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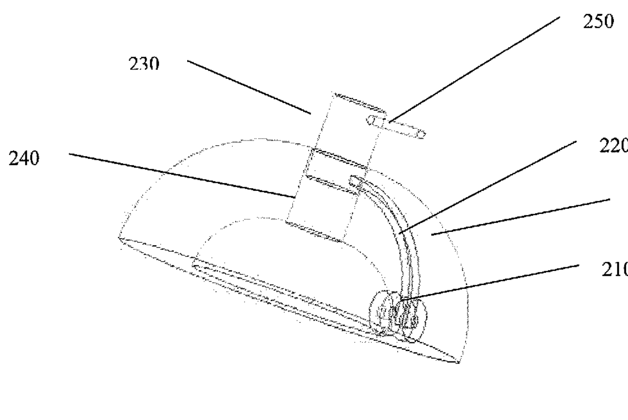

FIG. 2

(57) Abstract: Described herein are systems, methods and apparatus for cooling Transcranial Magnetic Stimulation (TMS) electromagnets, including arrays of TMS electromagnets that are configured for either static positioning around a subject's head, or for moving relative to the subject's head during a treatment. In general, these cooled TMS systems include an insulated enclosure that is adapted to fit at least partially over the subject's head and to at least partially surround one or more TMS electromagnets. The enclosure holds a coolant which may circulate within the enclosure and exchange heat with the TMS electromagnet(s). The systems and methods described may allow repetitive firing of TMS electromagnets over an extended period of time or at greater powers.

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SYSTEMS AND METHODS FOR COOLING ELECTROMAGNETS FOR TRANSCRANIAL MAGNETIC STIMULATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 60/975,176, filed on September 26, 2007, titled "COOLING ELECTROMAGNETS." This application is herein incorporated by reference in its entirety.

INCORPORATION BY REFERENCE

[0002] All publications and patent applications mentioned in this specification are herein incorporated by reference in their entirety to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

FIELD OF THE INVENTION

[0003] The devices and methods described herein relate generally to the cooling of electromagnets used for Transcranial Magnetic Stimulation.

BACKGROUND OF THE INVENTION

[0004] Transcranial Magnetic Stimulation (TMS) typically involves the application of electromagnetic fields to one or more target brain regions in order to excite or inhibit the target brain regions. TMS may be used to treat a large variety of disorders. TMS may be used to provide effective therapy of depression, chronic pain, addiction, obesity, and obsessive compulsive disorder, among others. For example, repetitive Transcranial Magnetic Stimulation (rTMS) has been successfully used to treat depression refractory to drug treatment (e.g., Avery et al., 2005). TMS may be directed to superficial (e.g., cortical targets). In addition, TMS applied to deep-brain (e.g., sub-cortical) targets is increasingly contemplated, providing additional therapies by focused brain stimulation at depth. A device for providing deep brain stimulation with Transcranial Magnetic Stimulation is Schneider and Mishelevich, U.S. Patent Application No. 10/821,807).

[0005] TMS Electromagnets inherently generate a lot of heat. Once the maximum acceptable temperature has been reached, repetitive TMS systems typically no longer allow additional pulses to be triggered, until the temperature falls back to an acceptable level. This may be applied as a failsafe mechanism, and may prevent injury or equipment malfunction. Thus, it has been proposed to cool the TMS electromagnets so they can be pulsed continually or for longer periods of time prior to resting.

[0006] For example, Magstim Ltd, (Whitland, South West Wales, UK) produces an air-cooled TMS coil (see, e.g., U.S. Patent 6,179,770 to Mould) which uses a small (e.g., vacuum cleaner) motor to force room air past a TMS coil at high speeds. Magstim has also described an "Air Film Coil" incorporating ambient air flow and temperature regulated fan technology that permits longer sessions of continuous firing TMS electromagnets than were previously possible. This system creates what is described as a cool "air cushion" between the electromagnet and the patient.

[0007] Cadwell Laboratories (Kennewick, WA) produced a TMS electromagnet having actively driven internal water circulation cooling the coil. Similar internal cooling techniques involve circulating a coolant through a channel in the center of a coil winding itself (e.g., see U.S. Patent 7,088,210, and US Patent Applications No. 11/424.577, 20050162248, and 20060218790). However, circulating fluid in such a long, narrow channel in the winding requires substantial electrical currents, and powerful fluid pumps. In one alternative method, fluid is circulated through a helical channel adjacent to an electromagnetic coil winding where both the channel and the winding wrap around a core. Another approach has been used for TMS electromagnets that have ferromagnetic cores. In this example, cooling may be provided by circulating a ferrofluid via convection (e.g., U.S. Patent Application 11/130,657 to Riehl et al.). Unfortunately, the cylindrical form factor employed in these examples is not well suited to TMS. Furthermore, ferrofluids conduct electricity as well as heat, and thereby tap a portion of the magnetic flux emitted by a coil, inducing eddy currents and reducing the magnetic field flux accordingly.

