

USF Patents

August 2010

Electroporation device

Richard Heller

Mark J. Jaroszeski

Richard Gilbert

Follow this and additional works at: https://digitalcommons.usf.edu/usf_patents

Recommended Citation

Heller, Richard; Jaroszeski, Mark J.; and Gilbert, Richard, "Electroporation device" (2010). *USF Patents*. 513.

https://digitalcommons.usf.edu/usf_patents/513

This Patent is brought to you for free and open access by Digital Commons @ University of South Florida. It has been accepted for inclusion in USF Patents by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact digitalcommons@usf.edu.



US007781195B1

(12) **United States Patent**
Heller et al.

(10) **Patent No.:** **US 7,781,195 B1**
(45) **Date of Patent:** **Aug. 24, 2010**

(54) **ELECTROPORATION DEVICE**

(75) Inventors: **Richard Heller**, Temple Terrace, FL (US); **Mark J. Jaroszeski**, Tampa, FL (US); **Richard Gilbert**, Tampa, FL (US)

(73) Assignee: **University of South Florida**, Tampa, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 139 days.

(21) Appl. No.: **10/710,423**

(22) Filed: **Jul. 9, 2004**

Related U.S. Application Data

(60) Division of application No. 09/696,350, filed on Oct. 24, 2000, now Pat. No. 6,778,853, which is a continuation of application No. 09/213,210, filed on Dec. 17, 1998, now Pat. No. 6,135,990.

(51) **Int. Cl.**
C12N 13/00 (2006.01)
C12M 1/00 (2006.01)
A61N 1/30 (2006.01)

(52) **U.S. Cl.** **435/173.6; 435/283.1; 604/21**

(58) **Field of Classification Search** **604/19-21, 604/501; 435/173.4, 173.5, 173.6, 285.2, 435/461, 173.1, 283.1**

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,309,910 A * 5/1994 Edwards et al. 600/381
5,334,193 A * 8/1994 Nardella 606/41

5,341,807 A * 8/1994 Nardella 600/381
5,389,069 A * 2/1995 Weaver 604/21
5,472,441 A * 12/1995 Edwards et al. 606/41
5,546,940 A * 8/1996 Panescu et al. 600/374
5,598,848 A * 2/1997 Swanson et al. 600/508
5,681,282 A * 10/1997 Eggers et al. 604/114
5,941,845 A * 8/1999 Tu et al. 604/500
5,944,715 A * 8/1999 Goble et al. 606/41
6,135,990 A * 10/2000 Heller et al. 604/500
6,233,482 B1 * 5/2001 Hofmann et al. 604/21
6,623,454 B1 * 9/2003 Eggers et al. 604/114
6,778,853 B1 * 8/2004 Heller et al. 604/20

* cited by examiner

Primary Examiner—Kevin C Sirmons

Assistant Examiner—Catherine N Witczak

(74) *Attorney, Agent, or Firm*—Molly L. Sauter; Smith & Hopon, P.A.

(57) **ABSTRACT**

A device for manipulating a molecule in vivo relative to a target tissue includes at least one elongated member having at least two discrete and separately activatable electrodes separated by an insulating material interposed therebetween. The electrodes are configured to establish at least one of a first electromagnetic field between selected electrodes sufficient to manipulate a molecule relative to a target tissue and a second, typically higher-level, electromagnetic field sufficient to cause transient permeability of a cell membrane within the target tissue. A third electromagnetic field may also be applied to cause further translation of the molecule into an electroporated cell and/or manipulated with respect to the tissue. Thus three-dimensional manipulation of the molecule relative to the target tissue may be effected to optimize a desired positioning thereof, such as entry into a cell.

