THERMAL FOOTWEAR SYSTEM

Inventor: Wylie Moreshead, Bainbridge Island, WA (US)

Assignee: Kinaptic, LLC, Evergreen, CO (US)

Appl. No.: 13/544,396

Filed: Jul. 9, 2012

Related U.S. Application Data

Continuation-in-part of application No. 12/390,209, filed on Feb. 20, 2009, which is a continuation of application No. 11/439,572, filed on May 23, 2006, now Pat. No. 7,494,945, Continuation-in-part of application No. 12/962,540, filed on Dec. 7, 2010, which is a continuation-in-part of application No. 11/972,577, filed on Jan. 10, 2008, which is a continuation-in-part of application No. 11/439,572, filed on May 23, 2006, now Pat. No. 7,494,945, said application No. 12/962,540 is a continuation-in-part of application No. 12/390,209, filed on Feb. 20, 2009.

Provisional application No. 60/684,890, filed on May 26, 2005.

Publication Classification

Int. Cl.
A43B 7/04 (2006.01)
A43B 7/02 (2006.01)

U.S. Cl. ........................................... 36/2.6

ABSTRACT

The Thermal Footwear System includes an energy storage section adapted to store electrical energy and an energy release section electrically coupled to the energy storage section, configured to receive electrical energy from the energy storage section and utilize the electrical energy for production of thermal energy without requiring the use of energy overhead elements which cause expenditure of energy for other than heat generation. The Thermal Footwear System also provides for an energy storage section and a self-regulating energy release section printed on a substrate that can be physically separate and still remain electrically coupled. The energy release section typically comprises a multilayer device that consists of an active thermal element with a wide resistive range generating the thermal output, a thermally conductive guidance layer evenly distributing the generated heat over a predetermined area, and a thermally insulating impedance layer reducing the loss of generated heat to the ambient environment.
**FIG. 7**

**Non-Regulating Heating System**

- **Energy Storage Section**
  - Power system with no output waveform
  - Electrical Energy
  - On/Off Switch

- **Energy Release Section**
  - Supply Regulation
  - Heat Output
  - Resistive load with limited or no resistance variation
  - Time

**Supply Side Regulated Heating System**

- **Energy Storage Section**
  - Power system with output waveform control
  - Electrical Energy
  - Output Control (Sensors, Thermostat, Processors, etc.)
  - On/Off Switch

- **Energy Release Section**
  - Supply Regulation
  - Heat Output
  - Resistive load with limited or no resistance variation
  - Time
  - Wavy line indicating varying waveform

**Variable Resistance Load Side Regulated Heating System**

- **Energy Storage Section**
  - Power system with no output waveform
  - Electrical Energy
  - On/Off Switch

- **Energy Release Section**
  - Supply Regulation
  - Heat Output
  - Varying resistive load
  - Time
  - Wavy line indicating varying waveform
THERMAL FOOTWEAR SYSTEM
CROSS-REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present Thermal Footwear System is directed to a self-regulating, battery-powered heat generator apparatus, which is located in a space enclosed by a footwear, for generating a thermal output to heat the wearer.

[0004] 2. Description of the Related Art

[0005] It is a problem in footwear, especially footwear for use in changing thermal environments, to provide the wearer with adequate thermal protection from the elements. In the case of footwear for outdoor cold weather sports, such as hunting, skiing, and hiking, there is also a need for a source of supplemental heat, since the ambient temperatures can be sufficiently low enough to cause significant heat loss from the wearer's body, especially their extremities, in spite of the thermal protection provided by the footwear.

[0006] Presently, there are footwear heating systems which respond to the changing thermal environment by regulating their heat output. These systems regulate their temperature by supplying temporally changing power out to a static resistive load or to a load with limited resistive range. As examples of this known technology, mention might be made of U.S. Pat. Nos. 6,049,062 and 6,439,942, both of which describe footwear heating systems with thermostatic control. These systems use a control system, including: sensors, thermostats, processors, electronic switches, etc., to change the output of the power system to achieve the desired heating response from the heater. U.S. Pat. No. 5,643,480 teaches a self-regulating heater that is stratified with the battery, thereby keeping the battery and the heater physically and thermally coupled so the heater can keep the battery at an elevated temperature. A British Patent, WO2005/020635, provides an example of a self-regulating heater element made of a heat-generating material that is poured into an open structure mold and then cured to produce a lattice-like heating element.