[0008] Alain Dussau of Campbell, California has developed another method of cooling magnetic coils that augments the Magstim (Wales, UK) air-cooled coil method. Magstim air-cooled coils utilize a vacuum cleaner type motor as a blower to move ambient air past the coil surface within an enclosure that surrounds a single double coil, held in place by an external positioning device. This method necessarily heats the room in which the TMS system is present by the warm air emitted from the coil in the process, which further reduces the temperature differential between the coil and the air that is used to cool it, and thus the efficiency of the cooling process. Dussau routes the warm air output from the coil back into a furniture-like cabinet, in which reside both the blower and an air chiller which is vented to the outside of the building. Unfortnuately, this method is not very effective when applied to TMS systems including moving coils (particularly rapidly moving coils), nor to multi-coil arrays, because of the large-diameter air hoses and blower necessarily associated with each double coil, and the need for external coil-positioning devices. These requirements make it difficult if not impossible to set up and manipulate an array of multiple coils for treating a patient.

[0009] As described herein, two categories of TMS electromagnets may be described. Category I includes TMS electromagnets in which the electrical connections are made using non-rotary connections. Category II TMS electromagnets are those including connections that are made through a rotary mechanism such as a slip ring. An example of Category II TMS electromagnets may be found in Schneider and Mishelevich, published U.S. Patent Application No. 10/821,807.

[00010] Current practice for Category I (e.g., non-rotary) TMS electromagnets calls for air to be blown over the electromagnet coils. While blown air does provide for some cooling, it does not function as an efficient heat transfer medium and, may be noisy. Passive heat conduction, such as placing a heat sink on an electromagnet, is inefficient. Active cooling elements, such as Peltier-effect devices, may also be inadequate by virtue of limited cooling capacity, and may have undesirable effects upon the magnetic field pattern produced. Some TMS electromagnets have iron cores that conduct heat away from the coil windings, however heat dissipation may be inadequate for fast pulse rates or high power levels. Furthermore, that heat which is dissipated into the ambient air may cause an uncomfortable rise the temperature of the treatment room.

[00011] Described herein are systems, devices and methods for cooling TMS electromagnets, and TMS systems including cooled electromagnets. These devices, systems and methods may address some of the problems described above.

SUMMARY OF THE INVENTION

[00012] Described herein are systems, methods and apparatus for cooling Transcranial Magnetic Stimulation (TMS) electromagnets, including arrays of TMS electromagnets that are configured for either static positioning around a subject's head, or for moving relative to the subject's head during a treatment course. In general, these TMS systems include an insulated enclosure that is adapted to fit at least partially over the subject's head and to at least partially surround one or more TMS electromagnets. The enclosure holds an "electromagnetically transparent," non-conductive media such a s air, ceramic micro-beads, or similar fluidic substance which is conductive to heat, but not electrical current. This coolant which may circulate within the enclosure and exchange heat with the TMS electromagnet(s). In some variations the TMS electromagnets are enclosed within the insulated enclosure. In some variations, the TMS electromagnets are partially surrounded by the enclosure; for example, the TMS electromagnets may be embedded in the enclosure. Alternatively, the TMS electromagnets may be attached to a thermal conductor that is connected to the enclosure. Any combination of these configurations may be used as well.

[00013] The enclosure may be configured as a helmet, helm or cap that fits at least partially over a subject's head, or that may be placed over the subject's head. For example, the enclosure may be a dome or portion of a dome. The inner surface of the enclosure may be configured to substantially conform to a subject's head. As mentioned, the enclosure may be insulated (e.g., thermally insulated). The enclosure, and particularly the inner (patient-facing) surfaces may be made of a material that does not interfere with the electromagnetic emissions from the TMS electromagnets. For example, the enclosure may be made (at least in part) of an "electromagnetically transparent" material. In variations in which the TMS electromagnet(s) are completely surrounded within the enclosure, the TMS electromagnets may be focused on a subject through the enclosure.

[00014] The enclosure is configured so that a coolant may be circulated within the enclosure to exchange heat (e.g., cool) the TMS electromagnet(s). In some variations the enclosure includes one or more attachment sites to a source of coolant. The enclosure may include a central cavity, or multiple cavities, into which coolant is passed so that it may contact the TMS electromagnet(s), or it may be directed into channels through the enclosure, or both. Any appropriate coolant may be used. For example, the coolant may be a fluid (such as a gas or liquid). The coolant may be a gas or gasses that is a refrigerant, and may be pressurized and expanded through a nozzle to cool. The coolant may be liquid nitrogen, or liquid nitrogen vapor. In one variation, the coolant is liquid nitrogen in a thermally conductive chamber of pocket that contacts the outer surface of a TMS electromagnet, or a portion thereof (e.g., the back surface). The coolant may be any temperature. Any of the TMS systems described herein may also include one or more sources of coolant (e.g., including a tank, pump, etc.). The coolant may be recirculating within the enclosure and/or within the source. One or more chillers may also be included for chilling the coolant. A controller or thermostat may be used to control the temperature of the coolant, and thereby regulate the temperature of the TMS electromagnets. Feedback control (either open- or closed-loop) may be used to regulate the temperature.