10 Claims, 7 Drawing Sheets

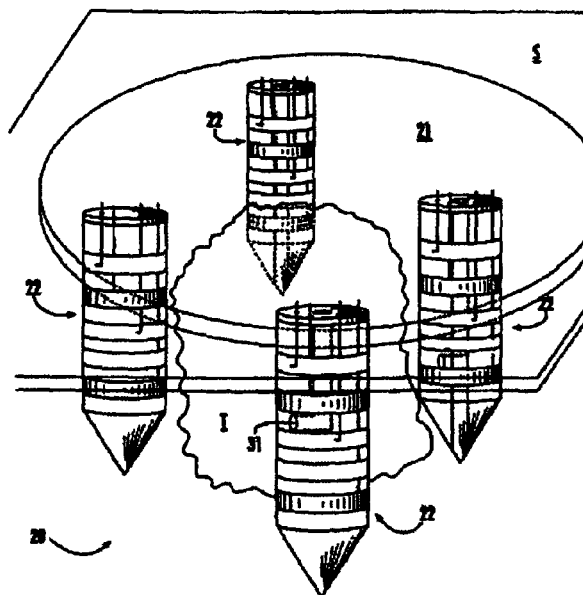


Fig. 1

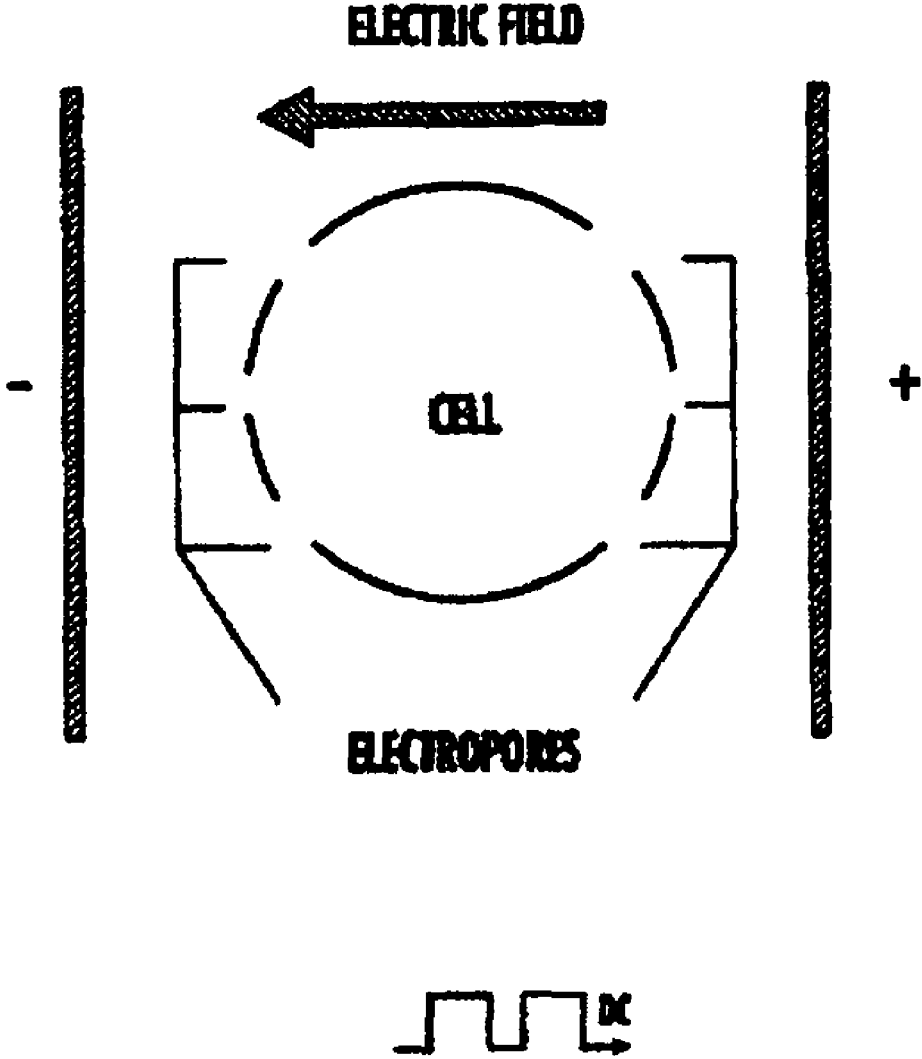


Fig. 2

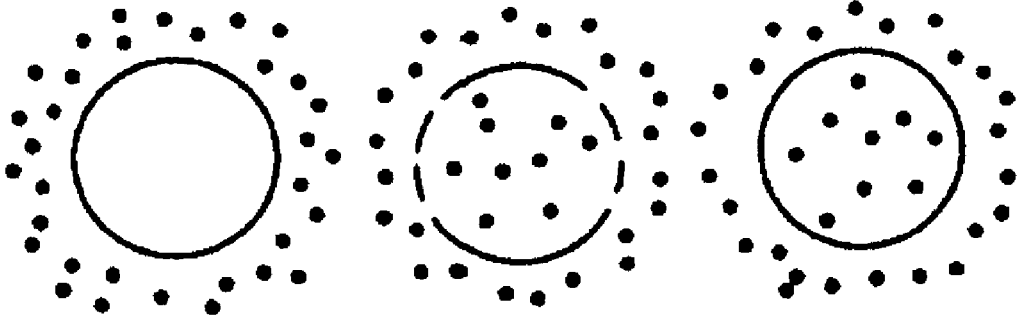


FIG 2A

FIG 2B

FIG 2C

Fig. 3

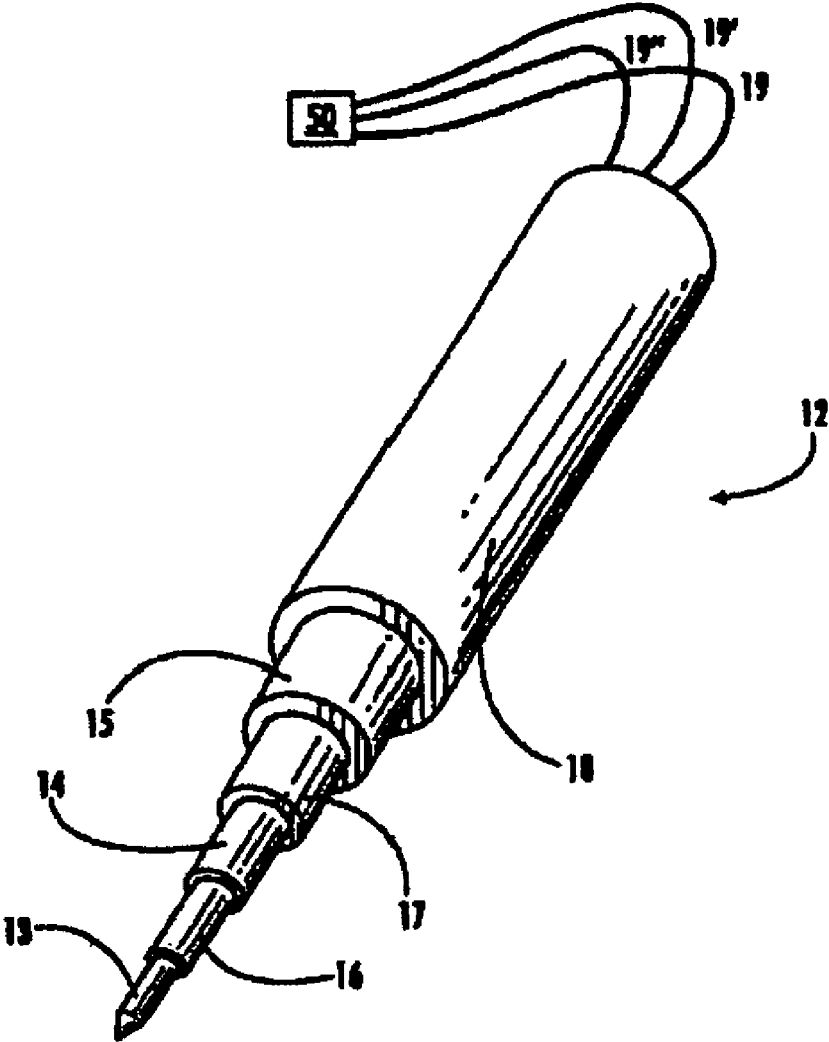


Fig. 4

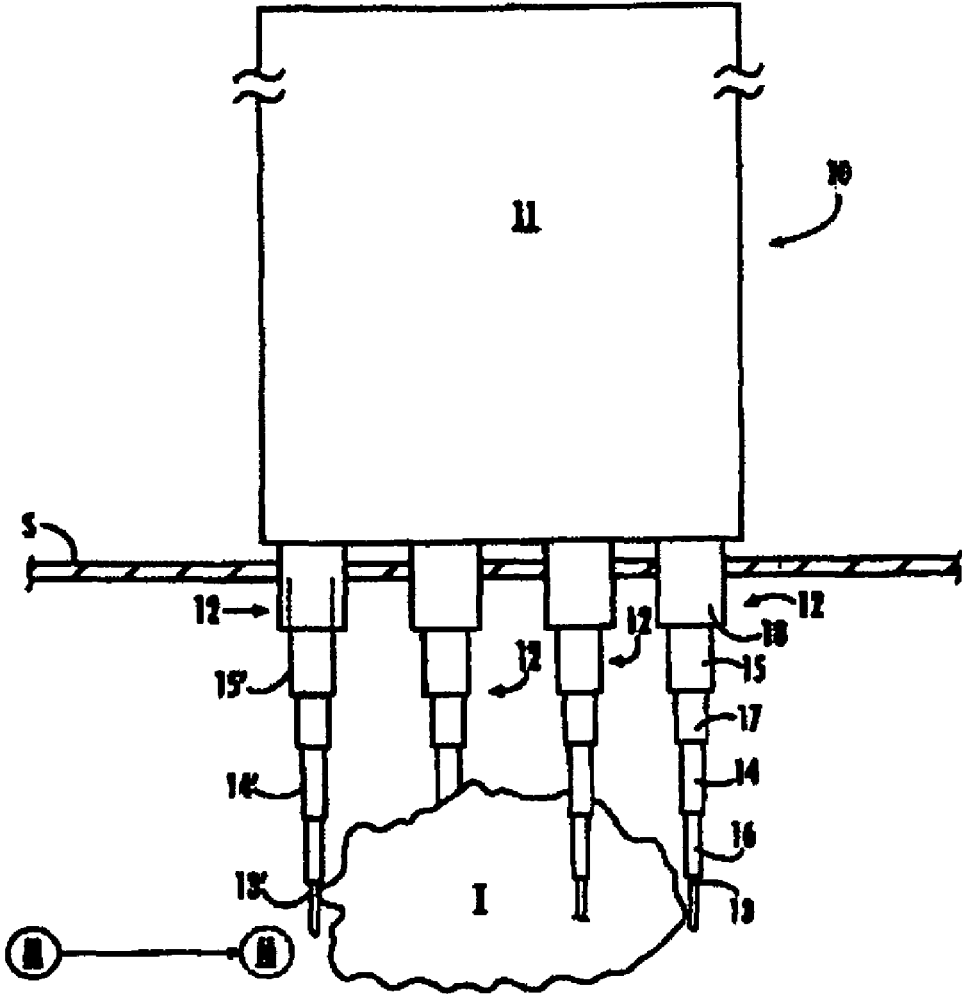


FIG. 4

Fig. 5

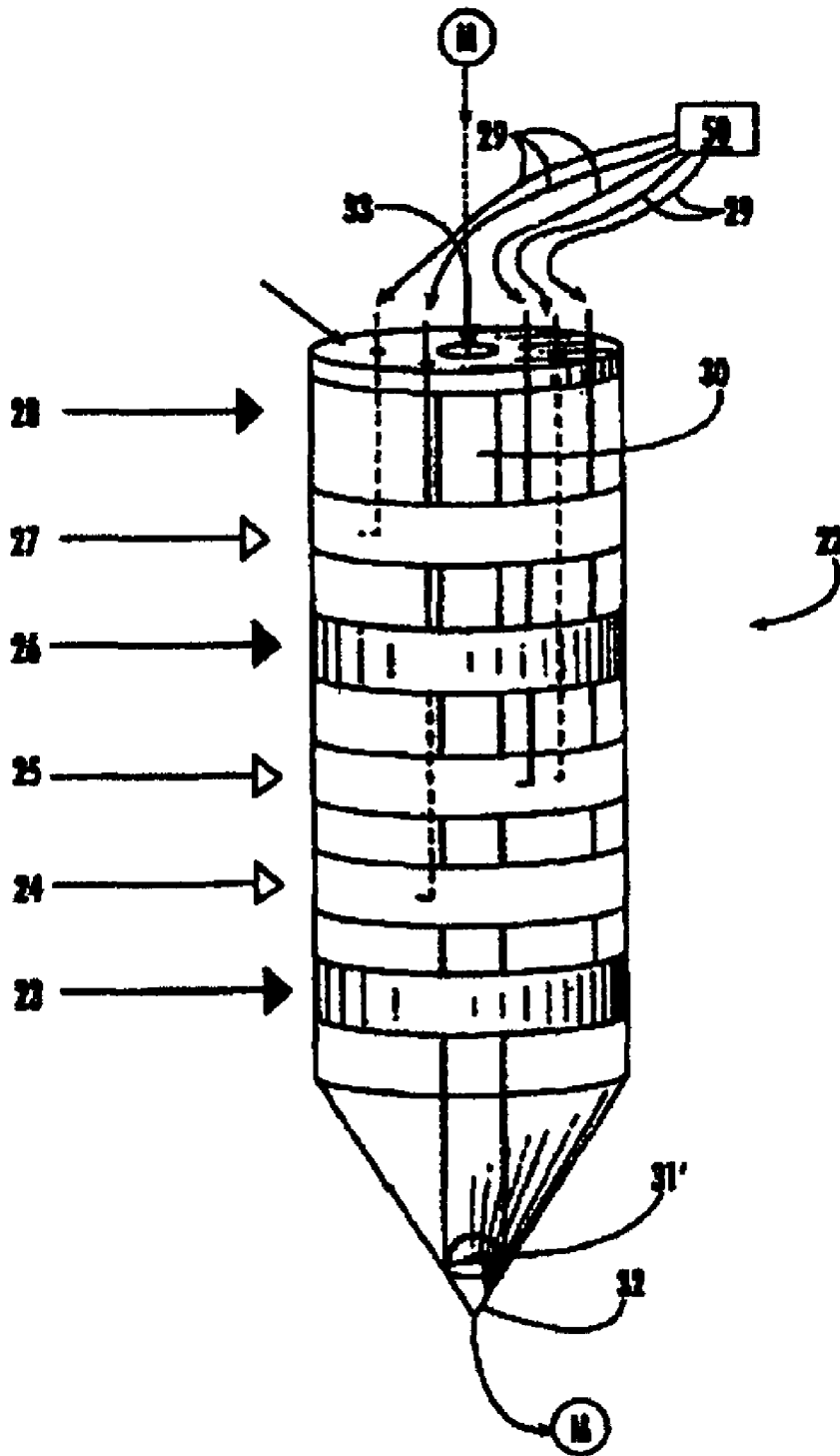


Fig. 6

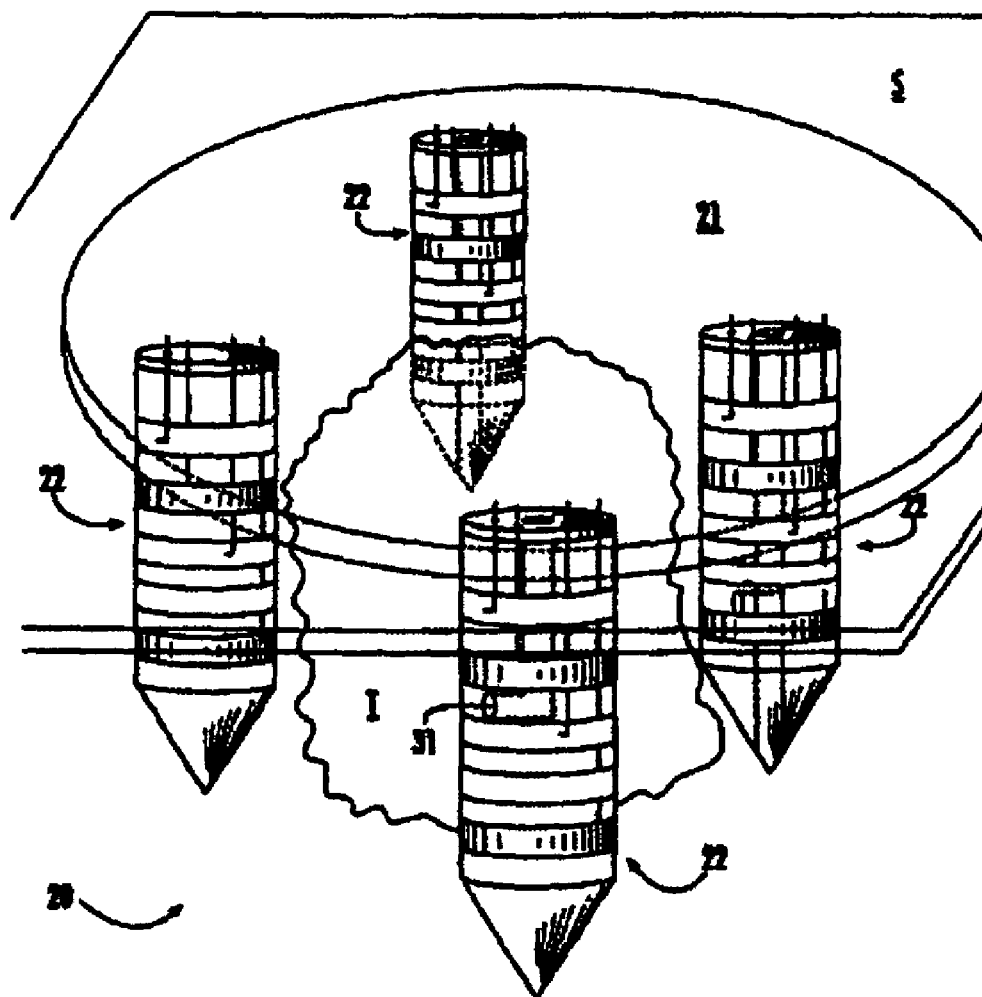
