# TITLE

# ELASTOMER FIBERS AND METHODS OF MAKING AND USING THEREOF

## BACKGROUND OF THE INVENTION

**[0001]** The invention relates to a fiber excellent in cool contact feeling which is excellent in hand and skin touch and capable of preventing unpleasant feeling in the wet state while also having excellent elasticity. The invention also relates to fabric, clothing, and underwear excellent in cool contact feeling and obtainable by using said fiber as well as the methods of making the fibers and articles thereof.

**[0002]** There is a continuing, never-ending desire for more comfortable feeling articles and garments, particularly in the areas of underwear and sports and/or exercise-related apparel. Users and/or wearers of such articles and garments want them to be as comfortable and refreshing feeling as possible, including after prolonged periods of use and adverse conditions. The fibers used to make such items, specifically their composition, can have a significant impact on the performance of the items in these areas.

**[0003]** There is also a desire for such fibers, in addition to being more comfortable, to retain or even increase their elasticity.

## SUMMARY OF THE INVENTION

**[0004]** The present invention provides an elastic cooling fiber with a Tg of no more than 22 degrees C and more specifically a fiber prepared from a composition comprising the reaction product of: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate: and (iii) a linear alkylene glycol chain extender.

**[0005]** The invention provides a fabric that is made from the fibers described herein, which in some embodiments are mixed with other fibers. The invention provides an article that is made from the fabric described here.

**[0006]** The invention provides a method of providing a cooling effect in an article that comes into close proximity with, in some embodiments even direct contact with, human skin, including the steps of: (1) preparing a fabric comprising the fibers described herein; (2) preparing an article that comprises said fabric; (3)

bringing said article into close proximity with, in some embodiments even direct contact with, human skin.

**[0007]** The invention provides a method of making a fiber including the steps of: (1) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate; and (iii) a linear alkylene glycol chain extender; and (2) melt-spinning said elastomer resin into a monofilament or multifilament fiber.

**[0008]** The invention provides a method of making a fabric including the steps of: (1) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate; and (iii) a linear alkylene glycol chain extender; (2) melt-spinning said elastomer resin into a fiber, in some embodiments a monofilament or multifilament fiber; and (3) processing said fiber, optionally in combination with one or more other fibers, into a fabric.

## DETAILED DESCRIPTION OF THE INVENTION

**[0009]** Various features and embodiments of the invention will be described below by way of non-limiting illustration.

*The Cooling Effect*

**[0010]** The invention provides a fiber excellent in cool contact feeling and also excellent in elasticity. While this cooling effect is generally observed in fabrics and/or articles made from the fiber, it is believed that the cooling effect is due to the properties of the fiber and so not dependent on the type and/or construction of the fabric and/or article involved, though these parameters may of course have a relative impact on the observed cooling effect. In other words, it is believed that the cooling effect is provided by the fiber, and more specifically, fibers having specific properties and/or chemical compositions. In this application, we often note that the fiber can give a cooling contact feeling when in contact with the skin, or even close to human skin, say on top of a layer or even two layers of clothing

between the fiber of the invention and the human skin. In some embodiments, the fiber is in direct contact with human skin. It is understood that the evaluation of the cooling effect may be done with fibers themselves, fabrics made from such fibers, any article made from such fibers and/or fabrics, or various combinations thereof.

**[0011]** The key factors considered responsible for the cooling effect provided by the invention are described below, primarily in the fiber section.

*The Fibers*

**[0012]** The invention provides a fiber excellent in cool contact feeling and also excellent in elasticity. The fiber can give a cooling contact feeling when in contact with the skin. The effect can be strong enough to be sensed in a sensory test.

**[0013]** The fiber may include a thermoplastic elastomer and may also include inorganic fillers, however, in certain embodiments; the composition is free of any inorganic filler.

**[0014]** The fibers of the invention may have a Tg of no more than 22 degrees C and are, as well as article made from them, exceptionally elastic and are also excellent in providing a cool contact feeling when using the fiber for clothing.

**[0015]** "Elastic" and "Elasticity" as used herein means that a fiber will recover at least about 50 percent of its stretched length after the first pull and after the fourth to 100% strain (doubled the length). Elasticity can also be described by the "permanent set" of the fiber. "Permanent Set" is the converse of elasticity. A fiber is stretched to a certain point, in some embodiments 50% of the fiber's known percent elongation at break, and subsequently released to the original position before stretch, and then stretched again. The point at which the fiber begins to pull a load is designated as the percent permanent set. "Elastic materials" are also referred to in the art as "elastomers" and "elastomeric".

**[0016]** The fibers of the present invention can provide this balance of benefits while also avoiding any sticky or inferior skin touch feelings, in the wet state owing to sweat and the like and therefore, which often leads to unpleasant feelings for the wearer when the fiber is used in a garment. The fibers of this invention balance all of these factors and provide superior performance in any one or any combination of these factors.

**[0017]** In some embodiments, the thermoplastic elastomer utilized in the preparation of the fibers described herein is substantially free of, or even free of, a polyamide type elastomer and/or a polyester type elastomer. More specifically, the present invention may be free of polyether block amide copolymers, polyether amide copolymers, and polyester amide copolymers, or any combination thereof. More specifically, the compositions involved in the present invention may be substantially free of, or even completely free of, Pebax (manufactured by Arkema). As used herein, the term polyamide elastomer, or polyamide block within an elastomer, is considered in its chemical sense to be different and distinct from a polyurethane elastomer, or a urethane block within an elastomer. In some embodiments, polyamide links and/or block refer to –N(R)-C(O)-R- units and/or linkages in the elastomer while polyurethane links and/or blocks refer to –N(R)-C(O)-O-R- units and/or linkages in the elastomer.

**[0018]** In other embodiments, the thermoplastic elastomer utilized in the preparation of the fibers described herein may include polyether block amide copolymers, polyether amide copolymers, polyester amide copolymers, or any combination thereof.

**[0019]** The polyester type elastomer is not particularly limited and examples are polyether ester copolymers and polyester ester copolymers. They may be used alone or two or more of them may be used in combination.

**[0020]** Commercialized polyester type elastomers among them are Grilux (manufactured by Dainippon Ink and Chemicals, Inc.), Nouvelan (manufactured by Teijin Chemicals Ltd.), Pelprene (manufactured by Toyobo Co., Ltd.), Hytrel (manufactured by DuPont-Toray Co., Ltd.), and Primalloy (manufactured by Mitsubishi Chemical Corporation).

**[0021]** The resin component contained in the fibers of the invention provides the excellent cool contact feeling of the invention, and so the thermoplastic elastomers alone may be used. Another benefit of the invention is that the fibers described here, when they contain only a thermoplastic elastomer as the resin component, generally have no sticky feeling and so do not become difficult for spinning. While additional resins may be used in combination with the resin described here, it is not required to address any stickiness or unpleasant feeling that may otherwise

accompany more conventional fibers. In some embodiments, an additional resin is used. While inorganic fillers resins may be used in combination with the resin described here, it is not required to address any stickiness or unpleasant feeling that may otherwise accompany more conventional fibers.

**[0022]** In some embodiments, the fiber, and/or the resin from which it is prepared is substantially free, to free of, any inorganic filler. When an inorganic filler is used, it is not particularly limited and examples may include mineral type pigments, such as calcium carbonate such as light calcium carbonate and heavy calcium carbonate, barium carbonate, magnesium carbonate such as basic magnesium carbonate, calcium sulfate, barium sulfate, titanium dioxide, iron oxide, tin oxide, titanium oxide, zinc oxide, magnesium oxide, ferrite powder, zinc sulfide, zinc carbonate, aluminum nitride, silicon nitride, Satin White, diatomaceous earth such as fired diatomaceous earth, calcium silicate, aluminum silicate, magnesium silicate, silica such as amorphous silica, amorphous synthesized silica, and colloidal silica, colloidal alumina, pseudo boehmite, aluminum hydroxide, magnesium hydroxide, alumina, hydrated alumina, litopon, zeolite, hydrated halloysite, clay, hydrotalcite, aluminosilicate, talc, pyrophyllite, smectite such as saponite, hectorite, sauconite, stevensite, montmorillonite, beidellite and nontromite, vermiculite, mica such as phologopite, biotie, zinnwaldite, muscovite, paragonite, celadonite and glauconite, clinochlore, chamosite, nimite, pennantite, sudoite, donbasite, clintonite, margarite, thulite, antigorite, lizardite, chrysotile, mesite, cronstedite, berthierine, greenalite, garnierite, kaolin such as kaolinite, dickite, nacrite and hallosite, delaminated kaolin, calcined kaolin, sepiolite, palygorskite, imogolite, allophane, hisingerite, penwithite, activated earth, bentonite, and sericite. They may be used alone or two or more kinds of them may be used in combination. In some embodiments, the filler is titanium oxide, zinc oxide, barium oxide, silica, or some combination thereof. The form of the inorganic fillers is not particularly limited and examples are finite forms such as spherical, needle-like, plate type forms and the like, or nonfinite forms.