[00015] In some variations, the TMS electromagnets are configured to move relative to the patient during treatment. In such variations, which may be referred to as Category II TMS systems, the TMS system may include a gantry on which the TMS electromagnets move. The gantry may be at least partially (or completely) within in the enclosure. The system may include a slip ring which allows the TMS electromagnet(s) to move while providing power to them. In some variations, the TMS electromagnets may move around the subject's head. In other variations, the TMS electromagnets may tilt (e.g., in pitch, roll and/or yaw), which may allow the TMS electromagnets to focus on different brain regions.

[00016] For example, in some variations including movable TMS electromagnets, the system includes an enclosure that encloses a rotating gantry. The enclosure may be configured as an insulating half-globe shell within which cooling fluid circulates to cool the TMS electromagnets. The coolant may be room temperature or cooled air or other gas (e.g., liquid-nitrogen vapor, refrigerant expanded through a nozzle, or the like). A slip ring may be included that allows transmission of liquid or gas to the rotating member in addition to electrical connections.

[00017] In variations in which the coolant touches either the electromagnet(s), the gantry, or other components of the system, insulation may be used to avoid shorting, e.g., shorting of the coils of the electromagnet. Shorting can occur if cooling of the electromagnet (e.g., by a gas) causes condensation of fluid on the magnet that would cause a short to another coil or other structure. In any of the applicable embodiments, insulation preventing shorting may be used. For example, a fluid barrier may be used. In some variations the insulation may be electrical insulation. In any event the insulation may allow heat transfer between the coolant and the TMS electromagnet). For example, heat from the TMS electromagnets can be transferred to the coolant by using a very thin insulation (e.g., PET plastic) over the electromagnetic coil, or by using a thermally conductive material, such as a thermally conducive paste like Thermal Adhesive from Arctic Silver. Thin insulation elements typically do not interfere with heat transfer significantly. While the current through an electromagnet such as that used for TMS is very high (e.g., 5000 amperes), the pulse durations are typically short (on the order hundredths of microseconds). Therefore only a small gap or thin insulation may be necessary to prevent electrical arc-over or shorting. Some thin forms of insulation such as lacquer or PET plastic insulation may provide a barrier to heat; so it may be preferable to use an insulating, but non-electrically conductive material (as the Thermal Adhesive material mentioned above) that has a higher index of thermal conductivity.

[00018] One variation of a Transcranial Magnetic Stimulation (TMS) includes: a plurality of TMS electromagnets; a coolant; and an enclosure at least partially surrounding the TMS electromagnets and configured to circulate the coolant, wherein the TMS electromagnets are in thermal communication with the coolant within the enclosure. For example, the coolant may be selected from the group consisting of: room air, liquid-nitrogen vapor, refrigerant, and water. In some variations, the enclosure is further configured so that the TMS electromagnet(s) are fully enclosed within the enclosure. As mentioned above, the TMS electromagnets may be insulated against the coolant.

[00019] Such a system may be configured for both moving (Category II) and non-moving (Category I), TMS electromagnets. For example, the TMS electromagnets may be configured to

move within the enclosure. In some variations the system includes a slip ring within the enclosure, which is configured to power the TMS electromagnets and allow them to move relative to the enclosure.

[00020] In some variations, the enclosure may be configured to fit over a patient's head. For example, the enclosure may have a dome shape.

[00021] In any of the variations described herein, the system may include a temperature controller configured to control the circulation of the coolant. In some variation, the system includes a chiller configured to chill the coolant. For example, the chiller may be part of the enclosure (or within the enclosure), or it may be external to the enclosure. A chiller may be external to the enclosure; for example, the chiller may be part of the source of coolant. Thus, any of the systems described herein may also include one or more temperature sensors which may be used to control the temperature. Temperature sensors are well known in the art, and may include any of thermisters, thermocouples, etc. The temperature sensor(s) may be positioned in any appropriate location in the system, including the coolant path and/or near one or more TMS electromagnet. Thus, the controller may be set to regulate the temperature to maintain a predetermined temperature (or range of temperatures) of the coolant and/or TMS electromagnet.

[00022] A controller for controlling the plurality of TMS electromagnets may also be used. The controller may be separate from the system controller controlling operation of the TMS electromagnets, or a single, integrated, controller may be used. In variations having multiple controllers (e.g., temperature controllers and/or stimulation and/or movement controllers), the controllers may communicate and/or coordinate with each other.

