A battery autoclaving system is provided including a battery pack having a housing, a battery cell disposed within the housing, and an isolation region disposed between the housing and the battery cell. The isolation region may be formed at least partially from at least one of a thermal insulating material, a phase change material or any combination thereof. The system may include a temperature sensor adapted to sense at least one of a temperature of the battery cell temperature of the isolation region. The system may include and an autoclave configured to receive a temperature indication from the temperature sensor and to inhibit autoclaving when the temperature indication exceeds a predetermined value.
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SK, SM, TR, OAPI (BF, BL, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TC), — without international search report and to be republished upon receipt of that report (Rule 48.2(g))
As may be appreciated, removable batteries or battery assemblies that are configured to quickly and easily couple or latch to a handpiece of the portable surgical instrument may prove advantageous in the surgical environment.

It may be desirable to re-sterilize a rechargeable battery pack using an autoclave. However, this high temperature method is above the temperature limits of currently available rechargeable battery cells.

SUMMARY

Disclosed is an apparatus and method for insulating a rechargeable battery pack to allow it to survive autoclave sterilization.

In at least one aspect of this disclosure, a method for autoclaving a battery pack includes providing the battery pack, wherein the battery pack includes a housing, a battery cell disposed within the housing, and an isolation region disposed between the housing and the battery cell, the isolation region being formed at least partially from at least one of a thermal insulating material, a phase change material, or a combination thereof.

In another aspect of this disclosure, the method may further include inserting the battery pack into the autoclave, sterilizing the battery pack in the autoclave, and removing the battery pack from the autoclave after sterilization.

In yet another aspect of this disclosure, the battery pack may further include a first and a second outer terminal connected a first and second battery terminal of the battery cell through at least one of the housing and the isolation region.
[0010] In yet another aspect of this disclosure, the method may further include providing an autoclave configured to accept the battery pack and to sterilize the battery pack.

[0011] In yet another aspect of this disclosure, the method may further include monitoring the temperature of at least one of the housing, the battery cell, and the isolation region.

[0012] In yet another aspect of this disclosure, the method may further include providing a sterile terminal cap and placing the sterile terminal cap over at least one of the first or second outer terminals.

[0013] In yet another aspect of this disclosure, the battery pack further comprises at least one temperature sensor configured to sense a temperature of at least one of the housing, the isolation region, or the battery cell.

[0014] In yet another aspect of this disclosure, the method may further include providing an autoclave configured to accept the battery pack and to sterilize the battery pack, wherein the autoclave is configured to read the at least one temperature sensor and provide an indication of temperature.

[0015] In yet another aspect of this disclosure, the isolation region further includes at least two layers, wherein each layer is formed from at least one of a phase change material or an insulation material.

[0016] In yet another aspect of this disclosure, a battery pack may include a housing, a battery cell disposed within the housing, and an isolation region disposed between the housing and the battery cell, the isolation region being formed at least partially from at least one of a thermal insulating material, a phase change material, or any combination thereof.
In yet another aspect of this disclosure, the battery pack may further include at least one temperature sensor configured to sense the temperature of at least one of the housing, the isolation region, or the battery cell.

In yet another aspect of this disclosure, the isolation region further includes at least two layers, wherein each layer is formed from at least one of a phase change material or an insulation material.

In yet another aspect of this disclosure, the isolation region is formed from two or more materials selected from the group consisting of a phase change material and an insulation material.

In yet another aspect of this disclosure, the battery pack may further include a sterile terminal cap configured to selectively cover at least one of the first and second outer terminals.

In yet another aspect of this disclosure, the sterile terminal cap may be puncturable such that at least one of the first or second outer terminals may be accessed by piercing or removing a portion of the sterile terminal cap.

In yet another aspect of this disclosure, a battery autoclaving system may include a battery pack having a housing, a battery cell disposed within the housing, and an isolation region disposed between the housing and the battery cell, wherein the isolation region is formed at least in part from at least one of a thermal insulating material, a phase change material, or any combination thereof, a temperature sensor adapted to sense at least one of a temperature of the battery cell, temperature of the isolation region, and an autoclave configured to receive a temperature indication from the temperature sensor and to inhibit autoclaving when the temperature indication exceeds a predetermined value.
**BRIEF DESCRIPTION OF THE DRAWINGS**

[0023] Embodiments according to the present disclosure are described, by way of example only, with reference to the accompanying drawings, wherein:

[0024] Fig. 1 illustrates an embodiment of a rechargeable battery pack in accordance with the present disclosure;

[0025] Fig. 2 illustrates another embodiment of a rechargeable battery pack in accordance with the present disclosure;

[0026] Fig. 3 illustrates yet another embodiment of a rechargeable battery pack in accordance with the present disclosure; and

[0027] Fig. 4 illustrates an embodiment of a system for autoclaving a battery in accordance with the present disclosure.

