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(54) FABRIC AND METHOD FOR MANUFACTURING SOCK

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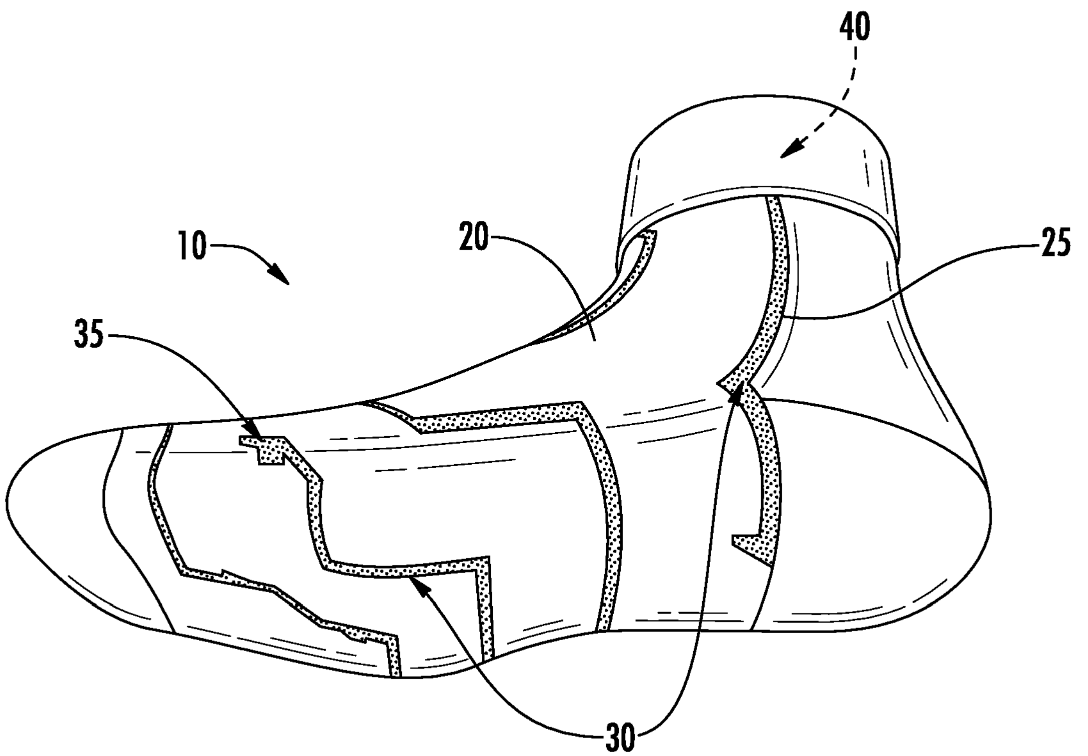
(57) **ABSTRACT**

Fabrics, socks, and methods are described in which conductive traces are integrally knit into fabric for making a sock. In some cases, certain stitches are selected for knitting conductive yarn in addition to or in place of the main body yarn of the sock. The conductive yarn creates a conductive trace in a wale-wise and/or a course-wise direction, with the conductive trace extending from a first connection point (such as a sensor pad) to a second connection point (such as an electrical contact for connecting a device). The conductive trace is designed to transmit an electrical signal between the first and second connection points, such that data collected at the first connection point may be transmitted via the pathway provided by the conductive trace to the second connection point and the connected device, where the data can be analyzed and/or displayed to the wearer.