[00023] Also described herein are Transcranial Magnetic Stimulation systems comprising: a plurality of TMS electromagnets; a coolant; and an enclosure surrounding the TMS electromagnets and configured to circulate coolant around the TMS electromagnets to cool them, wherein the enclosure is further configured to be placed over a subject's head for applying TMS. The TMS electromagnets may be configured to move within the enclosure.

[00024] Methods of cooling a TMS system are also described. For example, a method of cooling a Transcranial Magnetic Stimulation (TMS) system may include the steps of: circulating coolant within an enclosure at least partially surrounding a plurality of TMS electromagnets and transferring heat between the coolant and the TMS electromagnets, wherein the enclosure is configured to be placed over a subject's head; and applying power to one or more of the TMS electromagnets to emit an electromagnetic field.

[00025] In some variations, the method also includes the steps of moving one or more of the TMS electromagnets within the enclosure.

[00026] The method may also include the step of cooling the coolant. For example, the coolant may be recirculated and cooled, or a chiller may be used to cool the coolant or to maintain a predetermined temperature or range of temperatures. In some variations the temperature of the coolant is determined by the temperature of the TMS electromagnet(s) being cooled. For example, the method may include the step of regulating the temperature of the TMS electromagnets.

[00027] In some variations, the method may include the step of placing a subject's head within the array of TMS electromagnets. The method of cooling a TMS system may be performed even without a patient (e.g., to calibrate the system, for diagnostic purposes, or otherwise).

[00028] Methods of Transcranial Magnetic Stimulation of a subject are also described herein. For example, a TMS treatment method may include the steps of: placing an enclosure of a TMS system as described above over a subject's head, circulating coolant within an enclosure at least partially surrounding a plurality of TMS electromagnets and transferring heat between the coolant and the TMS electromagnets; and applying power to one or more of the TMS electromagnets to emit an electromagnetic field.

BRIEF DESCRIPTION OF THE DRAWINGS

[00029] FIG. 1 illustrates one variation of an enclosure for a fixed (e.g., category I) configuration of TMS electromagnets.

[00030] FIG. 2 shows another variation of an enclosure for a cooled TMS system, which may be used with movable (e.g., category II) TMS configurations of TMS electromagnets.

[00031] FIG. 3 shows one variation of a slip ring with electrical and cooling access.

[00032] FIG. 4A is a schematic of one variation of a cooled TMS system including a static coil array within a force-cooled space.

[00033] FIG 4B is a schematic of one variation of a cooled TMS system including a static coil array adjacent to a force-cooled space.

[00034] FIG 4C illustrates one variation of heat-conducting radiators attached to a TMS coil, such as the coils shown in FIG. 4B, which may protrude into a force- cooled enclosure.

DETAILED DESCRIPTION OF THE INVENTION

[00035] The cooled TMS systems described herein typically include an enclosure (which may be referred to as a housing) that is configured to fit over a subjects head, in which coolant may circulate to cool one or more (and typically an array) of TMS electromagnets. The systems

may also include one or more sources of coolant, a temperature regulator for controlling the temperature, and a chiller for cooling the coolant.

[00036] As mentioned above, cooled TMS systems may be used for static (e.g., non-moving) TMS electromagnets, or for movable TMS electromagnets. Static TMS electromagnets may be referred to as “Category I” electromagnets, and movable electromagnets may be referred to as “Category II” electromagnets. The movable TMS electromagnets may be movable in any appropriate manner. For example, movable TMS electromagnets may be jointly or independently movable. In some variations the moveable TMS electromagnets may be moveable around a subject’s head, and/or in rotation (e.g., pitch, roll, and/or yaw), to change the focus of the TMS electromagnet. Systems including movable TMS electromagnets may include a gantry or frame along which the TMS electromagnet(s) move. In some variations, the system includes an actuator or actuators which move the TMS electromagnet(s).

[00037] For example, FIG. 1 illustrates one variation of a portion of an enclosure for a static (Category I) TMS electromagnet. In FIG. 1 the enclosure 100, houses TMS electromagnet 110 (electrical connections are not shown), and the interior of the enclosure is cooled via injection channel 120. Coolant is supplied by this injection channel. The coolant can be any appropriate temperature; for example, coolant can be room temperature. Any appropriate coolant may be used, for example, the coolant may be cooled air or other gas, liquid nitrogen vapor, or refrigerant expanded through a nozzle. A vent can be included for outbound passage.

[00038] In some variations, an enclosure for a Category I TMS electromagnet does not surround the TMS electromagnet, but only partially encloses it. For example, the enclosure may be configured as a pocket or surface that contacts the back of the electromagnet (e.g., the side not facing the patient) into which liquid nitrogen or other coolant can be placed. Heat is exchanged with the TMS electromagnet by contact with the enclosure. In some variations the enclosure is thermally connected to coolant in the enclosure by a heat-conducting radiator.