**DETAILED DESCRIPTION**

[0028] Particular embodiments of the present disclosure are described hereinbelow with reference to the accompanying drawings; however, the disclosed embodiments are merely examples of the disclosure and may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for
teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

[0029] Like-referenced numerals may refer to similar or identical elements throughout the description of the drawings. As shown in the drawings and described throughout the following description, as is traditional when referring to relative positioning on a surgical instrument, the term "proximal" refers to the end of the apparatus that is closer to the user and the term "distal" refers to the end of the apparatus that is farther away from the user. The term "clinician" refers to any medical professional (e.g., doctor, surgeon, nurse, or the like) who may perform a medical procedure involving the use of embodiments described herein.

[0030] In accordance with at least one aspect of the present disclosure, a battery pack for use with a portable surgical instrument is disclosed. Referring to Fig. 1, the battery pack 100 may include an isolation region 105 disposed between at least one battery cell 101 and at least one housing 107, thereby sealing the at least one battery cell 101 and the isolation region 105 inside.

[0031] The battery cell 101 may be any suitable battery, including, but not limited to, rechargeable batteries for surgical devices now or in the future known. Non-limiting examples of such a battery cell may include a Li-ion battery, a NiMH battery, a NiCd battery, and the like. The at least one battery cell 101 may include a first terminal 103a and a second terminal 103b.

[0032] The housing 107 may be made from at least one of any rigid or semi-rigid material suitable to form a protective layer over the isolation region 105 and/or battery cell 101, including, but not limited to plastic, ceramic, metal, and the like. The housing 107 may further take any desired shaped such that the battery pack 100 may fit into a desired portable surgical device and/or autoclave.
[0033] The housing 107 may be selectively sealable and openable such as to allow for removal of the at least one battery cell 101 if desired.

[0034] A first outer terminal 109a and a second outer terminal 109b may be disposed on the housing 107, and are configured to conduct electricity. The outer terminals 109a, 109b may form part of the housing 107.

[0035] The first outer terminal 109a and a second outer terminal 109b may be connected to the first terminal 103a and second terminal 103b via a first electrical connection 111a and a second electrical connection 111b, respectively.

[0036] In some embodiments, the isolation region 105 is formed at least partially from at least one of a thermal insulating material, a phase change material and/or any combination thereof. The isolation region 105 may be formed from an insulating material such as, without limitation, silica aerogel with reinforcing fibers, e.g., Spaceloft™ insulation manufactured by Aspen Aerogel of Northborough, Massachusetts, USA.

[0037] In some embodiments, a phase change material is used in addition or alternatively to the insulation material to protect the battery from damaging heat. For example, and without limitation, the phase change material may include sodium sulfate decahydrate (e.g., Glauber's salt) or a similar material whose phase change temperature is below the damage threshold temperature of the battery cell 101.

[0038] This isolation region 105 is sized to maintain the temperature of the battery cell (or cells) below its temperature limit when the case is subjected to the known time and temperature profile of an autoclave sterilization cycle.
The battery pack 100 may further include at least one temperature sensor configured to sense the temperature of at least one of the housing 107, the isolation region 105, or the battery cell 101. For example, there may be at least one isolation region temperature sensor 113 and/or at least one battery cell temperature sensor 115.

Referring to Fig. 2, a battery pack 200 may include a battery cell 201, a housing 207, a first outer terminal 209a and a second outer terminal 209b, a first terminal 203a and second terminal 203b, a first electrical connection 211a and a second electrical connection 211b, and an isolation region 205, all similar to the embodiments as described above with respect to Fig. 1.

In some embodiments, and as shown in Fig. 2, battery pack 200 may further include a sterile terminal cap 217 configured to selectively cover at least one of the first outer terminal 209b and second outer terminal 209a. The sterile terminal cap 217 may be puncturable such that access to at least one of the first outer terminal 209b and second outer terminal 209a may be gained by piercing or removing a portion of the sterile terminal cap 217. This allows sterility of the terminals to be maintained underneath the sterile terminal cap 217 after autoclaving and during storage/installation into a surgical device.

