(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 July 2003 (31.07.2003)

PCT

(10) International Publication Number
WO 03/061497 A1

(51) International Patent Classification[7]: A61B 18/14

(21) International Application Number: PCT/IL03/00050

(22) International Filing Date: 22 January 2003 (22.01.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/051,285 22 January 2002 (22.01.2002) US

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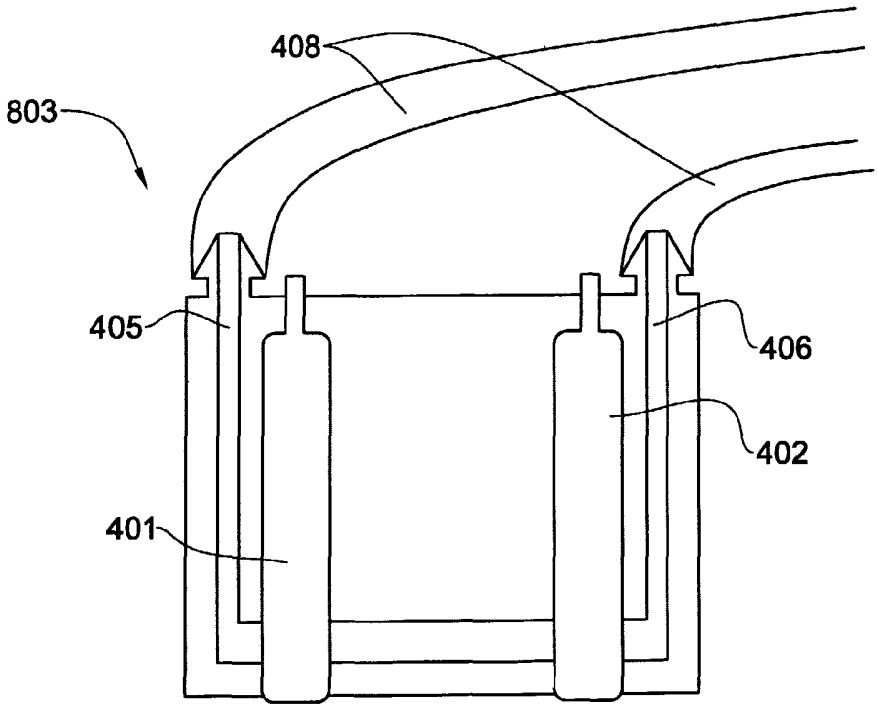
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: RF DEVICE AND METHOD OF SELECTIVE THERMOLYSIS



(57) Abstract: System and method for treating a skin target. A temperature effector creates a temperature difference between the target and the skin tissue surrounding the target such that the target is at a higher temperature than the surrounding tissue. One or more RF electrodes are attached to the skin and RF energy is applied. A cooling fluid circulates at the periphery of the effector to lower temperature at the skin surrounding the target.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

RF DEVICE AND METHOD OF SELECTIVE THERMOLYSIS

FIELD OF THE INVENTION

This invention relates to methods and systems for treating skin.

BACKGROUND OF THE INVENTION

The term *"target"* is used herein to denote a skin defect such as a vascular lesion, pigmented lesion, acne, unwanted hair or wrinkle. Selective thermal treatment of skin is commonly used in aesthetic medicine to remove skin targets. In order to be destroyed, the target must be raised to a temperature of about 70°C without raising the temperature of the surrounding epidermis or dermis to damaging levels. The most popular method of thermal skin treatment is selective photo-thermolysis in which light energy produced by a laser or flash lamp is selectively absorbed by a pigmented portion of the target. However, with this method it is often not possible to heat the entire target to a temperature necessary for destroying it without heating the surrounding skin to damaging levels. The main problem is that the optical contrast between the target and the surrounding skin tissue is not high enough to obtain a significant difference in temperature between the target and the surrounding skin tissue.

U.S. Patent No. 5,755,753 discloses use of the radio-frequency (RF) range of electro-magnetic energy for skin tightening, where RF energy is applied to a pre-cooled skin surface. U.S. Patent No. 5,846,252 discloses treating hairs to reduce their electrical resistance and then applying RF current.