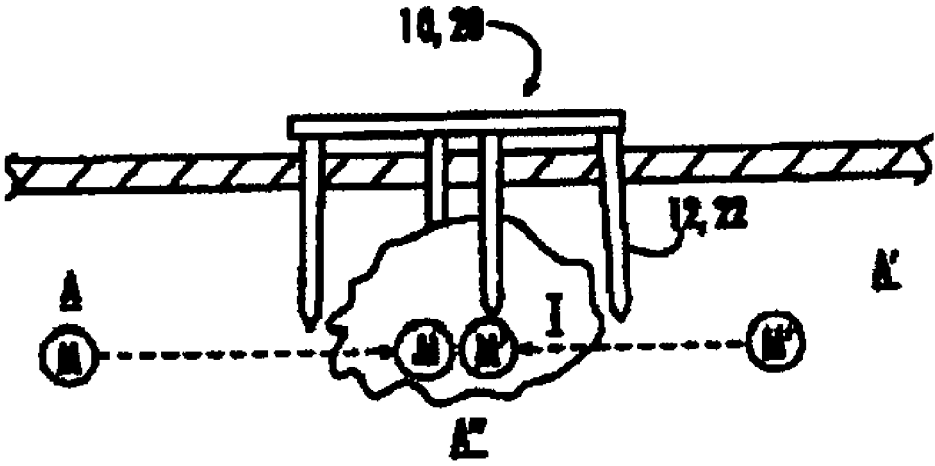


Fig. 7



ELECTROPORATION DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from and is a divisional of, "Electroporation Device and Method", U.S. patent application Ser. No. 09/696,350, which claims priority from previously filed provisional application, "Methods and Apparatus for Three Dimensional Distribution of Molecules within Tissues and Cells in Vivo," Ser. No. 60/069,876, filed Dec. 17, 1997; and from U.S. Pat. No. 6,135,990, Ser. No. 09/213,210, "Electroporation Device and Method," filed Dec. 17, 1998.

FIELD OF INVENTION

The present invention relates to methods and apparatus for delivering molecules into a target cell, and, more particularly, to such methods and apparatus for achieving such delivery through electroporation and electromigration.

