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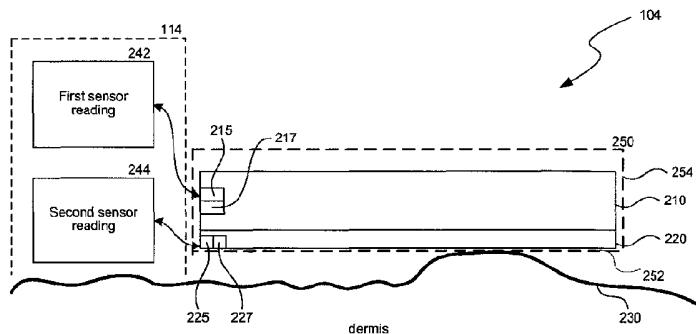


FIG. 4

(57) Abstract: Systems and methods that enable delivery of radiofrequency energy and cryotherapy applications to adipose tissue for reduction and contouring of body fat are described herein. Aspects of the disclosure are directed to methods for reducing surface irregularities in a surface of a subject's skin resulting from an uneven distribution of adipose tissue in the subcutaneous layer. The method can include delivering capacitively coupled or conductively coupled radiofrequency energy to a target region of the subject at a frequency which selectively heats fibrous septae in a subcutaneous layer of the target region to a maximum temperature less than a fibrous septae denaturation temperature. Furthermore, the method can include removing heat such that lipid-rich lobules in the subcutaneous layer are affected while non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae are not substantially affected.

COMBINED MODALITY TREATMENT SYSTEMS, METHODS AND
APPARATUS FOR BODY CONTOURING APPLICATIONS

INCORPORATION BY REFERENCE OF COMMONLY-OWNED APPLICATIONS

[0001] The following commonly assigned U.S. Patent Applications are incorporated herein by reference in their entirety:

[0002] U.S. Patent Application Serial No. 11/750,953, filed on May 18, 2007, entitled "METHOD OF ENHANCED REMOVAL OF HEAT FROM SUBCUTANEOUS LIPID-RICH CELLS AND TREATMENT APPARATUS HAVING AN ACTUATOR";

[0003] U.S. Patent No. 6,032,675 entitled "FREEZING METHOD FOR CONTROLLED REMOVAL OF FATTY TISSUE BY LIPOSUCTION";

[0004] U.S. Patent Publication No. 2007/0255362 entitled "CRYOPROTECTANT FOR USE WITH A TREATMENT DEVICE FOR IMPROVED COOLING OF SUBCUTANEOUS LIPID-RICH CELLS";

[0005] U.S. Patent Publication No. 2007/0198071 entitled "COOLING DEVICE FOR REMOVING HEAT FROM SUBCUTANEOUS LIPID-RICH CELLS";

[0006] U.S. Patent Publication No. 2008/0077201 entitled "COOLING DEVICES WITH FLEXIBLE SENSORS";

[0007] U.S. Patent Publication No. 2008/0077211 entitled "COOLING DEVICE HAVING A PLURALITY OF CONTROLLABLE COOLING ELEMENTS TO PROVIDE A PREDETERMINED COOLING PROFILE";

[0008] U.S. Patent Application Serial No. 11/933,066, filed October 31, 2007, entitled "METHOD AND APPARATUS FOR COOLING SUBCUTANEOUS LIPID-RICH CELLS OR TISSUE," now abandoned;

[0009] U.S. Patent Application Serial No. 11/777,995, filed July 13, 2007, entitled "LIMITING USE OF DISPOSABLE PATIENT PROTECTION DEVICES," now abandoned;

[0010] U.S. Patent Application Serial No. 11/777,992, filed July 13, 2007, entitled "SYSTEM FOR TREATING LIPID-RICH REGIONS," now abandoned;

[0011] U.S. Patent Application Serial No. 11/777,999, filed July 13, 2007, entitled "MANAGING SYSTEM TEMPERATURE TO REMOVE HEAT FROM LIPID-RICH REGIONS," now abandoned;

[0012] U.S. Patent Application Serial No. 11/778,003, filed July 13, 2007, entitled "SECURE SYSTEM FOR REMOVING HEAT FROM LIPID-RICH REGIONS," now abandoned;

[0013] U.S. Patent Application Serial No. 11/778,001, entitled "USER INTERFACES FOR A SYSTEM THAT REMOVES HEAT FROM LIPID-RICH REGIONS," filed July 13, 2007, now abandoned;

[0014] U.S. Patent Publication No. 2008/0077202 entitled "TISSUE TREATMENT METHODS"; and

[0015] U.S. Provisional Patent Application Serial No. 61/100,248, filed September 25, 2008, entitled "TREATMENT PLANNING SYSTEMS AND METHODS FOR BODY CONTOURING APPLICATIONS."

TECHNICAL FIELD

[0016] The present application relates generally to combined modality treatment apparatuses, systems and methods for body contouring applications including systems and methods for delivering radio frequency energy and cooling to affect subcutaneous lipid-rich cells.

BACKGROUND

[0017] Excess body fat, or adipose tissue, may be present in various locations of the body, including, for example, the thigh, buttocks, abdomen, knees, back, face, arms, and other areas. Excess adipose tissue can detract from personal appearance and athletic performance. Moreover, excess adipose tissue is thought to magnify the unattractive appearance of cellulite, which forms when subcutaneous fat lobules protrude or penetrate into the dermis and create dimples where the skin is attached to underlying structural fibrous strands. Cellulite and excessive amounts of adipose

tissue are often considered to be unappealing. Moreover, significant health risks may be associated with higher amounts of excess body fat.

[0018] A variety of methods have been used to treat individuals having excess body fat and, in many instances, non-invasive removal of excess subcutaneous adipose tissue can eliminate unnecessary recovery time and discomfort associated with invasive procedures such as liposuction. Conventional non-invasive treatments for removing excess body fat typically include topical agents, weight-loss drugs, regular exercise, dieting, or a combination of these treatments. One drawback of these treatments is that they may not be effective or even possible under certain circumstances. For example, when a person is physically injured or ill, regular exercise may not be an option. Similarly, weight-loss drugs or topical agents are not an option when they cause an allergic or negative reaction. Furthermore, fat loss in selective areas of a person's body often cannot be achieved using general or systemic weight-loss methods.

[0019] Other methods designed to reduce subcutaneous adipose tissue include laser-assisted liposuction and mesotherapy. Newer non-invasive methods include applying radiant energy to subcutaneous lipid-rich cells via, e.g., radio frequency and/or light energy, such as described in U.S. Patent Publication No. 2006/0036300 and U.S. Patent No. 5,143,063, or via, e.g., high intensity focused ultrasound (HIFU) radiation such as described in U.S. Patent Nos. 7,258,674 and 7,347,855. Additional methods and devices for non-invasively reducing subcutaneous adipose tissue by cooling are disclosed in U.S. Patent No. 7,367,341 entitled "METHODS AND DEVICES FOR SELECTIVE DISRUPTION OF FATTY TISSUE BY CONTROLLED COOLING" to Anderson et al. and U.S. Patent Publication No. 2005/0251 120 entitled "METHODS AND DEVICES FOR DETECTION AND CONTROL OF SELECTIVE DISRUPTION OF FATTY TISSUE BY CONTROLLED COOLING" to Anderson et al., the entire disclosures of which are incorporated herein by reference.

SUMMARY

[0019a] According to one embodiment of the present disclosure, there is provided a method for reducing surface irregularities in a surface of skin of a subject resulting from an uneven distribution of adipose tissue in the subcutaneous layer, the method comprising: delivering energy to a target region of the subject which selectively heats fibrous septae in a subcutaneous layer of the target region to warm non-lipid-rich cells and lipid-rich regions adjacent to the

fibrous septae; and cooling lipid-rich lobules in the subcutaneous layer at the target region to disrupt lipid-rich cells in the lipid-rich lobules such that the lipid-rich lobules are reduced in number and/or size to an extent while the warmed non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae are not reduced in number or size to the extent, thereby reducing surface irregularities in the surface of skin of the subject.

[0019b] According to another embodiment of the present disclosure, there is provided a combined modality treatment system for selectively removing heat from subcutaneous lipid-rich cells in a target region of a subject having skin, comprising: a treatment unit in thermal communication with a fluid chamber, the fluid chamber being configured to house and provide a coolant; a radiofrequency (RF) energy source for generating RF current; a controller; and a treatment device having a heat exchanging plate coupled to the RF energy source and a thermoelectric cooling element in communication with the treatment unit; wherein the controller has instructions that cause the treatment device to capacitively couple radiofrequency (RF) energy to the skin of the subject selectively to heat fibrous septae in the target region to a final temperature less than a fibrous septae denaturation temperature; and remove heat from the subcutaneous lipid-rich cells of the subject during a treatment process to cause disruption of the subcutaneous lipid-rich cells while non-lipid-rich cells and subcutaneous lipid-rich cells adjacent to the fibrous septae being warmed by the RF energy are not substantially affected.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] In the drawings, identical reference numbers identify similar elements or acts. The sizes and relative positions of elements in the drawings are not necessarily drawn to scale. For example, the shapes of various elements and angles are not

drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn are not intended to convey any information regarding the actual shape of the particular elements, and have been solely selected for ease of recognition in the drawings.

[0021] Figure 1 is an isometric view schematically illustrating a combined modality treatment system for treating subcutaneous lipid-rich regions of a patient in accordance with an embodiment of the disclosure.

[0022] Figure 2 is a schematic cross-sectional view of the skin and subcutaneous tissue of a subject.

[0023] Figure 3 is a schematic cross-sectional view of the skin and subcutaneous tissue of a subject illustrating the application of RF current thereto.

[0024] Figure 4 is a partial cross-sectional view illustrating a combined modality treatment device suitable to be used in the system of Figure 1 in accordance with embodiments of the disclosure.

[0025] Figure 5 is a flow diagram illustrating a method for reducing irregularities in a surface of a subject's skin resulting from an uneven distribution of adipose tissue in the subcutaneous layer in accordance with an embodiment of the disclosure.

[0026] Figure 6 is a schematic block diagram illustrating computing system software modules and subcomponents of a computing device suitable to be used in the system of Figure 1 in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

A. Overview

[0027] Systems, devices and methods are provided herein that enable simultaneous or sequential delivery of capacitively coupled radiofrequency (RF) energy and cooling to selectively affect targeted subcutaneous lipid-rich cells. Several of the details set forth below are provided to describe the following examples and methods in a manner sufficient to enable a person skilled in the relevant art to practice, make and use them. Several of the details and advantages described below, however, may not be necessary to practice certain examples and methods of the technology.

Additionally, the technology may include other examples and methods that are within the scope of the claims but are not described in detail.

[0028] Reference throughout this specification to "one example," "an example," "one embodiment," or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one example of the present technology. Thus, the occurrences of the phrases "in one example," "in an example," "one embodiment," or "an embodiment" in various places throughout this specification are not necessarily all referring to the same example. Furthermore, the particular features, structures, routines, stages, or characteristics may be combined in any suitable manner in one or more examples of the technology. The headings provided herein are for convenience only and are not intended to limit or interpret the scope or meaning of the claimed technology.

