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(54) **TEMPERATURE RESPONSIVE SMART TEXTILE**

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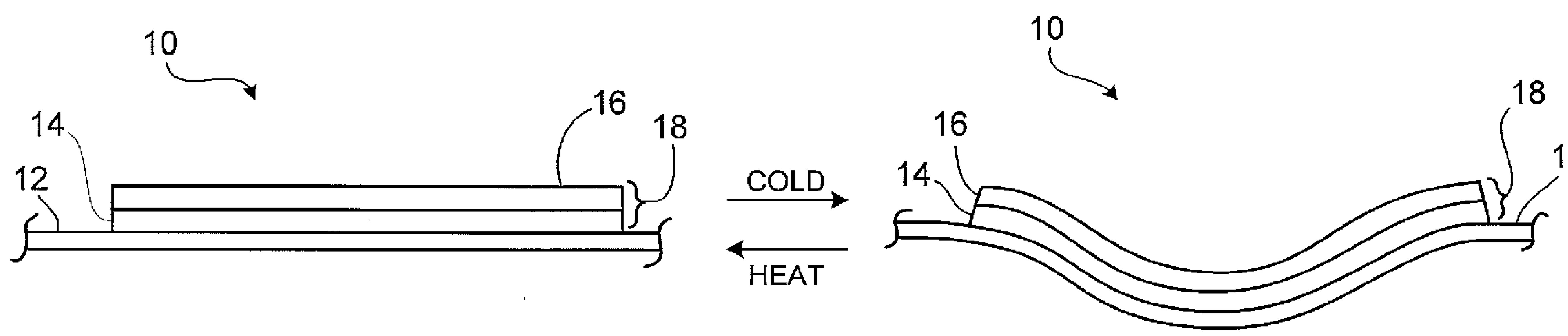
CPC . ***D04B 1/00*** (2013.01); ***D06B 19/00*** (2013.01)

USPC **428/96**; 428/212; 28/169

(57) **ABSTRACT**

A textile fabric includes a smooth surface with one or more regions having coating material exhibiting thermal expansion or contraction in response to change in temperature, adjusting insulation performance of the textile fabric in response to ambient conditions.