[0007] All of these prior art devices for heating larger or smaller parts of the body of a patient or general user suffer from numerous common drawbacks. One such drawback is that the non-self-regulating prior art heating systems consume considerable quantities of power and, therefore, are expensive in their power consumption during operation. The amount of power consumed in "Energy Overhead" to operate the control system (such as sensors, thermostats, processors, electronic switches, etc.) creates an inadequate length of time during which the systems generate heat. Another drawback is that the possibilities of regulating the heating effect locally, i.e., within a limited part of the body, are poor. In other words, the user must choose between either a heating effect which gives satisfactory heating of the coldest part of the body, which at the same time results in overheating of other parts of the body, or a heating effect which provides comfortable heating of the major part of the body but insufficient heating within certain other parts of the body. Another drawback is that some type of external thermostat is necessary in order to be able to obtain a determined average temperature. A further drawback inherent in the device of U.S. Pat. No. 5,643,480 is that it requires the battery and self-regulating heating element to be coupled together so that a certain temperature is maintained in the battery. This severely limits the design flexibility of a heating system with regard to both temperature and geometry, since the currently available battery technology cannot be exposed to high temperatures; and the battery thickness can decrease flexibility in an articulated area where heat is desired. Yet another drawback in the self-regulating prior art is that the heating element must be a heat-generating material that is poured and cast and cured in an open structure mold. This type of cast and molded heating element adds complexity to manufacturing a self-regulating heater as well as size and is not conducive to a highly diversified, mass-manufactured system.

[0008] Hence, there is a need for a footwear heating system that operates in a more energy efficient manner than existing footwear heating systems, does not require the heater and battery to be stratified, and, whose self-regulating heater designs can be quickly and simply printed on various thin substrates to achieve a virtually endless supply of geometries and heating performances.

BRIEF SUMMARY OF THE INVENTION

[0009] The Thermal Footwear System includes a power source electrically coupled to a temporally changing resistive load for the production of thermal energy (for heating and/or cooling) without requiring the use of Energy Overhead elements which cause the expenditure of energy for other than heat generation. The variable resistive load operates over a wide enough resistance range that no Pulse Width Modulation (PWM) is required by the system to control the heat output. The heating element or variable resistive load typically comprises a multilayer device that uses an active thermal element for generating the thermal output, a thermally conductive guidance layer for evenly distributing the generated heat over a predetermined area, and a thermally insulating impedance layer to reduce the loss of the generated heat to the ambient environment. The preferred thermal element is printed onto a substrate enabling many different geometric and heating designs to be easily constructed. Also, there is an energy recharge section, electrically connectable to the energy storage section, adapted to receive electrical energy either for storage by the energy storage section, or for use by the heating element, or simultaneous storage in the energy storage section and immediate use by the heating element.

[0010] The wide range of the variable resistance in the heating element portion of the system allows the system to regulate thermal energy without the use of a traditional PWM-type control system. In fact, the control system asserts no control over the output to the resistive load other than to
The changing resistance of the load is all that is used to regulate the power through the circuit and thereby regulate the heat output. A Positive Temperature Coefficient printed resistive heater with sufficient resistive range can be used to implement a thin film, self-regulating heater which can be coupled to a non-regulating power supply to form the heating system. In the case of the Positive Temperature Coefficient resistive heater, it is built to regulate itself specifically to a temperature determined before manufacture; and its resistive range is wide enough that no control of the supply side of the circuit is used to regulate the heat output of the system other than to turn the entire system on or off. This means that the resistive heating element changes its resistance depending on the instantaneous temperature of the heater without the use of sensors and added circuitry. In addition, the Positive Temperature Coefficient resistive heater is powered by the DC voltage output of the energy storage section without the need for voltage converters or complex control circuitry and does not need to be stratified with the energy storage section. The unregulated DC voltage output in this case can be a native battery voltage. As noted above, the heater includes a Thermal Guidance System which typically consists of two layers: a thermally conductive guidance layer which facilitates heat flow from areas of high concentration to areas of low concentration via a path of least resistance over a predetermined surface area, and a thermally insulating impedance layer to reduce the loss of the generated heat to the ambient environment. In the case of a lighting application, a photo-resistive load would be used to self-regulate the light emission; and in the case of cooling, a thermal-resistive load would be used to self-regulate the cooling.