[0029] Some embodiments of the disclosure are directed to methods for reducing irregularities in a surface of a subject's skin resulting from an uneven distribution of adipose tissue in the subcutaneous layer. For example, a method can include selectively heating tissue by one or more methods, such as, e.g., by delivering capacitively or conductively coupled radiofrequency (RF) energy to a target region of the subject at a frequency, duration and power. The delivered RF energy selectively heats fibrous septae in a subcutaneous layer of the target region. Furthermore, the method can include removing heat such that lipid-rich lobules in the subcutaneous layer at the target region are reduced in number and/or size to an extent while non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae are not reduced in number or size to the extent, thereby reducing irregularities in the surface of skin of the subject.

[0030] Other embodiments of the disclosure are directed to a system for non-invasive, transdermal removal of heat from subcutaneous lipid-rich cells of a subject. The system can include a treatment unit in thermal communication with a fluid chamber, wherein the fluid chamber can house and provide a coolant. The system can also include a radiofrequency (RF) energy generating unit for generating RF current, and a treatment device in fluid communication with the treatment unit and in electrical communication with the RF energy generating unit. The system can further include a controller in communication with the treatment unit, the RF energy generating unit and

the treatment device. In one embodiment, the controller has instructions for causing the treatment device to capacitively or conductively couple RF energy to the subject to selectively heat connective tissue in a target region beneath an epidermis of the subject to a maximum temperature less than a collagen denaturation temperature. The treatment device can be further configured to reduce a temperature of the target region beneath the epidermis of the subject to selectively reduce the temperature of subcutaneous lipid-rich cells in the target region such that the subcutaneous lipid-rich cells are substantially affected while non-lipid rich cells in the epidermis and subcutaneous lipid-rich cells adjacent to the connective tissue are not substantially affected (e.g., damaged, injured, disrupted or destroyed).

[0031] Other aspects of the disclosure are directed toward a combined modality treatment system for selectively removing heat from subcutaneous lipid-rich cells in a target region of a subject having skin. The combined modality treatment system can include treatment unit in thermal communication with a fluid chamber, wherein the fluid chamber can house and provide a coolant. The combined modality treatment system can also include a RF energy source for generating RF current. Further, the system can include a controller and a treatment device. The treatment device can include a heat exchange plate coupled to the RF energy source and a thermoelectric cooling element in communication with the treatment unit. In one embodiment, the controller includes instructions that cause the treatment device to capacitively or conductively couple radiofrequency (RF) energy to the skin of the subject to selectively heat fibrous septae in the target region to a final temperature less than a fibrous septae denaturation temperature. The controller can also include instructions that cause the treatment device to remove heat from the subcutaneous lipid-rich cells of the subject during a treatment process such that subcutaneous lipid-rich cells are substantially affected while non-lipid-rich cells and subcutaneous lipid-rich cells adjacent to the fibrous septae are not substantially affected.

B. Combined Modality Treatment System

[0032] Figure 1 and the following discussion provide a brief, general description of an example of a combined modality treatment system 100 in which aspects of the disclosure can be implemented. Those skilled in the relevant art will appreciate that other examples of the disclosure can be practiced with other treatment systems and

treatment protocols, including invasive, minimally invasive, other non-invasive medical treatment systems, and/or combinations of one or more of the above for treating a patient. In general, the term "treatment system", as used generally herein, refers to any of the above system categories of medical treatment as well as any treatment regimes or medical device usage.

[0033] In one embodiment, the combined modality treatment system 100 is suitable for treating a subject's subcutaneous adipose tissue, including such as by cooling. The term "subcutaneous tissue" means tissue lying beneath the dermis and includes subcutaneous fat, or adipose tissue, which primarily is composed of lipid-rich cells, or adipocytes. When cooling the subcutaneous tissues to a temperature lower than 37°C, subcutaneous lipid-rich cells can selectively be affected. In general, the epidermis and dermis of the patient 101 have lower amounts of lipids compared to the underlying lipid-rich cells forming the subcutaneous tissues. Because non-lipid-rich cells usually can withstand colder temperatures better than lipid-rich cells, the subcutaneous lipid-rich cells can selectively be affected while maintaining the integrity of the non-lipid-rich cells in the dermis and epidermis. In some embodiments, the treatment system 100 can apply cooling temperatures to the skin of the patient in a range of from about -20°C to about 20°C. In other embodiments, the cooling temperatures can be from about -20°C to about 10°C, from about -15°C to about 5°C, or from about -10°C to about 0°C.

[0034] Without being bound by theory, the selective effect of cooling on lipid-rich cells is believed to result in, for example, membrane disruption, shrinkage, disabling, destroying, removing, killing, or another method of lipid-rich cell alteration. Such alteration is believed to be an intermediate and/or final result of one or more mechanisms acting alone or in combination. It is thought that such mechanism or mechanisms trigger an apoptotic cascade, which is believed to be the dominant form of lipid-rich cell death by non-invasive cooling.

[0035] Apoptosis, also referred to as "programmed cell death", is a genetically-induced death mechanism by which cells self-destruct without incurring damage to surrounding tissues. An ordered series of biochemical events induce cells to morphologically change. These changes include cellular blebbing, loss of cell membrane asymmetry and attachment, cell shrinkage, chromatin condensation, and

chromosomal DNA fragmentation. Injury via an external stimulus, such as cold exposure, is one mechanism that can induce apoptosis in cells. Nagle, W.A., Soloff, B.L., Moss, A.J. Jr., Henle, K.J. "Cultured Chinese Hamster Cells Undergo Apoptosis After Exposure to Cold but Nonfreezing Temperatures" *Cryobiology* 27, 439-451 (1990).

[0036] One aspect of apoptosis, in contrast to cellular necrosis (a traumatic form of cell death causing local inflammation), is that apoptotic cells express and display phagocytic markers on the surface of the cell membrane, thus marking the cells for phagocytosis by, for example, macrophages. As a result, phagocytes can engulf and remove the dying cells (e.g., the lipid-rich cells) without eliciting an immune response. Temperature exposures that elicit these apoptotic events in lipid-rich cells may contribute to long-lasting and/or permanent reduction and reshaping of subcutaneous adipose tissue.

[0037] Without being bound by theory, one mechanism of apoptotic lipid-rich cell death by cooling is believed to involve localized crystallization of lipids within the adipocytes at temperatures that do not induce crystallization in non-lipid-rich cells. The crystallized lipids may selectively injure these cells, inducing apoptosis (and may also induce necrotic death if the crystallized lipids damage or rupture the bilayer lipid membrane of the adipocyte). Another mechanism of injury involves the lipid phase transition of those lipids within the cell's bilayer lipid membrane, which results in membrane disruption, thereby inducing apoptosis. This mechanism is well documented for many cell types and may be active when adipocytes, or lipid-rich cells, are cooled. Mazur, P., "Cryobiology: the Freezing of Biological Systems" *Science*, 68: 939-949 (1970); Quinn, P.J., "A Lipid Phase Separation Model of Low Temperature Damage to Biological Membranes" *Cryobiology*, 22: 128-147 (1985); Rubinsky, B., "Principles of Low Temperature Preservation" *Heart Failure Reviews*, 8, 277-284 (2003). Other yet-to-be understood apoptotic mechanisms may exist, based on the relative sensitivity of lipid-rich cells to cooling compared to non-lipid rich cells.

[0038] In addition to the apoptotic mechanisms involved in lipid-rich cell death, local cold exposure may induce lipolysis (i.e., fat metabolism) of lipid-rich cells. For example, cold stress has been shown to enhance rates of lipolysis from that observed under normal conditions which serves to further increase the volumetric reduction of

subcutaneous lipid-rich cells. Vallerand, A.L., Zamecnik, J., Jones, P.J.H., Jacobs, I. "Cold Stress Increases Lipolysis, FFA Ra and TG/FFA Cycling in Humans" *Aviation, Space and Environmental Medicine* 70, 42-50 (1999).

[0039] Cellulite (Gynoid lipodystrophy) typically is a hormonally mediated condition characterized by the uneven distribution of adipose tissue in the subcutaneous layer that gives rise to an irregular, dimpled skin surface common in women. Cellulite-prone tissue can be characterized by the uneven thickness and distribution of some fibrous septae strands. Piérard, G.E., Nizet, J.L., Piérard-Franchimont, C., "Cellulite: From Standing Fat Herniation to Hypodermal Stretch Marks," *Am. J. Dermatol.* 22:1, 34-37 (2000). Cellulite has proved to be a difficult and vexing problem to treat, although the demand for an effective treatment has been and remains quite high.

[0040] As shown schematically in Figure 2, adipose tissue is subdivided into fat cell chambers or lobules (also called "papillae adiposae") 201 by connective collagenous tissue called fibrous septae 202. The fibrous septae 202, which for females tend to generally be oriented perpendicular to the skin surface and anchor the dermal layers 203 to the underlying fascia and muscle (not shown), are organized within the subcutaneous layer to form a connective web around the adipose cells or fat lobules 202. Subcutaneous adipose cells and their lobules 202 are not uniformly distributed throughout the subcutaneous tissue layer (e.g., between the dermis and the muscle layers), but exhibit regional differences in size and shape. These regional differences can, in part, be due to gender, age, genetics, hormones and physical conditioning among other physiological factors. The number, size, distribution and orientation of fibrous septae 202 also vary by body location, gender and age. For example, as described above, histological studies have shown that fibrous septae architecture in females differs from that in males.

[0041] In males, fibrous septae 202 tend to form an intersecting network that divide the papillae adiposae into small, polygonal units. In contrast, fibrous septae 202 in some females may tend to be oriented perpendicularly to the cutaneous surface, creating fat cell chambers that are columnar in shape and sequestered by the connective strands and the overlaying dermis layer 203 (see, e.g., Figure 2). When the intersecting fibrous septae 202 are more uniform in size and elasticity as is characteristic of males, the forces within and between the fibrous septae and their

surrounding tissue tend to be distributed relatively evenly. However, the columnar architecture of the fibrous septae 202 found in some females can result in an uneven distribution of forces throughout the subcutaneous tissue. In particular, and without being bound by theory, it is believed that this uneven distribution of forces is partially manifested by the columnar fibrous septae 202 being held in a state of tension by the underlying fascia and other tissue, resulting in a tethering or anchoring effect at the point where each such septum 202 connects with the dermal tissue 203. This tethering or anchoring is in turn manifested at the skin surface as a low spot 204 relative to adjacent dermal tissue 203 not directly above such septae, which tends to herniate as the papillae adiposae bulge into the dermal tissue 203. When viewed over a larger scale of a few square centimeters, the non-homogeneous nature of the skin surface's relative high and low points results in a dimpled or irregular appearance characteristic of cellulite.