[00039] FIG. 2 illustrates one variation of a cooled TMS system that may be used with a movable (e.g., Category II) TMS electromagnet or electromagnets. In FIG. 2 an enclosure 200, houses a rotating gantry that is made up of electromagnet 210 (electrical connections not shown) attached to gantry arm 220 which is attached to slip ring 230 rotating in opening 240 in the enclosure with coolant supplied through the slip ring via injection channel 250. Alternate embodiments may have multiple electromagnets with gantry attachment, including other movable (or a combination of moveable and fixed) TMS electromagnets. FIG. 3 shows one variation of the internal structure of a slip ring, showing outer housing 300 containing a rotating inner core 310 with electrical slip rings 320 (electrical connections not shown). Coolant is supplied via external housing channels 330 communicating with internal cooling channels 340.

The cooling connections to the coolant containers on the electromagnets are not shown. Any appropriate coolant may be used. For example, coolant supplied by external housing channels 330 can be room temperature or cooled air or other gas, liquid nitrogen vapor, or refrigerant.

[00040] Cooled TMS system compatible with Category II (movable TMS electromagnet) systems may be the same as for Category I systems. In TMS systems including movable TMS electromagnets that move around the head, a contact such as a slip ring or other rotary union that provides the electrical and coolant connections may be used. An example of such a rotary union is the Part Number 012-N-21212-MTS-SRS15DP06 from Rotary Systems, Inc. Depending on the seals in the device, the coolant may be a gas, including liquid-nitrogen vapor, or a liquid, such as antifreeze (or even water). Slip-ring devices accomplish the electrical connections in the union and the mechanical channels accomplish the mechanical connections in the union.

[00041] The temperature of the system may be controlled (e.g., via a controller) to any appropriate temperature. A controller may be hardware, software, firmware, or any combination thereof. For example, a controller may be configured as a computer running control logic. The controller may receive input from one or more temperature sensors, and/or user input(s). The controller may use this input to adjust the temperature of the coolant so as to achieve a target temperature or range of temperatures. In some variations, the system is configured to allow the coolant to be room temperature. Although potentially not as efficient in removing heat from the electromagnets as lower-temperature coolant, coolants can be circulated at room temperature, and even room-temperature coolants offer benefit, because following stimulation the temperature of electromagnets rises significantly. More effective heat transfer, of course, can be obtained by lowering the temperature of the coolant via mechanical refrigeration or heat transfer to a substance such as liquid nitrogen.

[00042] Any appropriate TMS electromagnet(s) may be used. For example, figure-eight double coils are well known for use as TMS electromagnets. For instance, a 70 mm double-coil configuration from Magstim (Model 9925) may be used. The electromagnets can be powered by any appropriate power sources, such as the Magstim Rapid^2 (Magstim Ltd., Wales, UK) that provides for pulsed magnetic fields. When the Magstim Model 70 mm coil is repetitively stimulated, its temperature will increase and when the temperature reaches on the order of 40°C, the system may prevent further pulsing until the electromagnet cools.

[00043] FIG. 4A shows a static coil array 410 within a force-cooled space 445. Liquid or gas is cooled by cooling coil 431 (one variation of a chiller), and circulated through force-cooled space 445 with blower/impeller 430 with directions of coolant flow 433 and 434. Computer 432 controls the actions of power bank 442, which bring power pulses to coil array 410 via cables

443. Thus, in this example, the controller is a computer 432, and may also control or otherwise regulate the temperature as described above; alternatively a separate controller may be used.

[00044] FIG 4B shows a static coil array 450 adjacent to force-cooled space 465. In this variation the TMS electromagnets are not completely surrounded by the enclosure, although they are within the concavity formed by the enclosure, and are in thermal communication with the coolant within the enclosure. For example, liquid or gas may be cooled by cooling coil (chiller) 461and circulated through force-cooled space 465 with blower/impeller 460 with directions of coolant flow 463 and 464 including through cooled-space section 456 directly adjacent to static coil array 450. As in FIG. 4A, controller (computer) 452 controls the actions of power bank 462, which bring power pulses to coil array 450 via cables 453.

[00045] Figure 4C illustrates one variation of a thermal radiator that may be used in connection with one or more TMS electromagnets. In FIG. 4C, protruding radiators 490 attach to the surface of TMS electromagnet (coil 475), which may represent one coil of array 450, as shown in Fig. 4B. Protruding radiators 490 may be in substantial contact with coil 475 so as to conduct heat away from the coil, through cooled chamber wall 480, and into the space through which cooled medium 485 passes. Cooled medium (coolant) 485 may be liquid or gas, and may conduct and convect heat from protruding radiators 490. Warmed cooling media 486 may be returned for cooling in the circulating system as described in figures 4A and 4B.