The energy storage section of the Thermal Footwear System consists of a battery pack that can be placed inside a footwear pocket or panel separate from the heater and connected via wire. The battery pack contains an energy storage element such as at least one rechargeable lithium battery or rechargeable lithium polymer derivative battery and all the necessary electronic components needed for safe operation of the battery. In the preferred embodiment, the battery pack would provide the native battery voltage for use by the energy release section. In the case that the batteries are flexible lithium polymer, Protective Battery Layers are provided to keep the batteries from being punctured/creased/impacted, while an outer membrane is laminated around the batteries to maintain flexibility and moldability of the energy storage section.

The energy storage section also is electrically connected to an on/off switch via a connectorized cable. The use of a connector on the energy storage section also provides a means to recharge the batteries via an external battery charger which can be plugged into the energy storage section connector when the heating system is not in use.

While the following description uses the term “heating,” it is understood and described herein how electronic cooling or lighting can be implemented using the structures disclosed and claimed herein. Therefore, the description is simplified by using the term “heating,” which term is operationally interchangeable with the terms “cooling” and “lighting.”

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of the present Thermal Footwear System will be more readily appreciated as the same become better understood from the following detailed description when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an isometric illustration of the present Thermal Footwear System as embodied in footwear;

FIG. 2 is a perspective exploded view of one embodiment of the energy release section of the present Thermal Footwear System as embodied in footwear;

FIG. 3 is a cross-section view of the energy release section of the present Thermal Footwear System as embodied in footwear;

FIG. 4 is a perspective view of the energy release section of the present Thermal Footwear System as assembled into the footwear insole;

FIG. 5 is an exploded view of the elements used to implement the energy storage section;

FIG. 6 is a perspective exploded view of an alternative embodiment of the energy release section of the present Thermal Footwear System;

FIG. 7 is a comparison showing the differences in other regulation paradigms and control systems from the regulation and control system used in the present Thermal Footwear System;

FIG. 8 illustrates a perspective view of a boot equipped with the Thermal Footwear System;

FIG. 9 illustrates a perspective view of the Energy Storage Subsystem of the Thermal Footwear System; and

FIG. 10 illustrates a power plug used in the Thermal Footwear System.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

There are common terms which are used in the footwear industry to describe various footwear elements. Some of these are noted herein.

Sole—The bottom of a shoe is called the sole.

Insole—The insole is the interior bottom of a shoe, which sits directly beneath the foot under the footbed (also known as “sock liner”). The purpose of an insole is to attach to the lasting margin of the upper, which is wrapped around the last during the closing of the shoe during the lasting operation. Insoles usually are made of cellulose paper board or synthetic non-woven insole board. Many shoes have removable and replaceable footbeds. Extra cushioning is often added for comfort (to control the shape, moisture, or smell of the shoe) or health reasons (to help deal with defects in the natural shape of the foot or positioning of the foot during standing or walking). Basically, this is a main part of shoes which can absorb foot sweat. Footbeds typically should use foam cushioning sheets like latex and EVA (ethylene vinyl acetate), which provide good wearing comfort of the shoe.

Outsole—The outsole is the layer in direct contact with the ground. Dress shoes often have leather or resin rubber outsoles; casual or work-oriented shoes have outsoles made of natural rubber or a synthetic material like polyurethane. The outsole may comprise a single piece, or it may be an assembly of separate pieces of different materials. Often, the heel of the sole has a rubber plate for durability and traction, while the front is leather for style. Specialized shoes often will have modifications on this design: athletic or so-called cleated
shoes like soccer, rugby, baseball, and golf shoes have spikes embedded in the outsole to grip the ground.

