构可用于将热尖端和冷尖端模块连接到等离子体炬

101的主体。

[0083] 等离子体炬101的主体31的壁形成圆柱形腔室23直到隔板32的后部,该圆柱形腔室在后端由端盖30封闭,该端盖具有径向延伸的馈通板24,该径向延伸的馈通板24具有在其中通过的孔和用于经由气体供应导管133与电源51和气体供应53对接的连接器。端盖30借助于螺纹结合到主体31。

[0084] 抵靠隔板32的朝后的表面,不锈钢保持板21通过拧入到面朝后的陶瓷绝缘体18和隔板32中将阴极连接配件16保持在适当位置。从保持板21的轴向中心延伸的是整体式不锈钢心轴22,其具有在两端处开放的穿过中心延伸的钻孔。心轴22的后部结合到穿过馈通板24的型锻锁(swage lock)连接器26,该馈通板封闭并密封由圆柱形主体31形成的腔室23。在使用中,用于待在热尖端中电离的中心热等离子体的进料气体供应连接到型锻锁连接器26。因此,流体连通通道被设置为在型锻锁连接器26和腔33之间经由心轴22的中心钻孔,通过穿过被设置在经过阴极连机器16本身的阴极连机器16的后端处的陶瓷绝缘体18的中心的孔,并且还通过被设置为经过不锈钢阴极基座15的凹槽,允许进料气体绕过阴极基座15和阴极连接器16之间的干涉配合,并通过进入到在阴极棒2和接地的管3之间的空间中形成的腔33中。

[0085] 第二型锻锁连接器28连接到馈通板24,并且将流体连通通道提供到在由馈通板24封闭的主体31的后部内形成的腔室23中。在使用中,冷进料气体供应连接到型锻锁28,使得主体31后部中的腔室23被填充冷进料气体。丁腈橡胶O型圈29被布置在馈通板24和主体31之间,以在压缩时在外部大气压和设备内部之间提供密封。被设置为延伸穿过保持器21和隔板32的四个钻孔20为冷进料气体提供了从等离子体炬101的后部R处的腔室23到等离子体炬101的前部的流体连通路。在隔板32的前部F和黄铜板9之间形成的径向延伸的间隙允许来自钻孔20的冷等离子体进料气体进入到腔34中,其中冷等离子体在使用中由黄铜板9和接地的管3之间的环形间隙形成。

[0086] 钻孔20之一执行为高压同轴电缆8提供通道的可替代功能,该高压同轴电缆从等离子体炬101的后部的馈通板24中的孔延伸,穿过冷等离子体腔室23,穿过保持器板21中的孔,穿过隔板32中的钻孔20,穿过黄铜板9中的孔,并穿过陶瓷绝缘体12中的钻孔。在陶瓷绝缘体12中的钻孔的前部,同轴电缆8的导电芯通过高压连接器7连接到高电压电极6。通过这种方式,导电连接经由电力电缆131从高电压电极6和电源51之间形成。

[0087] 为了将电源51连接到阴极2,孔被设置在保持器21中,陶瓷绝缘体18到阴极连接器16的后部打开进入到阴极连机器16本身中的钻孔中。经由馈通板24中的孔延伸到等离子体炬中的单芯线延伸通过腔室23并通过保持器21和陶瓷绝缘体18中的孔,由此线芯被焊接到阴极连接器16。通过这种方式,导电连接经由电力电缆131在阴极2和电源51之间形成。

[0088] 在图3中所示的实施例中,第一腔33和第二腔34彼此密封,使得它们没有流体连通(除了经由开放的前端),并且单独的气体供应通过软管130连接以单独给第一腔33和第二腔34进料。诸如氮气或氩气或它们的混合物的惰性气体可用作进料气体,并且不同类型或组成的这些气体可单独被馈送到第一腔33和第二腔34。可替代地,相同类型或组成的气体可单独馈送到第一腔33和第二腔34二者。可替代地,在其他实施例中,用于将进料气体从等离子体101的后部R连通到其前部F的流体通道可以是统一的/流体连通的,使得单一气体供应可用于将相同类型的气体馈送到第一腔33和第二腔34。

[0089] 现在将参照图2、图4和图5对用于生成两阶段协作的等离子体羽流的装备100的操作进行描述。

[0090] 为了开始两阶段等离子体的产生,系统控制单元150中的气体供应51由控制器52响应于控制装置151的用户操作而引起,以开始将处于压力下的进料气体经由气体供应导管133释放到第一腔33和第二腔34。