[00046] In operation, any of the cooled TMS systems described herein may be used to treat a patient. For example, a patient's head may be inserted into the space formed by the enclosure, so that the TMS electromagnets may be aligned with the patient's head. Coolant may be circulated within the enclosure, transferring heat between the coolant and the TMS electrode(s). Heat may be transferred directly between the coolant and the TMS electromagnets, or through an insulator and/or a thermal radiator. In some variations, the magnets may be moved before, during or after the procedure. A target temperature or range of temperatures for the TMS electromagnets and/or the coolant may be entered into the system, such as into a controller for the temperature. One or more temperature sensors may also provide feedback to the controller. Treatment may be performed by energizing the TMS electrodes to apply pulses of TMS to the subject.

[00047] The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Based on the above discussion and illustrations, those skilled in the art will readily recognize that various modifications and changes may be made to the present invention without strictly following the exemplary embodiments and applications illustrated and described herein. Such modifications and changes do not depart from the true spirit and scope of the present invention, which is set forth in the following claims.

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CLAIMS

What is claimed is:

1. A Transcranial Magnetic Stimulation (TMS) system, the system comprising:
   a plurality of TMS electromagnets;
   a coolant; and
   an insulated enclosure configured to be worn over a subject's head, the enclosure at least partially surrounding the TMS electromagnets and configured to circulate the coolant, wherein the TMS electromagnets are in thermal communication with the coolant within the enclosure.

2. The system of claim 1, wherein the coolant is a liquid or gas.

3. The system of claim 1, wherein the coolant is selected from the group consisting of: room air, liquid-nitrogen vapor, refrigerant, and water.

4. The system of claim 1, wherein the enclosure is further configured so that the TMS electromagnets are fully enclosed within the enclosure.

5. The system of claim 4, wherein the TMS electromagnets are insulated against the coolant.

6. The system of claim 1, wherein the TMS electromagnets are configured to move within the enclosure.

7. The system of claim 1, further comprising a slip ring within the enclosure configured to power the TMS electromagnets and allow them to move relative to the enclosure.

8. The system of claim 1, wherein the enclosure comprises a dome shape.

9. The system of claim 1, further comprising a temperature controller configured to control the circulation of the coolant.

10. The system of claim 1, further comprising a chiller configured to chill the coolant.

11. The system of claim 1, further comprising a controller for controlling the plurality of TMS electromagnets.

12. A Transcranial Magnetic Stimulation (TMS) system, the system comprising:
    at least one movable TMS electromagnet;

a coolant; and

an enclosure surrounding the TMS electromagnet, wherein the enclosure is configured to circulate coolant around the TMS electromagnet, further wherein the TMS electromagnet is configured to move within the enclosure relative to a subject's head when the enclosure is placed over the subject's head.

13. A Transcranial Magnetic Stimulation (TMS) system, the system comprising:

a plurality of TMS electromagnets;

a coolant; and

an enclosure surrounding the TMS electromagnets and configured to circulate coolant around the TMS electromagnets to cool them, wherein the enclosure is further configured to be placed over a subject's head for applying TMS.

14. The system of claim 13, wherein the TMS electromagnets are configured to move within the enclosure.

15. The system of claim 14, further comprising a slip ring configured to power the TMS electromagnets.

16. A method of cooling a Transcranial Magnetic Stimulation (TMS) system, the method comprising:

circulating coolant within an enclosure at least partially surrounding a plurality of TMS electromagnets and transferring heat between the coolant and the TMS electromagnets, wherein the enclosure is configured to be placed over a subject's head; and

applying power to one or more of the TMS electromagnets to emit an electromagnetic field.