SUMMARY OF THE INVENTION

The present invention is based upon the finding that selective heating of a skin target by RF energy is enhanced if prior to the application of the RF energy the skin is treated to make the temperature of the target (T_t) higher than the temperature of the surrounding skin tissue (T_s). The initial temperature gradient (T_t-T_s>0) between the target and surrounding tissue may be achieved either by pre-heating the target or pre-cooling the surrounding tissue.

The invention thus provides a system for treating a skin target comprising:

(a) one or more RF electrodes configured to be attached to the skin, so as to apply an RF current to the skin;

(b) a temperature effector configured to create a temperature gradient between the target and skin surrounding the target such that the target is at a higher temperature than the surrounding skin.

The invention still further provides a method for treating a skin target comprising:

a) creating a temperature gradient between the target and skin surrounding the target such that the target is at a higher temperature than the surrounding skin; and

b) applying RF energy to the skin.

The system and method of the invention may be used for such skin targets as a vascular lesion, pigmented lesion, hair follicle, wrinkle and acne.

While not wishing to be bound by a particular theory, it is believed that selective thermolysis of a target by RF energy is enhanced when T_t-T_s>0 due to an increase in the electrical conductivity in the RF range of tissues when the tissue temperature is increased [Frances A. Duck, Physical Properties of Tissue, a Comprehensive Reference Book, Academic Press, 1990, p.173]. Accordingly, the dependence of the conductivity σ of a tissue on temperature T is given by:

$$\sigma = \sigma_o(1+\alpha(T-T_o)) \qquad (1)$$

where σ_o is the conductivity at the reference temperature T_0 and α is a constant known as the temperature coefficient.

Heat generation by RF current can be estimated by Joule's Law:

$$H = \sigma E^2 \qquad (2)$$

and the change in temperature in the tissue is obtained using the heat conductivity equation:

$$c\rho \frac{\partial T}{\partial t} = H \qquad (3)$$

where c is the heat capacity of the tissue, ρ is the mass density and E is the intensity of the electric field.

Inserting Equations 1 and 2 into (3),

$$c\rho \frac{\partial T}{\partial t} = \sigma_o (1 + \alpha (T - T_o) E^2 \qquad (4)$$

$$\text{Setting A} = \frac{\alpha \sigma_o E^2}{c\rho} \qquad (5)$$

and integrating Equation 4, the result is

$$T' = T_0 + \frac{e^{At} - 1}{\alpha} + (T_i - T_o) e^{At} \qquad (6)$$

where T_i is the initial temperature of the tissue before the application of RF energy, t is the duration of the application of RF energy, and T′ is the final temperature of the tissue at the end of the application of RF energy.

If the initial temperatures of the target and surrounding skin tissue are T_t and T_s respectively (T_t-T_s>0), then Equation 6 becomes for the target:

$$T_t' = T_0 + \frac{e^{At-1}}{\alpha} + (T_{ti} - T_{to})Ae^{it} \quad (7)$$

and for the surrounding skin,

$$T_s' = T_0' + \frac{e^{At} - 1}{\alpha} + (T_{si} - T_o)e^{At} \quad (8)$$

subtracting Equation (8) from Equation (7) yields

$$T_t' - T_s' = (T_{ti} - T_{si})e^{At} \quad (9)$$

where $T_{t_i} - T_{s_i}$ is the initial temperature gradient between the target and the surrounding skin, and $T_t' - T_s'$ is the final temperature gradient. Equation (9) shows that as the RF current is applied, the temperature gradient increases exponentially. Therefore, by creating an initial relatively small temperature gradient $Tt_i - Ts_i > 0$, and applying RF energy, a larger temperature gradient is obtained. This allows heating of the target to a sufficiently high temperature to destroy the target without heating the surrounding skin tissues to damaging levels.