**[0023]** When present, the lower limit of the content of the inorganic filler may be 1%, 2% or 7% by weight, and the upper limit of that is 30% by weight.

**[0024]** The fiber of the present invention may further comprise one or more additional additives, and in some embodiments must contain at least one or more additional additives (beyond the thermoplastic elastomer and any inorganic filler, of present). In addition, the fiber may be twisted and/or covered with another fiber for improving the factors required for underwear such as skin touch within an extent that the aim of the invention is not inhibited. Such another fiber is not particularly limited and examples are polyamide type resins such as nylon 6 and nylon 12; polyesters, cotton, and rayon.

**[0025]** In some embodiments, the fibers of the invention may be described by a $q_{max}$ value. The lower limit of a $q_{max}$ value of the fiber may be 0.20, 0.21 or 0.22 J/sec/cm$^2$. If the $q_{max}$ value is less than 0.20 J/sec/cm$^2$, subjects may not feel any cool contact feeling even if a sensory test is performed. In other embodiments, the $q_{max}$ value of the fiber may be less than 0.20 or even more than 0.22 J/sec/cm$^2$.

**[0026]** In this description, the $q_{max}$ value is defined as a peak value of the heat flow quantity of stored heat transferring to a sample at a lower temperature in the case a prescribed heat is stored in a heat plate with a specified surface area and a specified weight and immediately after the heat plate is brought into contact with the sample surface. It is supposed that the $q_{max}$ value simulates the body heat removed from the body by the sample when clothing is put on and it is supposed that as the $q_{max}$ value is higher, the body heat removed from the body is higher and the cool contact feeling is more excellent when the clothing is put on.

**[0027]** In some embodiments, the lower limit of the heat conductivity of the fiber of the invention may be $1x10^{-3}$ degrees C/Wm$^2$. The heat conductivity is also considered to be one of the important parameters to which the cool contact feeling is corresponding. If the heat conductivity is less than $1x10^{-3}$ degrees C./Wm2, most subjects may not feel any cool contact feeling even if a sensory test is performed.

**[0028]** In this description, the heat conductivity can be calculated by measuring the heat loss speed after a heat plate is layered on a sample put on a sample stand and the temperature of the heat plate is stabilized at a prescribed temperature and performing calculation by the following formula (2).

Heat conductivity(W/cm/degrees C.)=WD/A/$\Delta$T (2)

Where: W: heat flow quantity (J/sec)

D: thickness of a sample (cm)

A: heat plate surface area ($cm^2$)

ΔT: temperature difference (°C) between the sample stand and the heat plate

**[0029]** The fiber of the invention may be used in the form of a composite fiber comprising the thermoplastic elastomer and another resin and may have a core-sheath structure and comprises a core part containing a dyeable resin and a sheath part containing a thermoplastic elastomer resin, a thickness of the sheath part being 20 micrometers or thinner (hereinafter referred to as a core-sheath type composite yarn in some cases). The fiber excellent in cool contact feeling of the invention can be a fiber having the core-sheath structure having good dyeability, keeping excellent properties of the thermoplastic elastomer such as cool contact feeling by using such a dyeable resin for the core part and the thermoplastic elastomer having the cool contact feeling and excellent in the flexibility for the sheath part.

**[0030]** The form of the core-sheath type composite yarn is not particularly limited and the cross-sectional shape formed in the case the fiber is cut perpendicularly to the longitudinal direction of the fiber may be true round, elliptical and the like. Also, the fiber may have a concentric core-sheath type structure in which the core part and sheath part are formed concentrically or an eccentric core-sheath type structure in which the core part and sheath part are formed eccentrically. Also, the fiber may have a structure in which multiple core parts exist in the case the fiber is cut perpendicularly to the longitudinal direction of the fiber.

**[0031]** In some embodiments, the fiber of the invention is an elastic cooling fiber that has a Tg of no more than 22°C.

**[0032]** In some of these embodiments, the Tg of the fiber may be no more than 22, 15, 10, 0, -10, -20, -30 or even -40 degrees C. These Tg limits may apply to the fiber itself, the composition from which the fiber is made (before the composition is spun or otherwise processed into fibers), the intermediate from which the composition is prepared, or any combination thereof.

**[0033]** In some of these embodiments, the percent elongation achieved by the fiber may be from 200% to 300%.

**[0034]** The fibers of the invention are prepared from a composition that includes a reaction product of (i) a hydroxyl terminated intermediate, (ii) a diisocyanate and (iii) a linear alkylene glycol chain extender. The hydroxyl terminated intermediate may include a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C. In some embodiments, the intermediate is derived from polyethylene glycol. The diisocyanate may include diphenyl methane-4,4'-diisocyanate. The linear alkylene glycol may include 1,6-butanediol and similar materials. In some embodiments, the hydroxyl terminated intermediate used in the invention is substantially free of, or even free of, polyether block amide copolymers and/or units of the same.

**[0035]** In still other embodiments, the fibers of the invention are prepared from a composition itself prepared from (i) an intermediate that includes and/or is derived from polyethylene glycol or an adipate derived from one or more alkylene diols and adipic acid, (ii) a diisocyanate that includes methylene diphenyl diisocyanate; and (iii) a linear alkylene glycol chain extender that may include 1,4-butanediol, 1,6-hexanediol, or a combination thereof. In some of these embodiments, the chain extender includes 1,4-butanediol, and the adipate is prepared from 1,4-butanediol, 1,6-hexanediol, or a combination thereof. In some of these embodiments, the adipate is prepared from a mixture of 1,4-butanediol and 1,6-hexanediol. Further, in some of these embodiments, the compositions used to prepare the fiber are: from 40 to 80, 40 to 70, 50 to 60, or even 55 to 58 or 56 to 57 percent by weight intermediate; from 20 to 50, 30 to 40, 30 to 35, or even 31 to 34 or 32 to 33 percent by weight diisocyanate; and from 4 to 25, 5 to 20, 5 to 15, or even from 8 to 11, or 9 to 10 percent by weight chain extender. The fibers of the invention may be made from compositions that contain the material described above and which may also contain one or more polymer additives, including any of the additional additives described below. In some embodiments, the compositions may further include an antioxidant, a lubricant and/or processing aid, and may even have a metal containing catalyst.

**[0036]** In some embodiments, the fibers of the invention are prepared from a composition itself prepared from (i) an intermediate that includes and/or is derived from polyethylene glycol, (ii) a diisocyanate that includes methylene diphenyl

diisocyanate; and (iii) a linear alkylene glycol chain extender that includes 1,4-butanediol, 1,6-hexanediol, or a combination thereof. In some of these embodiments, the chain extender includes 1,4-butanediol. Further, in some of these embodiments, the compositions used to prepare the fiber are: from 40 to 80, 40 to 70, 40 to 60, or even 46 to 49 or 47 to 48 percent by weight intermediate; from 20 to 50, 30 to 50, 35 to 45, or even 40 to 43 or 41 to 42 percent by weight diisocyanate; and from 4 to 25, 5 to 20, 5 to 15, or even from 9 to 12, or 10 to 11 percent by weight chain extender.

**[0037]** In addition, the composition from which the fiber is prepared may be a polymer alloy that includes: (a) a multiphase copolymer prepared by reacting a polymer and/or copolymer segment with at least one other polymer and/or copolymer segment; (b) a polymer blend prepared mixing a polymer and/or copolymer with at least one other polymer and/or copolymer, wherein each of the polymers and/or copolymers is compatible and/or miscible in one another; or (c) combinations thereof. The polymer alloy may be derived from the reaction of: (i)(a) a polyol; (i)(b) a polyester intermediate itself derived from a polyol and a dicarboxylic acid; (ii) at least one diisocyanate; and (iii) at least one chain extender.

**[0038]** In general, the TPU polymer type used in this invention can be any conventional TPU polymer that is known to the art and in the literature as long as it (meaning the fiber itself, the composition from which the fiber is made, and/or the intermediate used to prepare the composition) exhibits the Tg, percent elongation, and/or elasticity described above. While not wishing to be bound by theory, Applicants consider that compositions which meet these requirements are expected to provide the same cooling effect demonstrated by the specific examples included in this application, or in the alternative, when at least one or more of the additional parameters described herein is met.