[0029] Midsole—The layer between the outsole and the insole typically is there for shock absorption. Some types of shoes, like running shoes, have another material for shock absorption, usually beneath the heel of the foot, where one puts the most pressure down. Different companies use different materials for the midsoles of their shoes. Some shoes may not have a midsole at all.

[0030] Heel—The bottom rear part of a shoe is the heel. Its function is to support the heel of the foot. They are often made of the same material as the sole of the shoe. This part can be high for fashion or to make the person look taller, or flat for a more practical and comfortable use.

[0031] Vamp/Upper—Every shoe has an upper part that helps hold the shoe onto the foot. In the simplest cases, such as sandals or flip-flops, this may be nothing more than a few straps for holding the sole in place. Closed footwear, such as boots, trainers, and most men’s shoes, will have a more complex upper. This part often is decorated or is made in a certain style to look attractive.

[0032] Lateral/Medial—The outside part of the shoe is referred to as the lateral, and the inside facing part of the shoe is the medial. This can be in reference to either the outsole or the vamp.

Boots

[0033] A boot is a type of footwear which generally completely covers the foot and the ankle and can extend up the leg, sometimes as far as the knee or even the hip. Most boots have a heel that is clearly distinguishable from the rest of the sole, even if the two are made of one piece. Traditionally made of leather or rubber, modern boots are made from a variety of materials. Boots are worn both for their functionality—protecting the foot and leg from water, snow, mud, or hazards, or providing additional ankle support for strenuous activities—and for reasons of style and fashion.

[0034] Boots designed for field use and outdoor cold weather sports, such as hiking, hunting, snowshoeing, and skiing, may be made of a single closely-stitched design (using leather, rubber, canvas, or similar material) to prevent the entry of water, snow, mud, or dirt through gaps between the laces and tongue found in other types of shoes. Waterproof gumboots are made in different lengths of uppers. In extreme cases, thigh-boots, called “waders” and worn by anglers, extend to the hip. Such boots also may be insulated for warmth. Boots normally are worn with socks to prevent chafes and blisters, to absorb sweat, and to improve the foot’s grip inside the boot. Before socks became widely available, footwraps were worn instead. Specialty boots have been designed for many different types of sports, particularly riding, skiing, snowboarding, ice skating, and sporting in wet conditions.

[0035] It is typical that boots designed for field use and outdoor cold weather sports are a desirable application for the present Thermal Footwear System. While this is just one example of an application, it is used for simplicity of description and to illustrate the concepts embodied in the present Thermal Footwear System, not as a limitation of the scope and content of the inventive concepts of the present Thermal Footwear System. Thus, the term “boot” as used herein is simply an illustration and represents just one example of a footwear.

Basic Architecture of the Thermal Footwear System

[0036] FIG. 1 is an isometric illustration of the present Thermal Footwear System 1 and illustrates the primary components which make up the present Thermal Footwear System 1. In particular, the Thermal Footwear System 1 includes an energy release section 11 and an energy storage section 12. The energy release section 11 is shown in FIG. 1 as part of a footpad 13 which is insertable into a boot or an integral part of a boot. The extent (surface area) of the energy release section 11 is a function of the portion of the wearer’s foot that is to be provided with supplemental heat and the quantity of heat that is to be generated. This illustration shows an energy release section 11 that is concentrated under the wearer’s toe area, since the heel and insole of the wearer’s foot are less susceptible to cold; and it is the peripheral circulation in the toe area of the wearer’s foot that is most impacted by cold temperatures. It is expected that another energy release section (not shown) to supplement this energy release section 11 or an energy release section 11 having a different areal pattern can be used for this purpose.

[0037] The footbed 13 has formed in the top surface thereof a recess 14A to receive the energy release section 11 in order to present a flat surface to the wearer’s foot. In addition, a recess 14B is formed in the footbed 13 to provide a channel for the insertion of a set of electrical conductors 15 which interconnect the energy release section 11 with the energy storage section 12.