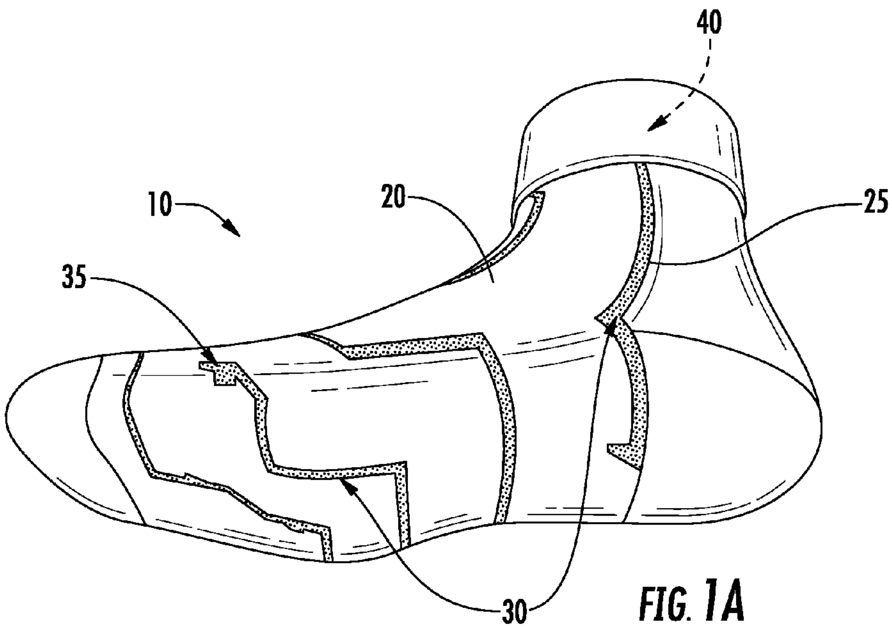


FIG. 1A

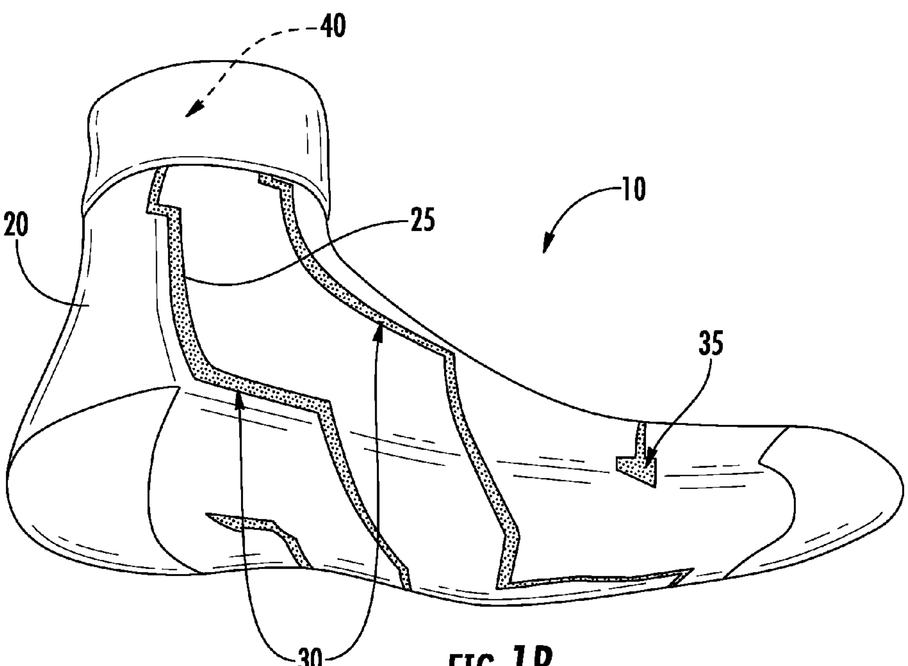


FIG. 1B

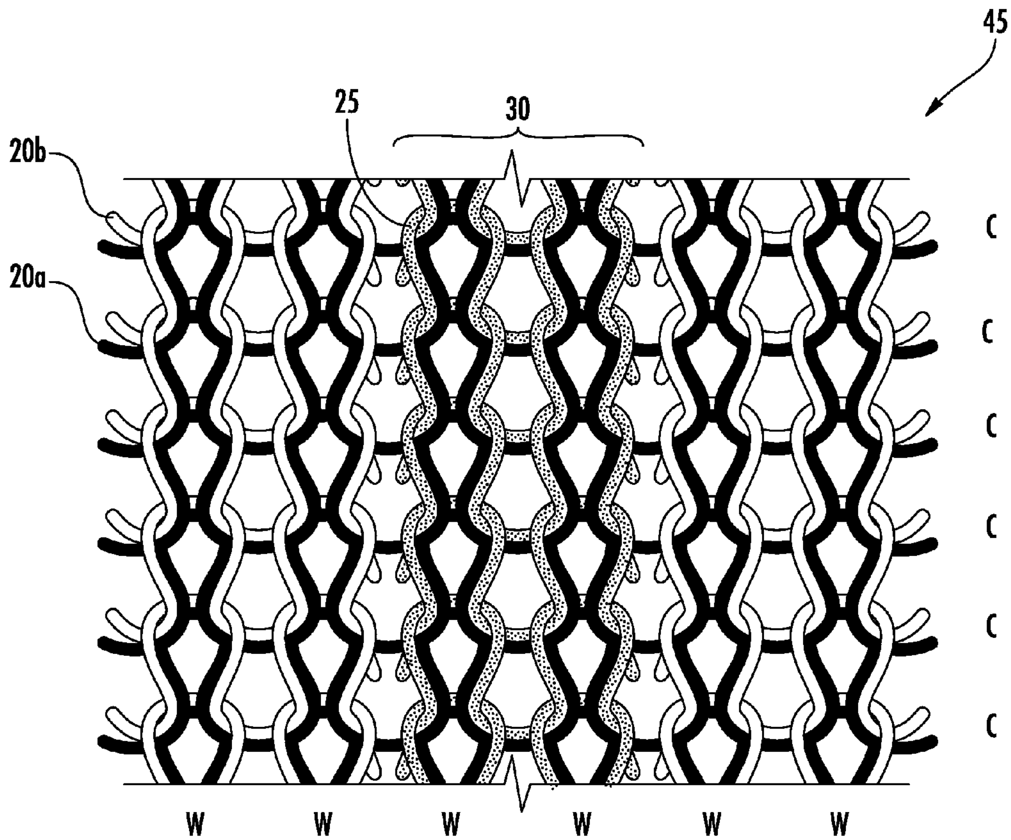
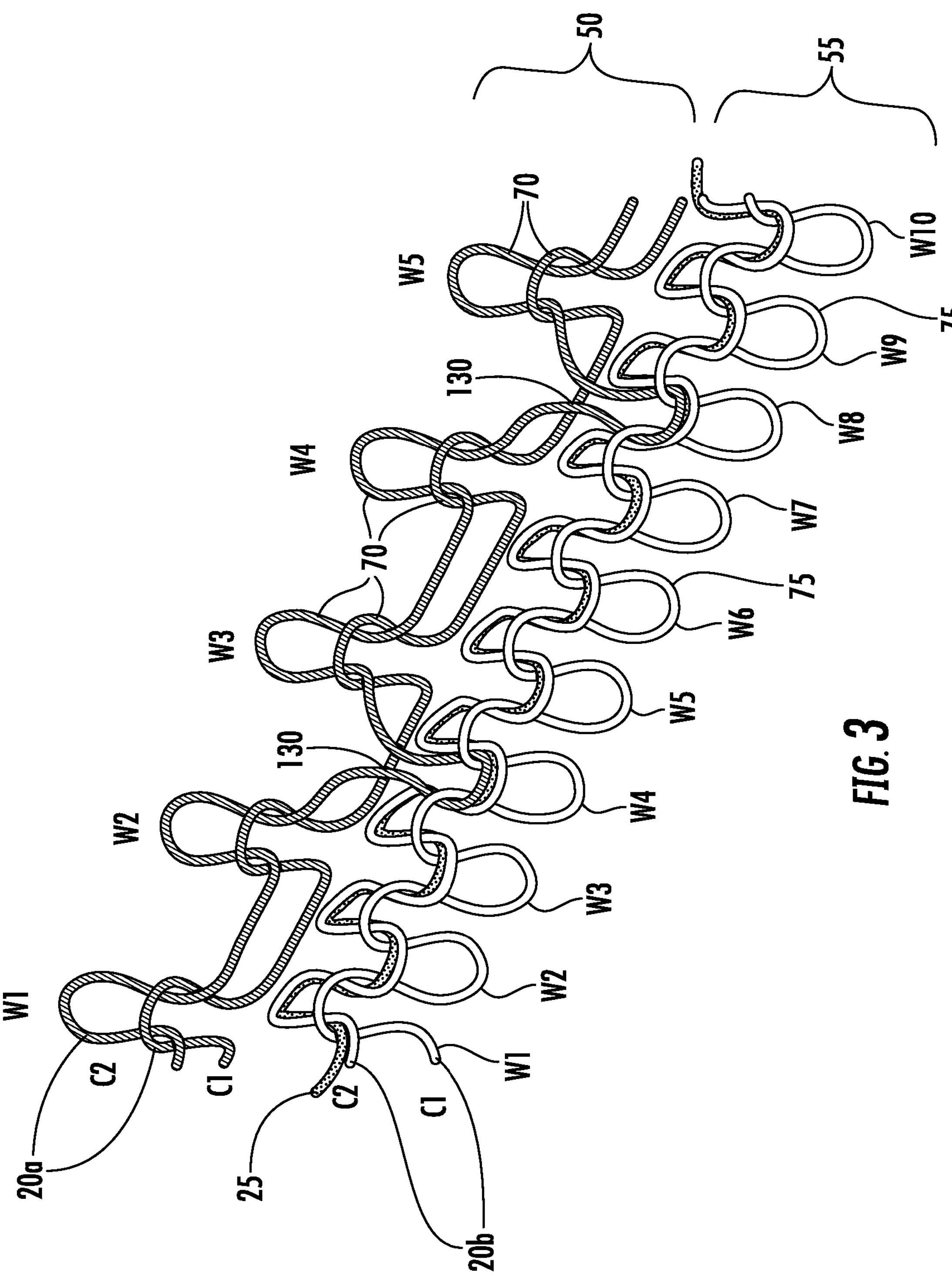