**[0039]** Suitable TPU polymers are generally prepared by reacting a polyisocyanate with an intermediate such as a hydroxyl terminated polyester, a hydroxyl terminated polyether, a hydroxyl terminated polycarbonate or mixtures thereof, with one or more chain extenders, all of which are well known to those skilled in the art.

**[0040]** The hydroxyl terminated polyester intermediate is generally a linear polyester having a number average molecular weight (Mn) of from about 500 to about 10,000, from about 700 to about 5,000, or from about 700 to about 4,000, an acid number generally less than 1.3 and preferably less than 0.8. The molecular weight is determined by assay of the terminal functional groups and is related to the number average molecular weight. The polymers are produced by (1) an esterification reaction of one or more glycols with one or more dicarboxylic acids or anhydrides or (2) by transesterification reaction, i.e., the reaction of one or more glycols with esters of dicarboxylic acids. Mole ratios generally in excess of more than one mole of glycol to acid are preferred so as to obtain linear chains having a preponderance of terminal hydroxyl groups. Suitable polyester intermediates also include various lactones such as polycaprolactone typically made from ε-caprolactone and a bi-functional initiator such as diethylene glycol. The dicarboxylic acids of the desired polyester can be aliphatic, cycloaliphatic, aromatic, or combinations thereof. Suitable dicarboxylic acids which may be used alone or in mixtures generally have a total of from 4 to 15 carbon atoms and include: succinic, glutaric, adipic, pimelic, suberic, azelaic, sebacic, dodecanedioic, isophthalic, terephthalic, cyclohexane dicarboxylic, and the like. Anhydrides of the above dicarboxylic acids such as phthalic anhydride, tetrahydrophthalic anhydride, or the like, can also be used. Adipic acid is a preferred acid. The glycols which are reacted to form a desirable polyester intermediate can be aliphatic, aromatic, or combinations thereof, and have a total of from 2 to 12 carbon atoms, and include ethylene glycol, 1,2-propanediol, 1,3-propanediol, 1,3-butanediol, 1,4-butanediol, 1,5-pentanediol, 1,6-hexanediol, 2,2-dimethyl-1,3-propanediol, 1,4-cyclohexanedimethanol, decamethylene glycol, dodecamethylene glycol, and the like, 1,4-butanediol is a preferred glycol.

**[0041]** Hydroxyl terminated polyether intermediates are polyether polyols derived from a diol or polyol having a total of from 2 to 15 carbon atoms, in some embodiments an alkyl diol or glycol which is reacted with an ether (or an epoxide) which comprises an alkylene oxide group having from 2 to 6 carbon atoms, typically ethylene oxide or propylene oxide or mixtures thereof. For example, hydroxyl functional polyether can be produced by first reacting propylene glycol

with propylene oxide followed by subsequent reaction with ethylene oxide. Primary hydroxyl groups resulting from ethylene oxide are more reactive than secondary hydroxyl groups and thus are preferred. Useful commercial polyether polyols include poly(ethylene glycol) comprising ethylene oxide reacted with ethylene glycol, poly(propylene glycol) comprising propylene oxide reacted with propylene glycol, poly(tetramethylene glycol) comprising water reacted with tetrahydrofuran (PTMEG). PTMEG is the preferred polyether intermediate. Polyether polyols further include polyamide adducts of an alkylene oxide and can include, for example, ethylenediamine adduct comprising the reaction product of ethylenediamine and propylene oxide, diethylenetriamine adduct comprising the reaction product of diethylenetriamine with propylene oxide, and similar polyamide type polyether polyols. Copolyethers can also be utilized in the current invention. Typical copolyethers include the reaction product of THF and ethylene oxide or THF and propylene oxide. These are available from BASF as Poly THF B, a block copolymer, and poly THF R, a random copolymer. The various polyether intermediates generally have a number average molecular weight (Mn) as determined by assay of the terminal functional groups which is an average molecular weight greater than about 700, such as from about 700 to about 10,000, from about 1000 to about 5000, or from about 1000 to about 2500. A particular desirable polyether intermediate is a blend of two or more different molecular weight polyethers, such as a blend of 2000 $M_n$ and 1000 $M_n$ PTMEG.

**[0042]** In some embodiments, the compositions of the present invention are prepared from polyethleneglycol (PEG). In other embodiments, the intermediate is a polyester made from the reaction of adipic acid with a 50/50 blend of 1,4-butanediol and 1,6-hexanediol.

**[0043]** The polycarbonate-based polyurethane resin of this invention may be prepared by reacting a diisocyanate with a blend of a hydroxyl terminated polycarbonate and a chain extender. The hydroxyl terminated polycarbonate can be prepared by reacting a glycol with a carbonate.

**[0044]** U.S. Patent No. 4,131,731 is hereby incorporated by reference for its disclosure of hydroxyl terminated polycarbonates and their preparation. Such polycarbonates are linear and have terminal hydroxyl groups with essential

exclusion of other terminal groups. The essential reactants are glycols and carbonates. Suitable glycols are selected from cycloaliphatic and aliphatic diols containing 4 to 40, and or even 4 to 12 carbon atoms, and from polyoxyalkylene glycols containing 2 to 20 alkoxy groups per molecule with each alkoxy group containing 2 to 4 carbon atoms. Diols suitable for use in the present invention include aliphatic diols containing 4 to 12 carbon atoms such as butanediol-1,4, pentanediol-1,4, neopentyl glycol, hexanediol-1,6, 2,2,4-trimethylhexanediol-1,6, decanediol-1,10, hydrogenated dilinoleylglycol, hydrogenated dioleylglycol; and cycloaliphatic diols such as cyclohexanediol-1,3, dimethylolcyclohexane-1,4, cyclohexanediol-1,4, dimethylolcyclohexane-1,3, 1,4-endo methylene-2-hydroxy-5-hydroxymethyl cyclohexane, and polyalkylene glycols. The diols used in the reaction may be a single diol or a mixture of diols depending on the properties desired in the finished product. Polycarbonate intermediates which are hydroxyl terminated are generally those known to the art and in the literature. Suitable carbonates are selected from alkylene carbonates composed of a 5 to 7 member ring. Suitable carbonates for use herein include ethylene carbonate, trimethylene carbonate, tetramethylene carbonate, 1,2-propylene carbonate, 1,2-butylene carbonate, 2,3-butylene carbonate, 1,2-ethylene carbonate, 1,3-pentylene carbonate, 1,4-pentylene carbonate, 2,3-pentylene carbonate, and 2,4-pentylene carbonate.

**[0045]** Also, suitable herein are dialkylcarbonates, cycloaliphatic carbonates, and diarylcarbonates. The dialkylcarbonates can contain 2 to 5 carbon atoms in each alkyl group and specific examples thereof are diethylcarbonate and dipropylcarbonate. Cycloaliphatic carbonates, especially dicycloaliphatic carbonates, can contain 4 to 7 carbon atoms in each cyclic structure, and there can be one or two of such structures. When one group is cycloaliphatic, the other can be either alkyl or aryl. On the other hand, if one group is aryl, the other can be alkyl or cycloaliphatic. Examples of suitable diarylcarbonates, which can contain 6 to 20 carbon atoms in each aryl group, are diphenylcarbonate, ditolylcarbonate, and dinaphthylcarbonate.

**[0046]** The reaction is carried out by reacting a glycol with a carbonate, for example an alkylene carbonate in the molar range of 10:1 to 1:10, but preferably 3:1 to 1:3 at a temperature of 100°C to 300°C and at a pressure in the range of 0.1

to 300 mm of mercury in the presence or absence of an ester interchange catalyst, and may also be carried out while removing low boiling glycols by distillation.

**[0047]** More specifically, the hydroxyl terminated polycarbonates are prepared in two stages. In the first stage, a glycol is reacted with an alkylene carbonate to form a low molecular weight hydroxyl terminated polycarbonate. The lower boiling point glycol is removed by distillation at 100°C to 300°C, preferably at 150°C to 250°C, under a reduced pressure of 10 to 30 mm Hg, preferably 50 to 200 mm Hg. A fractionating column may be used to separate the by-product glycol from the reaction mixture. The by-product glycol can be taken off the top of the column and the unreacted alkylene carbonate and glycol reactant may be returned to the reaction vessel as reflux. A current of inert gas or an inert solvent can be used to facilitate removal of by-product glycol as it is formed. When amount of by-product glycol obtained indicates that degree of polymerization of the hydroxyl terminated polycarbonate is in the range of 2 to 10, the pressure is gradually reduced to 0.1 to 10 mm Hg and the unreacted glycol and alkylene carbonate are removed. This marks the beginning of the second stage of reaction during which the low molecular weight hydroxyl terminated polycarbonate is reacted by distilling off glycol as it is formed at 100°C to 300°C, preferably 150°C to 250°C and at a pressure of 0.1 to 10 mm Hg until the desired molecular weight of the hydroxyl terminated polycarbonate is attained. Molecular weight (Mn) of the hydroxyl terminated polycarbonates can vary from about 500 to about 10,000 but in a preferred embodiment, it will be in the range of 500 to 2500.