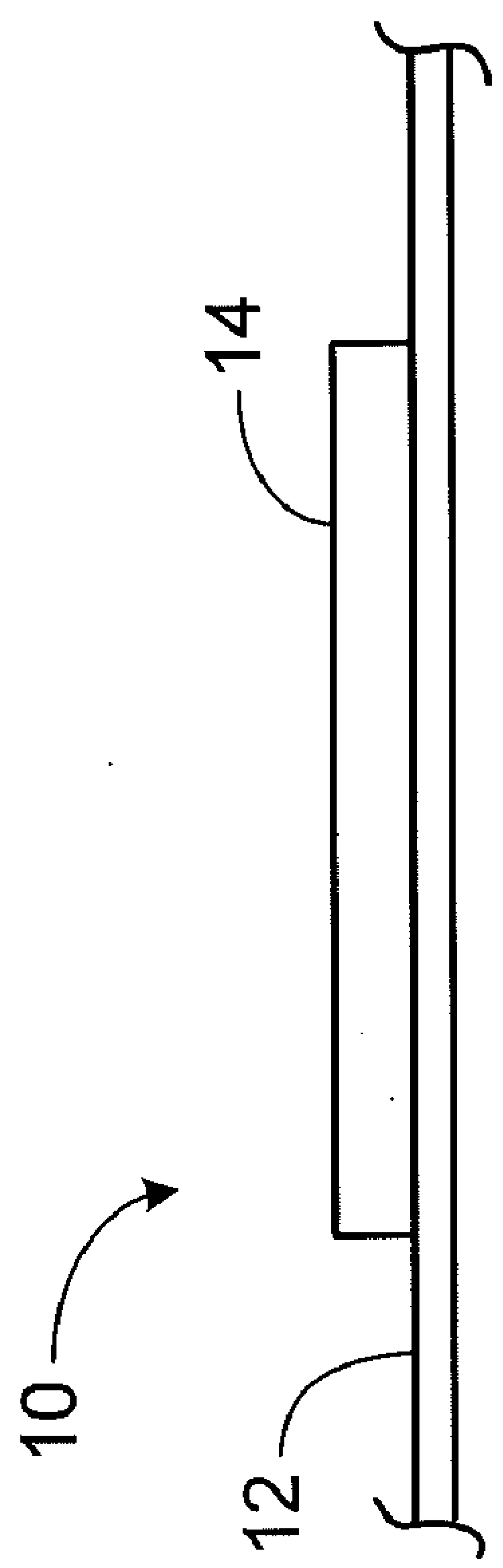


FIG. 1A

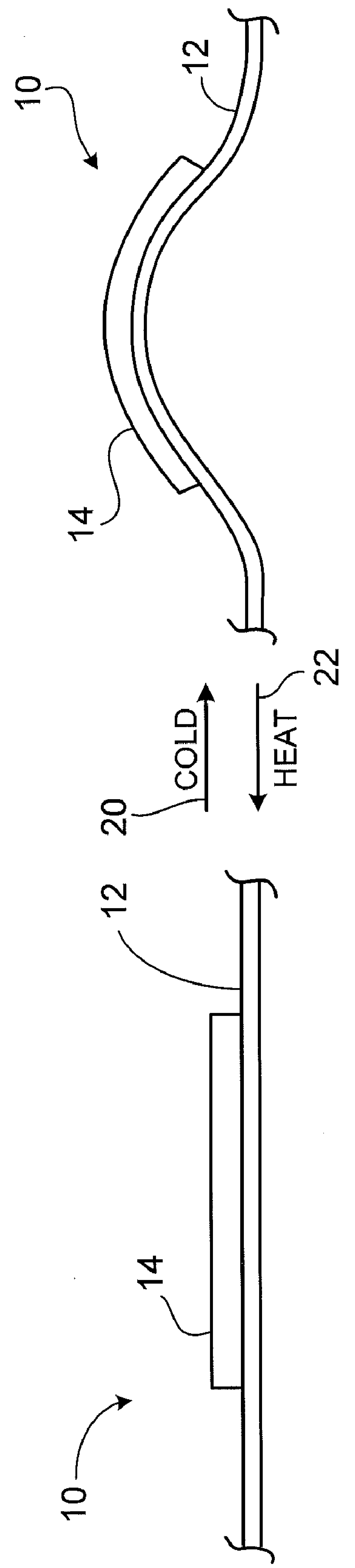


FIG. 1B

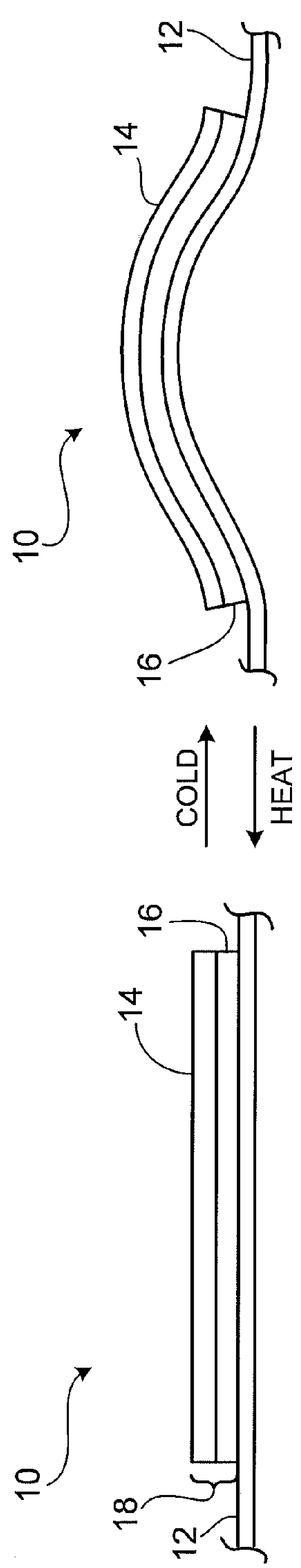


FIG. 2A

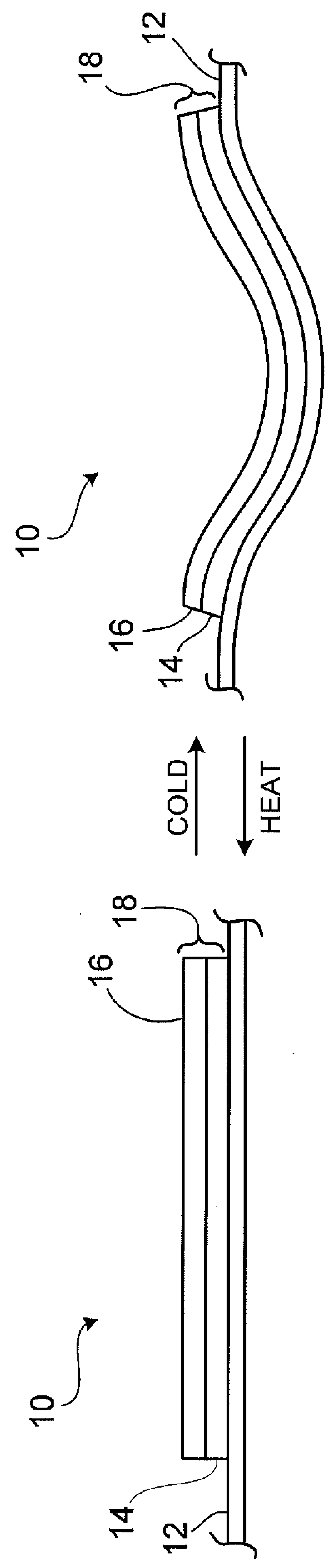


FIG. 2B

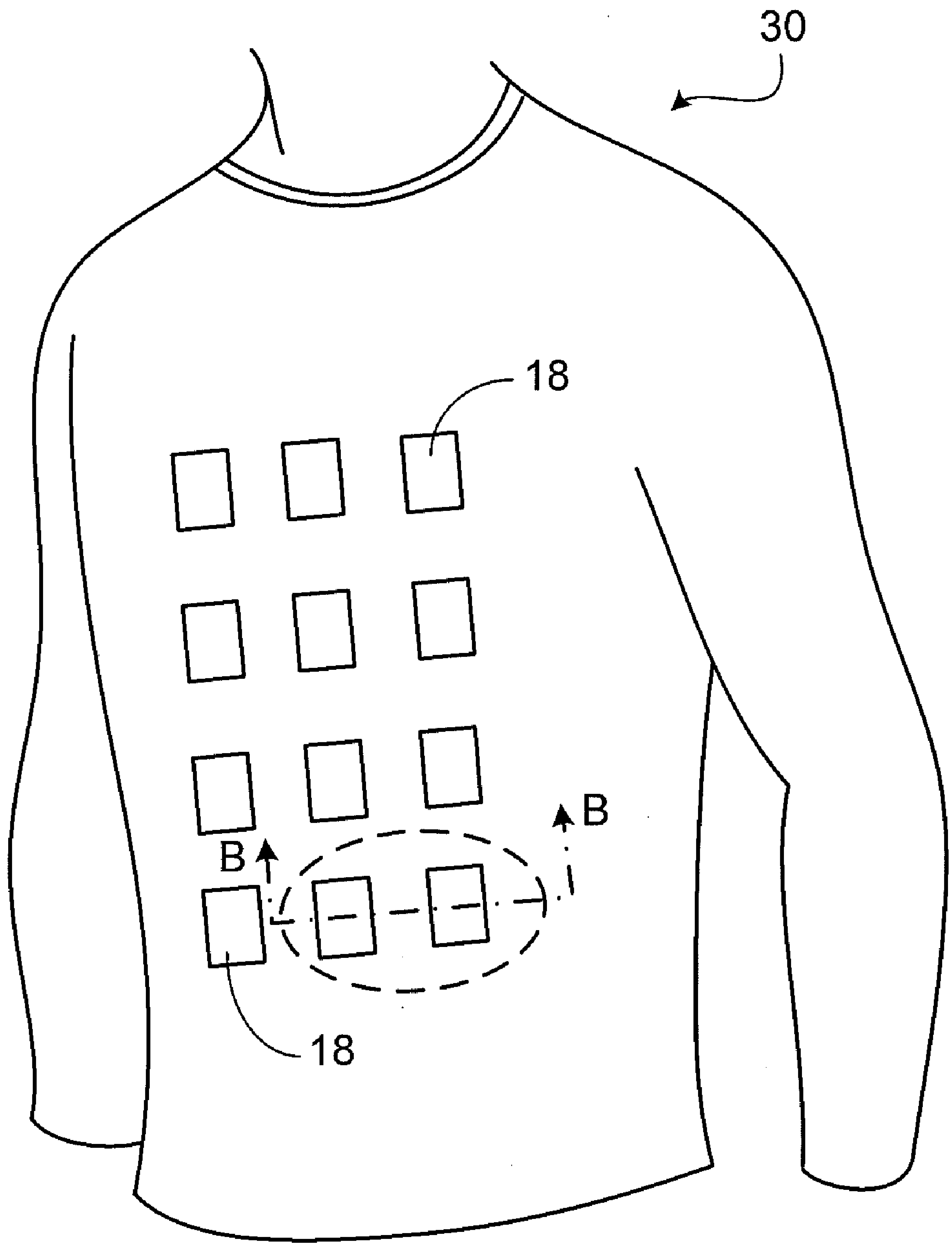


FIG. 3A

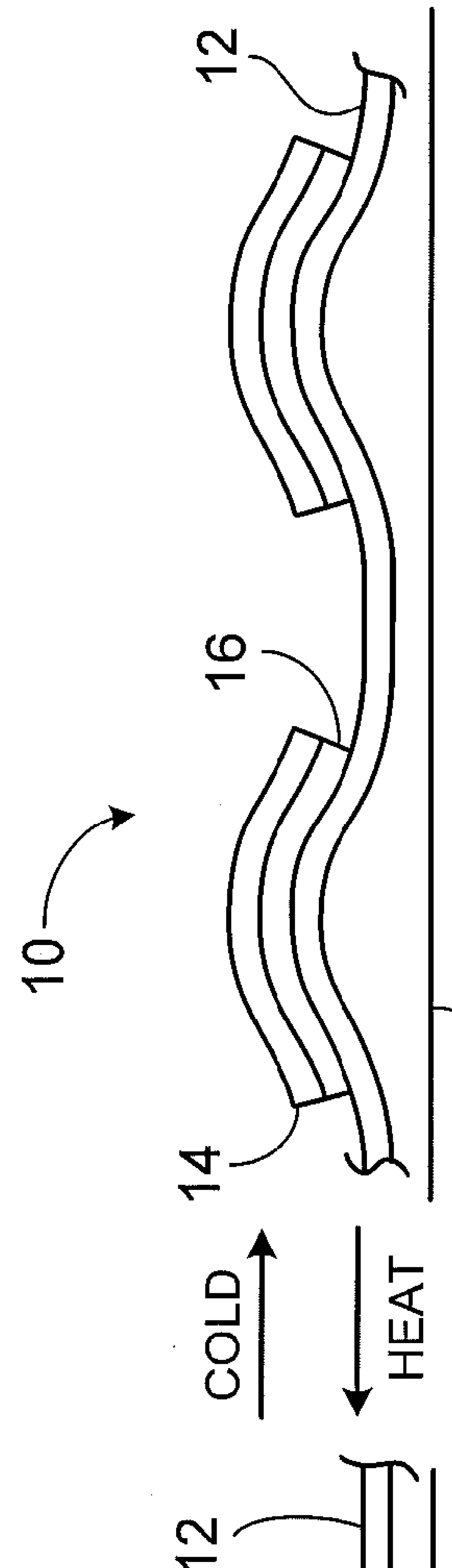


FIG. 3B

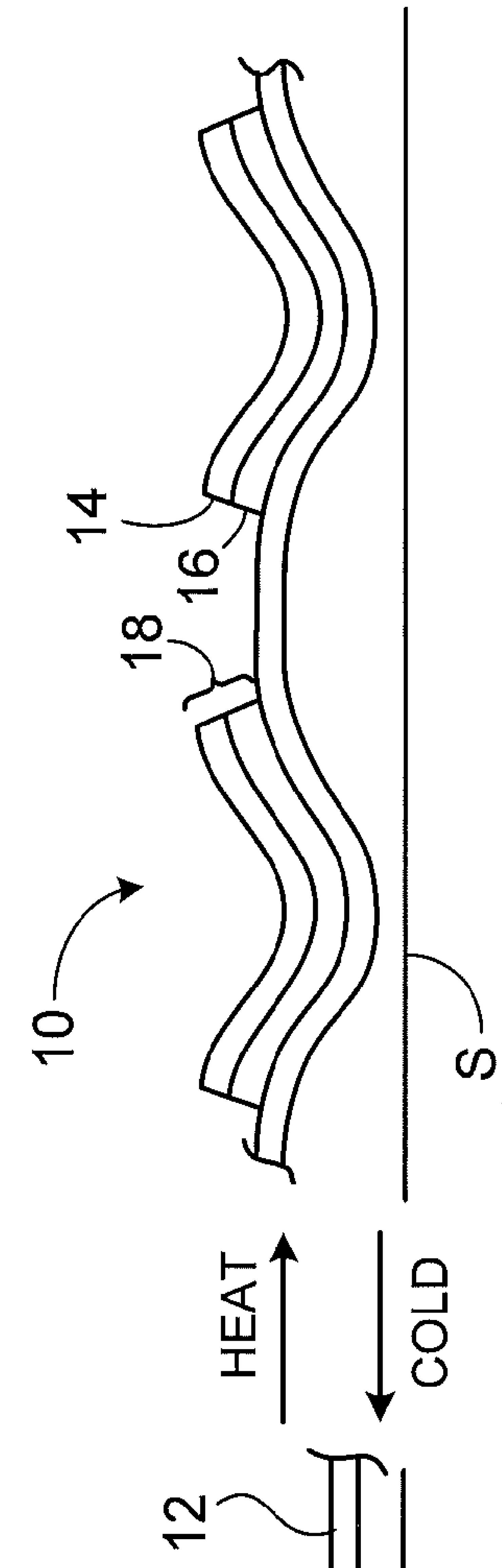


FIG. 3C

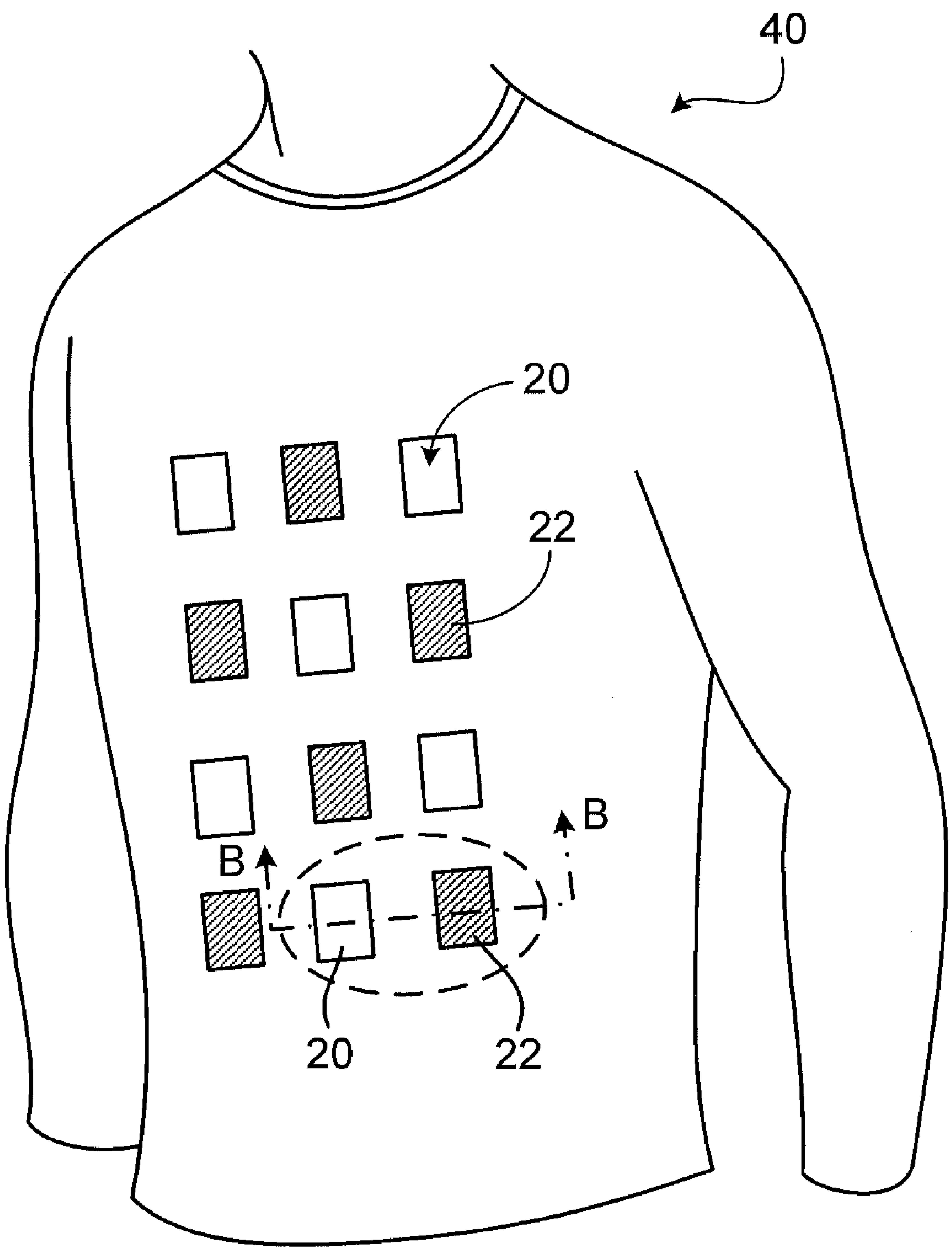


FIG. 4A