Assuming a typical RF fluence (F) in the skin of 20 J/cm^2, α = 0.03 $(C°)^{-1}$ and a heat capacitance $c\rho$ = 3.6 $J/cm^3\ {}^0K$, the factor e^{At} in Equation (9) is $e^{At} = e\frac{\alpha\sigma_o E^2}{c\rho} = e\frac{\alpha Ht}{c\rho} = e^{0.83} = 2.3$

Thus, the temperature gradient increases by a factor of about 2.3 during the application of the RF energy.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a system for heating a skin target and applying RF to an individual in accordance with one embodiment of the invention;

Fig. 2 shows a method for treating skin using the system of Fig. 1;

Fig. 3 shows an applicator with two electrodes, and a light source used in the system of Figure 1.

Fig. 4 shows a system for cooling skin surrounding a target and applying RF energy to an individual in accordance with another embodiment of the invention;

Fig. 5 shows an applicator with two electrodes, and a cooling system used in the system of Fig. 3; and

Fig. 6 shows a method for treating skin using the system of Figs 4 and 5.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figs. 1 and 2, a system for creating a temperature gradient between a skin target and the surrounding skin, in accordance with the invention is shown. An applicator **703**, to be described in detail below, contains a pair of RF electrodes **401** and **402** and a light source **403**. The applicator **703** is adapted to be applied to the skin of an individual **705** in the region of a target. The applicator **703** is connected to a control unit **701** via a cable **702**. The control unit **701** includes a power source **708**. The power source **708** is connected to an RF generator **715** that is connected to the RF electrodes in the applicator **703** via wires in the cable **702**. The power source **708** is also connected to a light source **403** in the applicator **703**

via wires in the cable **702**. The control unit **701** has an input device such as a keypad **710** that allows an operator to input selected values of parameters of the treatment, such as the frequency, pulse duration and intensity of the RF energy or the wavelength and intensity of the optical energy. The control unit **701** optionally contains a processor **709** for monitoring and controlling various functions of the device. For example, the processor **709** may monitor the electrical impedance between the electrodes in the applicator **703**, and determine the temperature distribution in the vicinity of the target. The processor **709** may also determine the parameters of the treatment based upon the impedance measurements.

Fig. 2 shows the applicator **703** in detail. The applicator contains a pair of electrodes **401** and **402** that apply RF energy to the skin. A light source **403** produces a light spectrum that is delivered to the skin surface by light guide **404**.

In accordance with the method of the invention, the system shown in Fig. 1 is used to first apply optical energy to a target having a diameter for example of 2 mm. The optical energy may have an intensity from about 5 to about 100 Joules/cm^2 and may be applied from about 1 to 200 msec.

The parameters of RF energy may have the following exemplary values:

Frequency of the RF energy: from about 300 kHz to about 100 MHz.

Output power of the RF energy: from about 5 to about 200 W.

Duration of the irradiation: from about 1 to about 500 msec.

Pulse repetition rate: from about 0.1 to about 10 pulses per second.

Fig. 3 shows a flow chart for a method of treating skin using the system shown in Figs. 1 and 2. In step **300**, the applicator **703** is applied to the skin of an individual in the region of a target in the skin. In step **310** the light source **403** is activated so that the target is irradiated with optical energy from the light source **403** conducted through the optic fiber **404** to the target. In step **320** the irradiation with optical energy is terminated. RF energy is then applied to the skin (step **330**). Finally, in step **340**, the application of RF energy is terminated.

Referring now to Figs. 4 and 5, a system for creating a temperature gradient between a skin target and the surrounding skin, in accordance with another embodiment of the invention is shown. An applicator **803**, to be described in detail below, contains a pair of RF electrodes **401** and **402**. The applicator **803** is adapted to be applied to the skin of an individual **805** in the region of a target. The control unit **801** includes a power source **808**. The power source **808** is connected to an RF generator **815** that is connected to the RF electrodes in the applicator **803** via wires in the cable **802**. The control unit **801** controls a refrigeration unit **812** that cools a fluid such as ethanol or water for cooling the applicator **803.** The cooled fluid flows from the refrigeration unit **812** to the applicator via a first tube in the cable **802,** and flows from the applicator **803** back to the refrigeration unit via a second tube in the cable **802** . The control unit **801** has an input device such as a keypad **810** that allows an operator to input selected values of parameters of the treatment, such as the frequency, pulse duration and intensity of the RF energy or the temperature of the coating fluid. The control unit **801** optionally contains a processor **809** for monitoring and controlling various functions of the device. For example, the processor **809** may monitor the electrical impedance between the electrodes in the applicator **803**, and determine the temperature distribution in the vicinity of the target. The processor **809** may also determine the parameters of the treatment based upon the impedance measurements.