[0091] 随后,控制器52使电源51生成经由电力电缆131提供给阴极2和高压电极6的电力信号。

[0092] 如图4中所示,为了生成等离子体的热阶段,阴极2连接到由电源51提供的DC电源。DC电源由 $\sim 25\text{V}$ 、 $\sim 4.2\text{ADC}$ 的恒定电源加镇流器/点火器高压脉冲电路组成,以启动电弧放电。该DC电源生成并维持如图8中所示的电压和电流相对于时间的波形,其中100–200V的初始电压脉冲由镇流器/点火器电路施加,该100–200V的初始电压脉冲随着电场击穿且电弧通过进料气体在阴极2和接地的管3之间被启动随后逐渐稳定到约20–60V的DC稳态。电弧提供加热和电离机构,以用于从进料气体生成高电离、高能量的热等离子体,该热等离子体提供设备的等离子体羽流的“热的”分量。由持续的电弧放电在接地的管6和阴极2中生成的电流 j 具有可在2–6A之间变化的电流。如图4中所示,该电流使方位磁场 B 在阴极周围生成。如在腔33的开口端所示,该方位磁场 B 与电弧 j 的相互作用生成作用于所生成的离子的洛伦兹力 F ,以使热等离子体在由图4中的箭头所示的方向上朝向等离子体炬101的轴向中心加速,从而使热等离子体朝向焦点 P 聚焦在腔33的开口端前方一定距离。通过这种方式,等离子体和磁场 B 的相互作用生成如图6中所示的成形的磁流体动力学(MHD)热等离子体“刀”601。这种高度电离聚焦的热等离子体的高能量在焦点处产生高的能量密度,这使装备100能够对组织(诸如在使用中可被引导到其的皮肤)具有显著更大和更好的穿透效果。因此,相较于已知的等离子体组织表面重塑的设备,装备100实现了显著改善的组织的表面重塑、再生和复原效果,改善了美容和外科手术组织治疗二者中的患者预后。实际上,由装备100实现的患者预后类似于以上所述描述的已知激光系统,而没有像皮肤上的针刺图案化的任何伴随的缺点。相反,使用两阶段等离子体的美容治疗的皮肤上的光洁度更平滑并且更容易混合,使得皮肤的较小“区”的美容治疗能够得以实现,同时仍提供均匀的表面光洁度。

[0093] 由磁体4在电弧上产生的磁矩使电弧放电在阴极2周围旋转,最小化了阴极2和接地的管3上的放电的加热损坏和损耗,延长了“热尖端”组件的使用寿命。

[0094] 在其他实施例中,等离子体生成系统100可被配置成使得在使用中,羽流的光斑大小和形状可以是可调整的。虽然未在图3的实施例中示出,但用户可控的电极几何形状改变机构可被设置在等离子体炬中,以允许操作者调整羽流的光斑大小和形状。例如,机构可被设置为允许用户调整阴极2和接地的管3的前端的相对轴向定位,以便调整作用在热等离子体上的聚焦的洛伦兹力的方向性,所得到的等离子体羽流的焦距、光斑大小和光斑能量/能量密度也是如此。这可以直接在等离子体炬上操纵,例如借助于机械滚轮,或借助于控制装置151。可替代地,电极几何形状可通过提供可互换的电极尖端或其他结构适物来调整。此外,控制装置可被设置为在等离子体羽流控制系统中可例如由控制面板151操作,这可允许用户通过使进料气体压力增加或减小来调整光斑大小或羽流几何形状,提供用于收缩或膨胀腔的开口端的孔径的一种或多种装置,或提供在使用中可操作的电源单元,以实现增加或减少或以其它方式改变电极的电源波形,从而生成两个等离子体阶段中的一个或两

个。单独或组合地精细调整这些参数允许实现各种斑点大小和羽流几何形状,允许等离子体生成设备提供可以以各种不同方式使用的等离子体羽流的调色板 (palette), 以便于治疗不同的皱纹和皮肤不规则, 并促进混合。例如, 较高能量的较小尺寸的光斑可用于治疗在嘴周围形成的深层笑线皱纹, 而较低能量的较大尺寸的光斑可用于混合经处理的笑线并处理细纹的较宽区域, 诸如眼睛周围的鱼尾纹。

[0095] 如图5中所示, 为了生成等离子体的冷阶段, 高电压电极6连接到由电源51提供的高压脉宽调制 (PWM) 电源 (在其他实施例中, 可使用AC电源而不是PWM, 但是PWM在该背景下更有效率和效果)。高压PWM电源包括可变频PWM电源, 该可变频PWM电源为了冷阶段放电的持续时间 (两个放电脉冲如图9中所示) 向高电压电极6提供如图9中所示的频率为23kHz至RF的 $\sim 2\text{--}8\text{kV}$ 、 $\sim 25\text{mA}$ 的PWM电压信号。这给接地的管3和介质阻挡层管5之间的介质阻挡层放电提供了能量, 提供了等离子体产生机构, 其每周电离在压力下被对流到下游的腔34中的进料气体, 以提供环形的相对低能量的非热等离子体的发射作为围绕中心高能量热等离子体刀601的晕603成形的冷阶段。介质阻挡放电在冷晕等离子体中产生相对高比例的自由基, 当它们入射在组织上时具有灭菌效果。