Details of the Thermal Footwear System Energy Release Section

[0038] FIG. 2 is a perspective exploded view of one embodiment of the energy release section 11 of the present Thermal Footwear System 1; FIG. 3 is a cross-section view of the energy release section 11 of the present Thermal Footwear System 1; and FIG. 4 is a perspective view of the energy release section 11 of the present Thermal Footwear System 1 as assembled into a footbed.

[0039] As noted above, the energy release section 11 typically comprises a multilayer device that consists of an active thermal element 21 for generating the thermal output, a thermally conductive guidance layer 22 for evenly distributing the generated heat over a predetermined area, and a thermally insulating impedance layer 23 to reduce the loss of the generated heat to the ambient environment. In the energy release section 11, a Positive Temperature Coefficient resistive heater can be used to implement a thin film, self-regulating heater section 21 which can be formed into the footbed 13 of the footwear or used as an insert in the footwear. In the case of the Positive Temperature Coefficient resistive heater, its heater is built to regulate itself specifically to a temperature determined before manufacture. This means that the resistive heating element changes its resistance depending on the instantaneous temperature of the heater without the use of sensors and added circuitry. In addition, the Positive Temperature Coefficient resistive heater is powered by the DC voltage output by the energy storage section 12 without the need for voltage converters, inverters, or complex control circuitry. As noted above, the energy release section 11 includes a Thermal Guidance System 20 which typically consists of two layers: a
thermally conductive guidance layer 22 which facilitates heat flow from areas of high concentration to areas of low concentration via a path of least resistance over a predetermined surface area, and a thermally insulating impedance layer 23 to reduce the loss of the generated heat to the ambient environment.

[0040] As shown in FIG. 3, the heat generated by the active thermal element 21 flows not only upward to the wearer’s foot (not shown), but also laterally through the thermally conductive guidance layer 22, and also upward from the thermally conductive guidance layer 22 to the wearer’s foot. Thus, the active thermal element 21 need not cover the entirety of the top surface area of the energy release section 11 but can operate by the heat distribution function of the thermally conductive guidance layer 22. In fact, FIG. 6 is a perspective exploded view of an alternative embodiment of the energy release section 11 of the present Thermal Footwear System 1, where the energy release section 11 includes a plurality of thermal energy output elements 31, 32, 33. Each of the plurality of thermal energy output elements 31, 32, 33 generates heat for release in an upward direction, while the intervening spaces between the plurality of thermal energy output elements 31, 32, 33 (and the margins of the energy release section 11) distribute heat upward through the action of the thermally conductive guidance layer 22.

[0041] Thus, the Thermal Footwear System 1 can be integrated into the footbed 13 of a boot, with its electrical conductors 15 routed through a channel 16 formed in the footbed 13 to the margin of the footbed 13, for routing through the vamps of the boot, the energy storage section 12, and thence to the switch 16.

[0042] Viewing heating and cooling more expansively, the thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a difference temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference (known as the Peltier effect). At atomic scale (specifically, charge carriers), an applied temperature gradient causes charged carriers in the material, whether they are electrons or electron holes, to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence, the thermally induced current. Mobile charged carriers migrating to the cold side leave behind their oppositely charged and immobile nuclei at the hot side, thus giving rise to a thermoelectric voltage ("thermoelectric" refers to the fact that the voltage is created by a temperature difference). Since a separation of charges also creates an electric potential, the buildup of charged carriers onto the cold side eventually causes at some maximum value, since there exists an equal amount of charged carriers drifting back to the hot side as a result of the electric field at equilibrium. Only an increase in the temperature difference can resume a buildup of more charge carriers on the cold side and thus lead to an increase in the thermoelectric voltage. Incidentally, the thermopower also measures the entropy per charge carrier in the material. To be more specific, the partial molar electronic heat capacity is said to equal the absolute thermoelectric power multiplied by the negative of Faraday’s constant.

[0043] This Peltier effect can be used to generate electricity, to measure temperature, to cool objects, to heat them, or to cook them. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices make very convenient temperature controllers. Traditionally, the terms “thermoelectric effect” or “thermoelectricity” encompass three separately identified effects: the Seebeck effect, the Peltier effect, and the Thomson effect.