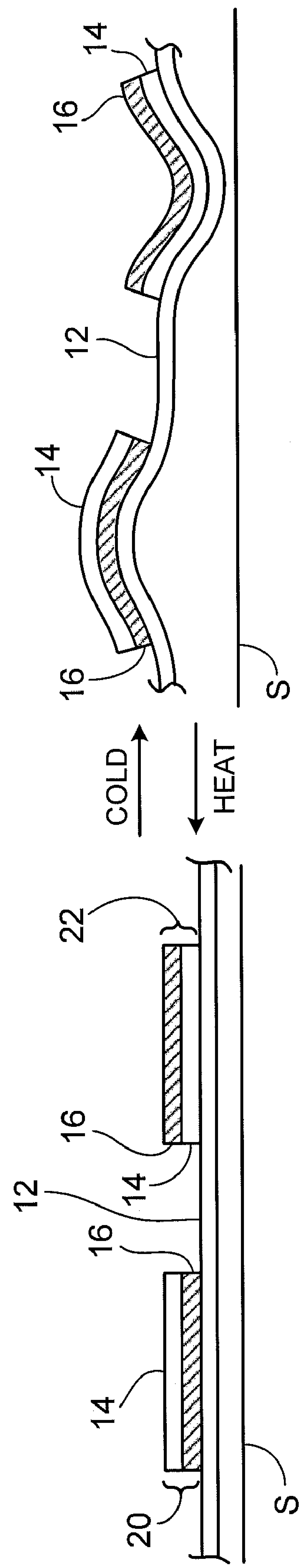


FIG. 4B

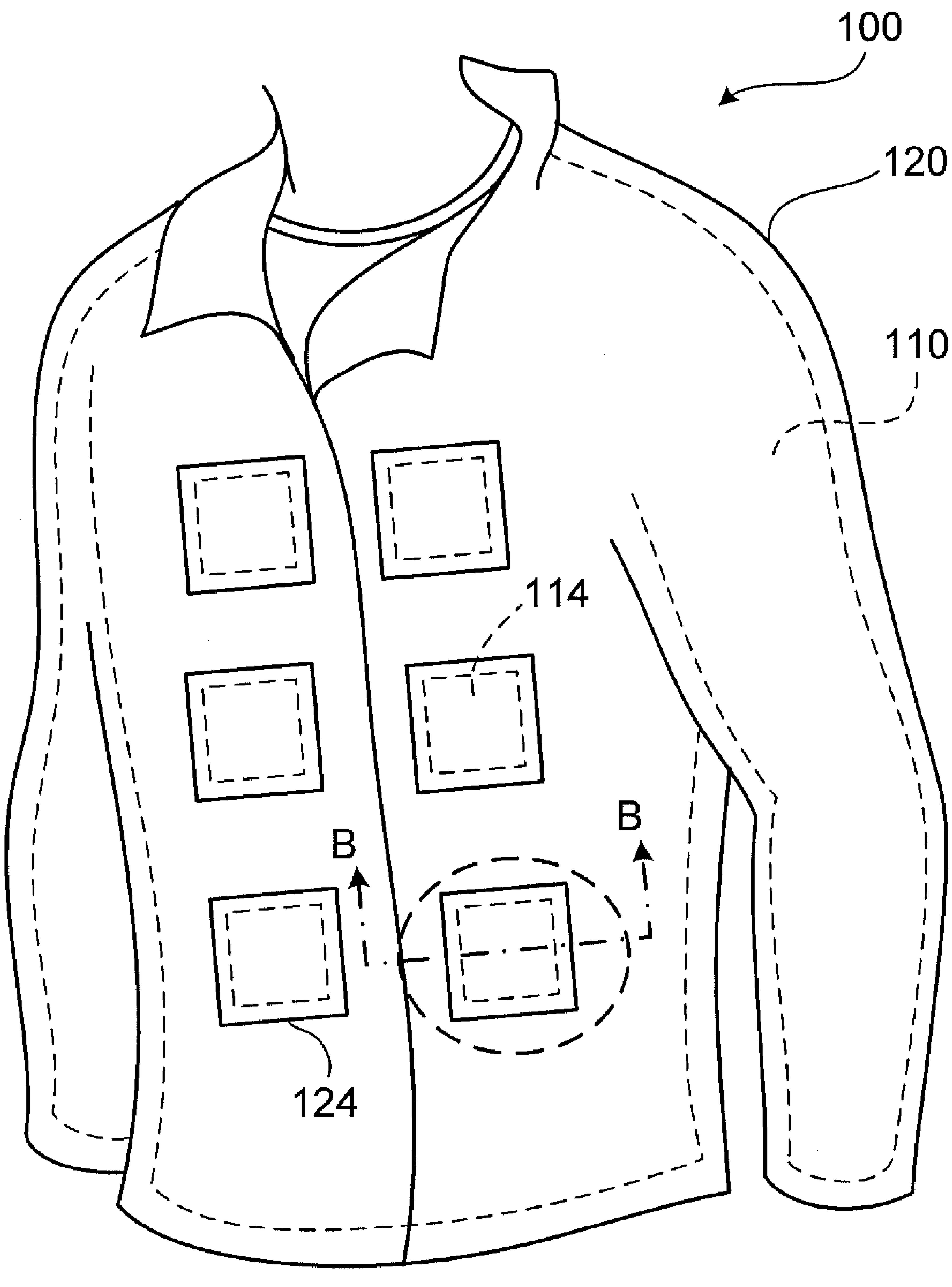
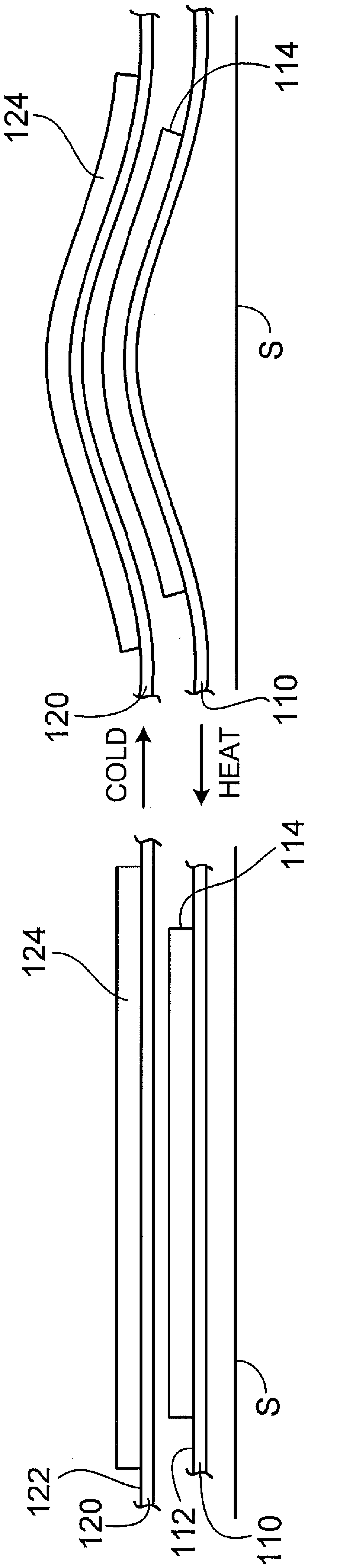


FIG. 5A


124
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120
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COLD
HEAT
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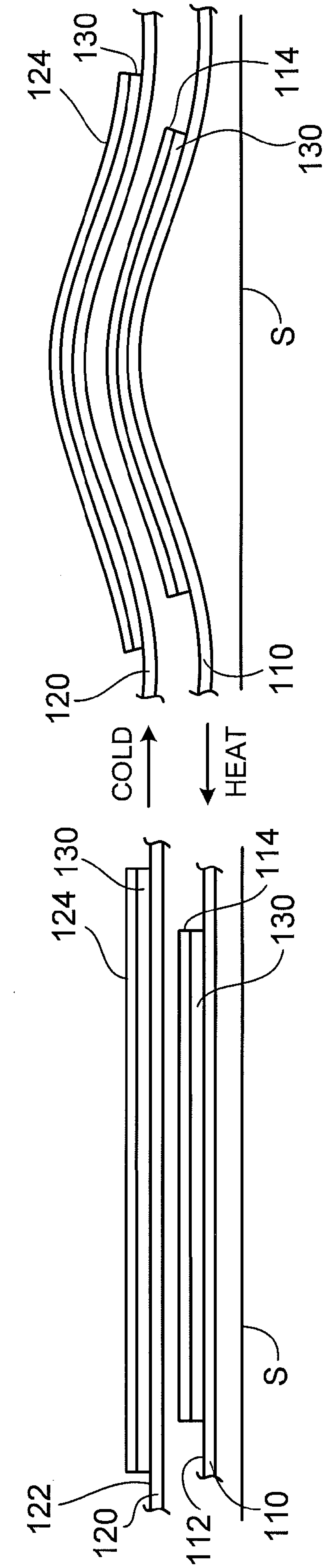
114
122
120
112
S
110

FIG. 5B


124
130
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COLD
HEAT
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114
130
122
120
112
S
110

FIG. 5C

TEMPERATURE RESPONSIVE SMART TEXTILE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Ser. No. 11/740,716, filed Apr. 26, 2007, now allowed, which claims benefit from U.S. Provisional Patent Application 60/804,334, filed Jun. 9, 2006, now expired. The entire contents of both applications are incorporated herein by reference.