[0096] 如图6中所示, 加速的高能量MHD中心热等离子体刀601对周围对流的相对低能量介质阻挡晕等离子体603具有准直和聚焦效应, 其由于剪切诱导的来自热等离子体刀601的湍流能量密度与热等离子体刀601夹带以产生协作聚焦的等离子体羽流610。羽流610具有带有相对高度的自由基的高能量的中心等离子体光斑, 其用于消融组织和加热表面下的真皮层。这由被夹带的灭菌的相对低能量的非热等离子体晕围绕, 其是自由基的源, 该自由基用于对在组织中原位诱导的创伤进行消毒并促进其愈合。

[0097] 当协作等离子体羽流610用于复原皮肤组织并治疗深层皱纹和其他显著的皮肤不规则时, 组织的被消融的表面层不会立即汽化, 而是在几小时到几天内使其分解和脱落。同时, 对促进胶原蛋白和弹性蛋白产生和复原的表面下表皮和真皮层引起的加热和创伤由羽流灭菌并由剩余的表面表皮层保护, 使得受创伤的表面下层被提供以原位无菌敷料, 显著促进了愈合并改善了恢复时间, 同时最小化了复原皮肤治疗的副作用和停药时间。

[0098] 图7示出了由根据图3所示的实施例构建的等离子体炬101生成的两阶段等离子体羽流的图片。该图片已经使用边缘检测算法进行了处理, 该图片揭示了协同羽流的结构, 其示出了聚焦的中心热MHD刀601和灭菌DBD非热晕603的夹带以产生准直协作的两阶段等离子体羽流610。

[0099] 为了使用等离子体羽流610用于美容或外科手术治疗, 操作者将启动等离子体羽流, 并以“漆刷”的方式按固定的距离沿着组织的治疗区域移动等离子体炬101的尖端, 以实现期望的效果和预后。该距离使用允许用户看到设备的区域和羽流的一次性“患者接口管”来控制。为了使等离子体的美容非外科手术的使用减少皱纹和复原皮肤, 美容治疗在非医疗环境中可由经过适当训练的非医疗人员 (诸如美容技师) 执行, 因为治疗是非侵入性的, 并且因为等离子体羽流本身提供了无菌敷料因此造成最小的健康风险和副作用。对于纯粹的美容治疗, 操作者不需要是熟练的医疗专业人员。然而, 对于出于医疗疗效目的的伤口清创和刺激组织的再生, 或者对于在外科手术环境中的烧灼或作为更广泛的外科手术干预的一部分, 两阶段等离子体羽流将需要由医疗专业人员操作。

[0100] 触发器控制器 (未示出) 可被设置在等离子体炬上, 以启动进料气体的释放和由系

统控制单元对电源的激活,以便由操作者按需生成协作羽流(或仅仅是非热等离子体)。装备可被配置成使得只要触发器被按压,触发器机构就可使等离子体羽流恒定地生成。可替代地,装备可被配置成使得响应于触发器的按压生成等离子体的短波(short blast)或脉冲。随后,触发器的重复操作可能是必须的,以便产生用在美容和外科手术治疗中的等离子体脉冲。待递送到表面的能量将在基座单元上进行控制。

[0101] 所展示的对本发明的优选实施例的描述其目的在于说明和描述,并非是详尽的,也并非是要将本发明限于所公开的形式。本领域中的那些技术人员将认识到,在不脱离以上所描述的实施例的广泛的发明概念的情况下,可对它们做出改变。因此,应理解,本发明不限于所公开的特定实施例,而是涵盖由所附权利要求限定的本发明范围内的修改。