Fig. 5 shows the applicator **803** in detail. The applicator contains a pair of electrodes **401** and **402** that apply RF energy to the skin. The housing and electrodes are cooled by fluid cooled by the refrigeration unit **812** that flows in a tube **408** between inlet **405** and outlet **406**. The inlet **405** and the outlet **406** are connected to the refrigeration unit **812** via the first and second tubes in the cable **802**.

Fig. 6 shows a flow chart for a method of treating skin using the system shown in Figs. 4 and 5. In step 600, the applicator 703 is applied to the skin of an individual in the region of a target in the skin. In step 610 cooling system 812 is activated so that the skin surrounding the target is cooled to a temperature below

that of the target. RF energy is then applied to the skin (step 620). Finally, in step 630, the application of RF energy is terminated.

CLAIMS:

1. A system for treating a skin target comprising:

(a) one or more RF electrodes configured to be attached to the skin, so as to apply an RF current to the skin;

(b) a temperature effector configured to create a temperature difference between the target and skin surrounding the target such that the target is at a higher temperature than the surrounding tissue.

2. The system according to Claim 1 wherein the temperature effector heats the target.

3. The system according to Claim 2 wherein the temperature effector comprises a light source configured to apply optical energy to the target.

4. The system according to Claim 1 wherein the temperature effector cools the surrounding tissue.

5. The system according to Claim 4 wherein the temperature effector comprises an irrigation unit cooling a fluid and tubes for allowing the cooled fluid to flow near the surrounding skin.

6. A method for treating a skin target comprising:

(a) creating a temperature gradient between the target and skin surrounding the target such that the target is at a higher temperature than the surrounding skin; and

(b) applying RF energy to the skin.

7. The method according to Claim 6 wherein the temperature gradient is created by heating the target.

8. The method according to Claim 7 wherein the target is heated by applying optical energy to the target.

9. The method according to Claim 5 wherein the temperature gradient is created by cooling the skin surrounding the target.

10. The method according to Claim 9 wherein the surrounding skin is cooled by contacting the skin with a pre-cooled fluid.

11. The method according to Claim 6 wherein the target is selected from the group comprising a vascular lesion, pigmented lesion, hair follicle, wrinkle and acne.