DESCRIPTION OF RELATED ART

The effect of electromagnetic fields on cell membranes has been studied since the 1960's. Early research focused on describing observations that an applied electric field can reversibly break down cell membranes in vitro. Throughout the 1970's the topic was more common in the literature and continued to focus on describing the phenomenon that resulted from brief exposure to intense electric fields as well as the entry of exogenous molecules to the cell interior as a result of membrane breakdown. Applications began to emerge along with a better understanding of reversible membrane breakdown in the 1980's.

Prior research led to the current understanding that exposure of cells to intense electric fields for brief periods of time temporarily destabilized membranes. This effect has been described as a dielectric breakdown due to an induced transmembrane potential, and was termed "electroporation," or "electropermeabilization," because it was observed that molecules that do not normally pass through the membrane gain intracellular access after the cells were treated with electric fields. The porated state was noted to be temporary. Typically, cells remain in a destabilized state on the order of minutes after electrical treatment ceases. The physical nature of electroporation makes it universally applicable. A variety of procedures utilize this type of treatment, which gives temporary access to the cytosol. These include production of monoclonal antibodies, cell-cell fusion, cell-tissue fusion, insertion of membrane proteins, and genetic transformation. In addition, dyes and fluorescent molecules have been used to investigate the phenomenon of electroporation. A notable example of loading molecules into cells in vivo is electrochemotherapy. The procedure utilizes a drug combined with electric pulses as a means for loading tumor cells with an anticancer drug, and has been performed in a number of animal models and in clinical trials by the present inventors. Also, plasmid DNA has been loaded into rat liver cells in vivo (Heller et al., *FEBS Lett.* 389, 225-28). Protocols for the use of electroporation to load cells in vitro typically use a suspension of single cells or cells that are attached in a planar manner to a growth surface. In vivo electroporation is more complex because tissues are involved. Tissues are composed of individual cells that collectively make up a three-dimensional structure. In either case, the effects on the cell are the same. FIG. 1 illustrates details of the electrical treatment procedure. Electrodes and electrode

Arrays for delivering electrical waveforms for therapeutic benefit, including inducing electroporation, have been described by Bernard (WO 98/47562). The loading of molecules by electroporation in vitro as well as in vivo is typically carried out by first exposing the cells or tissue of interest to a drug or other molecule (FIG. 2). The cells or tissue are then exposed to electric fields by administering one or more direct current pulses. Electrical treatment is conducted in a manner that results in a temporary membrane destabilization with minimal cytotoxicity. The intensity of electrical treatment is typically described by the magnitude of the applied electric field. This field is defined as the voltage applied to the electrodes divided by the distance between the electrodes. Electric field strengths ranging from 1000 to 5000 10 V/cm have been used for delivering molecules in vivo and are also specific to the cells or tissue under investigation. Pulses are usually rectangular in shape; however, exponentially decaying pulses have also been used. The duration of each pulse is called pulse width. Molecule loading has been performed with pulse widths ranging from microseconds (μ s) to milliseconds (ms). The number of pulses delivered has ranged from one to eight. Typically, multiple pulses are utilized during electrical treatment. For molecules to be delivered to the cell interior by electroporation, it is important that the molecule of interest be near the exterior of the cell membrane when in the cell is in a permeabilized state. It is also important to have molecules near substantially all cells within a treated tissue volume in order to provide efficient delivery to substantially all cells within the treatment volume. Currently, molecules are injected systemically, via methods well known to those of skill in the art, or directly into the treatment site. No attempt is made to produce a specific distribution.

These methods do not ensure that the distribution of molecules is sufficient to provide effective delivery to substantially all the cells. Electropermeabilization of tumor cell membranes in vivo has been reported (Rols et al., *Nature Biotechnology* 16, 173, 1998) using applied electric pulses from surface electrodes in contact with the skin. A protein can be transferred into or and expressed by the cells by incorporating either the protein or a plasmid carrying a reporter gene. The efficiencies of transfer for the protein and plasmid were, respectively, 20 and 4%. A first type of electrode known in the art comprises parallel-plate electrodes placed on opposite sides of the tumor. Other electrodes known in the art at the present time comprise needles that are inserted into or around the tissue of interest. Electric fields are applied in only two dimensions of the three-dimensional tissue matrix. This limits the area of each cell that can be electroporated (FIG. 1), which reduces delivery efficiency. A two-dimensional array of needles has also been disclosed (Gilbert et al., *Biochim. Biophys. Acta* 1334, 9, 1997; U.S. Pat. No. 5,702,359) in which circularly disposed pairs of needles surround a target tissue. Pulses of opposite polarity are applied across each pair of needles in a predetermined sequence, which has been shown to improve tumor regression in a mouse melanoma study. Electrodes and methods known in the art do not provide molecule movement during the preelectroporation period to enhance molecular distribution nor in the postelectroporation time period, when the cells are in a state of increased membrane permeability. The movement of molecules within the tissue is believed to effect an increase in the delivered quantity of molecules by enhancing movement into the cells.

SUMMARY OF INVENTION

It is therefore an object of the present invention to provide an improved device and method for manipulating molecules adjacent and/or within a target tissue site.

It is an additional object to provide such a device and method for manipulating molecules 5 in three-dimensional space such as a tissue volume element.

It is a further object to provide such a device and method that can provide a desired electromagnetic field distribution adjacent and/or within a target tissue.

It is another object to provide such a device and method that can be configured to activate a multicomponent labile system at a desired site.

It is yet an additional object to provide a system for effecting tumor reduction.

It is yet a further object to provide a system for effecting in vivo gene transfer to cells via electroporation.

These objects and others are attained by the present invention, a device for manipulating a molecule in vivo relative to a target tissue in three dimensions. The device comprises a support and at least one member affixed to and extending away from the support. The member has at least two discrete electrodes, each electrode in independent circuit communication with a respective portion of a source of electrical energy and therefore being differentially activatable.