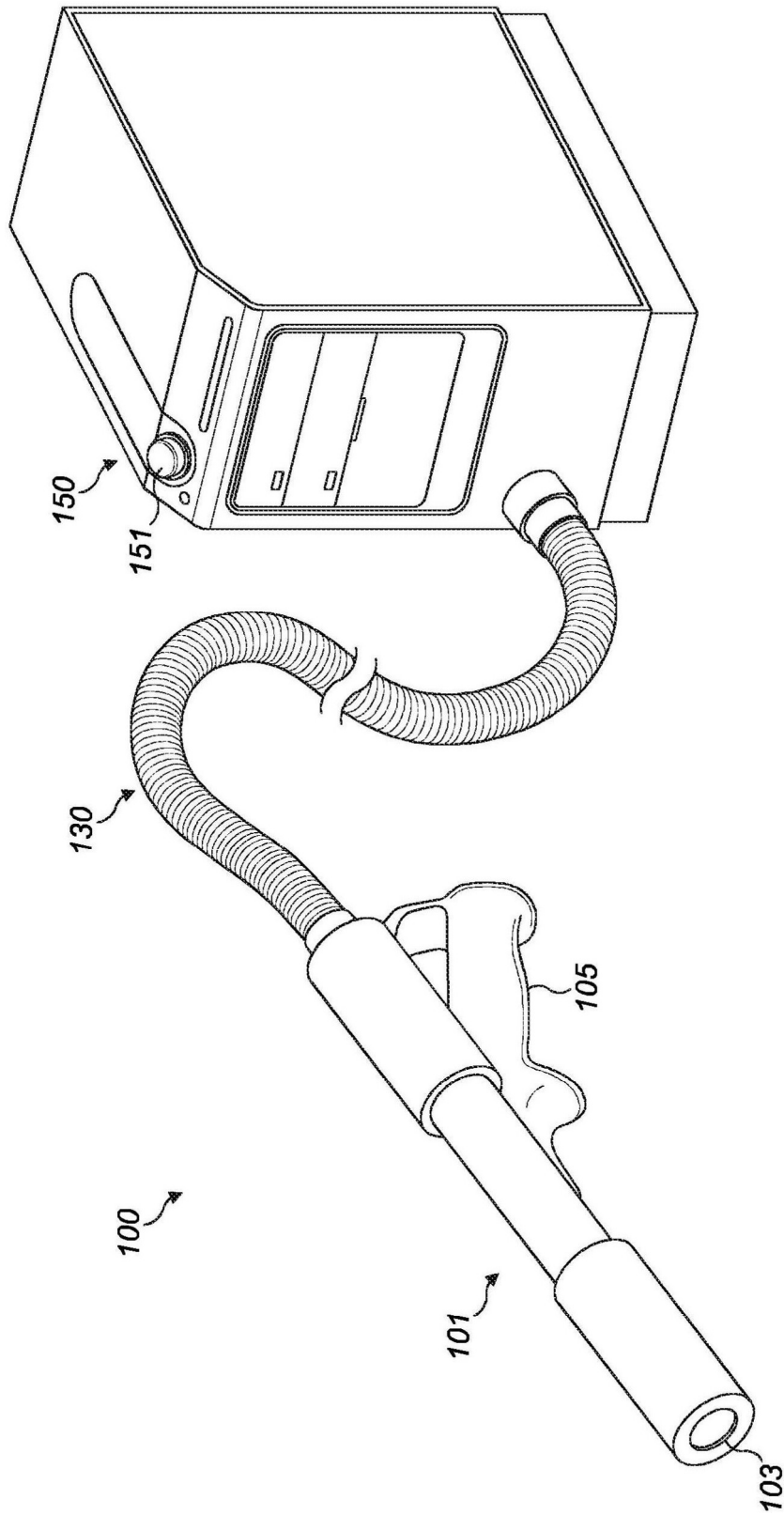


图1

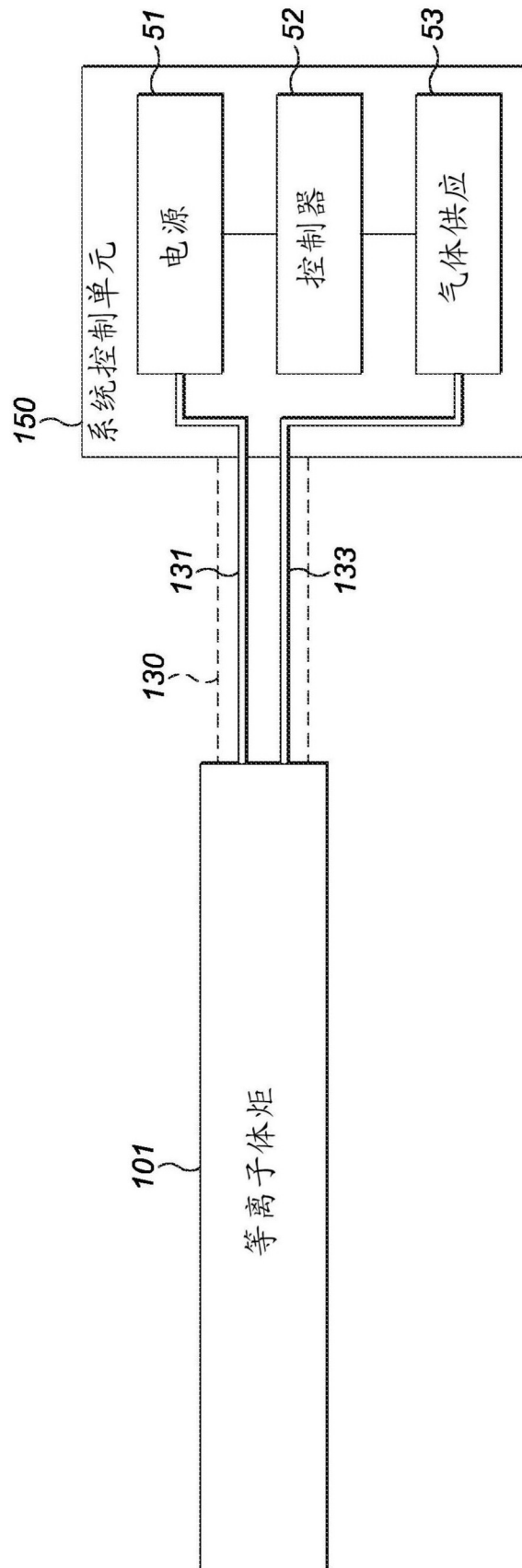