**[0048]** The second necessary ingredient to make the TPU polymer of this invention is a polyisocyanate. The polyisocyanates of the present invention generally have the formula $R(NCO)_n$ where n is generally from 2 to 4 with 2 being highly preferred inasmuch as the composition is a thermoplastic. Thus, polyisocyanates having a functionality of 3 or 4 are utilized in very small amounts, for example, less than 5% and desirably less than 2% by weight based upon the total weight of all polyisocyanates, inasmuch as they cause crosslinking. R can be aromatic, cycloaliphatic, and aliphatic, or combinations thereof generally having a total of from 2 to about 20 carbon atoms. Examples of suitable aromatic diisocyanates include diphenyl methane-4, 4'-diisocyanate (MDI), $H_{12}$ MDI, m-

xylylene diisocyanate (XDI), m-tetramethyl xylylene diisocyanate (TMXDI), phenylene-1, 4-diisocyanate (PPDI), 1,5-naphthalene diisocyanate (NDI), and diphenylmethane-3, 3'-dimethoxy-4, 4'-diisocyanate (TODI). Examples of suitable aliphatic diisocyanates include isophorone diisocyanate (IPDI), 1,4-cyclohexyl diisocyanate (CHDI), hexamethylene diisocyanate (HDI), 1,6-diisocyanato-2,2,4,4-tetramethyl hexane (TMDI), 1,10-decane diisocyanate, and trans-dicyclohexylmethane diisocyanate (HMDI). A highly preferred diisocyanate is MDI containing less than about 3% by weight of ortho-para (2,4) isomer.

**[0049]** The third necessary ingredient to make the TPU polymer of this invention is the chain extender. Suitable chain extenders are lower aliphatic or short chain glycols having from about 2 to about 10 carbon atoms and include for instance ethylene glycol, diethylene glycol, propylene glycol, dipropylene glycol, tripropylene glycol, triethylene glycol, cis-trans-isomers of cyclohexyl dimethylol, neopentyl glycol, 1,4-butanediol, 1,6-hexandiol, 1,3-butanediol, and 1,5-pentanediol. The present invention requires a linear alkylene glycol chain extender, but in some embodiments additional chain extenders may be used in combination with the linear alkylene glycol chain extender. In such embodiments, aromatic glycols can be used as the chain extender. Benzene glycol (HQEE) and xylylene glycols are suitable chain extenders for use in making the TPU of this invention. Xylylene glycol is a mixture of 1,4-di(hydroxymethyl) benzene and 1,2-di(hydroxymethyl) benzene. Benzene glycol is the preferred aromatic chain extender and specifically includes hydroquinone, bis(beta-hydroxyethyl) ether also known as 1,4-di(2-hydroxyethoxy) benzene; resorcinol, bis(beta-hydroxyethyl) ether also known as 1,3-di(2-hydroxyethyl) benzene; catechol, i.e., bis(beta-hydroxyethyl) ether also known as 1,2-di(2-hydroxyethoxy) benzene; and combinations thereof. The preferred chain extender is 1,4-butanediol.

**[0050]** The above three necessary ingredients (hydroxyl terminated intermediate, polyisocyanate, and chain extender) may be reacted in the presence of a catalyst.

**[0051]** Generally, any conventional catalyst can be utilized to react the diisocyanate with the hydroxyl terminated intermediate or the chain extender and the same is well known to the art and to the literature. Examples of suitable catalysts include the various oragno compounds, such as carbonates, of bismuth or

tin wherein the alkyl portion has from 1 to about 20 carbon atoms with specific examples including bismuth octoate, bismuth laurate, and the like. Preferred catalysts include the various tin catalysts such as stannous octoate, dibutyltin dioctoate, dibutyltin dilaurate, and the like. The amount of such catalyst is generally small such as from about 20 to about 200 parts per million based upon the total weight of the polyurethane forming monomers.

**[0052]** The TPU polymers of this invention can be made by any of the conventional polymerization methods well known in the art and literature.

**[0053]** In some embodiments, the polyurethanes of the invention are made via a "one shot" process wherein all the components are added together simultaneously or substantially simultaneously to a heated extruder and reacted to form the polyurethane. The equivalent ratio of the diisocyanate to the total equivalents of the hydroxyl terminated intermediate and the diol chain extender is generally from about 0.95 to about 1.10, desirably from about 0.97 to about 1.03, and preferably from about 0.97 to about 1.00. In some embodiments, the Shore A hardness of the TPU formed will typically be from less than 80A, 85A or even 95A. Reaction temperatures utilizing urethane catalyst may be from about 175°C to about 245°C or even from about 180°C to about 220°C. The molecular weight (Mw) of the thermoplastic polyurethane may be from about 100,000 to about 800,000 Daltons or from about 150,000 to about 400,000 or even from about 150,000 to about 350,000 as measured by GPC relative to polystyrene standards.

**[0054]** Useful additives can be utilized in suitable amounts in the TPU's described herein, where such additives may be added either before, during, or after the preparation of the TPU. Such additional additives include opacifying pigments, colorants, mineral fillers, stabilizers, lubricants, UV absorbers, processing aids, and other additives as desired. Useful opacifying pigments include titanium dioxide, zinc oxide, and titanate yellow, while useful tinting pigments include carbon black, yellow oxides, brown oxides, raw and burnt sienna or umber, chromium oxide green, cadmium pigments, chromium pigments, and other mixed metal oxide and organic pigments. Useful fillers include diatomaceous earth (superfloss) clay, silica, talc, mica, wallastonite, barium sulfate, and calcium carbonate. If desired, useful stabilizers such as antioxidants can be used and include phenolic

antioxidants, while useful photostabilizers include organic phosphates, and organotin thiolates (mercaptides). Useful antioxidants also include stearically hindered phenolic antioxidants. Useful lubricants include metal stearates, paraffin oils and amide waxes, for example, alkylene bisstearamides such as N,N' ethylene bisstearamide and esters of nonanic esters. Useful UV absorbers include 2-(2'-hydroxyphenol) benzotriazoles and 2-hydroxybenzophenones. Typical TPU flame retardants can also be added.

**[0055]** Plasticizer additives can also be utilized advantageously to reduce hardness without affecting properties, if they are used in small amounts. In some embodiments, no plasticizers are used.

**[0056]** In some embodiments, the cooling effect of the fiber may be expressed in terms of effective cooling power. While there are various means of measuring the cooling effect provided by the invention, this application includes details on two approaches to measure this effect. The first looks at the cooling effect provided by fabrics made from the fibers described herein, where the fabric and the area of "skin" in contact with the fabric, in this case a test surface taking the place of a person's skin, are both and where a constant wind is blowing across the fabric. While the specific conditions involved are considered to be important primarily for the purposes of comparing results, these type of evaluations can be of course be done at various ambient temperatures, levels of humidity, wind speed, starting temperature of the "skin", whether the "skin" heat source is left on or removed, and various other variables. In addition, this parameter is of course measured with respect to a specific area. Another approach follows the basic test methodology described above but adds the additional variable of sweat, various rates of moisture release from the "skin" over the course of the test. Using these types of tests, one can measure the amount of energy it takes to maintain the temperature of the "skin" under various conditions, or in the alternative, measure the rate at which the "skin" temperature drops if no heat source is applied, thus giving an indication of the cooling power of the fabric involved. Specific test conditions and results are provided in the examples section of this specification. It is important to note that regardless of the testing approach used, and the specific conditions selected, all testing conducted to date has shown that fabrics made from the fibers described

herein exhibit significantly higher cooling powers and allow for faster and greater temperature drops than the comparative materials also tested.