FIG. 2


50
55
70
70
70
W5
W4
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W2
W1
130
130
75
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W10
W9
W8
W7
W6
W5
W4
W3
W2
W1
C2
C1
C2
C1
20a
25
20b

FIG. 3

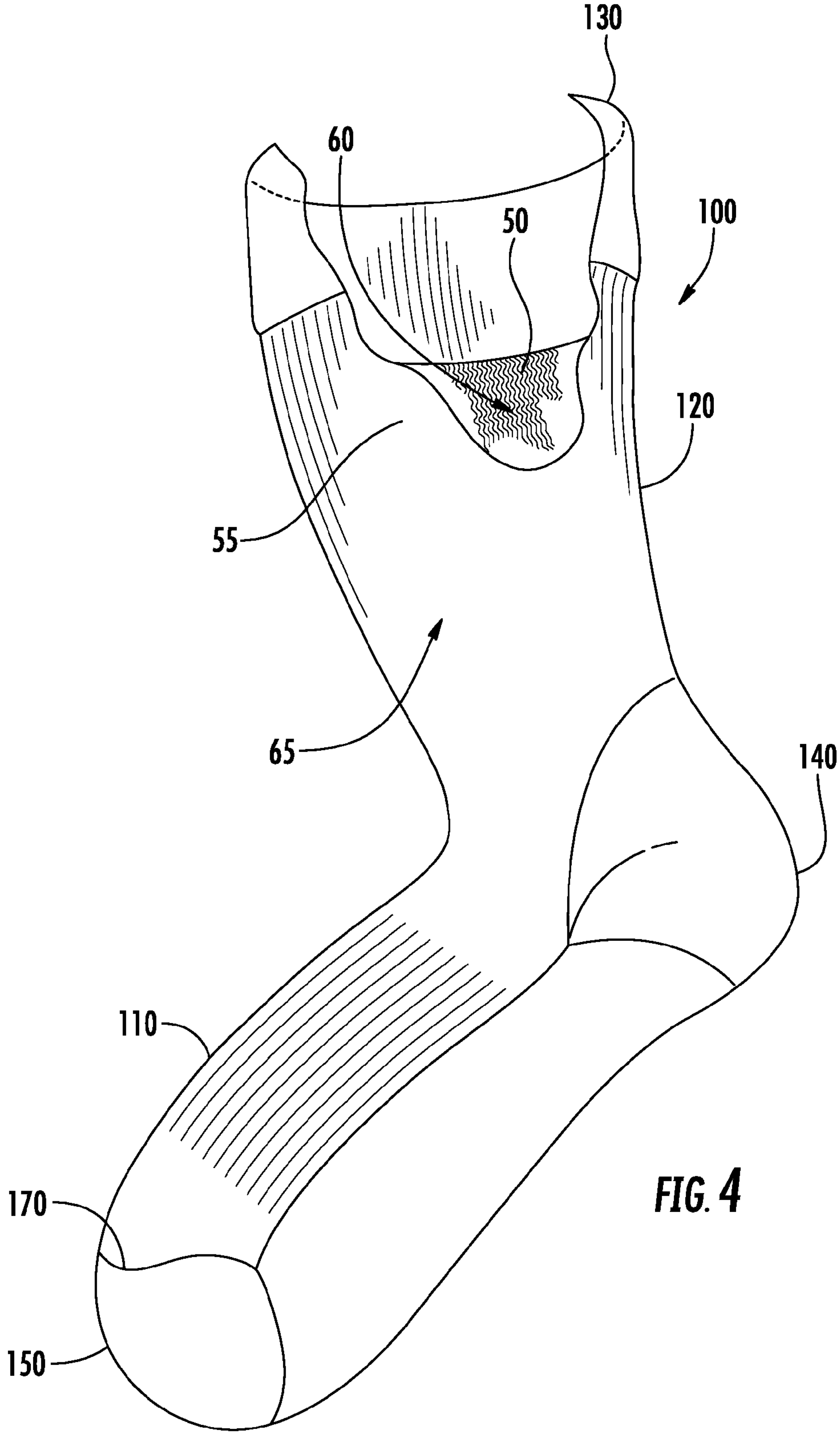

FIG. 4

FABRIC AND METHOD FOR MANUFACTURING SOCK

BACKGROUND

[0001] The present disclosure relates in general to a weft knit fabrics and associated methods for making a sock. In particular, the fabrics and methods described herein incorporate at least one conductive yarn that is structured and positioned to serve as a conductive trace, such as for facilitating the sensing of various data regarding the wearer of the sock.