图2

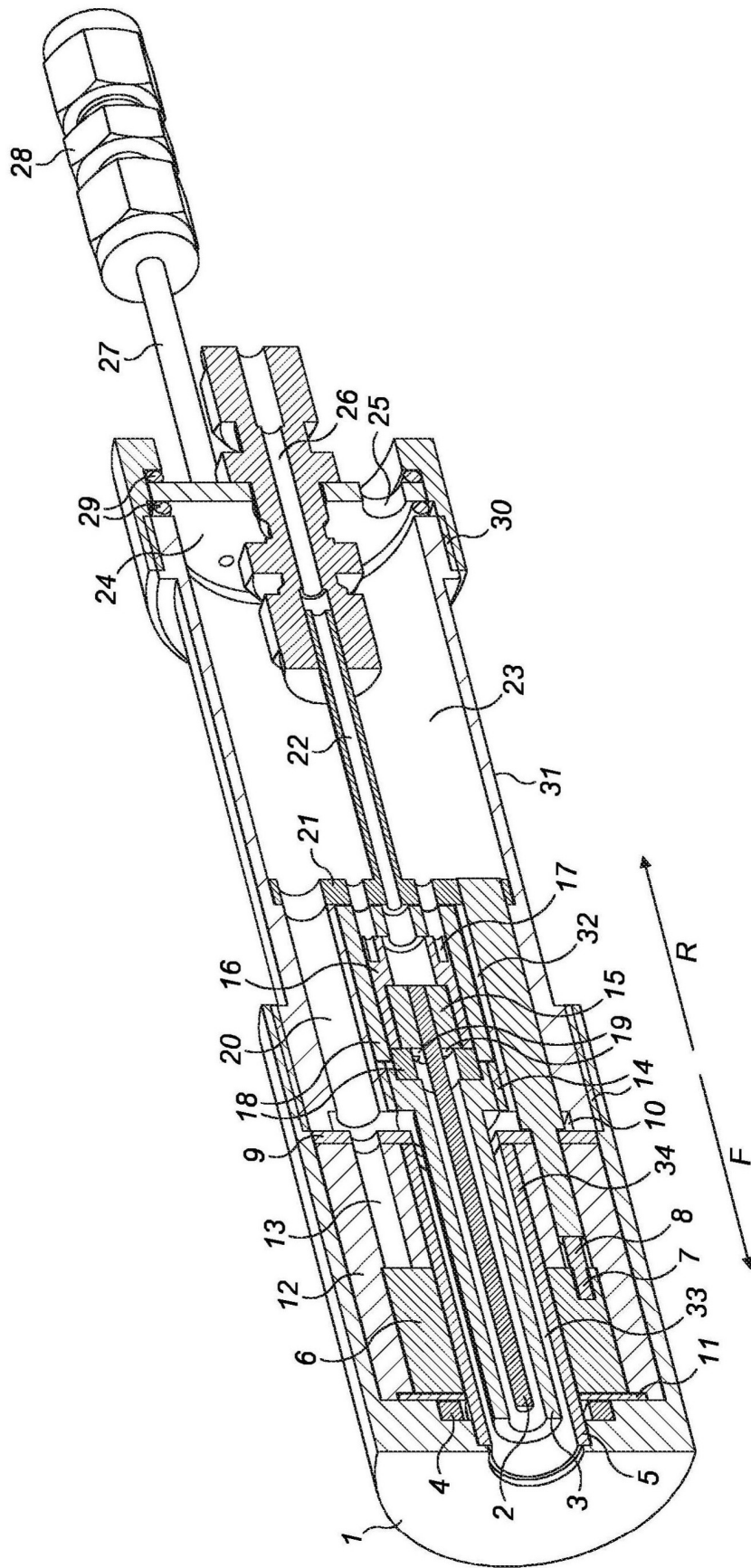


图3

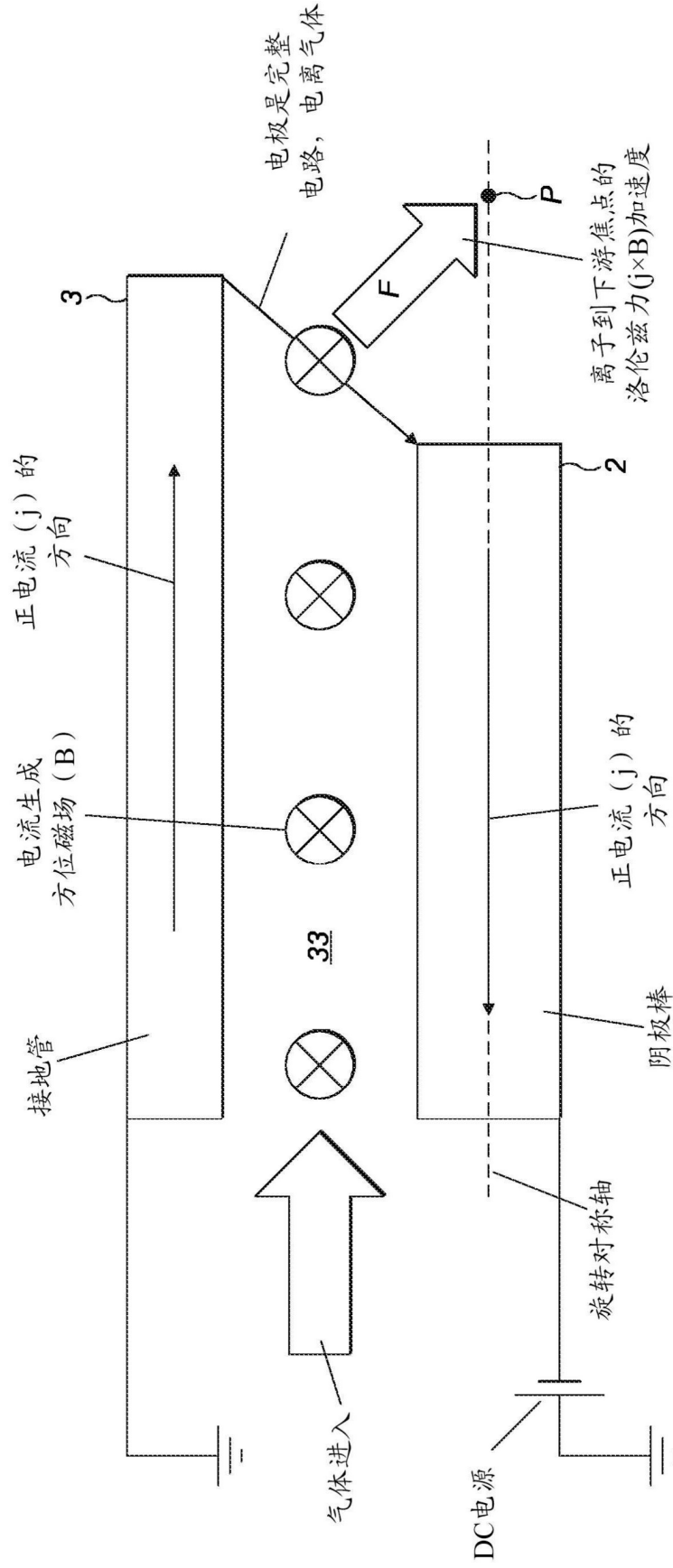