[0042] As described above, cooling the subcutaneous tissues to a temperature lower than 37°C selectively can affect lipid-rich cells. Cooling the lipid-rich cells of the subcutaneous layer tends uniformly to affect the adipose cells distributed throughout the subcutaneous tissue at a given depth below the dermis, for instance, when such lipid-rich cells are cooled non-invasively. As with the epidermal and dermal layers of the patient 101, however, the fibrous septae 202 generally are not affected by such treatment temperatures. To selectively treat the bulging or herniating adipose cells near the dermal – subcutaneous interface associated with cellulite conditions, the combined modality treatment system 100 can further be configured to selectively remove heat from (i.e., cool) the bulging and/or herniating fat lobules near the dermal layer and distal from the tethering fibrous septae 202, while limiting the disruption of adipose tissue near the septae, which lie near the low spots. Such selective disruption of the fat lobules 201 that constitute the high spots will have the general effect of flattening the overall contour of the skin.

[0043] Accordingly, in one embodiment, the combined modality treatment system 100 is configured to not only cool subcutaneous tissue as described herein but also to selectively heat tissue such as the fibrous septae 202 and certain adipose tissue according to the methods described herein. One method of selectively heating such tissue is by the delivery of radiofrequency (RF) energy, including for example

capacitively coupled RF energy, such as a low-level monopolar RF energy as well as conductively coupled RF energy, to the subcutaneous tissue selectively to heat regions of tissue bound by the connective web of fibrous septae. Adipose cells are composed almost entirely of lipids, which generally have low thermal and electrical conductivities relative to other tissue. In contrast, fibrous septae have similar properties to the dermis and, for example, have been shown to conduct electrical energy more efficiently. Due to this high electrical and thermal conductivity of fibrous septae relative to lipids in adipose cells, the connective strands can provide a path of least resistance for capacitively or inductively coupled RF current traveling via, e.g., the surface of the skin through the epidermis and dermis, and around subcutaneous adipose tissue. RF current, (which is high frequency current in the frequency range of about 0.3 MHz to about 100 MHz or higher, or in some embodiments in the range of about 0.3 MHz to about 40 MHz, while in other embodiments in the range of about 0.3 MHz to about 6 MHz), produces a thermal effect on living tissue depending on the electrical properties of the tissue. Other methods of applying energy to selectively heat tissue as described herein may be used in addition to or in place of RF energy, including, e.g., optical (e.g., laser light), acoustic (e.g., ultrasound), infrared, microwave, etc.

[0044] A schematic depiction of the application of energy such as RF current 210 to a region of dimpled tissue near a fibrous septum 202 is shown in Figure 3. As RF current 210 is applied via an electrode as described herein, the current 210 concentrates in the dermal and connective tissue such as the fibrous septum 202 as described above. Heating generated by application of this RF current, depicted by arrows 210, heats the fibrous septum 202 and selected of the adipose cells in the fat lobules 201 adjacent the fibrous septum 202. In the combined modality therapy associated with the embodiments described herein, the treatment parameters may be adjusted selectively to affect, in connection with cooling the subcutaneous tissue, the temperature profile of and the number of the adipose cells in the lobules 201 that are heated via the application of such RF current. For example, RF power in the range of about 0.02 to about 10 W/cm² or higher during cooling can have the desired effect of warming the affected fibrous septae 202 and the fat lobules in a region near the affected fibrous septae 202 while allowing the cooling and subsequent selective reduction of fat lobules 201 more distal from the fibrous septae 202.

[0045] Heat is generated by the tissue's natural resistance to the flow of current (e.g., movement of electrons and ions) within an electrical field as a reaction to the rapid change of polarity. This electrical field changes polarity at a desired rate (e.g., at approximately 0.3 to approximately 100 MHz), and the charged particles within the electric field change orientation at that same frequency. The tissue's natural resistance to the movement of these charged ions and molecules in the skin and subcutaneous tissue generates heat. Pope, K., Levinson, M., Ross, E.V., "Selective Fibrous Septae Heating: An Additional Mechanism of Action for Capacitively Coupled Monopolar Radiofrequency," *Thermage, Inc.* (2005).

[0046] In accordance with one embodiment, RF energy is generated and applied to a target region of the patient 101 while simultaneously cooling the subcutaneous tissues to a temperature lower than 37°C in a manner that (a) selectively heats the fibrous septae and the adipose tissue adjacent to the fibrous septae, and (b) selectively affects the lipid-rich cells in regions of thinning or absent fibrous septae. In some embodiments, the fibrous septae are heated to a maximum temperature less than a fibrous septae denaturation temperature. Thermal energy is known to denature collagenous tissue, such as fibrous septae, at temperatures of approximately 65°C (e.g., between 60° and 80°C). Therefore, in one embodiment, the capacitively coupled RF energy is delivered to the target region of the patient such that the fibrous septae are heated to a temperature approximately less than 60°C.

[0047] In some embodiments, the treatment system 100 can apply RF current to the skin of the patient while/during cooling treatment in a simultaneous manner, or in a sequential manner, such that the fibrous septae are warmed to a range of from about 0°C to about 60°C. In other embodiments, the fibrous septae can be warmed to temperatures from about 10°C to about 30°C, from 5°C to about 20°C, or from about 0°C to about 10°C. For example, capacitively coupled RF energy can be delivered to the target region of the patient 101 such that the lipid-rich cells adjacent to the fibrous septae are not cooled to temperatures below approximately 10°C – 15°C, while allowing the lipid-rich cells remote from the fibrous septae or near thinning fibrous septae strands to cool to a temperature below approximately 10°C.

[0048] In some embodiments, RF energy can be applied to the target region of the patient 101 simultaneously with cooling (i.e., removing heat) such that a controllable

temperature difference is maintained between (a) the fibrous septae and tissue adjacent to the fibrous septae, and (b) bulging or herniating adipose tissue spaced apart or otherwise separated from the fibrous septae. In other embodiments, the RF energy can be applied to the target region before, periodically during, or after cooling for selectively affecting bulging or herniating adipose tissue in the subcutaneous layer of the patient 101.

[0049] In various embodiments, the combined modality treatment system 100 includes a controller, a computing device, a data acquisition device, a treatment unit, an RF energy generating unit and one or more applicators. The system 100 can employ these components in various embodiments to receive a selection of a treatment profile and apply the selected treatment using an applicator.

[0050] Figure 1 is an isometric view schematically illustrating a combined modality treatment system 100 for selectively heating fibrous septae and removing heat from herniated and/or bulging subcutaneous lipid-rich regions of a subject patient 101 in accordance with an embodiment of the disclosure. The system 100 can include a combined modality device 104 including an applicator 105 that engages a target region of the subject 101, such as the abdominal region 102. It will be understood that combined modality devices 104 and applicators 105 can be provided having various shapes and sizes suitable for different body regions and body parts such that any suitable area for removing heat from a subcutaneous lipid-rich region of the subject 101 can be achieved.

[0051] An applicator, such as applicator 105, is a component of the system 100 that both cools subcutaneous tissue and selectively heats subcutaneous fibrous septae in a region of a subject 101, such as a human or animal (i.e., "patient"). Various types of applicators may be applied during treatment, such as a vacuum applicator, a belt applicator (either of which may be used in combination with a massage or vibrating capability), and so forth. Each applicator may be designed to treat identified portions of the patient's body, such as chin, cheeks, arms, pectoral areas, thighs, calves, buttocks, abdomen, "love handles", back, and so forth. For example, the vacuum applicator may be applied at the back region, and the belt applicator can be applied around the thigh region, either with or without massage or vibration. Exemplary applicators and their configurations usable or adaptable for use with the combined modality treatment

system 100 variously are described in, e.g., commonly assigned U.S. Patent Publication Nos. 2007/0198071, 2008/0077201, and 2008/0077211 and in U.S. Patent Application Serial No. 11/750,953. In further embodiments, the system 100 may also include a patient protection device (not shown) incorporated into or configured for use with the applicator that prevents the applicator from directly contacting a patient's skin and thereby reducing the likelihood of cross-contamination between patients, minimizing cleaning requirements for the applicator. The patient protection device may also include or incorporate various storage, computing, and communications devices, such as a radio frequency identification (RFID) component, allowing for example, use to be monitored and/or metered. Exemplary patient protection devices are described in commonly assigned U.S. Patent Publication No. 2008/0077201.

[0052] In the present example, the system 100 can also include a treatment unit 106 and supply and return fluid lines 108a-b between the combined modality treatment device 104 and the treatment unit 106. A treatment unit 106 is a device that, based on variable power input, can increase or decrease the temperature at a connected combined modality treatment device 104 that in turn may be attached to or incorporated into the applicator 105. The treatment unit 106 can remove heat from a circulating coolant to a heat sink and provide a chilled coolant to the combined modality treatment device 104 via the fluid lines 108a-b. Alternatively, treatment unit 106 can circulate warm coolant to the combined modality treatment device 104 during periods of warming. Examples of the circulating coolant include water, glycol, synthetic heat transfer fluid, oil, a refrigerant, and/or any other suitable heat conducting fluid. The fluid lines 108a-b can be hoses or other conduits constructed from polyethylene, polyvinyl chloride, polyurethane, and/or other materials that can accommodate the particular circulating coolant. The treatment unit 106 can be a refrigeration unit, a cooling tower, a thermoelectric chiller, or any other device capable of removing heat from a coolant. Alternatively, a municipal water supply (e.g., tap water) can be used in place of the treatment unit 106. One skilled in the art will recognize that there are a number of other cooling technologies that could be used such that the treatment unit or chiller need not be limited to those described herein.

[0053] The system 100 can further include an RF energy generating unit 107 and RF power lines 109a-b between the treatment device 104, an RF current return

electrode (not shown) and the RF energy generating unit 107. The RF energy generating unit 107 can include a variable powered RF generator capable of generating and delivering RF energy through the RF power line 109a to one or more RF electrodes, or other electrically conductive material that can be charged with RF current, in the combined modality treatment device 104 for capacitively coupling radiofrequency (RF) energy to the target region of the subject 101. One advantage among several of a system using capacitively coupled RF energy in the various embodiments described herein is the ability to reduce or eliminate electrode edge effects. In particular, and as described below, a dielectric layer or film may be used on the one or more RF electrodes to increase the impedance of the electrode and produce a more uniform current flow through the electrode to the skin of the patient. Such a layer or film creates a capacitance effect whose magnitude and other qualities may be controlled by the composition, surface area and thickness of the layer, the choice of methods by which the layer or film is deposited and/or adhered to the RF electrode, and the frequency of the RF signal.

[0054] Alternatively, system 100 can be configured to conductively couple RF energy to a patient. This may be accomplished by, e.g., the use of an RF electrode without a dielectric layer or film. The choice of whether to use a capacitively coupled RF system or a conductively-coupled RF system may be predicated upon the particular design of the electrode, the location on the patient which the system 100 is used, frequency and power settings, temperatures, treatment duration, and other such parameters and other considerations.