[0002] In the information age, the need to gather data regarding various aspects of a person's life and daily activities is continually growing. In the area of health, sports, and fitness, athletes and individuals who are engaging in recreational exercise and other physical activities may, for example, be interested to collect data regarding their physical condition before, during, and after they engage in the activity.

BRIEF SUMMARY

[0003] Embodiments of the invention described herein provide improved fabrics and methods of manufacturing fabrics for socks that can be worn by a person engaging in an activity, where the fabric is knit to incorporate electrically conductive traces that can transmit electrical signals from a collection point (e.g., a sensor) where data regarding the condition of the person engaging in the activity is detected or measured. In this way, the wearer need not be troubled with wearing extraneous data collection equipment or applying sensors to his or her body prior to exercising, but rather can put on a pair of socks (which he or she would likely wear regardless of the collection of data) that have such sensors and pathways for transmitting the collected data integrally formed with the sock fabric.

[0004] Fabrics, socks, and methods are thus described herein in which conductive traces are integrally knit into the fabric for making a sock. In some embodiments, certain stitches are selected for knitting conductive yarn in addition to or in place of the main body yarn of the sock. For example, certain needles of a knitting machine may be programmed to receive conductive yarn, whereas other needles may be programmed to receive nonconductive yarns in one course of fabric. Consecutive courses of fabric may use the same or slightly shifted stitches in the course to direct the conductive traces in the desired pathway between connection points, as described herein. The conductive yarns in consecutive courses, as a whole, thereby produce an electrical circuit knit into the sock.

[0005] Accordingly, in some embodiments, a weft knit fabric is provided that includes at least one non-conductive yarn and at least one conductive yarn that is weft knit with the at least one non-conductive yarn by selectively incorporating the conductive yarn at predefined locations for at least one stitch over a plurality of adjacent courses or wales to form a fabric having a plurality of wales and courses. The at least one conductive yarn defines a conductive trace in at least one of a wale-wise or a course-wise direction, respectively, of the fabric. The conductive trace extends from a first connection point to a second connection point and is configured to transmit an electrical signal between the first and second connection points.

[0006] In some cases, the first connection point may comprise a device selected from the group consisting of a temperature sensor, a humidity sensor, a pressure sensor, and a heart rate monitor. The second connection point may include an electrical contact that is configured to allow a device to be connected to the conductive trace and to receive the electrical signal from the first connection point. The conductive trace may, in some cases, comprise a plurality of adjacent wales.

[0007] In some embodiments, the at least one non-conductive yarn may comprise a first non-conductive yarn and a second non-conductive yarn, and the second non-conductive yarn may be selectively replaced with the at least one conductive yarn at predetermined locations to define the conductive trace. The at least one conductive yarn may define a plurality of conductive traces along respective wales, where each conductive trace is isolated from other conductive traces. In some cases, consecutive courses may include stitches of the conductive yarn of a respective conductive trace that are shifted with respect to adjacent courses.

[0008] The at least one non-conductive yarn may define an inner layer having wales and courses and an outer layer having wales and courses, wherein the inner and outer layers are connected together at spaced apart wales and courses by one of the non-conductive yarns extending between the layers, and wherein the at least one conductive yarn is knit between the inner and outer layers, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the fabric. The conductive yarn may, in some cases, form at least part of the outer layer.

[0009] In other embodiments, a double layer sock is provided, where the double layer sock is formed on a circular knitting machine from a first non-conductive yarn, a second non-conductive yarn, and at least one conductive yarn. The sock may include a tubular inner layer and a tubular outer layer surrounding the inner layer. The tubular inner layer may have at least a foot portion knit of at least a first non-conductive yarn and may have wales and courses, and the tubular outer layer may be knit of at least a second non-conductive yarn and a conductive yarn and may also have wales and courses. The outer layer may have at least a foot portion aligning with the foot portion of the inner layer. The inner and outer layers may be connected together at spaced apart wales and courses by one of the first or second non-conductive yarns extending between the layers. The at least one conductive yarn may define a conductive trace in a course-wise direction. The conductive trace may extend from a first connection point to a second connection point and may be configured to transmit an electrical signal between the first and second connection points, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the sock.

[0010] In some cases, the second course of the outer layer may include the second non-conductive yarn and the conductive yarn. The first non-conductive yarn may extend between the layers, may be knit predominantly in the inner layer, and may be knit only for connection purposes in the outer layer, and the conductive yarn may be weft knit between the inner and outer layers. The first non-conductive yarn extending between the inner and outer layers may be knit in the outer layer as tuck stitch loops. In some cases, at least one of the first connection points may form part of the inner layer.

[0011] In still other embodiments, a method of knitting a sock on a circular knitting machine is provided, in which a first non-conductive yarn is knit into courses and wales. A second non-conductive yarn may also be knit into courses and wales, and a conductive yarn may be selectively incorporated at predefined locations for at least one stitch over a plurality of adjacent courses or wales. The at least one conductive yarn may define a conductive trace in at least one of a wale-wise or a course-wise direction, respectively. Furthermore, the conductive trace may extend from a first connection point to a second connection point and may be configured to transmit an electrical signal between the first and second connection points.

[0012] In some cases, selectively incorporating the conductive yarn may comprise selectively replacing the second non-conductive yarn of the outer layer with the conductive yarn at the predefined locations. Knitting the first non-conductive yarn may comprise knitting the first non-conductive yarn into courses and wales to form an inner layer of the sock, and knitting the second non-conductive yarn may comprise knitting the second non-conductive yarn into courses and wales to form an outer layer of the sock in surrounding relation to said inner layer. Selectively incorporating the conductive yarn may comprise plating the conductive yarn between the inner and outer layers by selecting at least one stitch in a plurality of adjacent courses to receive the at least one conductive yarn. The method may further comprise connecting the inner and outer layers together at spaced apart wales and courses by causing one of the at least one first or second non-conductive yarns to extend between the inner and outer layers, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the fabric.