The discrete electrodes are configured to establish a first electromagnetic field in vivo between selected electrodes sufficient to manipulate a molecule translationally relative to a target tissue. The electrodes are further configured to establish a second electromagnetic field sufficient to cause transient permeability of a cell membrane within the target tissue. In a particular embodiment the electrodes are also configured to establish a third electromagnetic field sufficient to manipulate a molecule translationally following the second field to continue enhancing molecular distribution and/or uptake at cells. Typically the first and the third field levels will be lower than that of the second, although this is not intended as a limitation.

In an alternate embodiment, a system includes at least two members extending from a support. A first member includes at least one electrode as described above; a second member includes at least two electrodes. Such an arrangement permits triangulation between the independently activatable electrodes.

In a particular embodiment the electrodes are activatable in a predetermined sequence, which may include sequential or simultaneous activation of any or all of the electrodes.

The device can be used, for example, with alternating current, direct current, pulsed alternating current, pulsed direct current, high- and low-voltage alternating current with variable frequency and amplitude, variable direct current waveforms, variable alternating current signals biased with variable direct current waveforms, and variable alternating current signals biased with constant direct current.

Several embodiments of the methods of the present invention include the use of a device as described above to enhance the delivery of a molecule such as a bioactive molecule, nucleic acid, amino acid, polypeptide, protein, antibody, glycoprotein, enzyme, oligonucleotide, plasmid DNA, chromosome, or drug, although this list is not intended to be exhaustive or limiting. In a related embodiment the device may be used to cause the electromigration of at least two components of a multicomponent reactive system into apposition to permit a reaction to occur at a desired target tissue site. The target tissue may comprise a tumor, and organ, or wound site.

The features that characterize the invention, both as to organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description used in conjunction with the accompanying drawing. It is to be expressly understood that the drawing is for the purpose of illustration and description and is not intended as a definition of the limits of the invention. These and other objects attained, and advantages offered, by the present invention will become more fully apparent as the description that now follows is read in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference should be made to the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 (prior art) Conceptual two-dimensional depiction of electroporation of a cell subjected to an electromagnetic field. Regions of membrane breakdown, depicted as pores, are formed at the ends of cells facing the electrodes. Electromagnetic field exposure is achieved by applying a potential between electrodes – and +.

FIG. 2 (prior art) The process of delivering molecules by electroporation. FIG. 2A. Cells 15 in vitro or in vivo are exposed to the molecule of interest. FIG. 2B. Direct current pulses are administered to the cells to cause a temporary membrane destabilization that allows the molecules to more freely enter the cell interior. FIG. 2C. Cells return to their normal state after pulsation, leaving the molecule within the cells.

FIG. 3 A first embodiment of one electrode-bearing member of a molecule manipulator, including radially disposed coaxial electrodes spaced apart by nonconductive material.

FIG. 4 A molecule manipulator including a support and plural members as in FIG. 3.

FIG. 5 A second embodiment of one electrode-bearing member of a molecule manipulator, including circumferential bands of electrodes disposed along a generally cylindrical electrode.

FIG. 6 A molecule manipulator including a support and plural members as in FIG. 5.

FIG. 7 The use of a molecule manipulator to bring components of a multicomponent reactive system into apposition at a target tissue site.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A description of the preferred embodiments of the present invention will now be presented with reference to FIGS. 3-7. A first embodiment of a device 10 for manipulating a molecule M in vivo relative to a target tissue T (FIGS. 3 and 4) comprises a support 11 that is adapted to reside outside the site of the target tissue T, here shown as atop the skin S, although this is not intended as a limitation. At least one member 12, here shown as four members 12, are affixed to and extend away from the support 11. The members 12 are preferably disposed about the support 11 in spaced relation from each other and are configured to surround a periphery of and/or penetrate into at least a portion of the target tissue T, with at least a lower portion of the members 12 penetrating the skin S (or other organ or tissue) to reach the target tissue T. Here the target tissue is T represented as a tumor, although this is not intended to be a limitation.

In an alternate embodiment, the member or members **12** are not affixed to a support, but are independently configurable into a desired geometric configuration within the target tissue.

Each member **12** has at least two discrete electrodes disposed in axially spaced-apart relation from each other, here shown as three electrode portions **13,14,15**. Each electrode **13-15** is in circuit communication with a respective portion of a source **50** of electrical energy and is activatable thereby, simultaneously or differentially as desired. The term "in circuit communication" as used herein is used to describe (1) devices that are directly or indirectly electrically connected with each other; (2) devices having other devices or combinations of devices (e.g., breakers, relays, buffers, drivers, transmitters, receivers, and decoders) between them; (3) devices in optical communication with each other (via, e.g., an optoisolator or fiber optic link); (4) devices in electromagnetic communication with each other (via, e.g., radio frequency transmitter and receiver pair); (5) devices connected by and through other structures allowing them to communicate with each other; and (6) any combination of any of the above.

In a preferred embodiment this source comprises a pulse generator such as is known in the art (e.g., a PA-2000 or PA-4000, both from Cyto Pulse Sciences, Inc., Columbia, Md.; a T820, BTX, Inc., San Diego, Calif.) and adapted to deliver pulses of a predetermined shape, voltage, duration, and separation. In particular, the source **50** should be adapted to deliver voltage to each electrode **13-15** for establishing a lower-level and a higher-level electromagnetic field in vivo between selected electrodes. Selective control of the application of electrical signals between the individual electrodes can be accomplished in different ways, e.g., via the PA-201 Programmable Pulse Switch in combination with the PA-4000 generator (both from Cyto Pulse Sciences, Inc., Columbia, Md.) or it can be done manually, mechanically, or electrically.

The lower-level field is for manipulating (e.g., causing the electromigration of) the molecule M in three-dimensional fashion relative to the target tissue T, here shown as a mass. The higher-level field is for causing transient permeability of a cell membrane within the target tissue T. Such a permeability is useful for permitting the molecule M to enter the interior of the cell (see FIGS. 1 and 2). A lower-level field can also be applied following the application of a higher-level field to enhance molecule distribution within the target tissue and/or cause movement of the molecule(s) into the cell interior of the permeabilized cell by electroporation.

In the first embodiment, the member **12** comprises an elongated and pointed core electrode **13** that is made of a conductive material. A nonconductive insulator sleeve **16** is positioned in surrounding relation to a portion of the core electrode **13**, with a bottom portion of the core electrode **13** protruding and thus exposed.