Referring to Fig. 3, a battery pack 300 may include a battery cell 301, a housing 307, a first outer terminal 309a and a second outer terminal 309b, a first terminal 303a and second terminal 303b, a first electrical connection 311a and a second electrical connection 311b, and an isolation region 305, all similar to the embodiments as described above with respect to Fig. 1.

In some embodiments, and as shown in Fig. 3, the isolation region 305 may further include at least two layers, each layer being formed from at least one of a phase change material as described above or an insulation material as described above. In some embodiments where
multiple layers include at least one phase change material, the phase change materials of each layer may be selected to have different phase change temperatures. For example, an outer layer 306a may have a lower phase change temperature such that it melts at a first temperature and absorbs heat before an inner layer 306b melts.

[0044] The battery pack 300 may further include at least one temperature sensor configured to sense the temperature of at least one of the housing 307, the isolation region 305, or the battery cell 301. For example, there may be at least one isolation region temperature sensor 313 and/or at least one battery cell temperature sensor 315. In embodiments where there are multiple layers in the isolation region 305, there may be additional temperature sensors 314 for any combination of layers as desired.

[0045] An embodiment of a battery pack as described herein may protect a battery cell during a heating procedure. For example, during autoclaving, the heat of fusion of the phase change material enables the material to absorb a great deal of thermal energy, thus keeping heat from accumulating in the battery cell and thereby maintaining the cell (or cells) at a safe temperature.

[0046] Referring to Fig. 4, further disclosed is a battery autoclaving system 400 that may include a battery pack 500 as described herein, a temperature sensor as described above, and an autoclave 401 configured to receive a temperature indication from the temperature sensor and to inhibit autoclaving (e.g., sterilization) when the temperature indication exceeds a predetermined value.

[0047] The autoclave may have a controller module designed to periodically or constantly monitor temperature indications from one or more temperature sensors. The controller module
705 may include a processor, memory, and/or interface elements configured to communicate with one or more temperature sensors, an autoclave, and the like. The controller module may further be configured to shut down autoclaving or modify the temperature of autoclaving to avoid battery cell failure. The autoclave may alternatively be manually controlled based on a temperature display wherein the temperature information may be displayed on a text display 407 located on the autoclave 401, the housing, or through any other manner of indication such as audible means or visual display.

[0048] In some embodiments, a temperature sensor 513 is operatively associated with the battery pack 500 to enable a user to determine whether it is safe to autoclave the battery pack 500. This may be beneficial in situations such as where heat from a prior, recent autoclaving procedure remains in the phase change material or the battery cell. In one scenario, the phase change material may be fully or partially liquefied (having already undergone a phase change during the previous autoclaving session) and thus not be able to fully absorb the necessary heat from another autoclaving session until it necessarily cools. The temperature information may be displayed on a text display located on the housing or through any other means such as audible means or visual display.

[0049] In some embodiments, the temperature sensor 513 may be in operative communication with an autoclave 401 that is configured to receive a temperature signal from the temperature sensor 513 indicative of an internal temperature of the battery pack, e.g., the temperature of the battery cell and/or the phase change material. The autoclave may be further configured to inhibit the autoclaving process in the case that one or more battery cells indicate that an internal temperature thereof exceeds a safe threshold for autoclaving. In an embodiment,
the autoclave 401 may automatically determine the condition of any battery placed therein prior to initiating an autoclaving cycle. The autoclave 401 may communicate with the battery by any suitable manner of communication, e.g., by electrical connection (e.g., via mating terminals on the battery and autoclave), by wireless connection (e.g., active or passive RFID tags), and/or or any other suitable communication link between the battery and the autoclave. The autoclave 401 may even have an emergency door release feature to open door 403 and release heat quickly in the event of a near critical temperature reading inside the battery. The autoclave 401 may even have an emergency vent feature to open one or more vents and release heat quickly in the event of a near critical temperature reading inside the battery.

[0050] Further disclosed is a method for autoclaving a battery pack. The method may include providing the battery pack as described above.

[0051] The method may further include inserting the battery pack into an autoclave, sterilizing the battery pack in the autoclave, and removing the battery pack from the autoclave after sterilizing. The battery pack may be moved from the autoclave to a sterile storage area or into a sterile surgical device to maintain sterility.