[0013] In some cases, selectively incorporating the conductive yarn may comprise replacing the second non-conductive yarn of the second course of the outer layer with the conductive yarn. Additionally or alternatively, selectively incorporating the conductive yarn may comprise adding the conductive yarn to the second course of the outer layer, such that the second course of the outer layer includes the second non-conductive yarn and the conductive yarn.

[0014] In some embodiments, the method may further comprise attaching at least one of the first connection points to the inner layer and connecting the at least one first connection point to a corresponding conductive trace.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0015] Having thus described the disclosure in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0016] FIGS. **1**A and **1**B show perspective views of a sock with integrally knit conductive traces according to an example embodiment;

[0017] FIG. **2** is a simplified schematic view of an example knit structure incorporating non-conductive and conductive yarns according to an example embodiment;

[0018] FIG. **3** is a simplified schematic view of an example knit structure for a double layer sock including an inner layer and an outer layer and incorporating conductive yarns between the inner and outer layers according to an example embodiment; and

[0019] FIG. **4** illustrates a double layer sock incorporating non-conductive and conductive yarns according to an example embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

[0020] The present invention now will be described more fully hereinafter with reference to the accompanying drawings in which some but not all embodiments of the inventions are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements Like numbers refer to like elements throughout.

[0021] As noted above, individuals engaged in physical activity, such as walking, running, jogging, aerobic exercise, weight training, cycling, or any other sport or physical activity, as well as individuals with certain medical conditions who are undertaking physical activity, may have the need or the desire to monitor certain parameters regarding their physical response to the activity. Information such as regarding the person's body temperature, perspiration level, heart rate, blood pressure, and so on may, for example, help the person determine whether the level of activity in which they are engaged is adequate for their desired purposes (e.g., whether they are pushing themselves far enough) and, in some cases, can alert the wearer in the event the activity becomes too taxing or they begin to have a negative physical response to the activity (e.g., if the activity becomes too strenuous or lasts too long).

[0022] In one case, for example, a wearer, who is training for a certain athletic event, may have a goal of elevating his or her heart rate to a certain level for a certain period of time. On the other hand, in another case, the wearer may be an elderly person or a person with a certain medical condition who, although required to exercise, may be prohibited from exceeding a certain threshold of intensity of physical activity or duration of physical activity based on the physical response such activity might elicit. Thus, the fabrics, garments, and methods disclosed herein may have applications for both personal performance and medical products.

[0023] Conventional methods of monitoring physical parameters, such as heart rate, body temperature, blood pressure, etc., involve applying external sensors and monitoring devices to a person's skin, such as through the use of wired sensors with adhesive patches, pulse monitoring devices that are part of exercise equipment (e.g., a treadmill), or other devices that must be secured to the wearer's body using adhesives, clips, ties, elastic bands, etc. Such devices and monitoring accessories can thus be difficult, and at the very least cumbersome, to correctly position and secure on the wearer's body, and the size, location, method of attachment, etc. of such devices may end up negatively affecting or hindering the person's activity. Moreover, incorrect positioning or securement of conventional devices to the wearer's body may result in inaccurate data collection, providing poor information to the wearer.

[0024] Accordingly, embodiments of the invention described herein provide a fabric and method of manufacturing a fabric for a sock that can be worn by a user, where the sock fabric is knitted to include conductive yarns that form conductive traces to allow electrical signals carrying data regarding the physical parameters of the wearer to be transmitted between connection points on the sock. For example, one or more connection points may collect data such as body temperature, applied pressure, humidity level, blood pressure, heart rate (pulse), and other data, such as through the use of sensors, whereas other connection points may transmit the collected data to a remote location (e.g., an external processor, network server, cloud server, etc.) for processing, storage, reporting, display, etc.

[0025] In some embodiments, for example, a sock may be constructed of conductive and non-conductive traces, as described in greater detail below, with connection points having sensors at locations on the sock corresponding to the bottom of the wearer's foot. For example, three pressure sensors may be provided on the sock corresponding to points on the bottom of the wearer's foot to monitor the wearer's actual steps and the pressure at those points. By monitoring the pressure at certain points on the wearer's foot, the wearer's actual steps and the way the foot is landing with each stride can be analyzed via the pressure data, and the wearer may be able to determine ways to change his or her stride to improve his or her performance.

[0026] Turning now to FIG. **1**, a sock **10** made of fabric structured and manufactured according to embodiments of the present invention is shown. The sock **10** can be made of a single layer weft knit fabric or may, in some cases, incorporate a double layer construction, as described in greater detail below. In particular, the weft knit fabric may include at least one non-conductive yarn **20** and at least one conductive yarn **25** that is weft knit with the at least one non-conductive yarn to form a fabric having a plurality of wales w and courses c. The at least one conductive yarn may be knit with the non-conductive yarn in such a manner as to define a conductive trace **30** along at least a portion of one of the plurality of wales w, such as in a wale-wise direction (e.g., as shown in FIG. **2**). Additionally or alternatively, the at least one conductive yarn may be knit with the non-conductive yarn in such a manner as to define a conductive trace **30** along at least a portion of one of the plurality of courses c, such as in the course-wise direction (e.g., as shown in FIG. **3**). Thus, in some embodiments, the conductive trace **30** may run in both wales and courses. The conductive trace **30** may extend from a first connection point **35** to a second connection point **40** (e.g., under the ankle band of the sock **10**). The second connection point **40** may, for example, be configured to transmit the data collected at the first connection point **35** to a remote location (e.g., a location not on the sock itself, such as for processing, display, etc.). Thus, the conductive trace **30** may be configured to transmit an electric signal between the first and second connection points.

[0027] In some embodiments, the first connection point **35** may comprise a device such as a temperature sensor, a humidity sensor, a pressure sensor, and/or a heart rate monitor. In some cases, for example, a single first connection point **35** may be provided that includes a sensor that is capable of detecting a single parameter (e.g., a temperature sensor for detecting a body temperature of the wearer). In other cases, the single first connection point **35** may include a sensor that is capable of detecting multiple parameters, such as body temperature, blood pressure, humidity, and/or heart rate.