[0055] In this example, the combined modality treatment device 104 includes at least one applicator 105 and is associated with at least one treatment unit 106. The applicator 105 can provide mechanical energy to create a vibratory, massage, and/or pulsatile effect. The applicator 105 can include one or more actuators, such as, motors with eccentric weight, or other vibratory motors such as hydraulic motors, electric motors, pneumatic motors, solenoids, other mechanical motors, piezoelectric shakers, and so on, to provide vibratory energy or other mechanical energy to the treatment site. Further examples include a plurality of actuators for use in connection with a single combined modality treatment device 104 and/or applicator 105 in any desired combination. For example, an eccentric weight actuator can be associated with one

combined modality treatment device 104 or applicator 105, while a pneumatic motor can be associated with another section of the same treatment device or applicator. This, for example, would give the operator of the treatment system 100 options for differential treatment of lipid rich cells within a single region or among multiple regions of the subject 101. The use of one or more actuators and actuator types in various combinations and configurations with a combined modality treatment device 104 or applicator 105 may be possible.

[0056] The combined modality treatment device 104 can include one or more heat exchanging units. The heat exchanging unit can be a Peltier-type thermoelectric element, and the combined modality treatment device 104 can have multiple individually controlled heat exchanging units (e.g., between 1 and 50, between 10 and 45; between 15 and 21, approximately 100, etc.) to create a custom spatial cooling profile and/or a time-varying cooling profile. Each custom treatment profile can include one or more segments, and each segment can include a specified duration, a target temperature, and control parameters for features such as vibration, massage, vacuum, and other treatment modes. Treatment devices having multiple individually controlled heat exchanging units are described in commonly assigned U.S. Patent Publication No. 2008/0077211, U.S. Provisional Application No. 61/298,175, filed January 25, 2010, and U.S. Provisional Application No. 61/354,615 filed June 14, 2010.

[0057] Additionally, the combined modality treatment device 104 can include one or more RF electrodes. For example, the RF electrodes can be a single electrode or a plurality of electrodes positioned in a desired or segmented arrangement and can form a segmented flexible circuit. In another embodiment, the treatment device 104 can include an electrically conductive material, such as aluminum, that can be charged with RF current. RF power can be delivered to the RF electrodes via RF power line 109a and, thereafter, coupled to the target region of the subject 101 to achieve selective heating of the underlying fibrous septae collagen network and adjacent adipose tissue. Generally, RF electrodes can be monopolar or bipolar. Capacitively coupled monopolar RF current flows from the electrode into the epidermis and dermis, through the subcutaneous tissue via conduction along the less-resistant fibrous septae and into the muscle tissue (at which location it ideally has dissipated to a level that it does not have any appreciable effect thereon). The RF current continues to flow through the

body to a return electrode (not shown) adhered to a second site on the patient and then returns to the RF energy generating unit 107 via line 109b.

[0058] Alternatively, the treatment device 104 may operate without a return electrode and line 109b. The return RF current flows out of the body and through the air to the RF energy generating unit 107 to complete the circuit. The frequency in such a configuration, sometimes referred to a "unipolar" configuration, can be between about 30 MHz and about 50 MHz. In another embodiment, the frequency for such a configuration is between about 35 MHz and about 45 MHz. In yet another embodiment, the frequency for such a configuration is about 40 MHz.

[0059] The system 100 can further include a power supply 110 and a controller 114 operatively coupled to the combined modality treatment device 104 and the applicator 105. In one embodiment, the power supply 110 can provide a direct current voltage to the thermoelectric treatment device 104 and/or the applicator 105 to remove heat from the subject 101. The controller 114 can monitor process parameters via sensors (not shown) placed proximate to the combined modality treatment device 104 via a control line 116 to, among other things, adjust the heat removal rate and/or RF energy delivery rate based on the process parameters. The controller 114 can further monitor process parameters to adjust the applicator 105 based on treatment parameters, such as treatment parameters defined in a custom treatment profile or patient-specific treatment plan.

[0060] The controller 114 can exchange data with the applicator 105 via an electrical line 112 or, alternatively, via a wireless or an optical communication link. Note that control line 116 and electrical line 112 are shown in Figure 1 without any support structure. Alternatively, control line 116 and electrical line 112 (and other lines including, but not limited to fluid lines 108a-b and RF power lines 109a-b) may be bundled into or otherwise accompanied by a conduit or the like to protect such lines, enhance ergonomic comfort, minimize unwanted motion (and thus potential inefficient removal of heat from and/or delivery of RF energy to subject 101), and to provide an aesthetic appearance to system 100. Examples of such a conduit include a flexible polymeric, fabric, or composite sheath, an adjustable arm, etc. Such a conduit (not shown) may be designed (via adjustable joints, etc.) to "set" the conduit in place for the treatment of subject 101.

[0061] The controller 114 can include any processor, Programmable Logic Controller, Distributed Control System, secure processor, and the like. A secure processor can be implemented as an integrated circuit with access-controlled physical interfaces; tamper resistant containment; means of detecting and responding to physical tampering; secure storage; and shielded execution of computer-executable instructions. Some secure processors also provide cryptographic accelerator circuitry. Secure storage may also be implemented as a secure flash memory, secure serial EEPROM, secure field programmable gate array, or secure application-specific integrated circuit.

[0062] In another aspect, the controller 114 can receive data from an input device 118 (shown as a touch screen), transmit data to an output device 120, and/or exchange data with a control panel (not shown). The input device 118 can include a keyboard, a mouse, a stylus, a touch screen, a push button, a switch, a potentiometer, a scanner, or any other device suitable for accepting user input. The output device 120 can include a display or touch screen, a printer, video monitor, a medium reader, an audio device, any combination thereof, and any other device or devices suitable for providing user feedback.

[0063] In the embodiment of Figure 1, the output device 120 is a touch screen that functions as both an input device 118 and an output device 120. The control panel can include visual indicator devices or controls (e.g., indicator lights, numerical displays, etc.) and/or audio indicator devices or controls. The control panel may be a component separate from the input device 118 and/or output device 120, may be integrated with one or more of the devices, may be partially integrated with one or more of the devices, may be in another location, and so on. In alternative examples, the control panel, input device 118, output device 120, or parts thereof (described herein) may be contained in, attached to, or integrated with the combined modality treatment device 104 and/or applicator 105. In this example, the controller 114, power supply 110, control panel, treatment unit 106, input device 118, and output device 120 are carried by a rack 124 with wheels 126 for portability. In alternative embodiments, the controller 114 can be contained in, attached to, or integrated with the combined modality treatment device 104 and/or the applicator 105 and/or the patient protection device described above. In yet other embodiments, the various components can be fixedly installed at a treatment

site. Further details with respect to components and/or operation of combined modality treatment device 104, treatment unit 106, applicator 105 and other components may be found in commonly-assigned U.S. Patent Application Serial No. 11/750,953.

[0064] In operation, and upon receiving input to start a treatment protocol, the controller 114 can cause the applicator 105 to cycle through each segment of a prescribed treatment plan. In so doing, the applicator 105 applies power to one or more combined modality treatment devices 104, such as thermoelectric coolers (e.g., TEC "zones"), to begin a cooling cycle and, for example, activate features or modes such as vibration, massage, vacuum, etc. Additionally, the RF energy generating unit 107 is used to generate and transfer RF energy to the RF electrodes in the one or more combined modality treatment devices 104 to begin selectively heating the fibrous septae in the subcutaneous tissue in the target region of the subject 101.

[0065] Using temperature sensors (not shown) proximate to the one or more combined modality treatment devices 104, the patient's skin, a patient protection device, or other locations or combinations thereof, the controller 114 determines whether a temperature or heat flux is at a sufficient temperature close to the target temperature or heat flux. It will be appreciated that while a region of the body (e.g., adipose tissue) has been cooled or heated to the target temperature, in actuality that region of the body may be close but not equal to the target temperature, e.g., because of the body's natural heating and cooling variations. Thus, although the system may attempt to heat or cool the tissue to the target temperature or to provide by a target heat flux, a sensor may measure a sufficiently close temperature. If the target temperature has not been reached, power can be increased or decreased to change heat flux to maintain the target temperature or "set-point" to selectively affect bulging or herniating adipose lobules at or near the interface between the dermis and subcutaneous tissue, or to affect adipose tissue spaced apart from anchoring fibrous septae in the subcutaneous layer.

[0066] When the prescribed segment duration expires, the controller 114 may apply the temperature and duration indicated in the next treatment profile segment. In some embodiments, temperature can be controlled using a variable other than, or in addition to, power.

[0067] In some embodiments, heat flux measurements can indicate other changes or anomalies that can occur during treatment administration. For example, an increase in temperature detected by a heat flux sensor can indicate a freezing event at the skin or underlying tissue (i.e., dermal tissue). An increase in temperature as detected by the heat flux sensors can also indicate movement associated with the applicator, causing the applicator to contact a warmer area of the skin, for example. Methods and systems for collection of feedback data and monitoring of temperature measurements are described in commonly assigned U.S. Patent Application Serial No. 12/196,246, entitled "MONITORING THE COOLING OF SUBCUTANEOUS LIPID-RICH CELLS, SUCH AS THE COOLING OF ADIPOSE TISSUE," filed on August 21, 2008, which is incorporated herein in its entirety by reference.

[0068] The combined modality treatment devices 104 may also include additional sensors to detect process treatment feedback. For example, thermal sensors can be included on the combined modality treatment device 104 and/or the RF energy generating unit 107 to measure voltage and current that is delivered to the target region of the subject 101. Thermal sensor output can be used, by the controller 114 for example, to control the delivery of RF power to the RF electrodes, the temperature of the electrodes or the desired temperature of the fibrous septae tissue during a treatment session. Additional sensors may be included for measuring tissue impedance, treatment application force, tissue contact with the applicator and RF energy interaction with the skin of the subject 101 among other process parameters.

[0069] In one embodiment, feedback data associated with RF energy delivery and heat removal from lipid-rich lobules in the subcutaneous layer can be collected in real-time. Real-time collection and processing of such feedback data can be used in concert with treatment administration to ensure that the process parameters used to reduce irregularities in a surface of subject's skin and adipose tissue are administered correctly and efficaciously.

[0070] Although a noninvasive applicator is illustrated and discussed herein, minimally invasive applicators may also be employed. In such a case, the applicator and patient protection device may be integrated. As an example, a cryoprobe that may be inserted directly into the subcutaneous adipose tissue to cool or freeze the tissue is an example of such a minimally invasive applicator. Cryoprobes manufactured by, e.g.,

Endocare, Inc., of Irvine, California are suitable for such applications. This patent application incorporates by reference U.S. Patent No. 6,494,844, entitled "DEVICE FOR BIOPSY AND TREATMENT OF BREAST TUMORS"; U.S. Patent No. 6,551,255, entitled "DEVICE FOR BIOPSY OF TUMORS"; U.S. Publication No. 2007-0055173, entitled "ROTATIONAL CORE BIOPSY DEVICE WITH LIQUID CRYOGEN ADHESION PROBE"; U.S. Patent No. 6,789,545, entitled "METHOD AND SYSTEM FOR CRYOABLATING FIBROADENOMAS"; U.S. Publication No. 2004-0215294, entitled "CRYOTHERAPY PROBE"; U.S. Patent No. 7,083,612, entitled "CRYOTHERAPY SYSTEM"; and U.S. Publication No. 2005-0261753, entitled "METHODS AND SYSTEMS FOR CRYOGENIC COOLING".