TECHNICAL FIELD

[0002] This invention relates to textile fabrics, and more particularly to textile fabrics responsive to change in ambient temperature.

BACKGROUND

[0003] Standard textile fabrics have properties set during fabric construction that are maintained despite changes in ambient conditions and/or physical activity. These standard products are quite effective, especially when layered with other textile fabrics for synergistic effect and enhancement of comfort.

SUMMARY

[0004] According to one aspect, a textile fabric includes a smooth surface with one or more regions of a first coating material exhibiting thermal expansion or contraction in response to change in temperature, adjusting insulation performance of the textile fabric in response to ambient conditions.

[0005] Preferred implementations may include one or more of the following additional features. The textile fabric can include one or more regions of a second coating material overlying one or more regions of the first coating material, the first coating material together with the second coating material forming a bi-component coating at the smooth surface of the textile fabric. The second coating material may be chemically and/or physically bonded to the first coating material. The second coating material is disposed on a first surface of the first coating material opposite the smooth surface of the textile fabric. The first coating material and the second coating material exhibit differential thermal expansion to cause a change in a three dimensional configuration of the textile fabric in response to change in temperature. The first coating material and the second coating material exhibit differential thermal expansion in response to change in temperature over a predetermined temperature range. In some cases, the predetermined temperature range is between about −40° F. and about 140° F. In some examples, the predetermined temperature range is between about 50° F. and about 100° F. In other examples, the predetermined temperature range is between about −40° F. and about 60° F., e.g., between about −20° F. and about 40° F. The first coating material may be a polymer, such as polyurethane. The polymer exhibits volume change by crystallization. The polymer is configured to crystallize at a temperature of between about −40° F. and about 100° F. For example, in some cases, the polymer is configured to crystallize at a temperature of between about 50° F. and about 100° F., e.g., between about 60° F. and about 98° F., e.g., between about 69° F. and about 73° F. In another example, the polymer is configured to crystallize at a temperature of between about −40° F. and about 60° F., e.g., between about −20° F. and about 40° F.

[0006] The second coating material comprises polymer, selected, e.g., from the group consisting of: polyurethanes, silicones, and acrylates. In some embodiments, one or more regions of the second coating material are disposed on the smooth surface of the textile fabric, and the first coating material overlies one or more regions of the second coating material. In some cases, the first coating material is arranged in overlapping relationship with the second coating material such that at least a portion of the first coating material contacts the smooth surface of the textile fabric. The textile fabric includes one or more regions of a second material disposed in side-by-side relationship with the first coating material on the smooth surface of the textile fabric. The textile fabric has a circular knit construction, warp knit construction, and/or woven construction. In any of the above knit constructions, elastic yarn may be added (e.g., spandex such as Lycra® or Lycra® T-400) to, e.g., the stitch yarn. The spandex yarn can include, for example, bare spandex yarn, core spun yarn, wrap yarn, and/or air entangled yarn. The circular knit construction is formed in single jersey construction, double knit construction, or terry sinker loop construction. The terry sinker loop is formed in plaited construction. The terry sinker loop is formed in reverse plaited construction. The terry sinker loop may be raised by napping or may remain in an un-napped condition. The first coating material is disposed in a plurality of predetermined discrete regions on the smooth surface of the textile fabric. The plurality of predetermined discrete regions may be in the form of discrete dots. The first coating material covers between about 5% and about 80% of the surface area of the smooth surface.

[0007] According to another aspect, a method of forming a temperature responsive textile fabric element for use in an engineered thermal fabric garment includes combining yarns and/or fibers to form a continuous web; finishing the continuous web to form at least one smooth surface; and depositing first coating material on the smooth surface, the first coating material exhibiting thermal expansion or contraction in response to change in temperature, adjusting insulation performance of the textile fabric in response to ambient conditions.

[0008] Preferred implementations may include one or more of the following additional features. The step of combining yarn and/or fibers in a continuous web includes combining yarn and/or fibers by circular knitting to form a circular knit fabric. The step of combining yarn and/or fibers in a continuous web by circular knitting includes combining yarn and/or fibers by reverse plaiting. The step of finishing includes finishing one surface of the continuous web to form a terry sinker loop construction. The step of combining yarn and/or fibers in a continuous web by circular knitting includes combining yarn and/or fibers by plaiting. The step of finishing includes finishing one surface of the continuous web to form a terry sinker loop construction. The step of finishing includes finishing the continuous web to form a single jersey construction. The step of finishing includes finishing the continuous web to form a double knit construction. The step of combining yarn and/or fibers in a continuous web includes combining yarn and/or fibers by warp knitting. The step of combining yarn and/or fibers in a continuous web includes combining yarn and/or fibers to form a woven fabric element. The step of depositing the first coating material includes depositing the first coating material in one or more discrete regions on the smooth surface of the textile fabric. The one or more discrete regions are disposed in a pattern corresponding to predetermined areas on an engineered thermal fabric garment typically subjected to relatively high levels of liquid sweat. The predetermined discrete regions are in the form of a plurality of discrete dots. The step of depositing the first coating material includes depositing the first coating material over substantially the entire smooth surface of the textile fabric. The method can include depositing second coating material to overlie the first coating material, thereby forming a bi-component coating at the smooth surface of the textile fabric, wherein the first coating material and the second coating material exhibit differential thermal expansion to cause change in a three dimensional configuration of the textile fabric in response to change in temperature. The second coating material may be bonded to the first coating material, e.g., with a chemical and/or physical bond. The method may also include drying the first coating material prior to depositing the second coating material. In some cases, depositing the second coating material comprises depositing the second coating material to overlie one or more regions of the first coating material. The step of depositing the second coating material may include depositing the second coating material to overlie one or more regions of the first coating material such that at least a portion of the second coating material is disposed upon the smooth surface of the textile fabric (e.g., for bonding at least a portion of the second coating material to the surface of the textile fabric). The step of depositing the second coating material includes depositing the second coating material in side-by-side relationship with the first coating material on the smooth surface of the textile fabric. At least one of the first and second coating materials include crystallizing polymer. Depositing the first coating material includes depositing the first coating material by a process selected from the group consisting of: coating, lamination, and printing. Printing includes hot melt printing, gravure roll printing, screen printing, or hot melt gravure roll (i.e., hot melt by gravure roll application).

[0009] In yet another aspect, a temperature responsive textile fabric garment includes a thermal fabric having a smooth outer surface and a plurality of discrete regions of first coating material. The plurality of discrete regions of the first coating material are disposed in a pattern corresponding to one or more predetermined regions of a user's body. The first coating material exhibits thermal expansion or contraction in response to change in temperature, thereby adjusting insulation performance of the textile fabric in response to ambient conditions.