图4

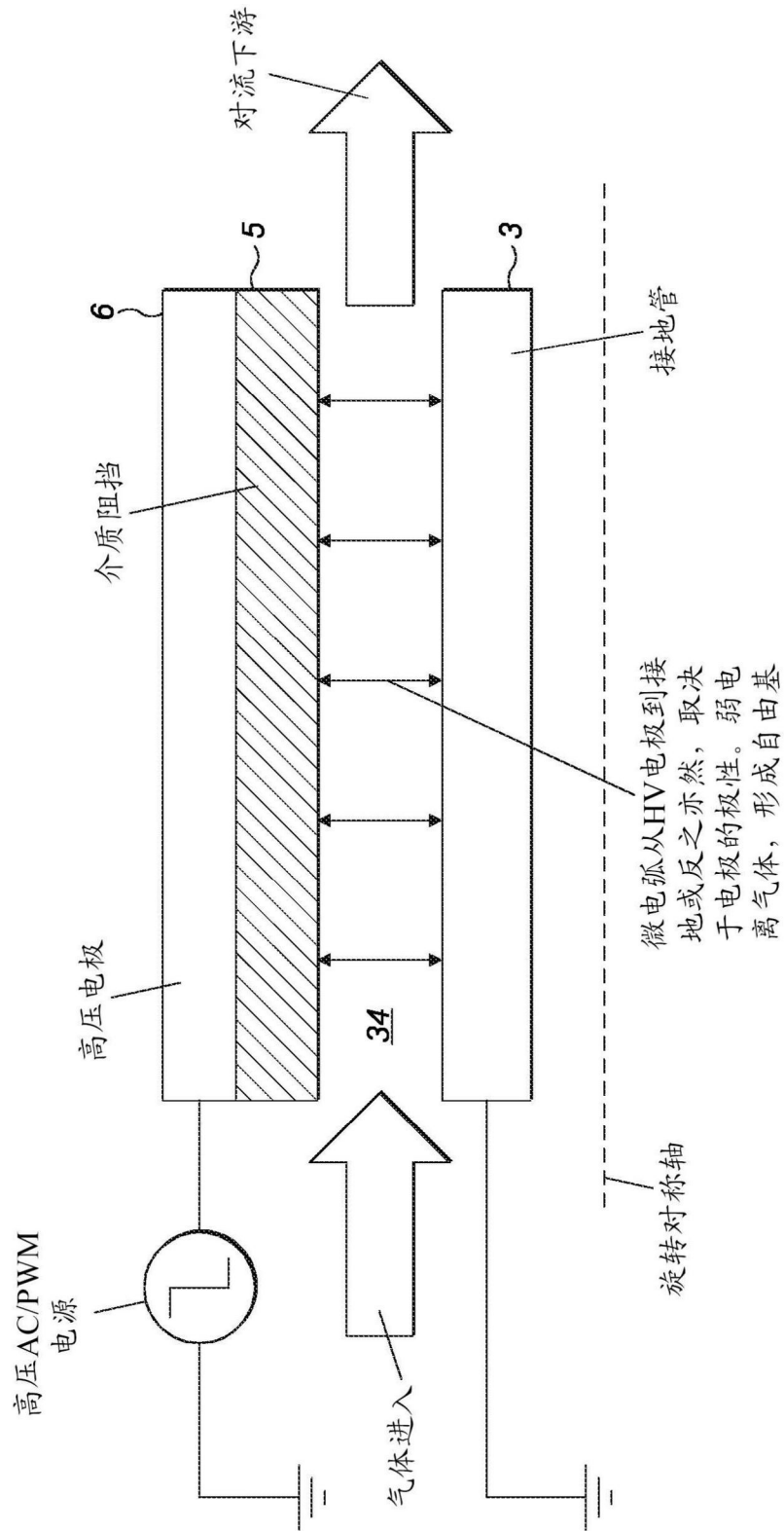


图5