[0071] According to examples of the system 100, the applicator 105 and the combined modality treatment device 104 combine to enhance disruption of cooled adipose tissue while preserving warmed adipose tissue adjacent fibrous septae strands. Further, the examples can provide reduced treatment time, reduced discomfort to the patient, and increased efficacy of treatment.

[0072] Examples of the system may provide the combined modality treatment device 104 and the applicator 105 which damage, injure, disrupt or otherwise reduce subcutaneous lipid-rich cells contributing to cellulite generally without collateral damage to non-lipid-rich cells or lipid-rich cells adjacent to selectively heated fibrous septae in the treatment region. In general, it is believed that lipid-rich cells can selectively be affected (e.g., damaged, injured, or disrupted) by exposing such cells to low temperatures that do not so affect non-lipid-rich cells. Moreover, as discussed above, RF energy can be administered simultaneously and/or in consecutive fashion to selectively heat (e.g., warm) fibrous septae in the treatment region so as to warm adjacent adipose tissue. As a result, lipid-rich cells, such as subcutaneous adipose tissue that is bulging and/or herniating into the dermis layer, can be damaged while other cells in the same region are generally not damaged even though the non-lipid-rich cells at the surface may be subject to even lower temperatures. The mechanical energy provided by the applicator may further enhance the effect on lipid-rich cells by mechanically disrupting the affected lipid-rich cells.

[0073] In some examples of the system 100, a cryoprotectant is used with the treatment device to, among other advantages, assist in preventing freezing of non lipid-

rich tissue (e.g., dermal tissue) during treatment as is described in commonly-assigned U.S. Patent Publication No. 2007/0255362.

[0074] In one mode of operation, the applicator 105 is coupled to a combined modality treatment device 104. The treatment device may be configured to be a handheld device such as the device disclosed in commonly-assigned U.S. Patent Application Serial No. 11/359,092, filed on February 22, 2006, entitled COOLING DEVICE FOR REMOVING HEAT FROM SUBCUTANEOUS LIPID-RICH CELLS, which is incorporated by reference in its entirety.

[0075] Applying the combined modality treatment device 104 with pressure or with a vacuum type force to the subject's skin or pressing against the skin can be advantageous to achieve efficient treatment. In general, the subject 101 has a body temperature of about 37°C, and the blood circulation is one mechanism for maintaining a constant body temperature. As a result, blood flow through the skin and subcutaneous layer of the region to be treated can be viewed as a heat source that counteracts the cooling of the subdermal fat. As such, cooling the tissue of interest requires not only removing the heat from such tissue but also that of the blood circulating through this tissue. Thus, temporarily reducing or eliminating blood flow through the treatment region, by means such as, e.g., applying the treatment device with pressure, can improve the efficiency of tissue cooling and avoid excessive heat loss through the dermis and epidermis. Additionally, a vacuum can pull skin away from the body which can assist in cooling targeted underlying tissue.

[0076] By cooling the subcutaneous tissue to a temperature lower than 37°C, subcutaneous lipid-rich cells selectively can be damaged. In general, the epidermis and dermis of the subject 101 have lower amounts of lipids compared to the underlying lipid-rich cells forming the subcutaneous tissues. Because non-lipid-rich cells usually can withstand colder temperatures better than lipid-rich cells, the subcutaneous lipid-rich cells can be selectively injured while maintaining the non-lipid-rich cells in the dermis and epidermis. An exemplary range for cooling the lipid-rich cells not warmed or otherwise protected from heat generated by RF energy-conducting fibrous septae can be from about -10°C to about 0°C.

[0077] Figure 4 is a schematic, cross-sectional view illustrating a combined modality treatment device 104 for removing heat from bulging or herniating

subcutaneous lipid-rich cells at or near the dermis – subcutaneous interface, or from adipose tissue separated or spaced apart from anchoring fibrous septae in the subcutaneous layer. The treatment device 104 can include a heat exchanging unit, such as a heat exchanging plate 210, and an interface layer 220. In one embodiment, the heat exchanging plate 210 is a thermally conductive aluminum plate that can be charged with RF current generated by the RF energy generating unit 107 (Figure 1).

[0078] The heat exchanging plate 210 can contain a communication component 215 that communicates with the controller 114 to provide a first sensor reading 242 as described herein, and a sensor 217 that measures, e.g., temperature of the heat exchanging plate 210, heat flux across a surface of or plane within the heat exchanging plate 210 or RF current. The interface layer 220 can be a plate, a film, a covering, a sleeve or other suitable materials described herein and may serve as the patient protection device described herein. The interface layer 220 is located between the heat exchanging plate 210 and the skin 230 of a subject (not shown), such as the skin of a patient receiving treatment via the combined modality treatment device 104.

[0079] The interface layer 220 can also contain a similar communication component 225 that communicates with the controller 114 to provide a second sensor reading 244 and a sensor 227 that measures, e.g., the temperature of the interface layer 220, heat flux across a surface of or plane within the interface layer 220, RF current or contact pressure with the skin 230 of the patient. For example, one or both of the communication components 215, 225 can receive and transmit information from the controller 114, such as temperature and/or heat flux information as determined by one or both of the sensors 217, 227. The sensors 217, 227 are configured to measure a parameter of the interface without substantially impeding heat transfer between the heat exchanging plate 210 and the subject's skin 230. The treatment device 104 can also contain power components and other components described with respect to Figure 1 and related applications.

[0080] In certain embodiments, the combined modality treatment device 104 can include a dielectric sleeve 250 for contacting the patient's skin 230 and for achieving a more uniform distribution of RF energy into the patient's underlying subcutaneous tissue. The sleeve 250 can include a first sleeve portion 252 and a second sleeve portion 254 extending from the first sleeve portion. The first sleeve portion 252 can

contact and/or facilitate the contact of the combined modality treatment device 104 with the patient's skin 230, while the second sleeve portion 254 can be an isolation layer extending from the first sleeve portion 252. The second sleeve portion 254 can be constructed from latex, rubber, nylon, Kevlar[®], or other substantially impermeable or semi-permeable material. The second sleeve portion 254 can prevent contact between the patient's skin 230 and the heat exchanging plates 210, among other things.

[0081] The surface of the first sleeve portion 252 can include a dielectric or variable resistance material providing an insulator between the RF conductive heat exchanging plate 210 and interface layer 220 and the patient's skin 230. For example, the material can include material coated or comprised of Teflon[®], silicon nitride, polysilanes, polysilazanes, polyimides, Kapton and other polymers or dielectric materials well known in the art. The capacitive effect of the dielectric layer (e.g., the first sleeve portion 252) can be controlled, for example, through sleeve thickness, surface area the dielectric constant of the material and the frequency of the RF energy generated. In some embodiments, the first sleeve portion 252 extends beyond the edges of the RF conductive heat exchanging plate 210 and/or other electrodes such that the RF current is required to flow through the dielectric material of the first sleeve portion 252. Further details regarding a suitable sleeve may be found in U.S. Patent Publication No. 2008/0077201.

[0082] In other embodiments, the combined modality treatment device 104 can include a belt that assists in forming a contact between the treatment device 104 (such as via an interface layer 220) and the patient's skin 230. For example, the treatment device 104 can include retention devices (not shown) coupled to a frame. The retention devices may be rotatably connected to the frame by a plurality of coupling elements that can be, for example, pins, ball joints, bearings, or other type of rotatable joints. Alternatively, the retention devices can be rigidly affixed to the end portions of heat exchanging element housings. Further details regarding a suitable belt device may be found in U.S. Patent Publication No. 2008/0077211.

[0083] In further embodiments, the combined modality treatment device 104 can include a vacuum (not shown) that assists in forming a contact between the treatment device 104 (such as via the interface layer 220 or dielectric sleeve 250) and the patient's skin 230. For example, the treatment device 104 can provide mechanical

energy to a treatment region. Imparting mechanical vibratory energy to the patient's tissue by repeatedly applying and releasing a vacuum to the subject's tissue, for instance, creates a massage action during treatment. Further details regarding a vacuum type device may be found in U.S. Patent Application Publication No. 2008/0287839.

[0084] In current practice, non-invasive cryotherapy applications used for body contouring applications are used to uniformly treat adipose tissue in a subject's target region. In body regions that are characterized by non-uniform distribution of adipose tissue due to bulging or herniating lipid-rich lobules at or near the dermis – subcutaneous interface, or other subcutaneous regions lacking sufficient connective tissue, cooling therapy alone may not result in selective disruption of the adipose tissue responsible for visible irregularities in the surface of the skin (e.g., cellulite). Also in current practice, thermal therapy has been used to disrupt and alter the three dimensional structure of collagen in subcutaneous tissue by applying thermal energy at frequencies sufficient to heat the fibrous septae to temperatures exceeding a collagen denaturation temperature. However, such thermal therapies do not address uneven distribution of adipose tissue or penetration of lipid-rich lobules into the dermis.

[0085] In contrast to the known practices in the art, the systems, devices and methods disclosed herein facilitate selective disruption of lipid-rich lobules in a manner that reduces irregularities in a surface of a subject's skin. For example, the systems, devices and methods disclosed herein use capacitively or conductively coupled RF energy in a manner to protectively and selectively heat fibrous septae and closely associated lipid-rich cells (e.g., closely packed adipose tissue) such that the resistively-generated heat in this tissue is sufficient to prevent cooling of this tissue to a disruption temperature (e.g., below 10°C-15°C). Accordingly the lipid rich lobules at or near the dermis – subcutaneous interface, or other subcutaneous regions lacking sufficient connective tissue, can be selectively disrupted during the treatment process such that treatment results in consistent and effective reduction in skin irregularities and cellulite.

C. Combined Modality Treatment Methods

[0086] The system 100 can be used to perform several combined modality treatment methods. Although specific examples of methods are described herein, one skilled in the art is capable of identifying other methods that the system could perform.

Moreover, the methods described herein can be altered in various ways. As examples, the order of illustrated logic may be rearranged, sub-stages may be performed in parallel, illustrated logic may be omitted, other logic may be included, etc.

[0087] Figure 5 is a flow diagram illustrating a method 300 for reducing irregularities in a surface of a subject's skin resulting from an uneven distribution of adipose tissue in the subcutaneous layer in accordance with embodiments of the disclosure. Even though the method 300 is described below with reference to the combined modality treatment system 100 of Figure 1 and the combined modality treatment device 104 of Figure 4, the method 300 may also be applied in other treatment systems with additional or different hardware and/or software components.

[0088] As shown in Figure 5, an early stage of the method 300 can include coupling a heat exchanging surface of a treatment device with the surface of the subject's skin at a target region (block 302). In one embodiment, the heat exchanging surface can be a surface of a heat exchanging plate. In another embodiment, the heat exchanging surface can be the surface of an interface layer or a dielectric layer. Coupling of the heat exchange surface to the surface of the skin can be facilitated by using restraining means, such as a belt or strap. In other embodiments, a vacuum or suction force can be used to positively couple the patient's skin at the target region to the heat exchange surface. Additionally, coupling the heat exchanging device to the subject's skin can also include providing a cryoprotectant to the patient's skin as is described in commonly assigned U.S. Patent Publication No. 2007/0255362.