[0044] The Seebeck effect is the conversion of temperature differences directly into electricity. The effect is that a voltage, the thermoelectric EMF (electromagnetic field), is created in the presence of a temperature difference between two different metals or semiconductors. This causes a continuous current in the conductors if they form a complete loop. The voltage created is of the order of several microvolts per kelvin of temperature difference. One such combination, copper-constantan, has a Seebeck coefficient of 41 microvolts per kelvin at room temperature. The thermopower, thermoelectric power, or Seebeck coefficient of a material measures the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material. The term “thermopower” is a misnomer, since it measures the voltage or electric field induced in response to a temperature difference, not the electric power.

[0045] Refrigeration is the process of removing heat from an enclosed space, or from a substance, and moving it to a place where it is unobjectionable. The primary purpose of refrigeration is lowering the temperature of the enclosed space or substance and then maintaining that lower temperature. The term “cooling” refers generally to any natural or artificial process by which heat is dissipated. The process of artificially producing extreme cold temperatures is referred to as “cryogenics.” Cold is the absence of heat; hence, in order to decrease a temperature, one “removes heat” rather than “adding cold.” In order to satisfy the Second Law of Thermodynamics, some form of work must be performed to accomplish this. The work traditionally is done by mechanical work; but it can also be done by magnetism, laser, or other means.

[0046] Thermoelectric cooling uses the Peltier effect to create a heat flux at the junction of two different types of materials. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference (known as the Peltier effect). At atomic scale (specifically, charge carriers), an applied temperature gradient causes charged carriers in the material, whether they are electrons or electron holes, to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence, the thermally induced current.

[0047] For the cooling embodiment of the energy release section 11, a thin film, superlattice, thermoelectric cooling device, as well as a Negative Temperature Coefficient material, is ideal for integration into the footbed 13. Being a thin film device, it can be deposited using fabric sections as its substrate, or it can be deposited on a separate substrate and then laminated with or without an adhesive to the other existing fabric sections.

Details of the Thermal Footwear System Energy Storage Section

[0048] A thin film, lithium ion polymer battery 91 is an ideal flexible, thin, and rechargeable electrical energy storage section 12. These batteries consist of a thin film anode layer, cathode layer, and electrolytic layer; and each battery 91 forms a thin, flexible sheet that stores and releases electrical energy and is rechargeable. Carbon nanotubes can be used in conjunction with the lithium polymer battery technology to...
increase capacity and would be integrated into the final fabric in the same manner as would a standard polymer battery. It should be noted that the energy storage section 12 should consist of a material whose properties do not degrade with use and flexing. In the case of lithium polymers, this generally means the more the electrolyte is plasticized, the less the degradation of the cell that occurs with flexing.

[0049] Another technology that can be used for the energy storage section 12 is a super-capacitor or ultra-capacitor which use different technologies to achieve a thin, flexible, and rechargeable energy storage film and are good examples in the ultra- and super-capacitor industry as to what is currently available commercially for integration and use in this Thermal Footwear System.

[0050] Thin film micro fuel cells of different types (poly-electrolyte multilayer [PEM], direct methanol fuel cells [DMFC], solid oxide, micro-electrical mechanical systems [MEMS], and hydrogen) can be laminated into the final fabric to provide an integrated power source to work in conjunction with (hybridized), or in place of, a thin film battery or thin film capacitor storage section.

[0051] FIG. 5 is an exploded view of the elements used to implement the energy storage section 12. Protective Battery Layers 92, 93 constitute sheets of polyethylene laminated around the batteries 91. This maintains flexibility and moldability of the energy storage section 12 and maintains the molded shape. The Protective Battery Layers 92, 93 keep the cells of the battery from being punctured/creased when impacted.