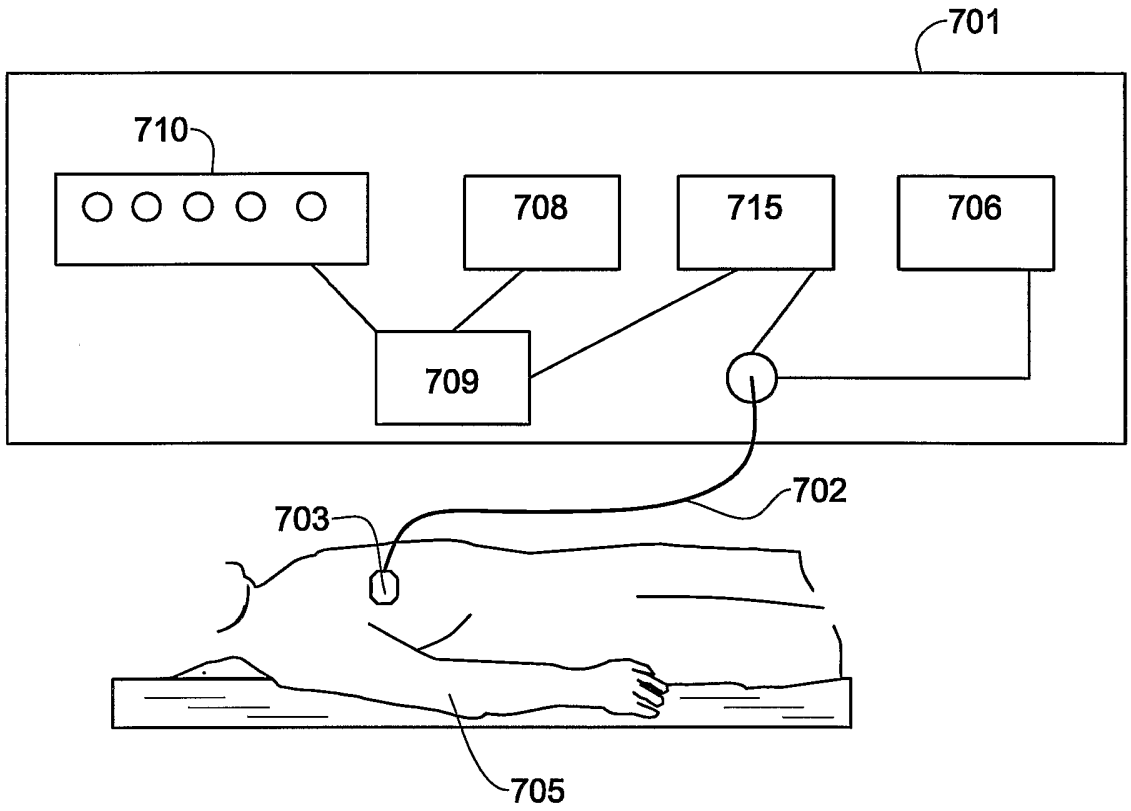

FIG. 1

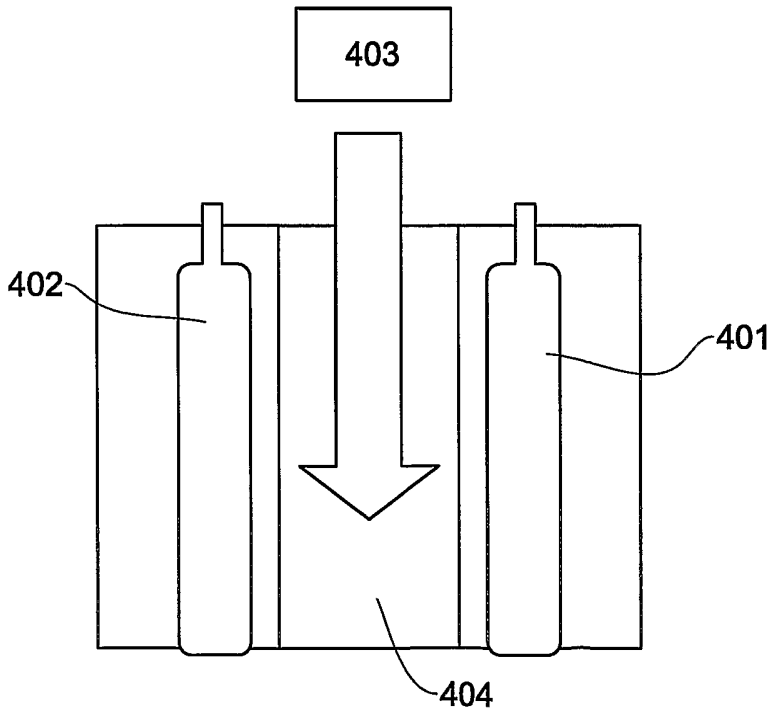

FIG. 2

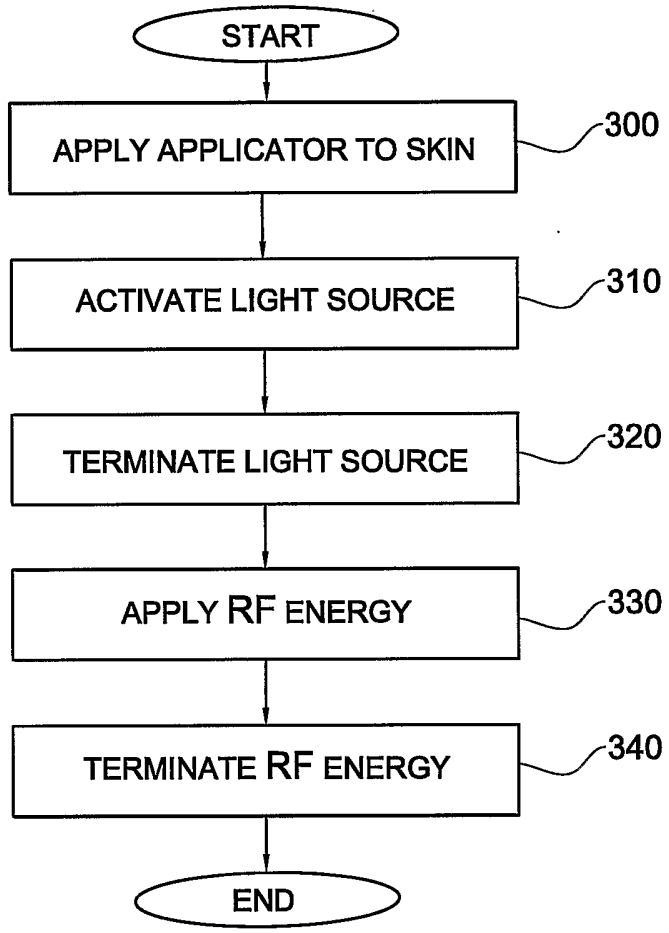
START
APPLY APPLICATOR TO SKIN
300
ACTIVATE LIGHT SOURCE
310
TERMINATE LIGHT SOURCE
320
APPLY RF ENERGY
330
TERMINATE RF ENERGY
340
END