[0052] The method may further include providing an autoclave configured to accept the battery pack and to sterilize the battery pack.

[0053] The method may further include monitoring the temperature of at least one of the housing, the battery cell, and the isolation region. The method may further include modifying the temperature of the autoclave or shutting down the autoclave in response to the monitored temperature.
[0054] The method may further include providing a sterile terminal cap and placing the sterile terminal cap over at least one of the first or second outer terminals.

[0055] The method may further include providing an autoclave configured to accept the battery pack and to sterilize the battery pack, wherein the autoclave is configure to read the at least one temperature sensor and provide an indication of temperature.
WHAT IS CLAIMED IS:

1. An autoclavable battery pack for use with a surgical instrument, comprising:
   providing the battery pack, wherein the battery pack comprises:
   a housing;
   a battery cell disposed within the housing; and
   an isolation region disposed between the housing and the battery cell, wherein the
   isolation region is formed at least in part from at least one of a thermal
   insulating material, a phase change material, or a combination thereof;
   providing an autoclave configured to accept the battery pack;
   inserting the battery pack into the autoclave;
   sterilizing the battery pack in the autoclave; and
   removing the battery pack from the autoclave after sterilizing.

2. The method in accordance with claim 1, wherein the battery pack further
   comprises a first and a second outer terminal connected to a first and second battery terminal of
   the battery cell through at least one of the housing or the isolation region.

3. The method in accordance with claim 1, further comprising monitoring the
   temperature of at least one of the housing, the battery cell, or the isolation region.

4. The method in accordance with claim 1, wherein the battery pack further
   comprises at least one temperature sensor configured to sense a temperature of at least one of the
   housing, the isolation region, or the battery cell.
5. The method in accordance with claim 4, further comprising providing an autoclave configured to accept the battery pack and to sterilize the battery pack, wherein the autoclave is configured to operably communicate with the at least one temperature sensor and to provide an indication of temperature.

6. The method in accordance with claim 1, wherein the isolation region further comprises at least two layers, wherein each layer is formed from at least one of a phase change material or an insulation material.

7. An autoclavable battery pack for use with a surgical instrument, comprising:
   a housing;
   a battery cell disposed within the housing; and
   an isolation region disposed between the housing and the battery cell, wherein the isolation region is formed at least in part from at least one of a thermal insulating material, a phase change material, or a combination thereof.

8. The autoclavable battery pack in accordance with claim 7, further comprising at least one temperature sensor configured to sense the temperature of at least one of the housing, the isolation region, or the battery cell.
9. The autoclavable battery pack in accordance with claim 7, wherein the isolation region further comprises at least two layers, wherein each layer is formed from at least one of a phase change material or an insulation material.

10. The autoclavable battery pack in accordance with claim 7, wherein the isolation region is formed from two or more materials selected from the group consisting of one or more of a phase change material and an insulation material.

11. The autoclavable battery pack in accordance with claim 7, wherein the battery cell includes first and second outer terminals and the autoclavable battery pack includes a sterile terminal cap configured to selectively cover the first and second outer terminals.

12. The battery pack in accordance with claim 14, wherein the sterile terminal cap is puncturable such that at least one of the first and second outer terminals may be accessed by puncturing a portion of the sterile terminal cap.

13. A battery autoclaving system, comprising:

an autoclavable battery pack, comprising:

a housing;

a battery cell disposed within the housing; and

an isolation region disposed between the housing and the battery cell, the isolation region being formed at least partially from at least one of a thermal insulating material, a phase change material, or a combination thereof;
a temperature sensor adapted to sense at least one of a temperature of the battery cell or
the temperature of the isolation region; and

an autoclave configured to receive a temperature indication from the temperature sensor
and to inhibit autoclaving when the temperature indication exceeds a predetermined value.

14. The system in accordance with claim 13, wherein the isolation region further
comprises at least two layers, wherein each layer is formed from at least one of a phase change
material or an insulation material.

15. The system in accordance with claim 13, wherein the isolation region is formed
from two or more materials selected from the group consisting of one or more of a phase change
material and an insulation material.

16. The system in accordance with claim 13, wherein the battery pack further
comprises a sterile terminal cap configured to selectively cover at least one of the first or second
outer terminals.

17. The system in accordance with claim 13, wherein the battery cell is a Li-ion
battery cell.