[0089] The method 300 can also include delivering radiofrequency (RF) energy to the target region at a frequency sufficient selectively to heat fibrous septae in a subcutaneous layer of the target region (block 304). In some embodiments, the RF energy may be monopolar while in other embodiments it may be bipolar. In some embodiments, the RF energy may be capacitively coupled while in other embodiments it may be conductively coupled. In one embodiment, the RF energy can be delivered at a frequency of about 0.3 MHz to about 6 MHz. In other embodiments, the RF energy can be delivered at a frequency of between about 0.3 MHz to about 100 MHz or higher while in still other embodiments such RF energy can be delivered at a frequency of between about 0.3 MHz to about 40 MHz. In some embodiments, selective heating of the fibrous septae can include heating the fibrous septae to a final temperature less

than a fibrous septae denaturation temperature (e.g., about 60°C). For example, selective heating of the fibrous septae can include heating the fibrous septae to a temperature that does not denature fibrous septae. The fibrous septae can provide a path for preferentially conducting RF current through the subcutaneous layer. As the natural resistance of fibrous septae to the movement of charged ions and molecules in the subcutaneous tissue causes the fibrous septae to generate heat. One of ordinary skill in the art will recognize that the RF power (e.g., measured in watts) delivered to the target region, to achieve a desired fibrous septae temperature range, will be proportional to the surface area of the target region treated among other factors. In some aspects, selectively heating the fibrous septae includes preventing the fibrous septae and the lipid-rich regions adjacent to the fibrous septae from cooling to a temperature below approximately 10°C – 15°C.

[0090] At block 306, the method 300 includes removing heat such that lipid-rich cells in the subcutaneous layer are reduced in number and/or size to an extent while non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae are not reduced in number or size to the extent. For example, removing heat from the subcutaneous layer in the target region can include cooling the lipid-rich tissue to a temperature below 10°C such that the lipid-rich lobules, and the adipose cells are disrupted.

[0091] Delivering the RF energy to the target region and removing heat from the subcutaneous layer in the target region may occur simultaneously. For example, the treatment method 300 may include a single stage or multiple stages of delivering RF energy with each such stage occurring simultaneously with a single stage or multiple stages of removing heat from the lipid-rich cells in the target region.

[0092] Alternatively, delivering the RF energy to the target region and removing heat from the subcutaneous layer in the target region may occur sequentially. For example, the method 300 may consist of a single stage of delivering RF energy that ceases prior to a single stage to remove heat from the lipid-rich cells in the target region. Additionally, such sequential application of the aforementioned stages may occur multiple times so that multiple non-overlapping stages of RF energy delivery and heat removal occur.

[0093] Another way that method 300 may be accomplished is by periodically or intermittently delivering RF energy to the target region of the subject simultaneously

with removing heat. For example, method 300 may comprise a single stage of removing heat from the lipid-rich cells in the target region during which stage RF energy is delivered in multiple stages in a regular, periodic fashion or in a less regular, intermittent fashion,

[0094] Alternatively, method 300 may include a single stage of delivering RF energy to the target region during which stage removing heat from the target region is accomplished in multiple stages in a regular, periodic fashion or in a less regular, intermittent fashion.

[0095] The duration of delivering the RF energy to the target region according to the embodiments described herein for reducing irregularities in a surface of skin of a subject resulting from an uneven distribution of adipose tissue in a subcutaneous layer of that subject, including in accordance with the method 300, may vary depending on the location of the target region, the degree of warming required, the power setting, whether the RF energy is capacitively or conductively coupled, the parameters of the stage of removing heat to reduce the number and/or size of the lipid-rich cells in the subcutaneous layer, and other parameters.

[0096] Such a duration may be calculated and described in terms of a single application of RF energy or cumulatively as summed over the course of more than one application of RF energy. For example, a single application of RF energy as described herein may range in duration from a second or less to several hours or more; e.g., the same or about the same duration as the duration of the stage of removing heat from the lipid-rich cells in the target region as described for example in U.S. Patent No. 7,367,341, particularly when the RF energy is applied commensurately with the stage of removing heat. A duration of a period of application of RF energy in such an embodiment may, e.g., be between about 1 minute and about 2 hours, between about 1 minute and about 1 hour, between about 1 minute and about 50 minutes, or between about 1 minute and about 40 minutes, or between about 1 minute and about 30 minutes, or between about 1 minute and about 20 minutes. Still another embodiment results in a single application of RF energy of between about 5 minutes and about 15 minutes.

[0097] Applying RF energy in multiple stages as described herein, whether in periodic or intermittent fashion, for example, may also range cumulatively over those

multiple stages in duration from a second or less to several hours or more. A cumulative duration of multiple stages of RF energy application in such embodiments may, e.g., be between about 1 minute and about 1 hour, or between about 1 minute and about 50 minutes, or between about 1 minute and about 40 minutes, or between about 1 minute and about 30 minutes, or between about 1 minute and about 20 minutes. Still another embodiment results in a cumulative duration of multiple stages of RF energy application of between about 5 minutes and about 15 minutes.

D. Suitable Computing Environments

[0098] Figure 6 is a schematic block diagram illustrating subcomponents of a computing device 400 in accordance with an embodiment of the disclosure. The computing device 400 can include a processor 401, a memory 402 (e.g., SRAM, DRAM, flash, or other memory devices), input/output devices 403, and/or subsystems and other components 404. The computing device 400 can perform any of a wide variety of computing processing, storage, sensing, imaging, and/or other functions. Components of the computing device 400 may be housed in a single unit or distributed over multiple, interconnected units (e.g., through a communications network). The components of the computing device 400 can accordingly include local and/or remote memory storage devices and any of a wide variety of computer-readable media.

[0099] As illustrated in Figure 6, the processor 401 can include a plurality of functional modules 406, such as software modules, for execution by the processor 401. The various implementations of source code (i.e., in a conventional programming language) can be stored on a computer-readable storage medium or can be embodied on a transmission medium in a carrier wave. The modules 406 of the processor can include an input module 408, a database module 410, a process module 412, an output module 414, and, optionally, a display module 416.

[00100] In operation, the input module 408 accepts an operator input 419 via the one or more input devices described above with respect to Figure 1, and communicates the accepted information or selections to other components for further processing. The database module 410 organizes records, including patient records, treatment data sets, treatment profiles and operating records and other operator activities, and facilitates storing and retrieving of these records to and from a data storage device (e.g., internal memory 402, an external database, etc.). Any type of

database organization can be utilized, including a flat file system, hierarchical database, relational database, distributed database, etc.

[00101] In the illustrated example, the process module 412 can generate control variables based on sensor readings 418 from sensors (e.g., the temperature measurement components 217 and 227 of Figure 4) and/or other data sources, and the output module 414 can communicate operator input to external computing devices and control variables to the controller 114. The display module 416 can be configured to convert and transmit processing parameters, sensor readings 418, output signals 320, input data, treatment profiles and prescribed operational parameters through one or more connected display devices, such as a display screen, printer, speaker system, etc. A suitable display module 416 may include a video driver that enables the controller 114 to display the sensor readings 418 or other status of treatment progression on the output device 120 (Figure 1).

[00102] In various embodiments, the processor 401 can be a standard central processing unit or a secure processor. Secure processors can be special-purpose processors (e.g., reduced instruction set processor) that can withstand sophisticated attacks that attempt to extract data or programming logic. The secure processors may not have debugging pins that enable an external debugger to monitor the secure processor's execution or registers. In other embodiments, the system may employ a secure field programmable gate array, a smartcard, or other secure devices.

[00103] The memory 402 can be standard memory, secure memory, or a combination of both memory types. By employing a secure processor and/or secure memory, the system can ensure that data and instructions are both highly secure and sensitive operations such as decryption are shielded from observation.

[00104] Suitable computing environments and other computing devices and user interfaces are described in commonly assigned U.S. Provisional Patent Application Serial No. 61/100,248, entitled "TREATMENT PLANNING SYSTEMS AND METHODS FOR BODY CONTOURING APPLICATIONS," filed on September 25, 2008, which is incorporated herein in its entirety by reference.

E. Conclusion

[00105] Various embodiments of the technology are described above. It will be appreciated that details set forth above are provided to describe the embodiments in a manner sufficient to enable a person skilled in the relevant art to make and use the disclosed embodiments. Several of the details and advantages, however, may not be necessary to practice some embodiments. Additionally, some well-known structures or functions may not be shown or described in detail, so as to avoid unnecessarily obscuring the relevant description of the various embodiments. Although some embodiments may be within the scope of the claims, they may not be described in detail with respect to the Figures. Furthermore, features, structures, or characteristics of various embodiments may be combined in any suitable manner. Moreover, one skilled in the art will recognize that there are a number of other technologies that could be used to perform functions similar to those described above and so the claims should not be limited to the devices or routines described herein. While processes or blocks are presented in a given order, alternative embodiments may perform routines having stages, or employ systems having blocks, in a different order, and some processes or blocks may be deleted, moved, added, subdivided, combined, and/or modified. Each of these processes or blocks may be implemented in a variety of different ways. Also, while processes or blocks are at times shown as being performed in series, these processes or blocks may instead be performed in parallel, or may be performed at different times. The headings provided herein are for convenience only and do not interpret the scope or meaning of the claims.

[00106] The terminology used in the description is intended to be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of identified embodiments.

[00107] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in a sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number, respectively. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following

interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

[00108] Some of the functional units described herein have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, modules may be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions which may, for instance, be organized as an object, procedure, or function. The identified blocks of computer instructions need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00109] A module may also be implemented as a hardware circuit comprising custom VLSI circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00110] A module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network.

[00111] Any patents, applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the described technology can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments.

[00112] These and other changes can be made in light of the above Detailed Description. While the above description details certain embodiments and describes the best mode contemplated, no matter how detailed, various changes can be made.

Implementation details may vary considerably, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the claims to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the claims encompasses not only the disclosed embodiments, but also all equivalents.

CLAIMS

1. A method for reducing surface irregularities in a surface of skin of a subject resulting from an uneven distribution of adipose tissue in the subcutaneous layer, the method comprising:
 - delivering energy to a target region of the subject which selectively heats fibrous septae in a subcutaneous layer of the target region to warm non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae; and
 - cooling lipid-rich lobules in the subcutaneous layer at the target region to disrupt lipid-rich cells in the lipid-rich lobules such that the lipid-rich lobules are reduced in number and/or size to an extent while the warmed non-lipid-rich cells and lipid-rich regions adjacent to the fibrous septae are not reduced in number or size to the extent, thereby reducing surface irregularities in the surface of skin of the subject.
2. The method of claim 1 wherein removing heat includes cooling the lipid-rich lobules to a temperature below 10°C.
3. The method of claim 2 wherein selectively heating the fibrous septae includes preventing the fibrous septae and the lipid-rich regions adjacent to the fibrous septae from cooling to a temperature below approximately 10°C – 15°C.
4. The method of claim 1 wherein the energy is RF energy which is capacitively coupled RF energy.
5. The method of claim 1 wherein the energy is RF energy which is conductively coupled RF energy.
6. The method of claim 4 wherein delivering capacitively coupled RF energy to a target region includes delivering capacitively coupled monopolar RF energy from an RF generator, and wherein the method further includes returning monopolar RF energy to the RF generator via a return electrode positioned on the surface of skin of the subject at a region separated from the target region.
7. The method of claim 1 wherein the fibrous septae are heated to a temperature that does not denature them.

