

ELECTROSURGICAL APPARATUS AND ELECTROSURGICAL INSTRUMENTTECHNICAL FIELD

5 The present application relates to an electrosurgical apparatus for delivering electromagnetic (EM) energy into biological tissue at multiple frequencies. In particular, the application relates to an electrosurgical instrument for non-invasive or percutaneous insertion to a treatment site, which
10 is configured for efficient delivery of EM energy to tissue at multiple microwave frequencies.

BACKGROUND TO THE INVENTION

15 Electrosurgical devices and apparatus for supplying EM energy to body tissue are known.

Typically, apparatus for delivering EM energy to body tissue comprises a generator comprising a source of EM energy, and an electrosurgical instrument connected to the generator,
20 for delivering the energy to tissue.

EM energy, and in particular microwave and radio-frequency (RF) energy, have been found to be useful in electrosurgical operations, for their ability to cut, coagulate, and ablate body tissue.

25 Furthermore, it is known to use microwave emitting probes to treat various conditions in the lungs. For example, microwave radiation can be used to treat asthma and ablate tumours or lesions in the lungs.

30 SUMMARY OF THE INVENTION

At its most general, there is herein disclosed an electrosurgical instrument capable of supporting resonance of microwave electromagnetic (EM) energy at multiple frequencies,
35 e.g. three or more frequencies greater than 1 GHz. By providing a single device that can effectively couple microwave energy into biological tissue at three or more frequencies, tissue ablation can be performed rapidly with accuracy.

Aspects of the invention are defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

5 There may be provided an electrosurgical instrument for delivering microwave electromagnetic (EM) energy into biological tissue, the instrument comprising: a coaxial cable for conveying microwave EM energy, the coaxial cable having an inner conductor, an outer conductor, and a first dielectric material separating the inner conductor and the outer
10 conductor; and a radiating tip portion disposed at a distal end of the coaxial cable to receive microwave EM energy from the coaxial cable, the radiating tip portion comprising a second dielectric material different from the first dielectric material, wherein the radiating tip portion has an electrical
15 length selected in conjunction with its dielectric properties at three or more frequencies of microwave EM energy to support resonance at the three or more frequencies of microwave EM energy. The disclosed techniques use the principle that
20 different frequencies of microwave EM energy penetrate into biological tissue to different depths, and in particular that higher frequencies of EM energy result in faster and more localised heating of body tissue. Conventional tissue ablation techniques tend to use frequencies that heat a larger
25 volume of body tissue, but take a longer period of time to produce a desired temperature increase. Thus there appears a necessary trade-off between size of ablation and speed of treatment.

 The normal mechanism by which energy is transferred into
30 biological tissue at microwave frequencies (i.e. greater than 1 GHz) is dielectric heating, where the microwave EM energy drives molecular oscillations in the tissue. Typically, biological tissue adjacent to the dielectric heating zone also experiences a rise in temperature. The mechanism for this is
35 conduction, i.e. heat energy dissipating from the dielectric heating zone. The inventors have observed that a combination of these two heating mechanisms at a plurality of frequencies can enable microwave EM energy to create a rise in temperature of a larger treatment zone than is typically associated with
40 microwave energy frequencies. Moreover, heating in this zone can be achieved in a shorter time frame than is possible if lower (non-microwave) EM energy is used.

The treatment technique may use a plurality of frequencies in part to adapt to changes in physical and dielectric properties of biological tissue caused by heating. In particular, changes in dielectric properties can affect a relative impedance match between the radiating tip portion, the coaxial cable, and the tissue. The efficiency of energy delivery to biological tissue at lower frequencies can be improved by first heating the tissue at a higher frequency.

Herein, references to microwave EM energy mean electromagnetic energy having a frequency greater than 1 GHz, e.g. in a range between 1 GHz and 300 GHz. Preferred frequencies are 2.45 GHz, 5.8 GHz and 14.5 GHz, since they are known to produce particularly desirable heating effects for ablating tumours, especially lung tumours. These three frequencies in combination can provide heating effects that are effective in the treatment of haemorrhoids and/or fistulas, and so it is envisioned that the present techniques can further be used to treat haemorrhoids and fistulas.

The frequencies at which the radiating tip portion supports resonance may not be limited to the three frequencies discussed above. For example, the radiating tip portion may support resonance at four frequencies. Preferably, the radiating tip portion may support resonance at five frequencies. More preferably, the radiating tip portion may support resonance at six frequencies.

Advantageously, the radiating tip portion may further support delivery of energy at other frequencies, e.g. 433 MHz and/or 915 MHz. These frequencies are also known to be particularly effective for ablating lung tumours, and for treating haemorrhoids and/or fistulas.

It is known to use radiofrequency (RF) EM energy to heat tissue by resistive heating to produce desired therapeutic effects. Hence, in some embodiments, the electrosurgical instrument may further be arranged to deliver RF EM energy, e.g. having a frequency between 3 kHz and 300 MHz. To assist with the delivery of RF energy to tissue, the distal-most point of the inner conductor may extend past a distal-most point of the second dielectric material, e.g. so that the

distal-most point of the radiating tip portion comprises an exposed portion of the inner conductor. Advantageously, the radiating tip portion may further support delivery of energy at a frequency of 400 kHz. This frequency is also known to be particularly effective for ablating lung tumours, and for treating haemorrhoids and/or fistulas.