[0010] Preferred implementations may include one or more of the following additional features. The first coating material comprises shape memory polymer. The shape memory polymer exhibits volume change by crystallization. The shape memory polymer is configured to crystallize at a temperature of between about −40° F. and about 100° F. For example, in some cases, the shape memory polymer is configured to crystallize at a temperature of between about 60° F. and about 98° F., e.g., between about 69° F. and about 73° F. In another example, the shape memory polymer is configured to crystallize at a temperature of between about −40° F. and about 60° F., e.g., between about −20° F. and about 40° F. The shape memory polymer is polyurethane. The textile fabric garment may be in the form of an article of outerwear, e.g., for use in relatively lower temperature environments (e.g., between about −40° F. and about 60° F.). For example, the textile fabric garment may be in the form of a jacket and/or outer shell. In some cases, for example, the thermal fabric is a substantially flat outer shell material, wherein the shape memory polymer exhibits expansion and/or contraction in response to change in temperature to cause change in a two-dimensional planar configuration of the thermal fabric in response to change in temperature, thereby increasing insulation performance of the textile fabric garment in response to a decrease in temperature. The thermal fabric can include spandex yarn or high stretch synthetic yarn for enhanced fit, comfort, and shape recovery (e.g., to aid in the reversibility of three dimensional changes in configuration of the thermal fabric). For example, in some cases, the spandex is incorporated in the stitch (e.g., in the form of bare spandex yarn, air entangled yarn, core-spun yarn, and/or wrap yarn, etc.). A plurality of discrete regions of a second coating material are disposed adjacent and corresponding to the plurality of discrete regions of the first coating material, wherein the first coating material and the second coating material exhibit differential thermal expansion to cause change in a three dimensional configuration of the garment in response to change in temperature, thereby adjusting insulation performance of the textile fabric.

[0011] In another aspect, a temperature response textile fabric garment system includes an inner thermal fabric layer formed of a first, inner textile fabric having a smooth outer surface with one or more regions of a first coating material exhibiting thermal expansion or contraction in response to change in temperature, adjusting insulation performance of the first, inner textile fabric in response to ambient conditions, and having an inner surface towards a wearer's skin. The temperature response textile fabric garment system may also include an outer thermal fabric layer formed of a second, outer textile fabric having a smooth outer surface with one or more regions of an other coating material exhibiting thermal expansion or contraction in response to change in temperature, adjusting insulation performance of the second, outer textile fabric in response to ambient conditions, and having an inner surface towards the smooth outer surface of the inner thermal fabric layer.

[0012] Preferred implementations may include one or more of the following additional features. At least one of the first coating material and the other coating material includes polymer that exhibits volume change by crystallization. The polymer is configured to crystallize at a temperature of between about −40° F. and about 100° F. For example, the polymer of the first, inner textile fabric may be configured to crystallize at a temperature of between about 50° F. and about 100° F., e.g., between about 60° F. and about 98° F., and preferably between about 69° F. and about 73° F., and the polymer of the second, outer textile fabric may be configured to crystallize at a temperature of between about −40° F. and about 60° F., e.g., between about −20° F. and about 40° F. The first, inner textile fabric may include one or more regions of second coating material underlying one or more regions of the first coating material, wherein the first coating material and the second coating material exhibit differential thermal expansion to cause change in three-dimensional configuration of the inner thermal fabric layer in response to change in temperature. The second, outer textile fabric may include one or more regions of second coating material underlying one or more regions of the other coating material, wherein the other coating material and the second coating material exhibit differential thermal expansion to cause change in three-dimensional configuration of the outer thermal fabric layer in response to change in temperature.

[0013] In another aspect, a bi-component layer for use in a textile fabric comprises a first coating material and a second coating material. The first material comprises a polymer that expands or contracts gradually over a temperature range. At least a portion of the first coating material directly contacts and overlies or underlies at least a portion of the second coating material. The second coating material comprises a polymer that remains soft and rubbery, e.g., without substantial expansion or contraction, over the temperature range. In response to changing temperature, the first coating material and the second coating material respectively exhibit different thermal expansion or contraction over the temperature range. A three dimensional configuration of the bi-component layer is changed gradually and reversibly in response to gradual temperature changes in ambient conditions.

[0014] Preferred implementations may include one or more of the following additional features. The first coating material comprises a crystallizing polymer. The second coating material comprises a soft rubbery polymer. The first coating material comprises polyurethane. The second coating material comprises polyurethane, silicone, polypropylene, polyethylene, or acrylate. The temperature range is between about −40° F. and about 140° F., e.g., between about −20° C. about 40° C. The temperature range is between about 50° F. and about 100° F. The temperature range is between about −40° F. and about 60° F. The temperature range is between about −20° F. and about 40° F. The second coating material is chemically bonded to the first coating material. The second coating material is physically bonded to the first coating material.

[0015] In another aspect, a textile fabric comprises a textile fabric substrate having a smooth surface and discrete bi-component coatings disposed upon and bonded to one or more regions of the smooth surface. Each bi-component coating comprises a first coating material and a second coating material. At least a portion of the first coating material directly contacts and overlies or underlies at least a portion of the second coating material. The first coating material comprises a crystallizing polymer. The second coating material comprises a soft rubbery polymer. In response to changing temperature within a temperature range, the first coating material expands or contracts gradually over the temperature range, and the second coating material remains soft and rubbery, e.g., without substantial expansion or contraction, over the temperature range. The first coating material and the second coating material exhibit respectively different thermal expansion or contraction characteristics in response to change in temperature over the temperature range. Insulation performance of the textile fabric is adjusted by changing three dimensional configuration of the textile fabric substrate gradually in response to gradual temperature changes in ambient conditions.

[0016] Preferred implementations may include one or more of the following additional features. The first coating materials and the second coating material gradually change the three dimensional configuration of the bi-component layer reversibly. The temperature range is between about −40° F. and about 140° F., e.g., between about −20° C. and about 40° C. The temperature range is between about 50° F. and about 100° F. The temperature range is between about −40° F. and about 60° F. Temperature range is between about −20° F. and about 40° F. The second coating material is chemically bonded to the first coating material. The second coating material is physically bonded to the first coating material. The textile fabric substrate has a construction selected from the group consisting of: circular knit construction, warp knit construction, and woven construction. The textile fabric substrate comprises elastic yarn. The elastic yarn comprises spandex yarn selected from the group consisting of: bare spandex yarn, air entangled yarn, core-spun yarn, and wrap yarn. The textile fabric substrate has a knitting construction selected from the group consisting of: single jersey, double knit, and terry loop, or is a two-end fleece or a three-end fleece. The terry loop is formed in plaited construction. The terry loop is formed in reverse plaited construction. The terry loop is raised by napping.

[0017] In another aspect, a method of forming a textile fabric element for use in an engineered thermal fabric garment comprises forming a textile fabric substrate having at least one smooth surface and disposing on and bonding to one or more regions of the smooth surface discrete bi-component coatings. Each bi-component coating comprises a first coating material and a second coating material. At least a portion of the first coating material directly contacts and overlies or underlies at least a portion of the second coating material. The first coating material comprises a crystallizing polymer. The second coating material comprises a soft rubbery polymer. In response to changing temperature within a temperature range, the first coating material expands or contracts gradually over the temperature range, and the second coating material remains soft and rubbery, e.g., without substantial expansion or contraction, over the temperature range. Each of the first coating material and the second coating material exhibits respectively different thermal expansion or contraction in response to change in temperature over the temperature range. Insulation performance of the textile fabric is adjusted by changing three dimensional configuration of the textile fabric substrate gradually and reversibly in response to gradual temperature changes in ambient conditions.

[0018] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0019] FIGS. **1**A-B are cross-sectional views of a textile fabric with a temperature responsive coating material.

[0020] FIGS. **2**A-**2**B are cross-sectional views of a temperature responsive textile fabric with a temperature responsive bi-component coating material.

[0021] FIG. **3**A is a front perspective view of a temperature responsive textile fabric garment.

[0022] FIGS. **3**B-**3**C are detailed cross-sectional views of the temperature responsive textile fabric garment of FIG. **3**A.