Protective Layers

[0052] There are many products available that can be used for the protective and decorative section(s) 94, 95 that are engineered for next-to-skin wickability, fibrous, fleece-type comfort, water repellency, specific color, specific texture, and many other characteristics that can be incorporated by laminating that section into the final fabric. There are also many thermoplastic urethanes (TPUs) available for use as sealing and protective envelopes. These materials exhibit very high moisture vapor transmission ratios (MVTRs) and are extremely waterproof, allowing the assembled energy storage, release, and recharge sections to be enveloped in a highly breathable, waterproof material that also provides a high degree of protection and durability. In addition to the TPUs, which are a solid monolithic structure, there are also microporous materials that are available for use as breathable, waterproof sealing and protective envelopes. This microporous technology is commonly found in Gore products and also can be used in conjunction with TPUs. It should also be noted that, when laminating these breathable waterproof envelopes around the assembled sections, care must be taken, whether one is using an adhesive or not, to maintain the breathability of the laminate. If adhesive is being used, this adhesive must also have breathable characteristics. The same should be said for a laminate process that does not use adhesive. Whatever the adhesion process is, it needs to maintain the breathability and waterproofing of the enveloping protective section, providing these are traits deemed necessary for the final textile panel.

Embedding Electronic Components in Film Substrates

[0053] The present Thermal Footwear System 1 also provides techniques for sealing devices, such as electronic circuits, components, and electrical energy storage devices inside a highly flexible, robust laminate panel for subsequent integration into a larger system. This Thermal Footwear System 1 provides a system where the devices, such as electronic circuits, components, and energy storage devices, are embedded between laminated film substrates to form a flexible, environmentally sealed, finished laminate able to be integrated into a larger system such as a footwear or accessory. The embedded circuits, components, and energy storage devices can be included in many different substrate layers within the finished laminate. The devices also can be located in separate panels and connected together via external connectors to provide a larger system. It is possible to produce a finished laminate with environmentally sealed and embedded electrical components, circuits, and energy storage devices that is thin and flexible.

Details of the Thermal Footwear System Variable Resistance Load Side Heating System

[0054] FIG. 7 shows how the self-regulating variable resistance load side heating system used in the Thermal Footwear System 1 differs with respect to a non-regulated heating system and a supply side regulated heating system. A non-regulated system is shown where the heat output does not change over time, and a supply side regulated heating system is shown where the heat output changes over time due to the supplied power changing over time. Both of these systems use a resistive load with limited or no resistance variation. In the case of the supply side regulated heating system, regulation is accomplished by changing the supplied power, or by some combination of changing supply power and limited load resistance changes, not by changes in the load resistance alone. To accomplish this type of supply side regulation, a processing system along with sensors must be used to calculate and manipulate the power output to the load in order achieve the desired performance from the system. In the case of the variable resistance load side regulated heating system, none of this calculation, manipulation, or external sensing is required. The variable resistive load intrinsically changes its resistance due to instantaneous environmental conditions and pulls the required power from the energy storage section. In this way, the self-regulating heating system is greatly simplified; and the energy overhead required to run the external sensors, processors, and ancillary components is eliminated. In FIG. 7, heat is shown to be the energy release of the system. However, it should be noted that the Thermal Footwear System 1 also provides for energy releases resulting in lighting and cooling.

[0055] FIG. 8 illustrates a perspective view of a boot equipped with the Thermal Footwear System; FIG. 9 illustrates a perspective view of the energy storage section 12 of the Thermal Footwear System; and FIG. 10 illustrates a power plug used in the Thermal Footwear System. As described above, a boot is a typical application of the Thermal Footwear System. In FIG. 8, a typical hiking boot 800 is shown in a perspective view, with the on-off switch 801 shown as installed on the upper of boot 800. The energy storage section 12 of FIG. 1 is located inside of boot 800 in the upper portion 802 thereof. FIG. 9 illustrates the energy storage section 12 of FIG. 1, where the assembly 900 consists of two battery packs 911, 912, encased in a protective, padded covering. A strip of Velcro™-type material 903 can be used to affix the energy storage section 12 to the inside surface of the boot 800. A plug 901 is also shown, which connects to on-off
switch 801 via plug 903 as shown in FIG. 10. The set of electrical conductors 15, which interconnect the energy release section 11 with the energy storage section 12 as shown in FIG. 1, are interconnected by these two connectors.