In another exemplary arrangement, there is provided an electrosurgical apparatus for delivering microwave electromagnetic (EM) energy into biological tissue, the apparatus comprising: a generator arranged to generate
5 microwave EM energy at three or more different frequencies; and an electrosurgical instrument as set out above, wherein the coaxial cable has a proximal end connected to the generator to receive microwave EM energy therefrom.

The generator may comprise three or more separate
10 microwave sources for generating microwave EM energy at a respective one of the three or more different frequencies. The generator may further comprise a signal combiner arranged to convey each signal to a common signal path that is connected to the coaxial cable. The signal combiner may be a
15 multiplexer. The multiplexer may be operable as a switching unit for selecting a signal to be conveyed on the common signal path. Alternatively or additionally, the multiplexer may be operable to convey two or more of the signals on the common signal path in a simultaneous or quasi-simultaneous
20 manner. For example, the multiplexer may be a time-domain multiplexer or a filter multiplexer.

The apparatus may include a surgical scoping device (e.g. bronchoscope or the like) having flexible instrument cord for non-invasive insertion to a treatment site, wherein the
25 instrument cord includes an instrument channel, and wherein the electrosurgical instrument is dimensioned to be insertable within the instrument channel.

The generator may be operable to deliver microwave EM energy at the three or more different frequencies according to
30 a predetermined energy delivery profile. The energy delivery profile may be selected according to a desired ablation depth, and/or a desired ablation zone shape. In some embodiments, the energy delivery profile may be selected based on a measured property of energy reflected from the radiating tip
35 portion.

In one example, the generator may be operable under the predetermined energy delivery profile to: deliver a first
signal during a first ablation period, the first signal comprises microwave EM energy having predominantly a first
40 frequency; deliver a second signal during a second ablation period, the second signal comprises microwave EM energy having

period to the next ablation period based on the detected reflected power.

BRIEF DESCRIPTION OF THE DRAWINGS

5

Examples of the present invention are discussed in detail below with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram of an exemplary electrosurgical apparatus;

10 Fig. 2 is a cross-sectional view of the radiating tip portion of an electrosurgical instrument;

Fig. 3 is a simulated plot showing radiation power absorption density at 2.45 GHz for the instrument of Fig. 2 inserted into albumen;

15 Fig. 4 is a simulated plot showing radiation power absorption density at 5.8 GHz for the instrument of Fig. 2 inserted into albumen;

Fig. 5 is a simulated plot showing radiation power absorption density at 14.5 GHz for the instrument of Fig. 2 inserted into albumen;

20 Fig. 6 is a graph showing a simulated $S_{1,1}$ resonance characteristic of the instrument of Fig. 2 over a range of frequencies.

25 DETAILED DESCRIPTION; FURTHER OPTIONS AND PREFERENCES

Fig. 1 is a schematic diagram of an electrosurgical apparatus 100. The apparatus 100 is operable to selectively supply EM energy having a plurality of frequencies into biological tissue at a treatment site in a localised manner. The apparatus 100 comprises a generator 102 for generating EM energy having a plurality of frequencies. The generator 102 has a output port 120 to which is connected a coaxial cable 104. The coaxial cable 104 conveys the EM energy away from the generator 102 towards an electrosurgical instrument 118. In this embodiment, the coaxial cable 104 is inserted through an instrument channel within an insertion cable 106 of a bronchoscope 114. The insertion cable 106 is a flexible, steerable shaft capable of non-invasive insertion into a

40

dynamically control energy delivery based on detected dielectric properties of the tissue being treated.

The apparatus 100 may further include a tuning network (not shown) between the signal generator 102 and the radiating tip portion 118, for helping to ensure a good impedance match with tissue as the tissue load changes. For example, a triple stub tuner may be used. Where a tuner is included between the generator 102 and the radiating tip portion 118, delivery of energy into tissue can be further improved by ensuring that the radiating tip portion has a good impedance match to the tissue in the middle of the tuning range.

Fig. 2 shows a cross-section view through a distal portion of the electrosurgical instrument 118. The instrument 118 comprises a coaxial cable 202 (which may be the same as the coaxial cable 104 that is connected to the generator 102) and a radiating tip portion 204 located at and extending distally away from a distal end of the coaxial cable 202.

The coaxial cable 202 comprises an inner conductor 206, an outer conductor 208, and a first dielectric material 210 for electrically insulating the inner and outer conductors from each other. The outer conductor 208 may also be sheathed by a protective sleeve (not shown) to prevent electrical contact between the outer conductor and the tissue of a patient. The sheath is a biocompatible material, such as PTFE. A typical coaxial cable for use in the present techniques has an impedance of 50 Ω .

In order for the instrument to be suitable for insertion into a patient for surgical procedures, the outer diameter of the cable should be less than 5 mm. In embodiments in which the instrument is passed down the instrument channel of a bronchoscope 114, the outer diameter of the coaxial cable should be less than 1.5 mm, e.g. less than 1.2 mm. The coaxial cable has a length sufficient for it to be inserted into the body of a patient. Typically, it would have a length of 1 m or more, but is not limited to such a length.

In this application, unless stated otherwise, the length of a component refers to its dimension in the direction along (i.e. parallel to) the longitudinal axis of the coaxial cable.

The radiating tip portion 204 in this embodiment consists a second dielectric material 212 that is different from the first dielectric material 210. The second dielectric material