**[0057]** In some embodiments, the fibers of the present invention, when evaluated by the methods described above, specifically where the fabric is placed on the test skin surface, with an active heat source working to maintain skin surface temperature, 30% relative humidity, a 3 m/s wind speed, and an ambient temperature of 15 degrees C, provide a cooling power of at least 31 watts for a test are of 629 $cm^2$, or stated differently a cooling power of at least 49 watts per square meter. That is, at least 49 watts of power per square meter of area is required to maintain skin temperature, giving an indication of the cooling effect the fabric would provide to a person where the fabric against their skin, compared to other materials (nylon and polyester, for example, could not break the 31 watt limit under the exact same test conditions). This cooling power may also be at least 34 watts for a test area of 629 $cm^2$, at least 55 watts per square meter, where the fiber is a monofilament and is not semi-dull. The same limits apply to testing conducted at 50% relative humidity and 3 m/s wind speed, as well as at 5 m/s wind speed at 50% relative humidity.

**[0058]** In similar embodiments, the fiber of the present invention when evaluated by the methods described above, specifically where the fabric is placed on the test skin surface, with an active heat source working to maintain skin surface temperature, 50% relative humidity, a 0.3 m/s wind speed, and an ambient temperature of 15 degrees C, provide a cooling power of at least 13 or 14 watts for a test area of 629 $cm^2$, at least 21 or 22 watts per square meter.

**[0059]** A method of producing the fiber excellent in cool contact feeling of the invention is not particularly limited and conventionally known methods such as a method of producing it by producing resin pellets containing the thermoplastic elastomer and the inorganic filler and melting and spinning, using the obtained resin pellets, may be employed.

**[0060]** The core-sheath type composite yarn may also be produced by, for example, loading resin pellets containing the dyeable resin, the thermoplastic elastomer, and the inorganic filler into a composite spinning apparatus and melting and spinning them.

**[0061]** The invention provides a method of making a fiber that includes the steps of: (I) preparing an elastomer resin in an internal mixing device. The elastomer resin is prepared by reacting: (i) a hydroxyl terminated intermediate, (ii) a diisocyanate and (iii) a linear alkylene glycol chain extender. The intermediate may be a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C. The second step, (II) is melt-spinning the elastomer resin into a fiber, for example, a monofilament or multifilament fiber. In some embodiments, the fiber is a monofilament fiber. All of the various features and embodiments discussed above with regards to the fiber and the composition used to prepare it apply here as well.

*The Fabric*

**[0062]** The fiber of the invention may be used in form of a fabric such as a knit, a textile, and a bonded textile. The resulting fabric is excellent in cool contact feeling while also possessing the excellent elasticity of the fiber.

**[0063]** The fabric excellent in cool contact feeling of the invention may solely comprise the fiber excellent in cool contact feeling of the invention and in other embodiments may comprise the fiber and another fiber twisted together for improving the factors required for specific applications. For example, in garments that come into direct contact with skin. Such optional co-fibers are not particularly limited and examples include polyamide type resins such as nylon 6 and nylon 12, polyesters, cotton, and rayon.

**[0064]** The invention includes fabrics made from any of the fibers described herein, including woven fabric, non-woven fabric, knitted fabric, and combinations thereof. In some embodiments, the fabrics of the invention are woven fabrics. In other embodiments, the fabrics of the invention are non-woven fabrics. In still other embodiments, the fabrics of the invention are knitted fabrics. In addition, the invention includes fabrics that further contain one or more additional fibers, other than the fibers of the invention. The fabric may be from 10 to 80 percent by weight of these additional fibers, or no more than 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, or 10% of these additional fibers. In some embodiments, no additional fibers are present. In embodiments where there are one or more additional fibers present

in the fabric, these additional fibers may be nylon fibers, polyester fibers, rayon fibers, acrylic fibers, and combinations thereof.

**[0065]** The invention also includes a method of making a fabric that includes the steps of (I) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared as described above. The process may optionally include the addition of a cross-linking agent, such as the reaction product of a polyalkylene ether glycol or triol and a diisocyanate. Step (II) is melt-spinning said elastomer resin into a fiber, for example, a monofilament or multifilament fiber. In some embodiments, the fiber, or rather the polymer making up the fiber, has a weight average molecular weight of at least 700,000. Step (III) is processing the fiber, optionally in combination with one or more other fibers, into a fabric.

**[0066]** An additional benefit of the invention is the improved mold-ability of fabrics that contain the fibers described herein. When utilized at suitable levels within the fabric, the fabric of the invention can be successful molded at lower temperatures and/or in less time, thus improving the ability to protect the fabric, dye, etc of the fabric which may be damaged by the high temperatures and/or low exposure time required by more conventional fabrics in order to successfully mold them. In some embodiments, the fabrics of the invention may be molded at temperatures of no more than 150 or even 140 degrees C, and/or where the molding is complete in less than 20, 15 or even 10 seconds. In some embodiments, a minimum level of the fibers of the invention must be present in the fabric for it to provide these benefits. In some embodiments, this lower limit is 40%, 50%, 60% or even 80% where the percentage represent the percent by weight of the fibers in the fabric that must be the fibers of the present invention. However, it is also understood that a much smaller amount of the fibers of the invention in a fabric will improve that fabric's mold-ability. It is noted that Spandex™ and similar materials are not moldable at low temperatures, and that fibers of these materials are not even knittable into fabrics unless a positive feeder is used, an expensive piece of equipment required due to the over-elasticity of Spandex™ fibers.

*The Articles*

**[0067]** The fiber excellent in cool contact feeling of the invention and the fabric excellent in cool contact feeling of the invention may be used for producing articles

including clothing. In the case of articles that come into contact with skin, again for example, clothing, the articles of the invention exhibit excellent elasticity, provide a cooling sensation to the wearer, and have no unpleasant and/or sticky feeling even at times of wetting.

**[0068]** Since the articles, and specifically the clothing, provide excellent cool contact feeling, it can cause sensation of cool feeling at the time of wearing and give refreshing feeling. Also, the present invention does not require the addition of the inorganic filler to make the clothing free from a sticky feeling at the time of wetting, as other fibers used in clothing with similar cooling effects may do. Thus, the present invention is extremely suitable for underwear.

**[0069]** The clothing excellent in cool contact feeling of the invention may be produced using the fiber excellent in cool contact feeling entirely and it is particularly preferable to be clothing excellent in cool feeling comprising a fabric having a reversible structure and excellent in refreshing feeling, 30 to 70% by number of total loops comprising the fiber excellent in cool contact feeling, the loops comprising the fiber excellent in cool contact feeling being arranged in a skin contact side (hereinafter, also referred to as refreshing clothing).

**[0070]** With respect to the clothing comprising a fabric having a reversible structure as clothing excellent in cool contact feeling of the invention, the ratio of the number of loops comprising the fiber excellent in cool contact feeling is controlled within a prescribed range and such loops comprising the fiber excellent in cool contact feeling are arranged only in the skin contact side, so that the clothing can have an effect of preventing unpleasant feeling caused by much sweating.

**[0071]** In recent years, various kinds of clothing having improved functions as underwear to be put on in an occasion of sweating in summer, in the case of exercises, sports and the like, have been developed and proposed, and such functional clothing is suggested, for example, clothing produced from hydrophobic fibers such as polyester. Also, a method of increasing the air permeability by using a hydrophilic fiber in combination with cotton and a method of increasing the air permeability by forming a mesh structure for a cloth or by forming a moss knitting of a derivative weave of a plain knitting and warp knitting, have been investigated,

and Japanese Kokai Publication 2003-155669 discloses a reformed cloth by depositing a hydrophilic chemical substance on the surface of a hydrophobic fiber composing the cloth. However, in the case of clothing comprising such hydrophobic fibers, although the generated heat can efficiently be released, it causes unpleasant feeling due to wet feeling in the case the skin or the clothing is wetted because of sweating and at the same time the fabric tends to be stuck to the skin to cause the problem that the clothing restrains the movement.

**[0072]** On the other hand, with respect to the refreshing clothing comprising the fabric having a reversible structure, it can cause sensation of cool feeling at the time of wearing and give refreshing feeling and simultaneously it can prevent unpleasant feeling due to wet feeling at the time of sweating and prevent sticking of the fabric to the skin due to deterioration of the separation from the skin by controlling the ratio of the number of loops comprising the fiber excellent in cool contact feeling to be within a prescribed range. Also, the loops comprising the fiber excellent in cool contact feeling are arranged only in the skin side, so that the fiber excellent in cool contact feeling can be brought into direct contact with the skin and clothing with further improved refreshing feeling and cool contact feeling can be produced.

**[0073]** In the refreshing articles and clothing of the invention, the lower limit of the ratio of the loops of the fiber excellent in cool contact feeling may be 30% of the total number of loops, and the upper limit may be 70% or even higher, such as 75%, 80%, 90% or even 100% of the total number of loops. If it is less than 30%, the effect to cause refreshing feeling and cool contact feeling may become insufficient in some cases. The high level can be obtained with the present invention without causing any unpleasant feeling due to wet feeling in the case the skin or the clothing is wetted because of sweating.