SUMMARY

The Thermal Footwear System includes an energy storage section adapted to store electrical energy and an energy release section electrically coupled to the energy storage section, configured to receive electrical energy from the energy storage section and to utilize the electrical energy for the production of thermal energy without requiring the use of energy overhead elements which cause the expenditure of energy for other than heat generation. The Thermal Footwear System also provides for an energy storage section and a self-regulating energy release section printed on a substrate that can be physically separate, not stratified to one another, and still remain electrically coupled. The energy release section typically comprises a multilayer device that consists of an active thermal element with a wide resistive range for generating the thermal output, a thermally conductive guidance layer for evenly distributing the generated heat over a predetermined area, and a thermally insulating impedance layer to reduce the loss of the generated heat to the ambient environment.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A thermal footwear system, comprising:
an energy storage section configured to store electrical energy; and
an energy release section configured to release electrical energy that is stored in the energy storage section, comprising:
a variably resistive heating element for generating regulated thermal emissions by utilizing the electrical energy stored in the energy storage section.

2. The thermal footwear system of claim 1 wherein the energy release section includes:
a thermal direction layer for spreading the generated thermal energy in a plane which is coplanar with the top surface of said thermal element.

3. The thermal footwear system of claim 2 wherein the thermal direction layer consists of two layers:
a highly conductive layer, and a reflective layer overlaid on an insulative layer.

4. The thermal footwear system of claim 1 wherein the energy release section is removable and replaceable.

5. The thermal footwear system of claim 1 wherein the variably resistive heating element includes:
a self-regulating thermal generator for maintaining a substantially constant temperature absent the use of control circuitry.

6. The thermal footwear system of claim 5 wherein the self-regulating thermal generator comprises:
a positive temperature coefficient resistive heater where the resistive heating element changes its resistance depending on the instantaneous temperature of the heater.

7. The thermal footwear system of claim 5 wherein the self-regulating thermal generator comprises:
a negative temperature coefficient cooling element which changes its thermal output depending on the instantaneous temperature of the element.

8. The thermal footwear system of claim 1, further comprising:
an energy recharge section connectable to the energy storage section for recharging said battery.

9. The thermal footwear system of claim 1 wherein the energy storage and energy release sections are formed to be flexible and to have at least one of the following characteristics of breathability, moisture wickability, water resistance, waterproof, and stretchability.

10. The thermal footwear system of claim 1 wherein the energy storage section further comprises:
at least one protective layer juxtaposed to said battery and having an extent substantially coextensive with said battery to protect the battery from forces originating exterior to said energy storage section.

11. A thermal footwear system, for use in an enclosed area formed by footwear, comprising:
an energy storage section configured to store electrical energy; and
an energy release section, located in the footwear enclosed area, juxtaposed to a top surface of a sole of the footwear, and electrically connected to the energy storage section, comprising:
a generator for generating thermal emissions utilizing the electrical energy stored in the energy storage section, and
a thermal direction layer for spreading the generated thermal energy in a plane which is coplanar with the top surface of the generator.

12. The thermal footwear system of claim 11 wherein the energy release section is removable and replaceable.

13. The thermal footwear system of claim 11 wherein said generator comprises:
a self-regulating thermal generator for maintaining a substantially constant temperature absent the use of control circuitry.

14. The thermal footwear system of claim 13 wherein the self-regulating thermal generator comprises:
a positive temperature coefficient resistive heater where the resistive heating element changes its resistance depending on the instantaneous temperature of the heater.

15. The thermal footwear system of claim 13 wherein the self-regulating thermal generator comprises:
a negative temperature coefficient cooling element which changes its thermal output depending on the instantaneous temperature of the element.

16. The thermal footwear system of claim 11, further comprising:
an energy recharge section connectable to the energy storage section for recharging the energy storage section.

17. The thermal footwear system of claim 11 wherein the energy storage and energy release sections are formed to be flexible and to have at least one of the following characteristics of breathability, moisture wickability, water resistance, waterproof, and stretchability.

18. The thermal footwear system of claim 11 wherein the energy storage section further comprises:
at least one protective layer juxtaposed to the energy storage section and having an extent substantially coextensive with the energy storage section to protect the energy storage section from forces originating exterior to the energy storage section.

* * * * *