[0028] In still other cases, multiple first connection points **35** may be provided. Each first connection point **35** may be connected to a corresponding second connection point **40** via corresponding conductive traces **30**. Accordingly, conductive traces **30** must be knit in such a manner that the conductive yarn **25** of one trace **30** is isolated from (e.g., has no electrical contact with) the conductive yarn of another trace. The second connection point **40** may, in some cases, be a transmitter or other electrical terminus that is configured to wirelessly transmit the electrical signal that is conducted from the first connection point **35** via the conductive trace **30** to a remote location, as noted above. In other cases, the second connection point **40** may include an electrical contact that is configured to allow a device, such as a hard-wired, Bluetooth®, or wireless device (e.g., a smart phone) to be connected.

[0029] With reference to FIG. **2**, in some embodiments, for example, non-conductive and conductive yarns **20**, **25** may be weft knit to form a single-layer fabric **45**. In this regard, the fabric **45** may include a first non-conductive yarn **20***a* that is continuously knit and a second non-conductive yarn **20***b* that is selectively replaced with the conductive yarn **25** at predetermined locations to create one or more conductive traces **30** in a wale-wise direction of the fabric. For example, in some embodiments, a sock may be knit on a circular knitting machine by knitting the first non-conductive yarn **20***a* to form courses and wales and knitting the second non-conductive yarn with the first non-conductive yarn to form the courses and wales. The second non-conductive yarn **20***b* may be replaced with a conductive yarn **25** at predefined locations for at least one stitch over a plurality of adjacent courses, such that conductive stitches in adjacent (e.g., contacting) courses define a conductive trace **30** in a wale-wise direction of the fabric, as illustrated.

[0030] In some cases, the conductive trace **30** may comprise a plurality of adjacent wales w. In the depicted embodiment of FIG. **2**, for example, the conductive trace **30** includes 2 stiches in each course c, where the stiches are aligned longitudinally such that a conductive trace **30** is formed that includes 2 wales w extending in a vertical direction (e.g., aligned vertically). In other cases, however, more than 2 stitches in each consecutive course c may be conductive, and the conductive trace **30** may thus include more than 2 wales, depending on the application. In still other cases, consecutive courses c may include stitches of conductive yarn **25** of a respective conductive trace **30**, where the stitches are shifted with respect to adjacent courses. For example, using 5 stitches and shifting one needle over for each subsequent course, in any given course 4 conductive stitches will remain in contact with 4 conductive stiches in the adjacent course above and below the given course. As long as at least one conductive stitch touches a conductive stitch of the previous course, the conductive trace **30** will allow the electrical signal to propagate to the subsequent course, thereby forming an electrical pathway. Thus, by shifting stiches over, one course at a time, a conductive trace **30** can be moved across the fabric at an angle to provide for slanted or angled pathways such as those shown in FIGS. **1**A and **1**B.

[0031] In some embodiments, the sock may be made of a single layer fabric, as described above. In other embodiments, however, the sock may include, at least in part, a double layer fabric construction.

[0032] For example, with reference to FIGS. **3** and **4**, in some cases the one or more non-conductive yarns **20***a*, **20***b* may define an inner layer **50** having wales w and courses c and an outer layer **55** having wales and courses. The inner and outer layers **50**, **55** may be connected together at spaced apart wales and courses by one of the non-conductive yarns **20***a* extending between the respective layers. The at least one conductive yarn **25** may be knit between the inner and outer layers **50**, **55**, such that each conductive trace **30** formed by the conductive yarn is isolated from an inner surface **60** of the fabric and from an outer surface **65** of the fabric. For example, the conductive traces **30** may be plated between the inner and outer layers **50**, **55** and may be protected from contact with objects contacting the inner layer **60** (e.g., the wearer's skin) as well as objects contacting the outer layer **65** (e.g., the wearer's shoe) and may thus not be exposed on either side of the fabric.

[0033] Accordingly, in some embodiments, a double layer sock **100** may be formed on a circular knitting machine from at least one non-conductive yarn **20***a*, **20***b* and at least one conductive yarn **25**. Each layer **50** and **55** may extend through a foot portion **110** of the sock **100** and through at least a portion of leg portion **120**. In some embodiments, the yarns forming the inner layer **50** and the outer layer **55** may be knit together as a single layer (e.g., using a construction shown in FIG. **2**) to form at least a cuff **130**, a heel pocket **140**, and toe pocket **150**. In other embodiments, however, only the foot portion **110** of the sock may be formed using the double layer construction of FIG. **3**. The double layer construction may be used in the foot portion **110**, for example, to shield the conductive traces **30** in that area from direct contact with the wearer's skin in areas corresponding to the bottom of the wearer's feet, where the sensors at the respective connection points may be more susceptible to short circuiting when in contact with the conductive surface of the wearer's skin under an applied pressure (as may be experienced by the bottoms of the wearer's feet).

[0034] In the double layer regions, the inner layer **50** may be connected to the outer layer **55**, or vice versa, at spaced locations during knitting thereof. This connection may, for example, be provided by tuck stitches **160** that are in selected courses and wales of the inner layer **50** and outer layer **55**, as shown in FIG. **3**.

[0035] In some embodiments, the sock **100** may be knit on a conventional circular knitting machine having a cylinder and dial capable of knitting socks, two examples of which are a 4-inch diameter **156** needle cylinder circular hosiery knitting machine with a cooperating dial having needles therein and with or without a LIN toe closing device, and a 4-inch diameter **112** needle cylinder circular knitting machine with a cooperating dial and a LIN toe device. Such knitting machines are conventionally provided with two yarn feeds that supply yarns to the cylinder and dial needles at spaced apart locations around the circular knitting machine.

[0036] The outer layer **55** of the sock **100** may be knit on the cylinder needles while the inner layer **50** may be knit on the dial needles. The main yarn feed of the knitting machine (not shown) may, for example, feed a second non-conductive yarn **20***b* to the cylinder needles to form stitch loops **75** arranged in courses c**1**, c**2** and wales w**1**-w**10**, shown in FIG. **3**. For illustration only, the stitch pattern illustrated in FIG. **3** is a plain or jersey stitch pattern, but it would be understood that the outer layer **55** may be knit in any desired stitch pattern.