8. The method of claim 1 wherein the energy is RF energy, wherein the delivering the RF energy to the target region at a frequency which selectively heats fibrous septae in a subcutaneous layer of the target region includes delivering an RF current at a frequency of approximately 0.3 MHz to approximately 40 MHz.

9. The method of claim 1 wherein the energy is RF energy, wherein the delivering RF energy to the target region at a frequency which selectively heats fibrous septae in a subcutaneous layer of the target region includes delivering an RF current at a frequency of approximately 0.3 MHz to approximately 6 MHz.

10. The method of claim 1 wherein the energy is RF energy, wherein the steps of delivering RF energy to the target region and removing heat from the subcutaneous layer in the target region occurs simultaneously.

11. The method of claim 1 wherein the energy is RF energy, wherein the steps of delivering RF energy and removing heat occurs sequentially.

12. The method of claim 1 wherein the energy is RF energy, wherein delivering RF energy includes delivering RF energy periodically to the target region of the subject simultaneously with removing heat.

13. The method of claim 1 wherein the energy is RF energy, wherein delivering RF energy includes delivering RF energy periodically to the target region of the subject intermittently with removing heat.

14. The method of claim 1 wherein delivering energy to the target region which selectively heats fibrous septae in a subcutaneous layer of the target region is accomplished such that a total duration of a period of delivery of the energy is between about 1 minute and about 2 hours.

15. The method of claim 1 wherein the energy is delivered at a power of between about 0,02 W/cm² and about 10 W/cm².

16. The method of claim 14 wherein the energy is delivered at a power of between about 0.1 W/cm² and about 5 W/cm².

17. The method of claim 1 wherein delivering energy to the target region includes delivering radiofrequency energy, optical energy, acoustic energy, infrared energy, and or microwaves to the target region.

18. A combined modality treatment system for selectively removing heat from subcutaneous lipid-rich cells in a target region of a subject having skin, comprising:

 a treatment unit in thermal communication with a fluid chamber, the fluid chamber being configured to house and provide a coolant;

 a radiofrequency (RF) energy source for generating RF current;

 a controller; and

 a treatment device having a heat exchanging plate coupled to the RF energy source and a thermoelectric cooling element in communication with the treatment unit;

 wherein the controller has instructions that cause the treatment device to—

 capacitively couple radiofrequency (RF) energy to the skin of the subject selectively to heat fibrous septae in the target region to a final temperature less than a fibrous septae denaturation temperature; and

 remove heat from the subcutaneous lipid-rich cells of the subject during a treatment process to cause disruption of the subcutaneous lipid-rich cells while non-lipid-rich cells and subcutaneous lipid-rich cells adjacent to the fibrous septae being warmed by the RF energy are not substantially affected.

19. The system of claim 18 wherein the fibrous septae denaturation temperature is approximately 60°.

20. The method of claim 1, further comprising cooling the lipid-rich lobules to damage and/or injure the lipid-rich cells.

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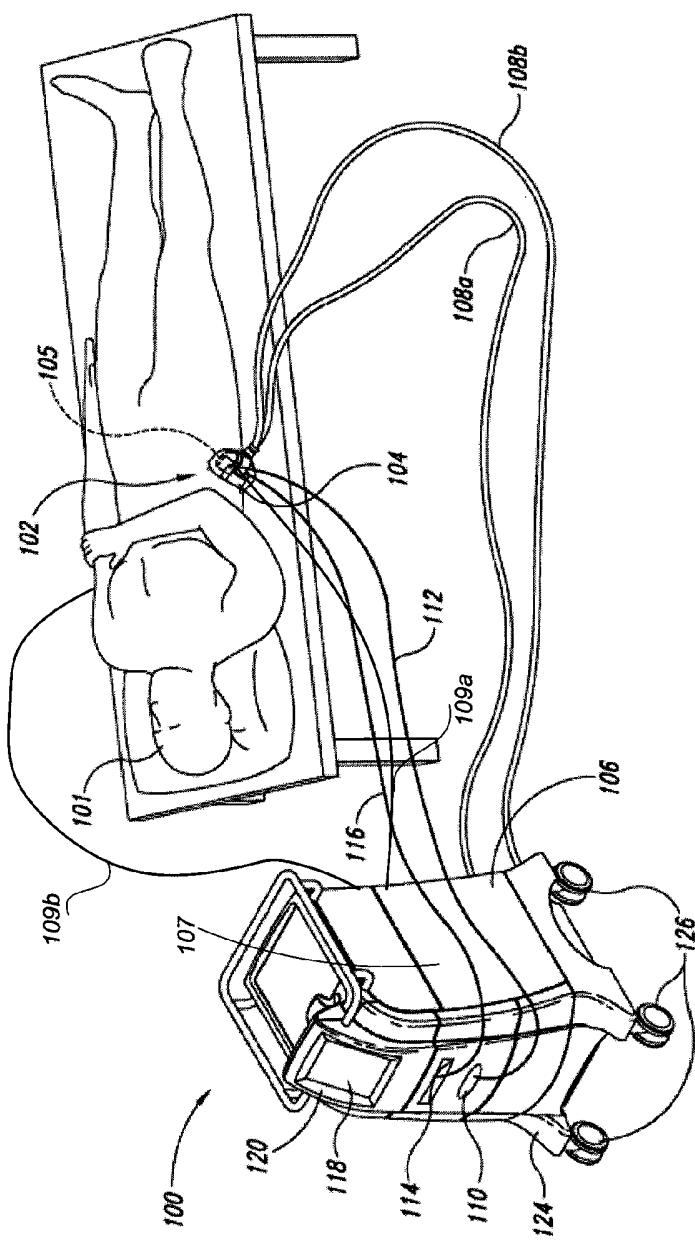