[0023] FIG. **4**A is a front perspective view a temperature responsive textile fabric having first and second discrete regions of coating that exhibit contrasting thermal elongation/contraction in response to changes in temperature.

[0024] FIG. **4**B is a detailed cross-sectional view of the temperature responsive textile fabric garment of FIG. **4**A.

[0025] FIG. **5**A is a front perspective view of a temperature response textile fabric garment system having inner and outer fabric layers that change in three-dimensional configuration in response to changes in temperature.

[0026] FIGS. **5**B and **5**C are detailed cross-sectional views of the temperature responsive textile fabric garment system of FIG. **5**A.

[0027] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0028] Referring to FIGS. **1**A-**1**B, a temperature responsive smart textile fabric **10** has a smooth fabric surface **12** with a region of coating material **14**. The textile fabric **10** can be circular knit (e.g., single jersey, double knit, terry sinker loop in plaited or reverse plaited construction, two-end fleece, and/or three-end fleece), warp knit, or woven construction. Preferred textile fabrics contain spandex for enhanced fit, comfort, and shape recovery. As illustrated in FIG. **1**B, the coating material responds to change in temperature by exhibiting thermal expansion or contraction, thereby changing the three dimensional configuration of the fabric **10**. As shown in FIGS. **1**A and B, the coating material **14** is a single polymer layer capable of changing volume through crystallization. The polymer is capable of crystallization in a temperature range of between about −40° F. and about 100° F. In some cases, e.g., where the textile fabric is incorporated next to the wearer's skin or as an inner layer of a garment, the polymer is selected to be capable of crystallization in a temperature range of between about 60° F. to about 98° F. (e.g., a skin temperature range), e.g., between about 69° F. and about 73° F. (e.g., a room temperature range). In some other cases, e.g., where the temperature responsive textile fabric is incorporated as an outer layer in a garment of outerwear, e.g., a jacket and/or an outer shell, for cold weather applications, the polymer preferably is selected to be capable of crystallizing in a temperature range of between about −40° F. and about 60° F., e.g., between about −20° F. and about 40° F.

[0029] Preferred materials include shape memory polymer, e.g., polyurethane, which can be designed (formulated) to have a crystalline melting temperature selected from a wide range of temperatures. Crystallization is accompanied by the change in volume. Referring again to FIG. **1**B, as the ambient temperature is reduced (indicated by arrow **20**) below a threshold temperature, the coating material **14** shrinks (i.e., contracts) and buckles, thereby changing the surface geometry of the fabric **10**. This process is also highly reversible (as indicated by arrow **22**).

[0030] As shown in FIG. **2**A, a second coating material **16** is introduced between the first layer of coating material **14** and the fabric surface **12**, forming a bi-component coating layer **18**. The second coating material **16** is added to adjust the effect of the first coating material **14** has on the textile fabric **10**. For example, in some embodiments, the first layer **14** includes a crystallizing polymer, of the type described above, and the second layer **16** includes a soft rubbery polymer (e.g., polyurethanes, silicones, polypropylene, polyethylene and/or acrylates). The crystallizing polymer shrinks as the temperature drops below the crystallization temperature (preferably, below 100° F.), while the second polymer remains soft at the same temperature, resulting in differential shrinkage that changes the three dimensional configuration of the textile fabric **10**. As a result, a convex dome is formed on the surface of the fabric.

[0031] A contrasting effect can be achieved by reversing the sequence of the first and second coating layers **14**, **16**. As illustrated in FIG. **2**B, the sequence of the layers is reversed, placing the first coating material (i.e., crystallizing polymer) in contact with the fabric surface **12**, while the second polymer material is disposed above the first polymer material, forming the bi-component coating layer **18**. As temperature decreases, the differential shrinkage of the two polymer layers causes a concave dome to form on the surface of the fabric.

[0032] In the embodiment depicted in FIG. **3**A, a temperature responsive textile fabric **10** is incorporated in a fabric garment **30**. The temperature responsive garment **30** consists of a fabric formed as a woven or knit textile fabric, e.g. as single jersey, plaited jersey, double knit, terry sinker loop in plaited or reverse plaited construction, two-end fleece, or three-end fleece, with or without spandex stretch yarn. The textile fabric **10** will preferably still have other comfort properties, e.g. good water management, good stretch recovery, and/or kindness to the wearer's skin. The inner surface of the textile knit fabric, i.e. the surface opposite the wearer's skin, can be raised, e.g. raised terry loop, to reduce the touching points to the skin

[0033] A plurality of discrete regions **18** of single component coating (as illustrated for example in FIGS. **1**A and **1**B) or bi-component coating **18** (as shown, e.g., in FIGS. **3**A-**3**D) are arranged on a smooth outer surface **12** of the garment **30**. Referring to FIG. **3**B, for example, as the ambient temperature drops, the first and second coating materials **14**, **16**, of the bi-component coating **18** exhibit differential thermal contraction causing a change in the three dimensional configuration of the textile fabric. More specifically, the change in the three dimensional configuration of the textile fabric generates increased bulk, and, as a result, increased thermal insulation, thereby providing enhanced overall comfort in cooler temperatures. In addition, the change in three dimensional configuration can reduce clinging of the textile fabric to the user's skin (e.g., when saturated with liquid sweat), thereby to minimize user discomfort.

[0034] FIG. **3**C illustrates the behavior of the fabric garment **30** as the temperature increases above a threshold value. In this example, as the ambient temperature increases, the first and second coating materials **14**, **16** of the bi-component coating **18** exhibit differential thermal expansion, again causing a change in the three dimensional configuration of the textile fabric. However, as the ambient temperature increases, the change in the three dimensional configuration of the textile fabric increases the air gap between the user's skin S and the fabric garment **30**, thereby allowing increased air flow in the area between the user's skin S and the fabric garment **30**, while at the same time reducing the thermal insulation provided by the fabric garment.

[0035] FIGS. **4**A and **4**B illustrate another embodiment in which a temperature responsive textile fabric **10** is incorporated in a fabric garment **40**. The temperature responsive fabric garment **40** includes a plurality of first discrete regions of coating **20** and a plurality of second discrete regions of coating **22** disposed on a smooth outer surface of the garment **40**, the first and second discrete regions of coating **20**, **22** exhibiting differential thermal contraction in response to change in temperature. As shown in FIG. **4**B, the first discrete regions of coating **20** are a bi-component coating having a first layer **14**, including a crystallizing polymer, and a second layer **16**, including a soft rubbery polymer (e.g., polyurethanes, silicones, polypropylene, polyethylene, and/or acrylates). Referring still to FIG. **4**B, the second discrete regions of coating **22** are also a bi-component coating; however, the sequence of the layers is reversed, placing the first coating material **14** (i.e., the crystallizing polymer) in contact with the fabric surface **12** while the second polymer material **16** is disposed above the first polymer material **14**, forming the second discrete region(s) of bi-component coating **22**. In this manner, three dimensional changes in bulk and thermal insulation of the fabric garment can be adjusted as a function of differential thermal expansion/contraction of the selected polymers, and the pattern and density of the coating regions.

[0036] Referring to FIGS. **5**A and **5**B, a temperature response textile fabric garment system **100**, e.g., as shown, embodied in a jacket constructed for use in cold weather conditions, consists of an inner fabric layer **110** and an outer fabric layer **120**. The inner fabric layer **110** is disposed in contact with, or relatively close to, the wearer's skin when the garment **100** is worn. In contrast, the outer fabric layer **120** is disposed at, or relatively close to, the exterior surface of the garment, and spaced from the wearer's skin, when the garment **100** is worn.