**[0074]** As noted above, for the fiber and fabric, the refreshing article, for example, the clothing, may contain the thermoplastic elastomer and an inorganic filler, but in other embodiments is substantially free of, to even free of, any inorganic filler.

**[0075]** In the articles of the invention, for example, the clothing, the thickness of the fabric is to be made as thin as possible, the fiber excellent in cool contact

feeling may be used in combination with another fiber. The lower limit of the content of the thermoplastic elastomer in the fiber excellent in cool contact feeling may be 50% by weight. If it is less than 50% by weight, sufficient cool contact feeling may not be caused in some cases. In other embodiments, the content of the fiber of the invention is present in the fabric and articles is at least 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85%, or even 95% by weight. While not wishing to be bound by theory, it is believed that some minimum fiber content in the fabric and/or article in question must be the fiber of the invention for the cooling effect to be noticeable. This minimum required content may vary across the various formulations included in the present invention, but in some embodiments may be fairly consistent across the various formulations. This minimum content may be any of the percentages described above.

**[0076]** In some embodiments, in the articles and/or clothing of the invention, the loops comprising the fiber excellent in cool contact feeling are preferable to be arranged only in the skin side. Arrangement in such a manner makes the loops comprising the fiber excellent in cool contact feeling have mainly contact with the skin and causes the cool contact feeling and refreshing feeling, and as described later, arrangement of loops comprising a hydrophobic fiber in the outside improves the diffusion and evaporating property of the heat and water emitted from the skin.

**[0077]** In the articles and/or clothing of the invention, the loops other than the loops comprising the fiber excellent in cool contact feeling are preferably the loops comprising a hydrophobic fiber. Since the loops comprising the fiber excellent in cool contact feeling are arranged only in the skin side, the loops comprising a hydrophobic fiber are arranged mainly in the outside.

**[0078]** In this description, the hydrophobic fiber means a chemical fiber having a official water percentage of 5.0% or less. Practically, fibers comprising polypropylenes (official water percentage: 0%), polyesters (0.4%), acrylic resins (2.0%), nylon (4.5%), and vinylon (5.0%) can be exemplified. They may be used alone or two or more kinds of them may be used in combination. In this connection, the official water percentage means water percentage at 20 degrees C. and 65% RH.

**[0079]** The articles and/or clothing of the invention may contain natural fibers such as cotton and flax, and semi-synthesized fibers such as rayon and acetate based on the necessity besides the fiber excellent in cool contact feeling and the hydrophobic fiber.

**[0080]** In some embodiments, the articles and/or clothing of the invention has an air permeability of the refreshing clothing from 200 $cm^3/cm^2/sec$ up to 500 $cm^3/cm^2/sec$. If it is less than 200 $cm^3/cm^2/sec$, the air permeability may be deteriorated and the diffusion of heat and evaporation of sweat emitted from the skin may possibly be inhibited and if it is more than 500 $cm^3/cm^2/sec$, transfer of the heat and water through the clothing may not be carried out sufficiently and contrarily the outer air may penetrate. The air permeability can be measured by using a air permeability tester according to JIS L 1096 A method.

**[0081]** In the fabric, articles and/or clothing of the invention, the upper limit of the weight per square-meter may be 120, 100 or even 90 $g/m^2$. Unlike other means of providing such cooling feelings, if the weight per square-meter is more than 120, 100 or even 90 $g/m^2$, the mechanism at work may be stifled and so the cooling feeling may possibly be deteriorated.

**[0082]** A method of producing the articles and/or clothing of the invention is not particularly limited and for example, conventionally known methods such as a method of producing clothing by weaving the fiber excellent in cool contact feeling of the invention can be employed. These materials may also be produced by the conventionally known methods of sewing, cutting and the like, using the fabrics with the reversible structure obtained by the above-mentioned manner.

**[0083]** Underwear excellent in cool contact feeling can be produced by using the fiber of the invention or the fabric of the invention. Also, the clothing excellent in cool contact feeling of the invention can be used as underwear. In such embodiments, the invention may provide any one or more of the benefits described above for the fiber, fabric, article, and/or clothing.

**[0084]** In addition to the underwear, the present invention includes stockings, gloves, face masks, mufflers and the like that may be produced by using the fiber of the invention or the fabric excellent in cool contact feeling of the invention. They

are brought into direct contact with the skin and therefore, they can cause a particularly excellent effect.

**[0085]** The invention includes an article made from the fabrics described above. For example, various garments can be made with the fabrics of this invention. In some embodiments, the fabric is used in making undergarments or tight fitting garments, for which the fabrics of this invention are well-suited due to the comfort and cooling effect provided by the fiber. Undergarments, such as bras and T-shirts as well as sport garments used for activities such as running, skiing, cycling, or other sports, can benefit from the properties of these fibers. Garments worn next to the body benefit from the elasticity and cooling effect the invention provides. It will be understood by those skilled in the art that any garment can be made from the fabric and fibers of this invention.

**[0086]** In other embodiments, the fibers described herein are used to make one or more of any number of garments and articles including but not limited to: sports apparel, such as shorts, including biking, hiking, running, compression, training, golf, baseball, basketball, cheerleading, dance, soccer and/or hockey shorts; shirts, including any of the specific types listed for shorts above; tights including training tights and compression tights; swimwear including competitive and resort swimwear; bodysuits including wrestling, running and swimming body suits; and footwear. Additional embodiments include work wear such as shirts and uniforms. Additional embodiments include intimates including bras, panties, men's underwear, camisoles, body shapers, nightgowns, panty hose, men's undershirts, tights, socks and corsetry. Additional embodiments include medical garments and articles including: hosiery such as compression hosiery, diabetic socks, static socks, and dynamic socks; therapeutic burn treatment bandages and films; wound care dressings; medical garments. Additional applications include military applications that mirror one or more of the specific articles described above. Additional embodiments include bedding articles including sheets, blankets, comforters, mattress pads, mattress tops, and pillow cases.

**[0087]** In some embodiments, the article of the invention is a garment and the fibers that make up the fabric in the garment are arranged in the garment as to be in

direct contact with the skin of a wearer of said garment. This allows the wearer to gain the full benefit of the cooling effect provided by the invention.

**[0088]** The invention also provides a method of providing a cooling effect in an article, such as a garment, that comes into direct contact with human skin, comprising the steps of: (I) preparing a fabric comprising the fiber of claim 1; (II) preparing an article that comprises said fabric; and (II) bringing said article into direct contact with human skin.

**[0089]** It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) can migrate to other acidic or anionic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included within the scope of the present invention; the present invention encompasses the composition prepared by admixing the components described above.

## EXAMPLES

**[0090]** The invention will be further illustrated by the following examples, which sets forth particularly advantageous embodiments. While the examples are provided to illustrate the present invention, they are not intended to limit it.

*Example Set*

**[0091]** Seven materials were evaluated to demonstrate the benefits of the invention. These materials are summarized in the table below.

**Table 1 – Sample Descriptions and Properties**

| Ex | Sample Description[1] | Fabric Diameter [cm] | Fabric Length [cm] | Fabric Weight [g/m$^2$] |
|---|---|---|---|---|
| 1 | Baseline: No Material (bare test surface) | NA | NA | NA |
| 2 | Multifilament Red Core Polyester Fiber | 13.9 | 42.0 | 27 |
| 3 | Multifilament Blue Core Nylon Fiber[2] | 14.7 | 43.0 | 25 |
| 4 | Monofilament Fiber A[3] | 5.3 | 37.5 | 90 |
| 5 | Monofilament Fiber B[4] | 8.4 | 35.5 | 65 |
| 6 | Multifilament Fiber C[5] | 9.2 | 29.0 | 66 |
| 7 | Monofilament Fiber D – Semi Dull[6] | 10.8 | 43.0 | 43 |

*1 – Each fabric sample is in the form of a open sock/sleeve. The diameter refers to the diameter of the sleeve the fabric creates while the length is the actual length of the sample. For the fabric weight, each sample was weighed and then, using the other measurements reported, a weight in terms of grams per meter squared was calculated for each fabric.*

*2 This fiber is commercially available from Invista™.*

*3 Fiber A is prepared from a polyalkylene glycol, an alkylene diol, and MDI.*

*4 Fiber B is prepared from alkylene diol adipate, an alkylene diol, and MDI.*

*5 Fiber C is a multifilament version of Fiber B, and is chemically identical to Fiber B.*

*6 Fiber D is Fiber B but with a commercially available dulling agent added.*

**[0092]** Comparative Example 1 is a baseline and represents no fiber and/or fabric. Comparative Examples 2 and 3 are comparative materials that do not represent the invention. Examples 4, 5, 6 and 7 represent various embodiments of the invention.