A first outer electrode **14** is positioned in surrounding relation to a portion of the sleeve **16**, with a bottom portion of the sleeve **16** protruding therefrom and thus exposed. A second sleeve **17** is positioned in surrounding relation to a portion of the first outer electrode **14**, with a bottom portion of the second electrode **14** protruding therefrom and thus exposed.

A second outer electrode **15** is positioned in surrounding relation to a portion of the second sleeve **17**, with a bottom portion of the second sleeve **17** protruding therefrom and thus exposed.

A third sleeve **18** is positioned in surrounding relation to a portion of the second outer electrode **15**, with a bottom portion of the second outer electrode **15** protruding therefrom and thus exposed.

In a prototype embodiment, which is not intended as a limitation, the device **10** comprises a stainless steel 30-gauge needle as the core electrode **13** placed in the hollow space of a 25-gauge hypodermic tubing as the first outer electrode **14** with a layer of nonconductive insulation between the electrodes **13,14** as the first sleeve **16**. A layer of insulation is placed over the first outer electrode **14** to serve as second sleeve **17**, and a section of 23-gauge tubing, serving as second outer electrode **15**, is placed over the second sleeve **17**. Insulation placed over the second outer electrode **15** serves as third sleeve **18**. The bottom portions of each of these elements are exposed to form a series of conductive bands **13-15** separated by nonconductive regions **16-18**.

This arrangement provides three electrodes exposed to the exterior with an insulator between each adjacent pair of electrodes. It can be appreciated by one of skill in the art that any number of electrodes and insulators could be successively configured in overlapping fashion to produce a multielectrode member tailored to a particular application based upon such considerations as, for example, the size of the target tissue and the space available.

Each electrode **13-15** has an independent lead **19, 19', 19''**, respectively, affixed to its top end **15** to provide the circuit communication with the pulse generator. In use the members **12** are typically arranged in opposing spaced-apart pairs, so that at least one electrode on each of a pair of members **12** can be adapted to provide at least one pair of opposite-polarity voltages approximately simultaneously. Further, it may be desired to selectively apply electrical potentials to each electrode pair in a predetermined pattern. Such a means for imposing a preselected pattern may include, for example, a software program for driving a pulse generator to deliver signals to each selected electrode in the preselected pattern.

It can be seen that three-dimensional manipulation can be effected by activating opposing pairs of electrodes at different axial levels to induce molecular movement and/or electroporation along a desired pathway. For example, activating the pair **13-13'** would induce movement generally in a plane normal to the member **12**, whereas activating the pair **13-15'** would induce movement at an angle relative to the plane. These presupposed movements are, of course, subject to other conditions within and surrounding the tissue, and are only to be construed as relative and indicative of possible general directionalities achievable by the devices of the present invention.

A second embodiment of a device **20** for manipulating a molecule M in vivo relative to a target tissue T (FIGS. 5 and 6) comprises a support **21** and at least one member **22**, here shown as four members **22**, affixed to and extending away from the support **21**. The members **22** are preferably disposed about the support **21** in spaced relation from each other and are configured to surround a periphery of and/or penetrate into at least a portion of the target tissue T. In FIG. 6 the target tissue is T represented as a tumor, although this is not intended to be a limitation.

Each member **22** has at least two discrete electrodes, here shown as five electrodes **23-27** configured as circumferential rings disposed about a generally cylindrical nonconducting core post **28**. As above, each electrode **23-27** is in independent circuit communication with a respective portion of a source **50** of electrical energy. Such independent circuit communi-

cation may be formed, for example, by respective insulated leads **29** extending through the core **28** from the top end to each ring electrode **23-27**.

Additionally, the core **28** may have a lumen **30** therein extending from a top opening **33** for dispensing a molecule M to a tissue through a portal **31**. The portal **31** in one embodiment may be adjacent an electrode or may **31'** be at the core's tip **32**, which in a particular embodiment may be pointed.

Several embodiments of methods of the present invention will now be disclosed. These methods will be illustrated with the device **10** described above, although this is not intended as a limitation, since either device **10** or **20** could be used therein, or other equivalents appreciated by one of skill in the art.

A first embodiment comprises a method for achieving an improved distribution and delivery of a desired molecule M into a target tissue T. This method comprises the steps of inserting at least one elongated member **12** into a body tissue generally adjacent and/or within a target tissue T. Such an insertion may be aided by any of the visualization techniques known in the art, such as computed tomography, ultrasound, x-radiography, although these are not intended as limitations. A substance that includes the desired molecule M, such as a solution thereof, is introduced into the body into an area near the target tissue T, either before or after the insertion of the device **10**. A particular introduction method comprises delivering the substance through a lumen **30** and portal **31** as in the embodiment of FIGS. **5** and **6**. Any other method of introduction such as known to one of skill in the art may also be employed.

A first electrical potential is established between a pair of electrodes **13-15'** that is sufficient to cause a redistribution and electromigration of the desired molecule M toward the target tissue T. Then subsequently a second electrical potential is established between a pair of electrodes, which may or may not be the same electrode pair as previously activated. The second potential has a sufficiently high electrical potential to cause electroporation in the target tissue T to enhancing a movement of the desired molecule M into a cell. An additional, third, low-level field after electroporation induction can be applied to further enhance molecular movement into cells and/or redistribution. Exemplary pulse magnitude and duration ranges include, but are not intended to be limited to, 1-10,000 volts/cm for a duration in the nanosecond to second range. A particular embodiment comprises a pulse or plurality of pulses in a range of 1-500 V/cm for a duration in the millisecond range for the first and the third potentials and a pulse or plurality of pulses in a range of 750-1500 V/cm in the microsecond range for the second potential. Naturally these values are not intended to be limiting, and one of skill in the art will appreciate that, for example, shorter pulses of higher magnitude or longer pulses of lower magnitude may be employed as required to achieve the desired effect.