FIG. 3

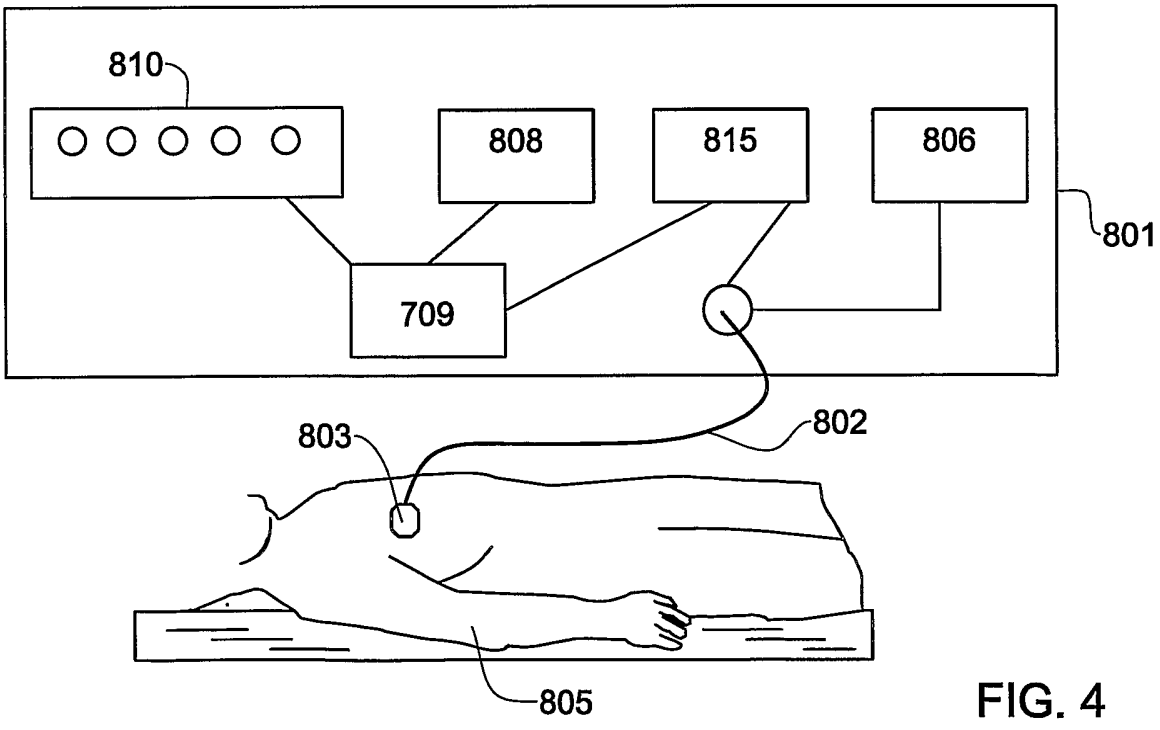
810
808
815
806
801
709
802
803
805

FIG. 4

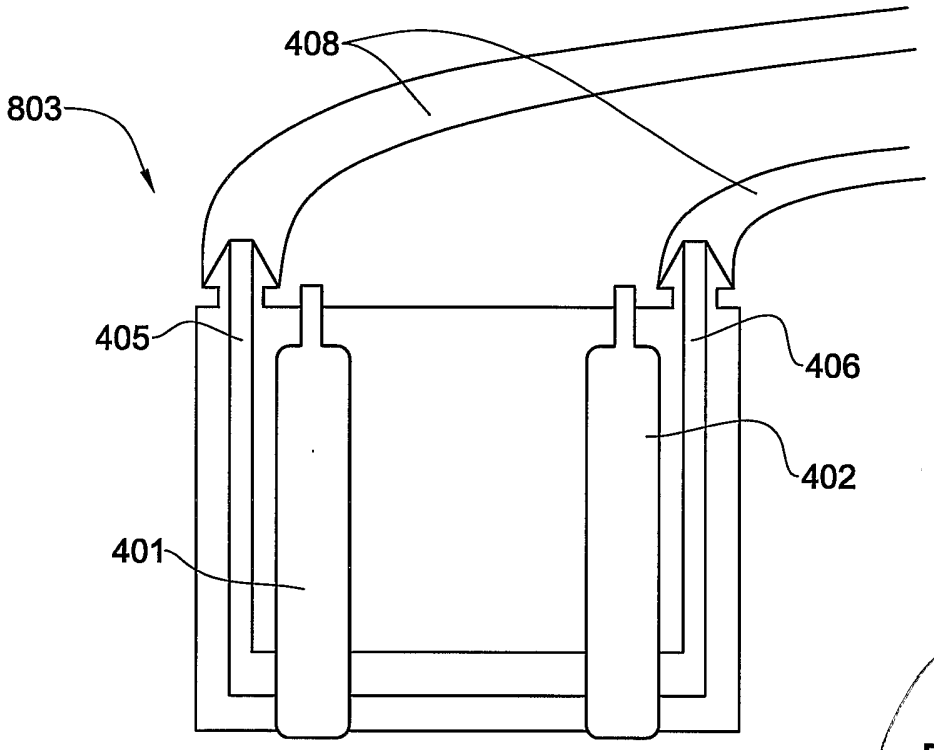
408
803
405
406
402