17. The method of claim 16, further comprising moving one or more of the TMS electromagnets within the enclosure.

18. The method of claim 16, further comprising cooling the coolant.

19. The method of claim 16, further comprising regulating the temperature of the TMS electromagnets.

20. The method of claim 16, further comprising placing a subject's head within the array of TMS electromagnets.

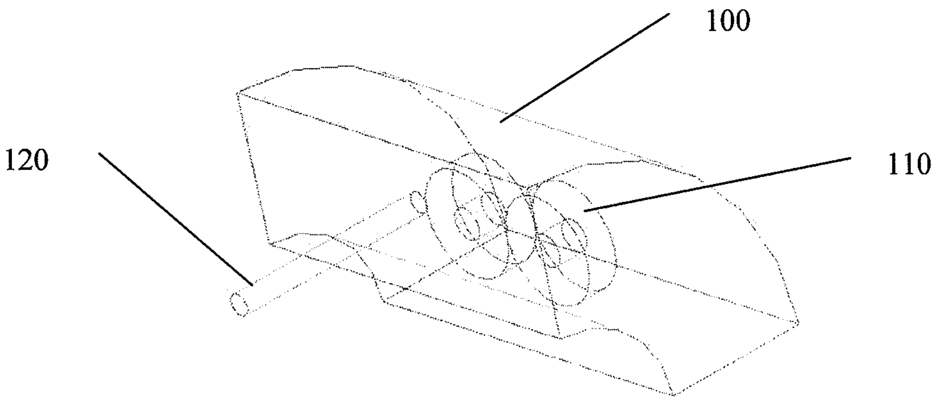

FIG. 1

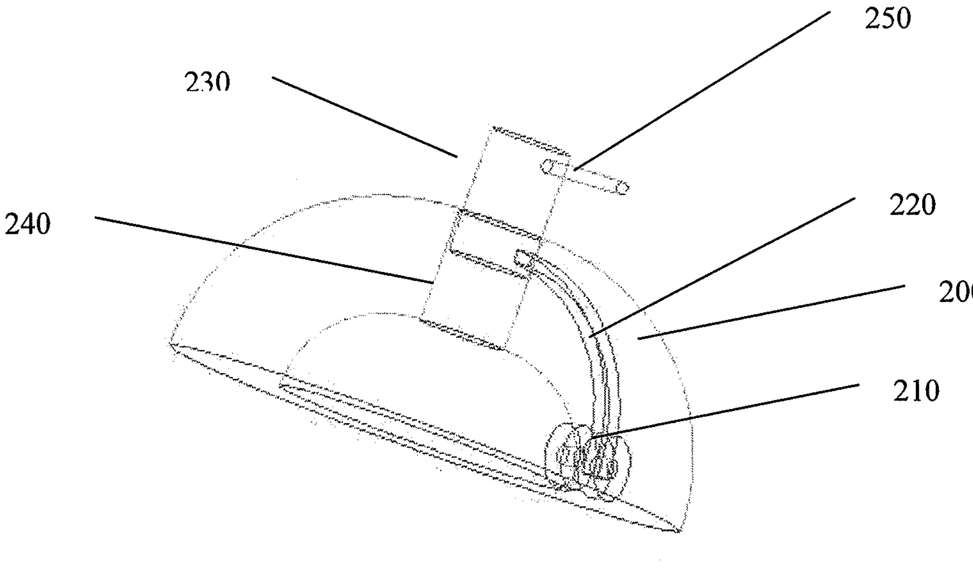

FIG. 2

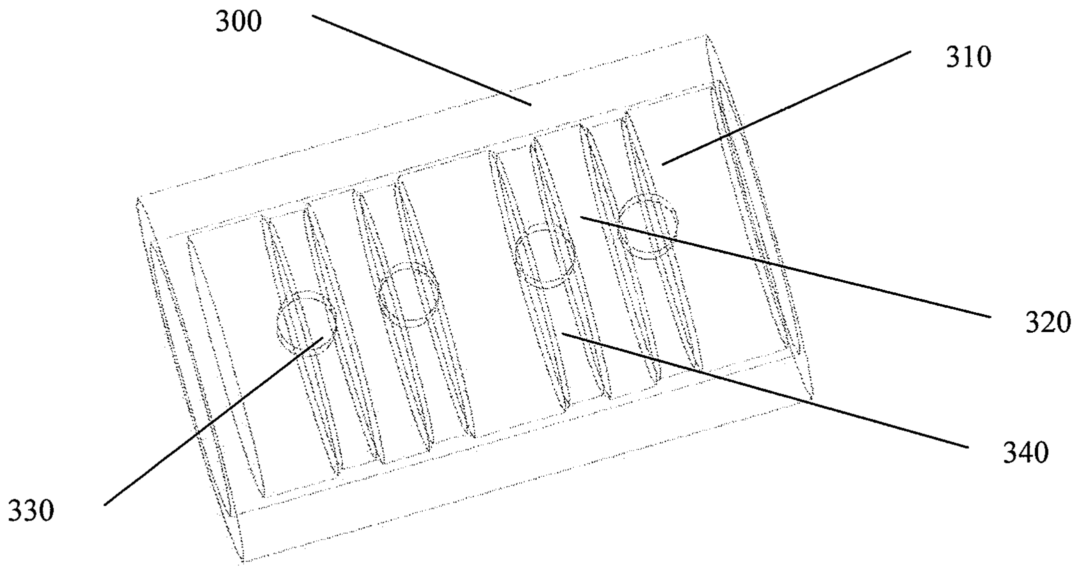

FIG. 3

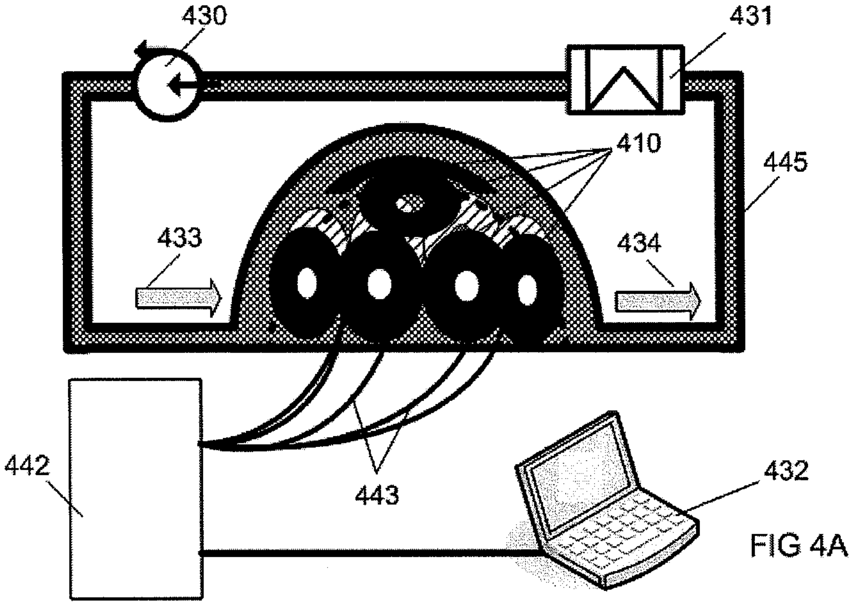

FIG 4A

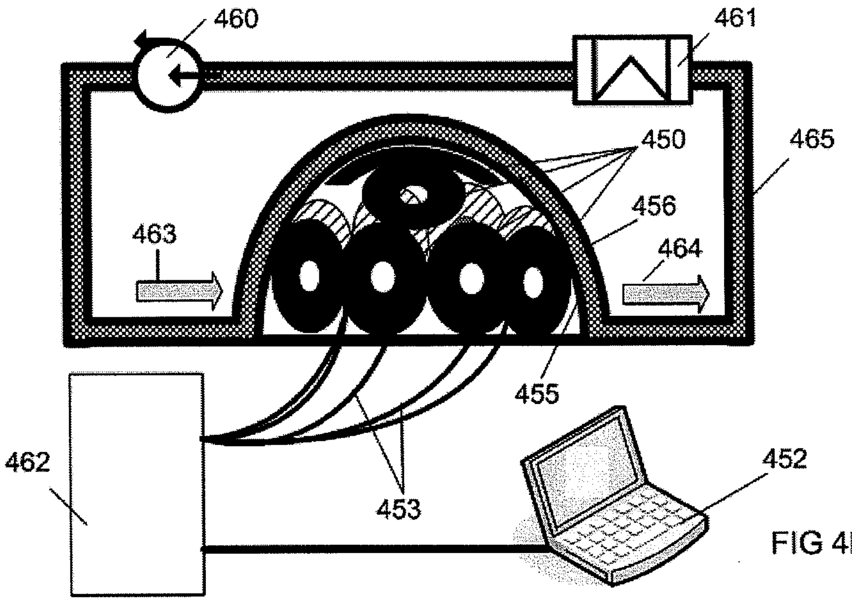

FIG 4B

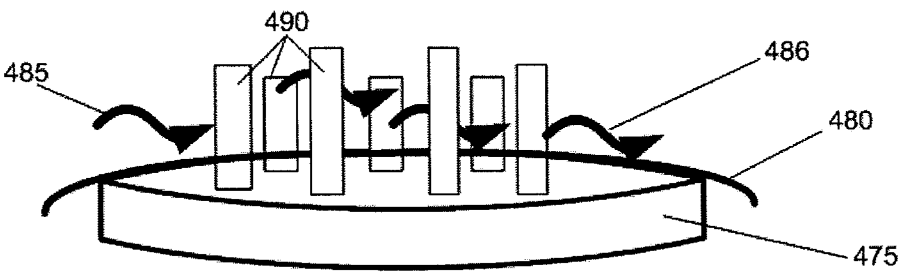

FIG 4C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/077851

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61N2/02 A61N2/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	GB 2 336 544 A (MAGSTIM CO LTD [GB]) 27 October 1999 (1999-10-27) page 1, line 23 - line 26; figure 3 page 2, line 23 - page 5, line 17; claims 1,2; figures	1-4,11, 13,16 9,12
X A	US 2005/228209 A1 (SCHNEIDER M B [US] ET AL) 13 October 2005 (2005-10-13) paragraphs [0040], [0048] - [0050], [0054], [0056], [0060], [0064]; figures 1-4	1-4,6-8, 11-17,20 5,8-10, 18,19
A	WO 2006/124914 A (NEURONETICS INC [US]) 23 November 2006 (2006-11-23) paragraphs [0024] - [0033]; figures	1,12,13, 16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 February 2009	12/02/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Rakotondrajaona, C

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/077851

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			US	2008114199	A1	15-05-2008
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