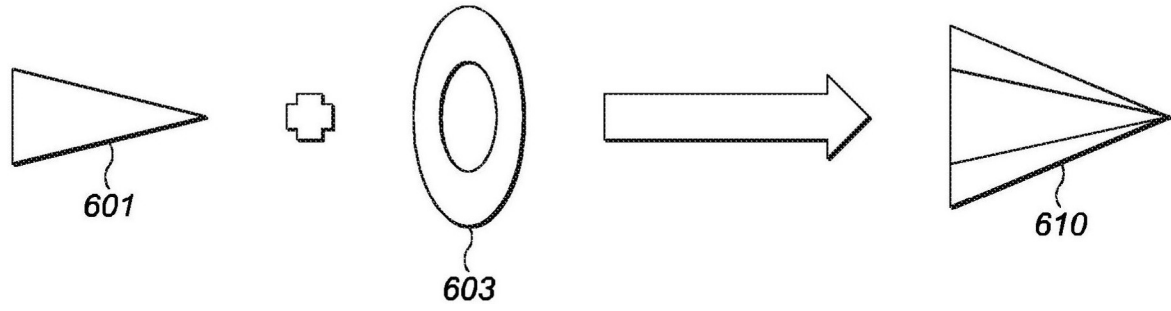


图6

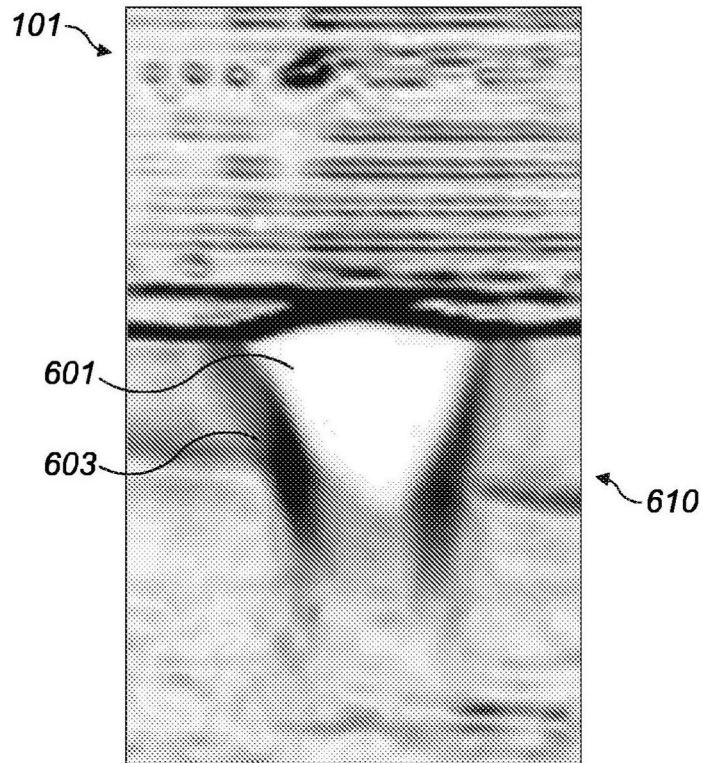


图7