401

FIG. 5

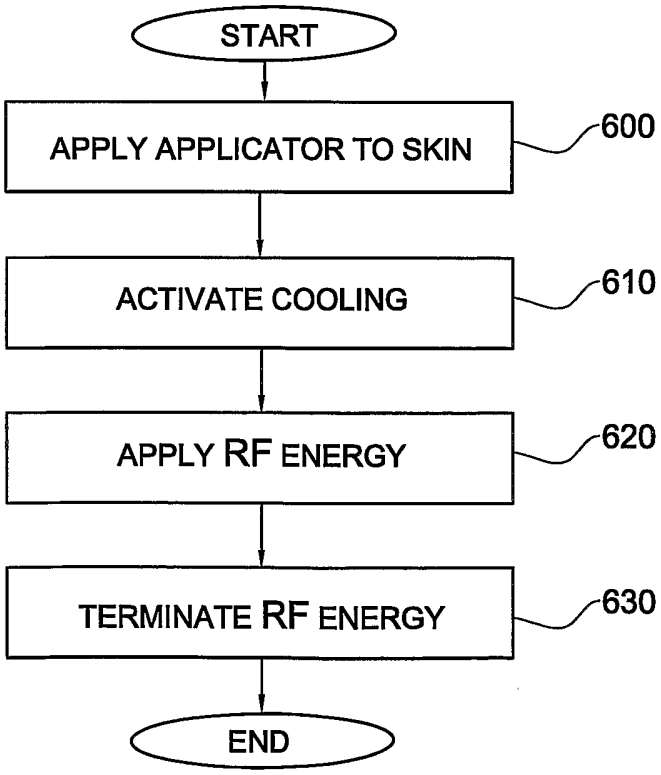
START
APPLY APPLICATOR TO SKIN
600
ACTIVATE COOLING
610
APPLY RF ENERGY
620
TERMINATE RF ENERGY
630
END