FIG. 1

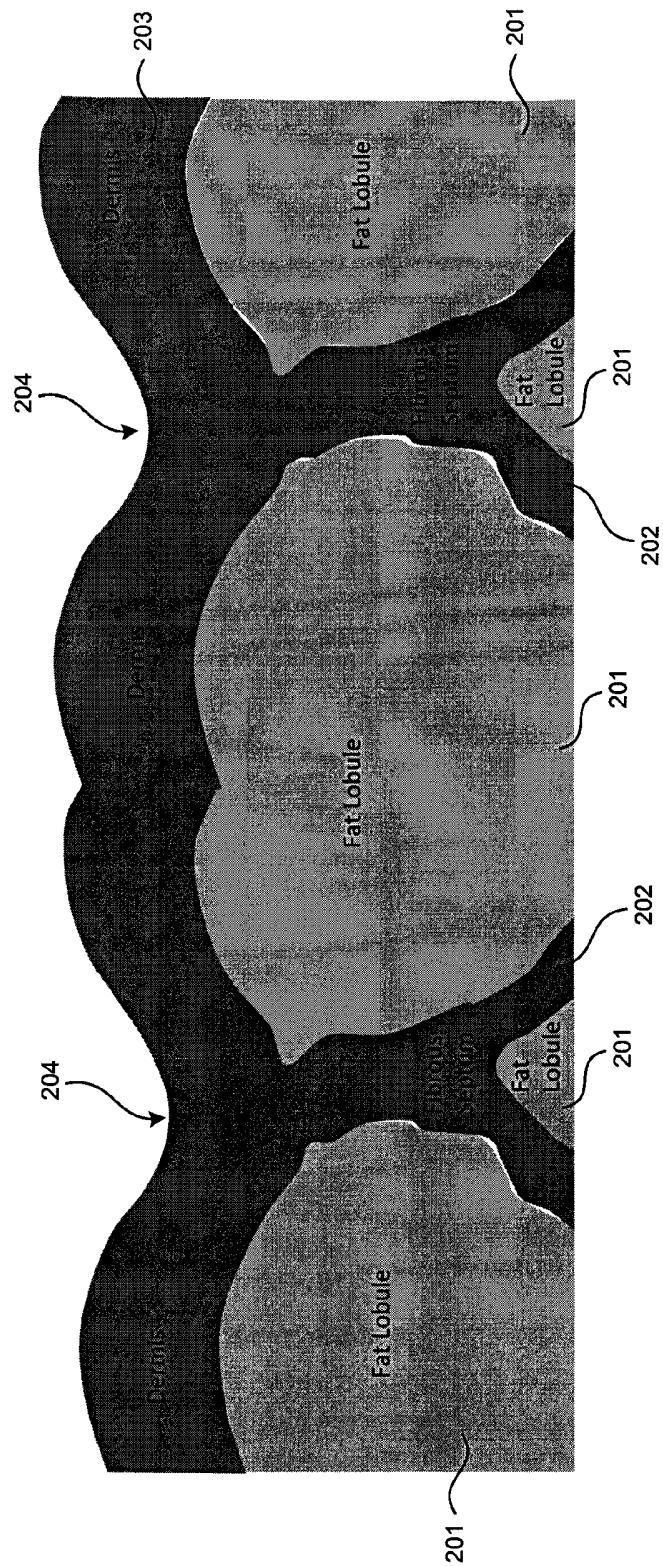


FIG. 2

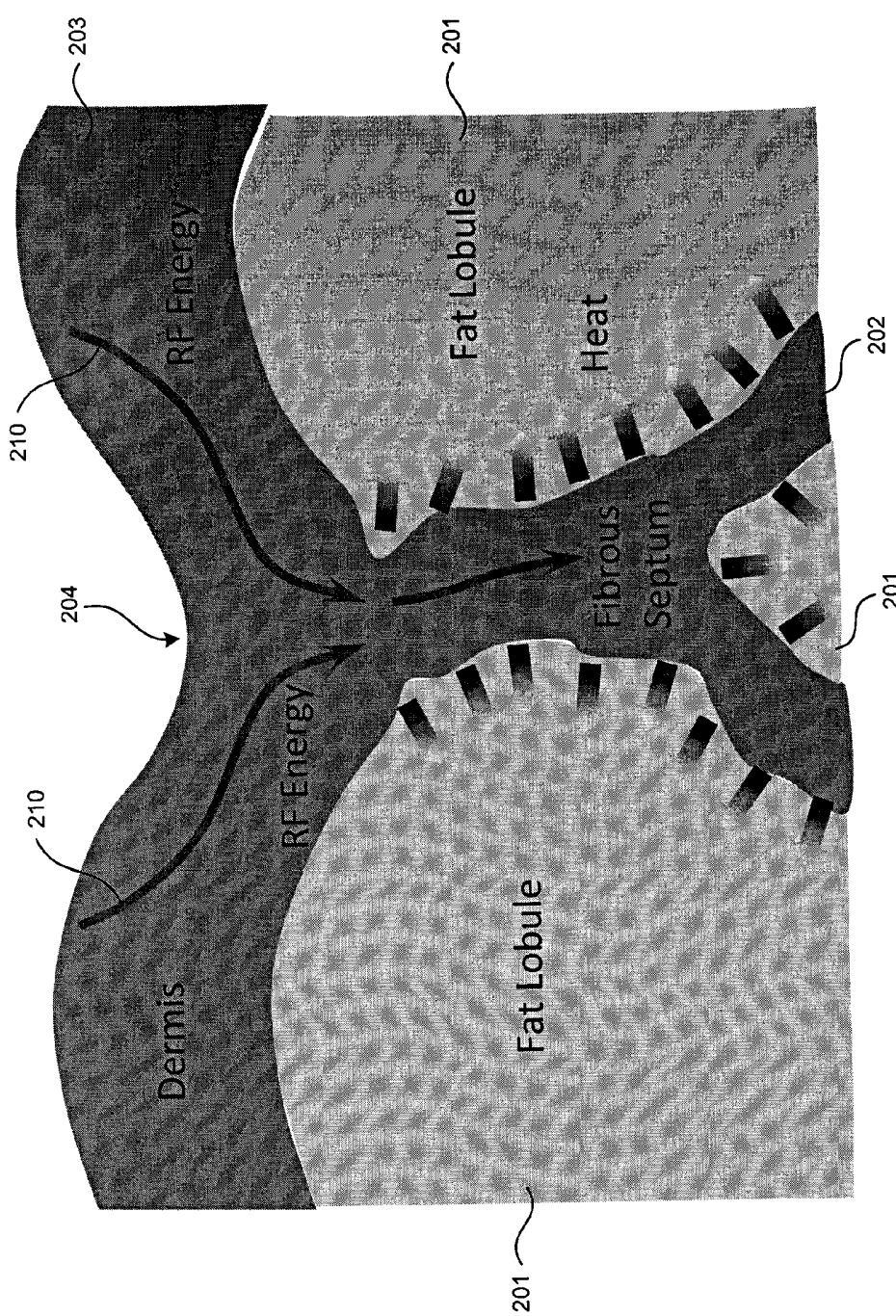


FIG. 3

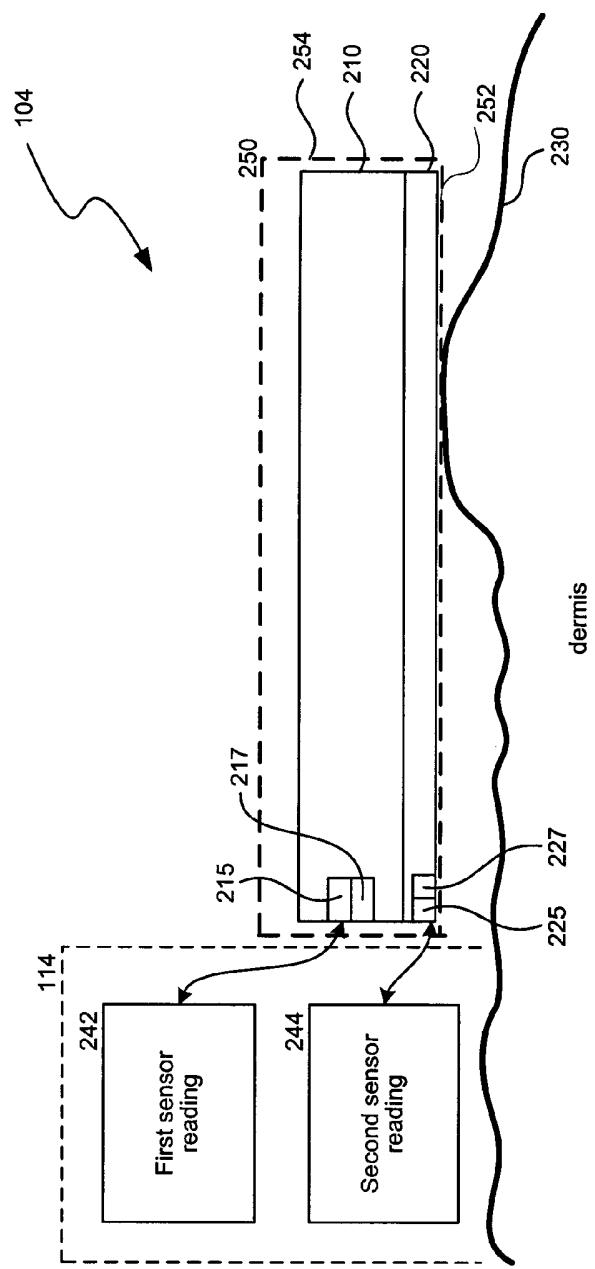
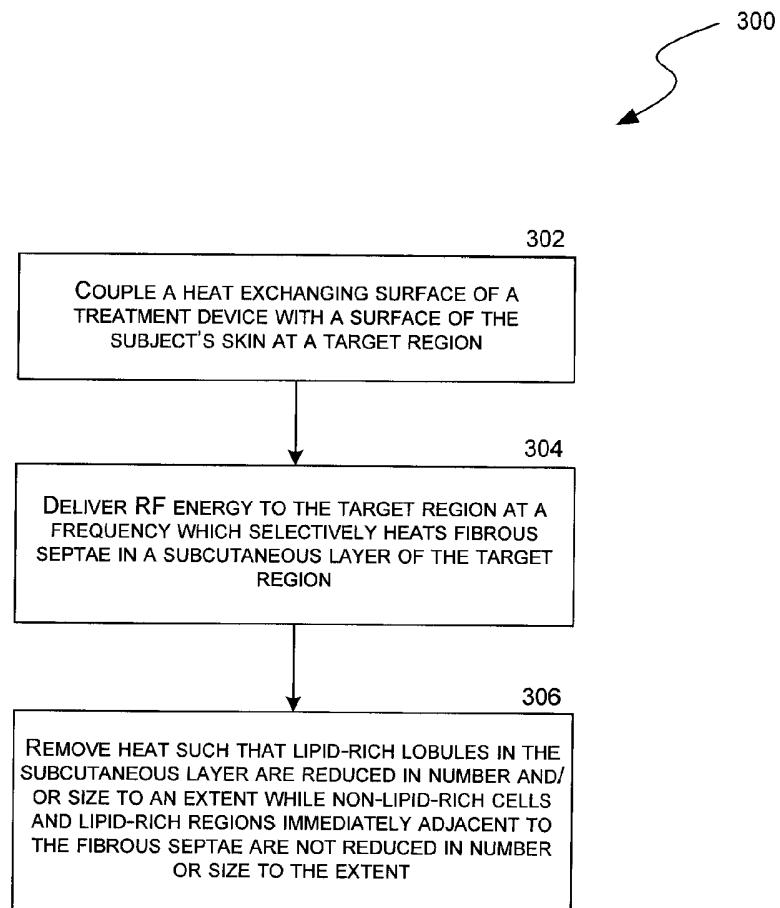


FIG. 4

**FIG. 5**

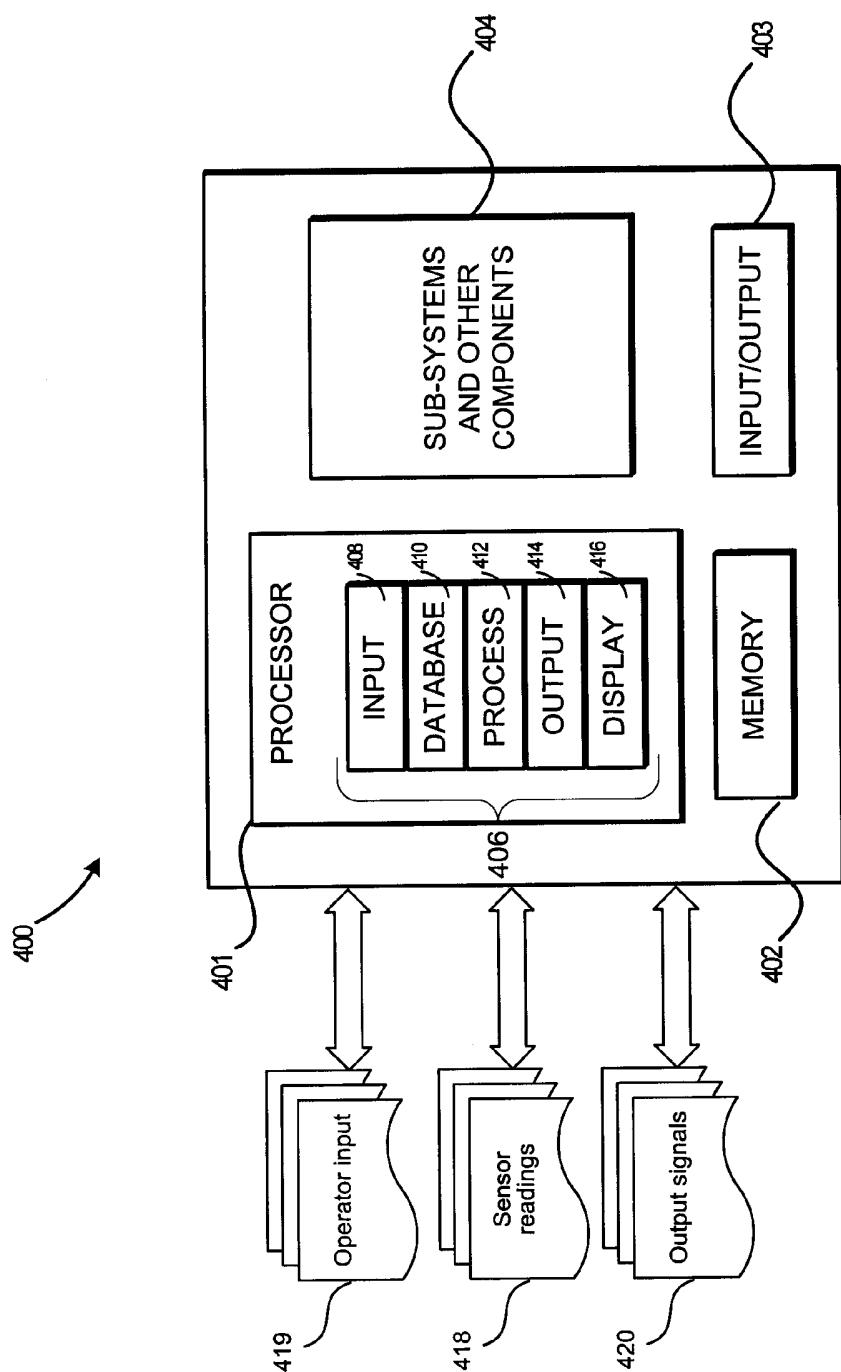


FIG. 6