DUAL-FUNCTION PLASMA AND NON-IONISING MICROWAVE COAGULATING ELECTROSURGICAL INSTRUMENT AND ELECTROSURGICAL APPARATUS INCORPORATING THE SAME

FIELD OF THE INVENTION

The invention relates to electrosurgical apparatus in which radiofrequency and/or microwave frequency energy is used to treat biological tissue by causing haemostasis (i.e. sealing broken blood vessels by promoting blood coagulation). In particular, the invention relates to surgical apparatus in which the radiofrequency (RF) and/or microwave energy is used in conjunction with a flow of gas to strike and sustain a thermal plasma.

BACKGROUND TO THE INVENTION

Argon plasma coagulation (APC) or argon beam coagulation (ABC) is a known surgical technique for controlling surface bleeding in a manner that does not require physical contact between a surgical probe delivering the plasma and the lesion. APC can be performed endoscopically, whereby a jet of argon gas is directed through a probe passed through an endoscope. Ionization of the argon gas as it is emitted creates the plasma that causes coagulation.

To strike plasma it is desirable to have a high electric field (e.g. high voltage or high impedance condition). Accordingly, it is necessary to set-up a high impedance state in order to enable the high voltage (high electric field) necessary to break down the gas to generate plasma. In one embodiment discussed in WO 2009/060213, a high voltage (high impedance) condition is set up using a flyback circuit that uses a low frequency (e.g. radiofrequency) oscillator circuit and a transformer whose primary winding is connected to the low frequency oscillator circuit by a suitable driver and switching device (e.g. gate drive chip and a power MOSFET or BJT). The arrangement generates high voltage pulses or spikes which strike or otherwise initiate the plasma. Once struck, the plasma may be maintained by a supply of microwave energy.

coagulation and/or non-thermal for sterilisation/disinfection) can be struck and sustained;

- Plasma strike using microwave energy only: the proximity between the inner and outer conductors is adjusted to generate a high enough E-field to strike plasma;

- Plasma sustain using the microwave field only: the proximity between the inner and outer conductors is adjusted to generate a low impedance environment to allow plasma to be sustained.

The sleeve may have a plurality of predetermined set positions corresponding to each configuration. The instrument may include a mechanism for retaining the sleeve in each one of the set positions, e.g. a locating groove or ratchet mechanism.

The instrument may thus provide four functions: sterilisation using non-thermal plasma, surface tissue coagulation using thermal plasma, deep tissue coagulation using non-ionising microwave radiation and sterilisation using non-ionising microwave radiation. It may be appreciated that having a single instrument capable of performing two or three or four functions as described above enables rapid and efficient treatment because the instrument does not need to be withdrawn if a different function is required.

The RF and microwave EM energy may be delivered separately or simultaneously in any of the use modes of the apparatus. For example, only RF EM energy may be used to strike and sustain the plasma in the surface coagulation mode, and only microwave EM energy may be used only to deliver non-ionising radiation in the deep coagulation mode. Alternatively, a high voltage RF electric field may be created to strike the plasma, followed by a microwave frequency field augmented with a RF field to sustain plasma.

Similarly, the microwave frequency EM energy may be used to augment the RF strike voltage to help guarantee a plasma strike. This may be done by controlling the microwave signal generator to produce peak power for the duration of the RF strike pulse, and then produce a reduced power level to sustain plasma after it has been struck.

In a disclosure helpful for understanding the present invention, there is disclosed an instrument suited for performing APC where the plasma is struck by a pulse of RF

energy and sustained by a pulse of microwave frequency energy. According to this disclosure, there may be provided an electrosurgical instrument comprising: an elongate probe comprising a coaxial cable for conveying radiofrequency (RF) and microwave frequency electromagnetic (EM) radiation, and a probe tip connected at the distal end of the coaxial cable for receiving the RF and microwave radiation separately or simultaneously from the coaxial cable; and a gas passage for conveying gas through the elongate probe to the probe tip, wherein the coaxial cable comprises an inner conductor, an outer conductor and a dielectric material separating the inner conductor from the outer conductor, wherein the probe tip comprising a first electrode connected to the inner conductor of the coaxial cable and a second electrode connected to the outer conductor of the coaxial cable, and wherein the first electrode and second electrode are arranged to produce a high electric field from the received RF EM energy across a flow path of gas received from the gas passage in order to strike a plasma, and arranged to deliver the received microwave energy to sustain the plasma after it is struck.