FIG. 6

INTERNATIONAL SEARCH REPORT

Ir ional Application No
PCT/IL 03/00050

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B18/14

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)
IPC 7 A61B

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 6 413 255 B1 (STERN ROGER A) 2 July 2002 (2002-07-02) the whole document	1-5
X	WO 00 53113 A (STERN ROGER ;THERMAGE INC (US)) 14 September 2000 (2000-09-14) the whole document	1-5
A	US 6 162 217 A (KANNENBERG DONALD P ET AL) 19 December 2000 (2000-12-19) the whole document	1,2,5
A	US 5 948 011 A (KNOWLTON EDWARD W) 7 September 1999 (1999-09-07) the whole document	1-5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in 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 document 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	Date of mailing of the international search report
25 April 2003	07/05/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Papone, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 03/00050

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 99 35983 A (SURX INC) 22 July 1999 (1999-07-22) abstract _____	1-5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 03/00050

Box I Observations where certain claims were found unsearchable (Continuation of item 1 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. [X] Claims Nos.: 6-11
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery

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 II Observations where unity of invention is lacking (Continuation of item 2 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 fee, this Authority did not invite payment of any additional fee.

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.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IL 03/00050

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6413255 B1	02-07-2002	US 2002151887 A1	17-10-2002
		US 2002156471 A1	24-10-2002
		AU 3741500 A	28-09-2000
		EP 1158919 A1	05-12-2001
		JP 2002537939 A	12-11-2002
		WO 0053113 A1	14-09-2000
WO 0053113 A	14-09-2000	AU 3741500 A	28-09-2000
		EP 1158919 A1	05-12-2001
		JP 2002537939 A	12-11-2002
		WO 0053113 A1	14-09-2000
		US 2002151887 A1	17-10-2002
		US 2002156471 A1	24-10-2002
		US 6413255 B1	02-07-2002
US 6162217 A	19-12-2000	AU 4205800 A	02-11-2000
		WO 0062695 A1	26-10-2000
		US 2003060818 A1	27-03-2003
		US 2001029369 A1	11-10-2001
US 5948011 A	07-09-1999	US 5755753 A	26-05-1998
		US 6311090 B1	30-10-2001
		US 6453202 B1	17-09-2002
		AU 5789396 A	21-11-1996
		EP 0957791 A1	24-11-1999
		JP 11504828 T	11-05-1999
		US 6377855 B1	23-04-2002
		US 6381497 B1	30-04-2002
		US 6381498 B1	30-04-2002
		WO 9634568 A1	07-11-1996
		US 6405090 B1	11-06-2002
		US 6241753 B1	05-06-2001
		US 6470216 B1	22-10-2002
		US 6461378 B1	08-10-2002
		US 6430446 B1	06-08-2002
		US 5919219 A	06-07-1999
		US 2002062142 A1	23-05-2002
		US 6377854 B1	23-04-2002
WO 9935983 A	22-07-1999	AU 743478 B2	24-01-2002
		AU 2113699 A	02-08-1999
		CA 2317410 A1	22-07-1999
		EP 1047347 A1	02-11-2000
		WO 9935983 A1	22-07-1999
		US 6283987 B1	04-09-2001
		US 6533780 B1	18-03-2003