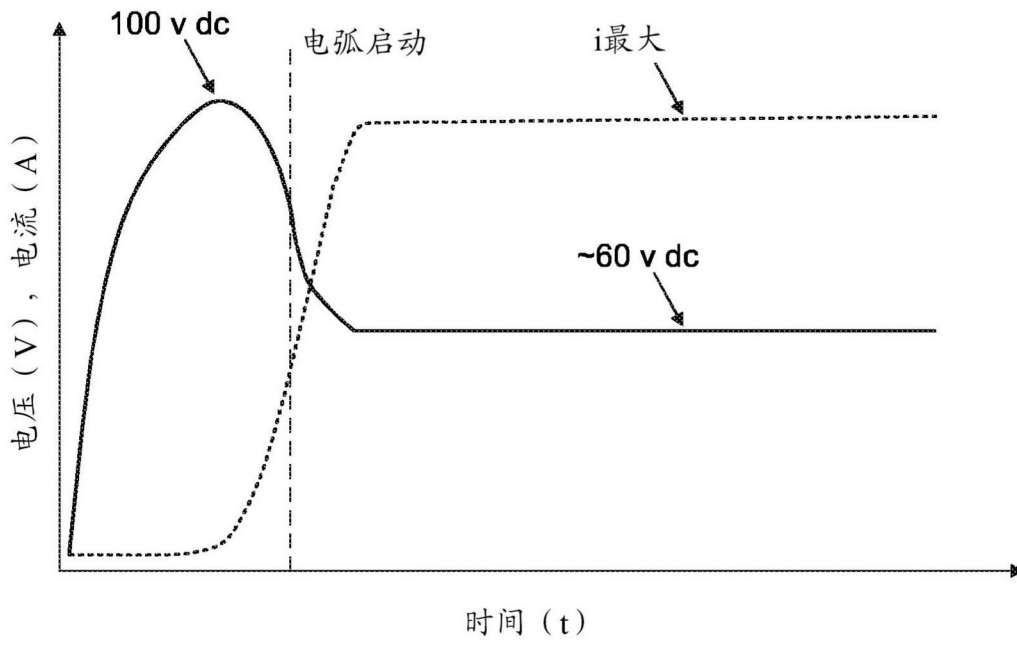


图8

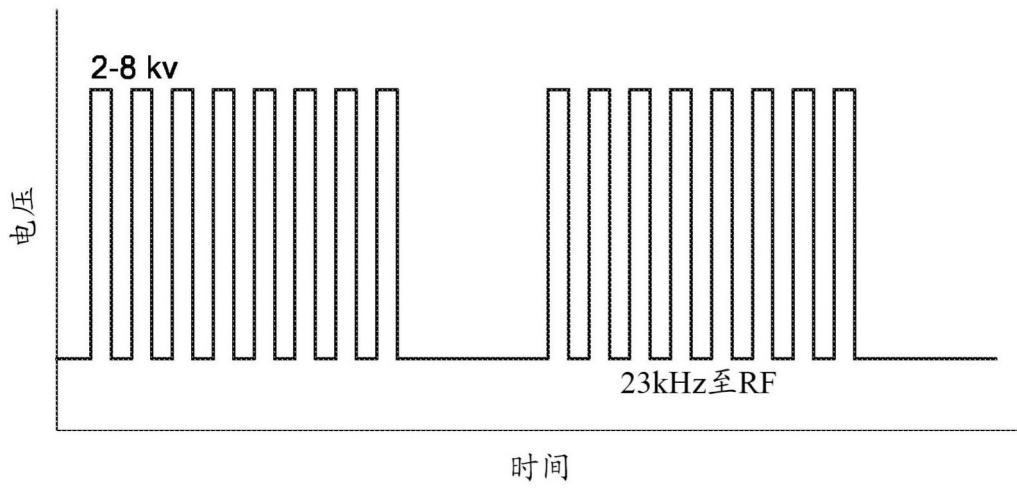


图9