[0037] The secondary yarn feed of the knitting machine (not shown) may feed a first non-conductive yarn **20***a* to the dial needles to form stitch loops **70** arranged in courses c**1**, c**2** and wales w**1**-w**5**. As shown in FIG. **3**, the dial needles may be used to form stitch loops **70** in the inner layer **50** while the cylinder needles may be used to form the stitch loops **75** in outer layer **55**.

[0038] At spaced locations, such as in alternate courses c**2** of the outer layer **55** and c**2** of the inner layer **50** and such as in every fourth wale w**4** and w**8** of the outer layer **55**, the inner layer **50** and outer layer **55** may be connected together by tuck stitches **130**. To form such tuck stitches **130**, for example, the cylinder needles forming such wales in those courses may be raised to the tuck position as they approach the secondary yarn feed of the knitting machine (feeding the first non-conductive yarn **20***a*) so that the first non-conductive yarn **20***a* is captured by the cylinder needles and knit into the outer layer **55** along with a stitch loop of the second non-conductive yarn **20***b* from the main yarn feed to connect the two layers **50**, **55** together. The spacing between the locations of the connecting stitch loops **130** and the type of connections may vary without departing from embodiments of the present invention.

[0039] The conductive yarn **25** may be incorporated into the sock **100** in different ways. In one embodiment, for example, the conductive yarn **25** may be fed by the main yarn feed of the knitting machine (not shown) along with the second course c**2** of the second non-conductive yarn **20***b* to the cylinder needles, but on an inner side of the outer layer **55**, as shown in FIG. **3** (e.g., behind the second non-conductive yarn **20***b* when viewed from an outer surface of the sock). In other embodiments, however, the conductive yarn **25** may replace the second course c**2** of the second non-conductive yarn **20***b*, such that one of the outer body yarns is replaced with conductive yarns as needed for the application (e.g., to form the desired number and position of the conductive traces **30**). After the sock blank has been knit, the toe may be closed, such as by a LIN Toe device or seaming machine, with a toe closure seam **170**, shown in FIG. **4**.

[0040] Accordingly, in some embodiments, a double layer sock **100** is provided that is formed on a circular knitting machine from a first non-conductive yarn **20***a*, a second non-conductive yarn **20***b*, and a conductive yarn **25**, as shown in FIGS. **3** and **4**. The sock **100** may include a tubular inner layer **50** having a foot portion **110** and a leg portion **120** merging substantially at the ankle of a wearer knit of at least the first non-conductive yarn **20***a* and having wales and courses, as described above. The sock **100** may further include a tubular outer layer **55** surrounding the inner layer **50** knit of at least the second non-conductive yarn **20***b* and the conductive yarn **25** and having wales and courses. The outer layer **55** may also have a foot portion **110** and a leg portion **120** merging substantially at the ankle of the wearer and aligning with the foot portion and the leg portion, respectively of the inner layer **50**.

[0041] The inner and outer layers **50**, **55** may be connected together at spaced apart wales and courses by the first non-conductive yarns **20***a* extending between the layers. The conductive yarn **25** may, for example, be knit with the second non-conductive yarns **20***b*, such as in one of the courses cl, c**2** of the outer layer **55**, to define a conductive trace in a course-wise direction. For example, in some embodiments, the second course c**2** of the outer layer **55** may include the second non-conductive yarn **20***b* and the conductive yarn **25**, as shown in FIG. **3**. In other cases, however, the second non-conductive yarn **20***b* of the second course c**2** of the outer layer **55** may be replaced in some locations with the conductive yarn **25**, as shown in FIG. **2**. In this way, a conductive trace defined by connected (e.g., contacting) locations of the conductive yarn **25** may be knit into the sock such that the trace extends from a first connection point to a second connection point and is configured to transmit an electrical signal between the first and second connection points, as described above with respect to FIGS. **1** and **2**. Moreover, by virtue of the double layer design, each conductive trace formed by the conductive yarn **25** may be isolated from at least the inner surface **60** of the sock **100** in those portions of the sock in which the double layer construction is used, and in some cases may be isolated from the outer surface **65** of the sock as well.

[0042] As described above, the first non-conductive yarn **20***a* and may extend between the layers **50**, **55**, may be knit predominantly in the inner layer **50**, and may be knit only for connection purposes in the outer layer **55**. The conductive yarn **25** may thus be weft knit between the inner and outer layers **50**, **55**. In some embodiments, the first non-conductive yarn **20***a* extending between the inner and outer layers **50**, **55** may be knit in the outer layer **55** as tuck stitch loops. Additionally or alternatively, at least one of the first connection points **35** (shown in FIG. **1**), such as a sensor, may form part of the inner layer **50**. For example, the first connection point **35** (e.g., a sensor pad) may be sewn on the inner surface **60** of the inner layer **50** with conductive thread.

[0043] In socks that include regions having a single layer construction (e.g., shown in FIG. **2**) and a double layer construction (e.g., shown in FIG. **3**), the conductive yarn **25** may have tails (e.g., free ends) resulting from switching needles during knitting, etc. The tails may, in some cases, be the free ends of the conductive yarn **25** used in a single layer portion of the sock, and the tails may thus be disposed proximate a transition between the single layer portion and a double layer portion of the sock. In such cases, the tails may be placed between the inner and outer layers **50**, **55** of the double layer portion to avoid unintended conductivity via the tails.

[0044] Accordingly a method of knitting a sock on a circular knitting machine is provided according to embodiments described above. With respect to a single layer sock for example, a first non-conductive yarn **20***a* may be knit to form courses and wales, and a second non-conductive yarn **20***b* may be knit with the first non-conductive yarn to form the courses and wales. The second non-conductive yarn **20***b* may be selectively replaced with a conductive yarn **25** at predefined locations for at least one stitch over a plurality of adjacent courses. In this way, conductive stitches in adjacent courses may define a conductive trace in a wale-wise direction, and the conductive trace may thus extend from a first connection point to a second connection point, as described above, such that the conductive trace can transmit an electrical signal between the first and second connection points.