A second method is for delivering a bioactive molecule to a subcutaneous target tissue T. This method comprises the steps of, as above, introducing a substance containing the bioactive molecule M systemically or into a subcutaneous area adjacent the target tissue T. A device such as device **10** is inserted into a body tissue generally adjacent a target tissue T, and electrode pairs are again activated at a low and high and again low level to achieve, respectively, an electromigration of the bioactive molecule M adjacent and within the target tissue T, an electroporation of a cell membrane within the target tissue T sufficient to permit entry of the bioactive molecule M into the cell interior, and additional electromigration within the target tissue.

A third method (FIG. **7**) is for bringing two molecules M, M' into apposition at a desired target tissue site T for permitting a reaction therebetween, as in multicomponent reactive system, or a cell "bomb." This method comprises the steps of introducing a substance containing a first molecule M into a first area A adjacent and/or within the target tissue site T and introducing a substance containing a second molecule M' into a second area A' adjacent and/or within the target tissue site T.

Next an electromigration of the first M and the second molecule M' is caused to a third area A" that is adjacent and/or within the target tissue site T. The third area A" may actually comprise the first A or the second area A', or another area distinct therefrom.

Next the first M and the second M' molecule are permitted to react at the third area A". Because of the unique structure of the electrode of the instant invention, the unitary member allows for a variety of uses not permitted by the structures of known prior art devices. The self-contained structure of each electrode member means that it is only necessary to have one member inserted into the cells to effect procedures, where before, using conventional electrodes, since the electrodes were in pairs, insertion angles were limited, preventing many geometries from being usable. In addition, because of this additional flexibility, numerous other treatment protocols are possible. These include, but are not intended to be limited to: (1) electromigration, electroporation, and then electromigration again as described earlier, (2) electromigration, followed by electroporation: (3) electroporation, followed by electromigration; (4) electroporation alone; (5) electromigration alone; and (6) electromigration from a plurality of sides, either alone or (7) in combination with electroporation, either (8) before the electromigration or (9) after the electromigration. In addition, by using the instant electrode members it is possible to perform electromigration as well as electroporation using the same electrode members or, alternately, different electrode members. As is known by those of ordinary skill in the art, the magnitude and duration of the electromagnetic fields is dependent on the particular combination of molecule(s) and tissue(s) under investigation; therefore, the electromagnetic field magnitudes and durations may be the same, similar, or different for inducing the migration of molecules and the electroporation of cells within tissues. Also, because of the nature of the instant electrodes, the processes of electromigration, electroporation, and any combinations thereof can be carried out by this invention with fewer deleterious effects on surrounding tissues due to the fact that each electrode is housed on a single member as opposed to the pair structure of the known prior art.

It may be appreciated by one skilled in the art that additional embodiments may be contemplated, including different electrode configurations adapted to provide high- and low-level fields for causing electromigration and/or electroporation. In this application, a device being "configured" to produce an electromagnetic field in vivo means that (i) the portion of the device that comes in contact with body tissue or fluid is made of biocompatible materials, (ii) the electrodes are capable of carrying the current required for electroporation and/or electromigration of living cells in vivo in an electrolyte which may include the tissue being treated, interstitial fluid, injected material at the treatment site, material applied to the target tissue, and combinations of the foregoing, and (iii) the material between the electrodes on each support member, which may be the same material as the support member, should have a sufficient dielectric constant so that it does not break down as a result of nearby electrodes being of opposite polarity during electrical treatment. Moreover, it

will be apparent to those skilled in the art that where an electrode or system is configured to perform both electromigration and electroporation, such an electrode or system may be used to perform either or both functions.

In the foregoing description, certain terms have been used for brevity, clarity, and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such words are used for description purposes herein and are intended to be broadly construed. Moreover, the embodiments of the apparatus illustrated and described herein are by way of example, and the scope of the invention is not limited to the exact details of construction.

It will be seen that the advantages set forth above, and those made apparent from the foregoing description, are efficiently attained and since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matters contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween. Now that the invention has been described,

The invention claimed is:

1. A device for manipulating a molecule in vivo relative to a target tissue comprising:

a plurality of generally cylindrical nonconducting core posts for insertion into the target tissue, each of the plurality of core posts comprising at least three discrete electrodes, each of the at least three discrete electrodes being circumferential rings disposed to surround the nonconductive core post and each of the at least three electrodes positioned in axially spaced apart relation along the nonconducting core post, each electrode being in independent circuit communication with a respective portion of a source of electrical energy, the electrodes being configured to establish a first electromagnetic field in vivo between selected electrodes sufficient to cause electromigration of a molecule through the target tissue along the axial length of the core post between the selected electrodes and a second electromagnetic field

sufficient to cause transient permeability of a cell membrane within the target tissue between the selected electrodes and an insulating material interposed axially between the circumferential ring electrodes for achieving relative electromagnetic isolation of the electrodes; and

the plurality of core posts affixed to the support member and the plurality of core posts being disposed about the support member in spaced relation from each other and the plurality of core posts extending in an axial direction from the support member such that the plurality of core posts are perpendicular to the support member along the axial length of the core posts, the plurality of core posts configurable to surround a periphery of at least a portion of the target tissue.

2. The device recited in claim **1**, wherein the second field is higher in strength than the first field.

3. The device recited in claim **1**, wherein the nonconducting core post is geometrically adapted for insertion into the target tissue.

4. The device recited in claim **1**, wherein the nonconducting core post has a tip positioned at a distal end of the core post to aid in the insertion of the post into the target tissue.

5. The device recited in claim **1**, wherein at least two of the plurality of core posts are adapted to provide at least one pair of opposite-polarity voltages approximately simultaneously on at least one electrode on each core post.

6. The device recited in claim **1**, further comprising means for selectively activating a selected plurality of electrodes in a predetermined pattern.

7. The device recited in claim **1**, wherein the electrodes are substantially simultaneously activatable.

8. The device recited in claim **1**, wherein the nonconducting core post has a lumen therethrough extending from an opening adjacent a top of the post to a portal positioned along the post beneath the top opening for passing a substance therethrough to the target tissue.

9. The device recited in claim **8**, wherein the portal is positioned adjacent a bottom tip of the post.

10. The device recited in claim **8**, wherein the portal is positioned along the post adjacent an electrode.

* * * * *