This device may not have the dual functionality discussed above, but instead utilises microwave frequency energy to improve on existing APC systems. The advantage of using combined RF and microwave frequency energy to create the plasma beam is that the energy required to strike the plasma does not rely on an external return path and the energy to sustain the plasma can be accurately controlled to ensure rapid and efficient treatment. Alternatively, the plasma may be generated using the RF only, as is conventional, and the microwave energy may be provided only in order to provide the additional function of deep tissue coagulation or sterilisation in the scope instrument channel cleaning application or sterilisation of biological tissue in the NOTES or natural orifice application.

As with the dual functionality aspect discussed above, the plasma may be generated at the distal end of a flexible microwave cable with a diameter of less than 2.5 mm, which enables the instrument to be introduced down the instrument channel of any scoping device, i.e. endoscope, gastroscope, etc. It may also be used to clean or disinfect the instrument channel of endoscopes and be used to disinfect tissue before

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The instrument may thus provide four functions: sterilisation using non-thermal plasma, surface tissue coagulation using thermal plasma, deep tissue coagulation using non-ionising microwave radiation and sterilisation using non-ionising microwave radiation. It may be appreciated that having a single instrument capable of performing two or three or four functions as described above enables rapid and efficient treatment because the instrument does not need to be withdrawn if a different function is required.

The RF and microwave EM energy may be delivered separately or simultaneously in any of the use modes of the apparatus. For example, only RF EM energy may be used to strike and sustain the plasma in the surface coagulation mode, and only microwave EM energy may be used only to deliver non-ionising radiation in the deep coagulation mode. Alternatively, a high voltage RF electric field may be created to strike the plasma, followed by a microwave frequency field augmented with a RF field to sustain plasma.

Similarly, the microwave frequency EM energy may be used to augment the RF strike voltage to help guarantee a plasma strike. This may be done by controlling the microwave signal generator to produce peak power for the duration of the RF strike pulse, and then produce a reduced power level to sustain plasma after it has been struck.

In another aspect, the present invention may provide an instrument suited for performing APC where the plasma is struck by a pulse of RF energy and sustained by a pulse of

microwave frequency energy. According to this aspect, there may be provided an electrosurgical instrument comprising: an elongate probe comprising a coaxial cable for conveying radiofrequency (RF) and microwave frequency electromagnetic (EM) radiation, and a probe tip connected at the distal end of the coaxial cable for receiving the RF and microwave radiation separately or simultaneously from the coaxial cable; and a gas passage for conveying gas through the elongate probe to the probe tip, wherein the coaxial cable comprises an inner conductor, an outer conductor and a dielectric material separating the inner conductor from the outer conductor, wherein the probe tip comprising a first electrode connected to the inner conductor of the coaxial cable and a second electrode connected to the outer conductor of the coaxial cable, and wherein the first electrode and second electrode are arranged to produce a high electric field from the received RF EM energy across a flow path of gas received from the gas passage in order to strike a plasma, and arranged to deliver the received microwave energy to sustain the plasma after it is struck.

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4. An electrosurgical instrument according to claim 2, wherein the second electrode is formed on the distal end of the sleeve, and the coaxial cable is retractable relative to the sleeve.

5. An electrosurgical instrument according to any preceding claim, wherein the first electrode is a radiating microwave monopole antenna structure coupled to receive RF and/or microwave EM energy from the coaxial cable.

6. An electrosurgical instrument according to claim 5, wherein the radiating microwave monopole antenna structure comprises a cylinder of dielectric material having a hemispherical distal end surrounding a length of the inner conductor of the coaxial cable which protrudes beyond the outer conductor and extends through the cylinder of dielectric material to protrude at its hemispherical distal end.

7. An electrosurgical instrument according to claim 6, wherein the end of the length of inner conductor that protrudes from the hemispherical distal end of the cylinder is shaped into a hemisphere.

8. An electrosurgical instrument according to claim 3, wherein the outer ~~electrode~~ conductor of the coaxial cable is connected to the second electrode by a gas permeable conductive structure that is slidable relative to the second electrode or outer conductor of the coaxial cable and permits gas to flow through it.

9. An electrosurgical instrument according to claim 8, wherein the gas permeable conductive structure is any one of:

a conductive mesh;

a cage of radially extending conductive wires or springs; and

a plurality of circumferentially spaced radially protruding dents.

10. An electrosurgical instrument according to claim 8 or 9, wherein the gas permeable conductive structure is soldered or crimped to the second electrode.