[0045] In some embodiments, the method of knitting the sock may be modified, at least in some regions of the sock, to provide a double layer sock construction. In such cases, the first non-conductive yarn **20***a* may be knit to form courses and wales of an inner layer **50** of the sock, and the second non-conductive yarn **20***b* may be knit to form courses and wales of an outer layer **55** of the sock. The conductive yarn **25** may be plated between the inner and outer layers **50**, **55** by selecting at least one stitch in a plurality of consecutive courses c to receive the conductive yarn **25**. The inner and outer layers **50**, **55** may be connected together, as described above with respect to FIGS. **3** and **4**, at spaced apart wales and courses by causing the first non-conductive yarn **20***a* to extend between the inner and outer layers **50**, **55**. In this way, each conductive trace formed by the conductive yarn may be isolated from at least an inner surface **60** of the fabric.

[0046] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. For example, although the fabric described herein is described as being used to make socks, in other embodiments other types of garments may be made using embodiments of the fabrics and methods described. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A weft knit fabric comprising:

at least one non-conductive yarn; and

at least one conductive yarn that is weft knit with the at least one non-conductive yarn by selectively incorporating the conductive yarn at predefined locations for at least one stitch over a plurality of adjacent courses or wales to form a fabric having a plurality of wales and courses,

wherein the at least one conductive yarn defines a conductive trace in at least one of a wale-wise or a course-wise direction, respectively, of the fabric,

wherein the conductive trace extends from a first connection point to a second connection point and is configured to transmit an electrical signal between the first and second connection points.

2. The weft knit fabric of claim **1**, wherein the first connection point comprises a device selected from the group consisting of a temperature sensor, a humidity sensor, a pressure sensor, and a heart rate monitor.

3. The weft knit fabric of claim **1**, wherein the second connection point includes an electrical contact configured to allow a device to be connected to the conductive trace and to receive the electrical signal from the first connection point.

4. The weft knit fabric of claim **1**, wherein the conductive trace comprises a plurality of adjacent wales.

5. The weft knit fabric of claim **3**, wherein the at least one non-conductive yarn comprises a first non-conductive yarn and a second non-conductive yarn, wherein the second non-conductive yarn is selectively replaced with the at least one conductive yarn at predetermined locations to define the conductive trace.

6. The weft knit fabric of claim **1**, wherein the at least one conductive yarn defines a plurality of conductive traces along respective wales, wherein each conductive trace is isolated from other conductive traces.

7. The weft knit fabric of claim **1**, wherein consecutive courses include stitches of the conductive yarn of a respective conductive trace that are shifted with respect to adjacent courses.

8. The weft knit fabric of claim **1**, wherein the at least one non-conductive yarn defines an inner layer having wales and courses and an outer layer having wales and courses, wherein the inner and outer layers are connected together at spaced apart wales and courses by one of the non-conductive yarns extending between the layers, and wherein the at least one conductive yarn is knit between the inner and outer layers, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the fabric.

9. The weft knit fabric of claim **8**, wherein the conductive yarn forms at least part of the outer layer.

10. A double layer sock formed on a circular knitting machine from a first non-conductive yarn, a second non-conductive yarn, and at least one conductive yarn, the sock comprising:

a tubular inner layer having at least a foot portion knit of at least a first non-conductive yarn and having wales and courses; and

a tubular outer layer surrounding the inner layer knit of at least a second non-conductive yarn and a conductive yarn and having wales and courses, wherein the outer layer has at least a foot portion aligning with the foot portion of the inner layer,

wherein the inner and outer layers are connected together at spaced apart wales and courses by one of the first or second non-conductive yarns extending between the layers,

wherein the at least one conductive yarn defines a conductive trace in a course-wise direction,

wherein the conductive trace extends from a first connection point to a second connection point and is configured to transmit an electrical signal between the first and second connection points, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the sock.

11. The sock of claim **10**, wherein the second course of the outer layer includes the second non-conductive yarn and the conductive yarn.

12. The sock of claim **10**, wherein the first non-conductive yarn extends between the layers, is knit predominantly in the inner layer, and is knit only for connection purposes in the outer layer, and wherein the conductive yarn is weft knit between the inner and outer layers.

13. The sock of claim **12**, wherein the first non-conductive yarn extending between the inner and outer layers is knit in the outer layer as tuck stitch loops.

14. The sock of claim **10**, wherein at least one of the first connection points forms part of the inner layer.

15. A method of knitting a sock on a circular knitting machine comprising:

knitting a first non-conductive yarn into courses and wales;

knitting a second non-conductive yarn into courses and wales; and

selectively incorporating a conductive yarn at predefined locations for at least one stitch over a plurality of adjacent courses or wales,

wherein the at least one conductive yarn defines a conductive trace in at least one of a wale-wise or a course-wise direction, respectively,

wherein the conductive trace extends from a first connection point to a second connection point and is configured to transmit an electrical signal between the first and second connection points.

16. The method of claim **15**, wherein selectively incorporating the conductive yarn comprises selectively replacing the second non-conductive yarn of the outer layer with the conductive yarn at the predefined locations.

17. The method of claim **15**, wherein

knitting the first non-conductive yarn comprises knitting the first non-conductive yarn into courses and wales to form an inner layer of the sock;

knitting the second non-conductive yarn comprises knitting the second non-conductive yarn into courses and wales to form an outer layer of the sock in surrounding relation to said inner layer;

selectively incorporating the conductive yarn comprises plating the conductive yarn between the inner and outer layers by selecting at least one stitch in a plurality of adjacent courses to receive the at least one conductive yarn; and

the method further comprising connecting the inner and outer layers together at spaced apart wales and courses by causing one of the at least one first or second non-conductive yarns to extend between the inner and outer layers, such that each conductive trace formed by the conductive yarn is isolated from at least an inner surface of the fabric.

18. The method of claim **17**, wherein selectively incorporating the conductive yarn comprises replacing the second non-conductive yarn of the second course of the outer layer with the conductive yarn.

19. The method of claim **17**, wherein selectively incorporating the conductive yarn comprises adding the conductive yarn to the second course of the outer layer, such that the second course of the outer layer includes the second non-conductive yarn and the conductive yarn.

20. The method of claim **15** further comprising attaching at least one of the first connection points to the inner layer and connecting the at least one first connection point to a corresponding conductive trace.

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