[0037] The inner fabric layer has a smooth outer surface **112** with discrete regions of coating material **114**. The coating material **114** expands or contracts in response to change in temperature, thereby changing the three-dimensional configuration of the inner fabric layer (as shown, for example, in FIG. **5**B) in response to change in temperature, e.g. at a temperature of between about −40° F. and about 60° F., e.g. between about −20° F. and about 40° F., and, as a result, adjusting the insulation performance of the inner fabric layer **110**.

[0038] The outer fabric layer **120** also includes a smooth outer surface **122** with discrete regions of another coating material **124**. The outer fabric layer **120** may be, for example, a jacket or an outer shell. The other coating material **124** expands or contracts in response to change in temperature, e.g. at a temperature of between about 50° F. and about 100° F., e.g. between about 60° F. and about 98° F., e.g. between about 69° F. and about 73° F., thereby changing the three-dimensional configuration of the outer fabric layer **120**, and, as a result, adjusting the insulation performance of the outer fabric layer **120**.

[0039] The respective coating materials **114**, **124** may be of the type described above with respect to FIGS. **1**A and **1**B. Referring to FIG. **5**C, the inner fabric layer **110** and/or the outer fabric layer **120** may also include a second coating material **130**, for example, of the type described above with respect to FIGS. **2**A and **2**B (i.e., second coating material **16**). The second coating material **130** and the coating material **114** exhibit differential thermal expansion in response to change in temperature, thereby adjusting the effect that the coating material **114** has on the inner fabric layer **110**. Similarly, the second coating material **130** exhibits differential thermal expansion with respect to the other coating material **124**, thereby adjusting the effect of the other coating material **124** on the outer fabric layer **120**.

[0040] The respective changes in three-dimensional configuration of the inner and outer fabric layers **110** and **120** generate enhanced bulk and increased thermal insulation in response to decrease in the ambient temperature, thereby providing enhanced comfort in cooler climate applications.

[0041] A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, the polymer or polymer layers may be applied on a textile fabric garment in a body mapping pattern. The polymer layers may be applied over high coverage area (i.e., a large part of the surface of the textile fabric is covered), or low coverage area. The polymer or polymer layers may be deposited on the textile fabric utilizing coating, laminating, and/or printing techniques, e.g., hot melt printing, gravure roll printing, and/or screen printing. The first polymer layer may be applied by itself directly on the fabric or over the second polymer layer. The polymer layers may be deposited on the surface of the textile fabric in side-by-side relationship.

[0042] Also, the temperature responsive textile fabric garment system shown in FIG. **5**A has a first, inner textile fabric layer responsive in a first range of temperatures and a second, outer textile fabric layer responsive in a second, contrasting range of temperatures. In other embodiments, a temperature responsive textile fabric garment system may have only single fabric layer responsive to temperature or it may have multiple fabric layers responsive to temperature. Also, each fabric layer may be responsive in a desired range or ranges of temperatures selected on the basis of one or more factors, including, e.g., sequential position of the fabric layer in constructions of the garment, expected temperature and other environmental conditions of use, etc.

[0043] Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A bi-component layer for use in a textile fabric, the layer comprising:

a first coating material comprising a polymer that expands or contracts gradually over a temperature range; and

a second coating material, at least a portion of the first coating material directly contacting and overlying or underlying at least a portion of the second coating material, the second coating material comprising a polymer that remains soft and rubbery over the temperature range, and, in response to changing temperature,

the first coating material and the second coating material respectively exhibiting different thermal expansion or contraction over the temperature range, thereby to change a three dimensional configuration of the bi-component layer gradually and reversibly in response to gradual temperature changes in ambient conditions.

2. The bi-component layer of claim **1**, wherein the first coating material comprises a crystallizing polymer.

3. The bi-component layer of claim **2**, wherein the second coating material comprises a soft rubbery polymer.

4. The bi-component layer of claim **1**, wherein the first coating material comprises polyurethane.

5. The bi-component layer of claim **1**, wherein the second coating material comprises polyurethane, silicone, or acrylate.

6. The bi-component layer of claim **1**, wherein the temperature range is between about −20° C. and about 40° C.

7. The bi-component layer of claim **1**, wherein the temperature range is between about 50° F. and about 100° F.

8. The bi-component layer of claim **1**, wherein the polymer of the second coating material remains soft and rubbery without substantial expansion or contraction over the temperature range.

9. The bi-component layer of claim **1**, wherein the second coating material comprises polypropylene or polyethylene.

10. The bi-component layer of claim **1**, wherein the second coating material is chemically bonded to the first coating material.

11. The bi-component layer of claim **1**, wherein the second coating material is physically bonded to the first coating material.

12. A textile fabric comprising:

a textile fabric substrate having a smooth surface; and

discrete bi-component coatings disposed upon and bonded to one or more regions of the smooth surface, each bi-component coating comprising a first coating material and a second coating material, at least a portion of the first coating material directly contacting and overlying or underlying at least a portion of the second coating material, the first coating material comprising a crystallizing polymer, and the second coating material comprising a soft rubbery polymer, and,

in response to changing temperature within a temperature range, the first coating material expanding or contracting gradually over the temperature range, and the second coating material remaining soft and rubbery over the temperature range,

the first coating material and the second coating material exhibiting respectively different thermal expansion or contraction characteristics in response to change in temperature over the temperature range, thereby to adjust insulation performance of the textile fabric by changing three dimensional configuration of the textile fabric substrate gradually in response to gradual temperature changes in ambient conditions.

13. The textile fabric of claim **12**, wherein the first coating materials and the second coating material gradually change the three dimensional configuration of the bi-component layer reversibly.

14. The textile fabric of claim **12**, wherein the temperature range is between about −20° C. and about 40° C.

15. The textile fabric of claim **12**, wherein the polymer of the second coating material remains soft and rubbery without substantial expansion or contraction over the temperature range.

16. The textile fabric of claim **12**, wherein the second coating material comprises polypropylene or polyethylene.

17. The textile fabric of claim **12**, wherein the second coating material is chemically bonded to the first coating material.

18. The textile fabric of claim **12**, wherein the second coating material is physically bonded to the first coating material.

19. The textile fabric of claim **12**, wherein the textile fabric substrate has a construction selected from the group consisting of: circular knit construction, warp knit construction, and woven construction.

20. The textile fabric of claim **12**, wherein the textile fabric substrate comprises elastic yarn.

21. The textile fabric of claim **20**, wherein the elastic yarn comprises spandex yarn selected from the group consisting of: bare spandex yarn, air entangled yarn, core-spun yarn, and wrap yarn.

22. The textile fabric of claim **12**, wherein the textile fabric substrate has a knitting construction selected from the group consisting of: single jersey, double knit, and terry loop.

23. The textile fabric of claim **22**, wherein the terry loop is formed in plaited construction.

24. The textile fabric of claim **22**, wherein the terry loop is formed in reverse plaited construction.

25. The textile fabric of claim **22**, wherein the terry loop is raised by napping.

26. The textile fabric of claim **12**, wherein the textile fabric substrate comprises a two-end fleece or a three-end fleece.

27. A method of forming a textile fabric element for use in an engineered thermal fabric garment, the method comprising:

forming a textile fabric substrate having at least one smooth surface; and

disposing on and bonding to one or more regions of the smooth surface discrete bi-component coatings, each bi-component coating comprising a first coating material and a second coating material, at least a portion of the first coating material directly contacting and overlying or underlying at least a portion of the second coating material, the first coating material comprising a crystallizing polymer, and the second coating material comprising a soft rubbery polymer, and,

in response to changing temperature within a temperature range, the first coating material expanding or contracting gradually over the temperature range, and the second coating material remaining soft and rubbery over the temperature range,

each of the first coating material and the second coating material exhibiting respectively different thermal expansion or contraction in response to change in temperature over the temperature range, thereby to adjust insulation performance of the textile fabric by changing three dimensional configuration of the textile fabric substrate gradually and reversibly in response to gradual temperature changes in ambient conditions.

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