**[0093]** It is noted that the fabrics tested have different diameters and the fabrics obtained for testing are of different weights. To account for these differences, the testing described below has been carried out with the use of clamps to fix the fabric samples in such a way as to provide comparable tension and fabric density over the testing surface, thus allowing for a valid comparison of the materials. Any differences not accounted for by these controls are not expected to have a significant impact on the parameters tested.

*Test Methods and Results*

**[0094]** The examples described above were tested to determine their cooling power. This testing was conducted in a climatic chamber at controlled temperature and humidity using a sweating thermal mannequin as a test surface. The test surface of the mannequin, with a known surface area, is equipped with thermocouples to monitor temperature and heating elements to allow the test surface to be heated to a realistic human skin temperature for the testing. In addition, the power demands of the heating elements could also be monitored to see

the amount energy required to maintain a specific skin temperature at the test surface. The test surface is also capable of moisture release, simulating the sweat release of human skin. A high power fan was used as a wind source. The area of the test surface used for all of this testing is 629 $cm^2$.

**[0095]** For this testing, the sweating thermal mannequin is placed inside the climatic chamber, which is set to 15 degrees C. Testing was carried out at 30% and 50% relative humidity, with winds speeds of 0.3 m/s, 3 m/s and 5 m/s. A wind speed of 0.3 m/s is the normal condition inside the climatic chamber and so indicates the high speed fan is in the off position. Circular knitted, open-ended sock samples of each material, also referred to as sleeves, are placed on the test surface of the sweating thermal mannequin, in this case the forearm of the mannequin. Samples are placed on the test surface for testing and then are removed and replaced with the next sample. As noted above, clamps are used to secure each sample to the forearm of the sweating thermal mannequin and care is taken to ensure the samples are placed with comparable levels of tension and fabric density.

**[0096]** At the start of each test, the chamber is brought up to the desired conditions. The test surface, covered with the sample of fabric being testing, is heated to the desired starting skin temperature of either 31 or 34 degrees C, selected to approximate human skin temperature, and if wind is included in the test conditions, the fan is turned on to the desired setting. Once all of these conditions are set, the test period begins by monitoring the amount of power required by the heating element to maintain the set test surface temperature. This amount of power is measured in Watts and is referred to as the cooling power of the fabric being tested under the given conditions of the test. The reported cooling power the power the system stabilized at under the given test conditions. At the end of each test, the sample fabric was replaced with a different sample and the testing was repeated, changing conditions as needed.

**[0097]** For the Example 1 baseline, the test was carried out with a bare, uncovered test surface, providing the effect one could expect from bare skin. This bare skin baseline was included in the testing for purposes of comparison.

**[0098]** The table below summarizes the test conditions used and the examples tested under each set of conditions:

**Table 2 – Summary of Cooling Power Test Conditions using the Mannequin**

| Condition Set[1] | Chamber Temp [C] | Chamber Humidity [%] | Wind Speed [m/s] | Target Skin Temp[2] [C] | Examples Tested at these Conditions |
|---|---|---|---|---|---|
| I | 15 | 50 | 3.0 | 34 | 1,2,3,4,5,6,7 |
| II | 15 | 50 | 5.0 | 31 | 1,2,3,4,5,6,7 |
| III | 15 | 30 | 3.0 | 34 | 1,2,3,4,5,6,7 |
| IV | 15 | 50 | 0.3 | 34 | 1,2,3,4,5,6,7 |
| V | 15 | 50 | 0.3 | 34 | 1,2,3,4,5,6,7 |
| VI | 15 | 30 | 0.3 | 34 | 1,2,3,4,5,6,7 |

*1 These condition sets were carried out in the testing in the following order: IV, I, V, II, VI, III. Condition Sets IV and V are identical, and were not run consecutively, thus providing a duplicate set of data that shows the repeatability of the results and relative difference between samples.*
*2 – The target skin temperature for this testing is always 34 degrees C except for the Condition Set where the wind is at 5 m/s. Under these conditions a 31 degrees C skin temperature is used to ensure the system, which has limited heating capabilities, can maintain the desired temperature.*

**[0099]** The results of this testing are summarized in the table below:

**Table 3 – Summary of Cooling Power Test Results[1]**

| Example | Condition Set I | Condition Set II | Condition Set III | Condition Set IV | Condition Set V | Condition Set VI |
|---|---|---|---|---|---|---|
| 1 - Baseline | 39.65 | 41.36 | 38.92 | 16.02 | 13.16 | 15.40 |
| 2 - Comparative | 28.82 | 29.43 | 27.78 | 11.83 | 9.54 | 10.96 |
| 3 - Comparative | 30.19 | 30.16 | 30.36 | 12.93 | 10.60 | 12.25 |
| 4 - Inventive | 38.18 | 37.03 | 37.19 | 15.42 | 13.10 | 15.14 |
| 5 - Inventive | 36.12 | 34.54 | 34.92 | 15.24 | 13.01 | 15.01 |
| 6 - Inventive | 31.39 | 31.91 | 33.33 | 14.18 | 11.55 | 14.47 |
| 7 - Inventive | 31.98 | 34.18 | 31.36 | 14.08 | 12.43 | 14.32 |

*1 – All reported results in this table are cooling power, measured in Watts [W]. This is the amount of power the heating element in the sweating thermal mannequin required in order to maintain the temperature of the test surface, the surface of the foreman covered with the test fabric, at the set point under the specified conditions. The higher the cooling power reported, the more power was required to maintain the temperature, and so the larger the cooling effect the fabric creates. In other words, the larger the cooling power reported, the larger the cooling effect one would expect to experience when wearing a garment made of the fabric tested. These results are all in relation to a standard test surface area of 629 $cm^2$. A cooling power per square meter may be calculated by dividing the reported result by 0.629.*

**[0100]** The results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, greater than that of conventional synthetic fibers, and more specifically fabric made from conventional synthetic fibers. In addition the results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, comparable to that seen in the baseline, bare skin example. In other words, the present invention provides fibers, fabrics and various garments, including the means of making such articles

that would give a wearer whose skin comes into contact with said articles, a cooling sensation similar to that felt when no fabric is in contact with the skin that is when the skin is bare.

**[0101]** An additional set of testing is also included that adds the additional variable of moisture release from the test surface during the testing. In these tests, a sweating thermal foot model was used, where the model was equipped with similar controls to the mannequin described above. The moisture releases used in this testing are designed to simulate different sweat rates that a person would experience when wearing a garment made of the test fabric, for example, during exercise, and to see what impact if any this has on the cooling power of the fabric.

**[0102]** The same seven examples listed in Table 1 were tested here. The conditions used in this testing are summarized in the table below. For each test condition, the system was allowed to stabilize for 30 minutes without any wind or moisture release, during which time the cooling power of the fabric was measured. The moisture release was then started and the system was again allowed to stabilize over 30 minutes, during which the cooling power was measured. Finally, the wind condition was added and the system was again allowed to stabilize over 30 minutes, during which the cooling power was measured.

**Table 4 – Summary of Cooling Power Test Conditions Using the Foot Model**

| Condition Set[1] | Chamber Temp [C] | Chamber Humidity [%] | Wind Speed [m/s] | Target Skin Temp [C] | Sweat Rate [grams/hr] | Examples Tested at these Conditions |
|---|---|---|---|---|---|---|
| VII | 15 | 50 | 3.0 | 34 | 4 | 2,3,4,5,6,7 |
| VIII | 15 | 50 | 3.0 | 34 | 8 | 2,3,4,5,6,7 |
| IX | 15 | 50 | 3.0 | 34 | 16 | 2,3,4,5,6,7 |
| X | 15 | 50 | 5.0 | 34 | 4 | 2,3,4,5,6,7 |
| XI | 15 | 50 | 5.0 | 34 | 8 | 2,3,4,5,6,7 |

*1 – These condition sets were carried out in the testing in the following order: VII, VIII, IX, X, XI.*

**[0103]** The results of this testing are summarized in the table below. As noted above, each test condition included three distinct measurements of the cooling power, one with no wind or moisture release (A), one with moisture release and no wind (B), and one with both the target moisture release and wind (C). For each condition set, the measured cooling power are present below:

**Table 5A – Summary of Cooling Power Test Results[1]**

| Example | Condition Set VII | | | Condition Set VIII | | | Condition Set IX | | |
|---|---|---|---|---|---|---|---|---|---|
| | (A) | (B) | (C) | (A) | (B) | (C) | (A) | (B) | (C) |
| 2 - Comparative | 3.9 | 4.9 | 11.0 | 4.2 | 6.5 | 13.0 | 4.1 | 7.8 | 15.3 |
| 3 - Comparative | 4.3 | 5.3 | 11.6 | 4.3 | 6.9 | 13.4 | 4.7 | 8.6 | 16.2 |
| 4 - Inventive | 5.2 | 6.4 | 15.2 | 5.2 | 8.1 | 16.8 | 4.9 | 8.6 | 19.7 |
| 5 - Inventive | 4.9 | 6.1 | 14.6 | 4.9 | 6.5 | 16.2 | 5.0 | 6.6 | 17.5 |
| 6 - Inventive | 4.6 | 5.5 | 12.6 | 4.8 | 7.6 | 15.5 | 4.7 | 10.9 | 19.5 |
| 7 - Inventive | 4.5 | 5.8 | 13.8 | 4.7 | 7.2 | 15.6 | 4.6 | 7.4 | 18.8 |

*1 – All reported results in this table are cooling power, Watts [W]. See also footnote 1 of table 3.*

**Table 5B – Summary of Cooling Power Test Results[1]**

| Example | Condition Set X | | | Condition Set XI | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (A) | (B) | (C) | (A) | (B) | (C) | | | |
| 2 - Comparative | 4.2 | 5.2 | 15.5 | 4.4 | 6.7 | 16.7 | | | |
| 3 - Comparative | 4.3 | 5.7 | 16.9 | 4.8 | 7.0 | 17.9 | | | |
| 4 - Inventive | 5.4 | 6.7 | 21.2 | 5.0 | 8.0 | 22.0 | | | |
| 5 - Inventive | 5.0 | 6.2 | 19.9 | 5.0 | 6.8 | 22.0 | | | |
| 6 - Inventive | 5.2 | 6.3 | 17.9 | 4.8 | 7.8 | 19.7 | | | |
| 7 - Inventive | 4.8 | 6.1 | 18.5 | 4.2 | 6.2 | 21.0 | | | |

*1 – All reported results in this table are cooling power, Watts [W]. See also footnote 1 of table 3.*

**[0104]** The results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, greater than that of conventional synthetic fibers, and more specifically fabric made from conventional synthetic fibers, particularly when the both moisture release and wind conditions are present. As these conditions are common, and indeed expected, when a person is wearing a garment, especially sports apparel and similar clothing, the results reinforce the conclusion that articles made from the fibers of the invention would provide a person wearing said articles, or otherwise bring their skin into contact with said articles, a cooling effect.

*Example Set 2*

**[0105]** Various materials are prepared so that they may further demonstrate the present invention. These materials are summarized in the tables below.

**Table 6 – Sample Descriptions and Properties**

| Ex | Sample Description[1] | Hydroxyl Terminated Intermediate | Diisocyanate | Linear Alkylene Glycol |
|---|---|---|---|---|
| 8 | Monofilament Fiber | BDO Adipate[2] | MDI | BDO |
| 9 | Monofilament Fiber | HDO Adipate[3] | MDI | BDO |
| 10 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | BDO |
| 11 | Monofilament Fiber | PTMEG | MDI | BDO |
| 12 | Monofilament Fiber | PEG | MDI | BDO |
| 13 | Monofilament Fiber | BDO Adipate[2] | HDI | BDO |
| 14 | Monofilament Fiber | HDO Adipate[3] | HDI | BDO |
| 15 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | BDO |
| 16 | Monofilament Fiber | PTMEG | HDI | BDO |
| 17 | Monofilament Fiber | PEG | HDI | BDO |
| 18 | Monofilament Fiber | BDO Adipate[2] | HMDI | BDO |
| 19 | Monofilament Fiber | HDO Adipate[3] | HMDI | BDO |
| 20 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | BDO |
| 21 | Monofilament Fiber | PTMEG | HMDI | BDO |
| 22 | Monofilament Fiber | PEG | HMDI | BDO |
| 23 | Monofilament Fiber | BDO Adipate[2] | MDI | HDO |
| 24 | Monofilament Fiber | HDO Adipate[3] | MDI | HDO |
| 25 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | HDO |
| 26 | Monofilament Fiber | PTMEG | MDI | HDO |
| 27 | Monofilament Fiber | PEG | MDI | HDO |
| 28 | Monofilament Fiber | BDO Adipate[2] | HDI | HDO |
| 29 | Monofilament Fiber | HDO Adipate[3] | HDI | HDO |
| 30 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | HDO |
| 31 | Monofilament Fiber | PTMEG | HDI | HDO |
| 32 | Monofilament Fiber | PEG | HDI | HDO |
| 33 | Monofilament Fiber | BDO Adipate[2] | HMDI | HDO |
| 34 | Monofilament Fiber | HDO Adipate[3] | HMDI | HDO |
| 35 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | HDO |
| 36 | Monofilament Fiber | PTMEG | HMDI | HDO |
| 37 | Monofilament Fiber | PEG | HMDI | HDO |

*1 – Each fabric sample is in the form of an open sock/sleeve woven from the described fiber.*
*2 – BDO Adipate is an adipate prepared from 1,4-butanediol and adipic acid.*
*3 – HDO Adipate is an adipate prepared from 1,6-hexandiol and adipic acid.*
*4 – BDO/HDO Adipate is an adipate prepared from adipic acid and a mixture of 114-butanediol and 1,6-hexandiol.*

**Table 7 – Sample Descriptions and Properties**

| Ex | Sample Description[1] | Hydroxyl Terminated Intermediate | Diisocyanate | Linear Alkylene Glycol |
|---|---|---|---|---|
| 38 | Multifilament Fiber | BDO Adipate[2] | MDI | BDO |
| 39 | Multifilament Fiber | HDO Adipate[3] | MDI | BDO |
| 40 | Multifilament Fiber | BDO/HDO Adipate[4] | MDI | BDO |
| 41 | Multifilament Fiber | PTMEG | MDI | BDO |
| 42 | Multifilament Fiber | PEG | MDI | BDO |
| 43 | Multifilament Fiber | BDO Adipate[2] | HDI | BDO |
| 44 | Multifilament Fiber | HDO Adipate[3] | HDI | BDO |
| 45 | Multifilament Fiber | BDO/HDO Adipate[4] | HDI | BDO |
| 46 | Multifilament Fiber | PTMEG | HDI | BDO |
| 47 | Multifilament Fiber | PEG | HDI | BDO |
| 48 | Multifilament Fiber | BDO Adipate[2] | HMDI | BDO |
| 49 | Multifilament Fiber | HDO Adipate[3] | HMDI | BDO |
| 50 | Multifilament Fiber | BDO/HDO Adipate[4] | HMDI | BDO |
| 51 | Multifilament Fiber | PTMEG | HMDI | BDO |
| 52 | Multifilament Fiber | PEG | HMDI | BDO |
| 53 | Multifilament Fiber | BDO Adipate[2] | MDI | HDO |
| 54 | Multifilament Fiber | HDO Adipate[3] | MDI | HDO |
| 55 | Multifilament Fiber | BDO/HDO Adipate[4] | MDI | HDO |
| 56 | Multifilament Fiber | PTMEG | MDI | HDO |
| 57 | Multifilament Fiber | PEG | MDI | HDO |
| 58 | Multifilament Fiber | BDO Adipate[2] | HDI | HDO |
| 59 | Multifilament Fiber | HDO Adipate[3] | HDI | HDO |
| 60 | Multifilament Fiber | BDO/HDO Adipate[4] | HDI | HDO |
| 61 | Multifilament Fiber | PTMEG | HDI | HDO |
| 62 | Multifilament Fiber | PEG | HDI | HDO |
| 63 | Multifilament Fiber | BDO Adipate[2] | HMDI | HDO |
| 64 | Multifilament Fiber | HDO Adipate[3] | HMDI | HDO |
| 65 | Multifilament Fiber | BDO/HDO Adipate[4] | HMDI | HDO |
| 66 | Multifilament Fiber | PTMEG | HMDI | HDO |
| 67 | Multifilament Fiber | PEG | HMDI | HDO |

*1 – Each fabric sample is in the form of an open sock/sleeve woven from the described fiber.*
*2 – BDO Adipate is an adipate prepared from 1,4-butanediol and adipic acid.*
*3 – HDO Adipate is an adipate prepared from 1,6-hexandiol and adipic acid.*
*4 – BDO/HDO Adipate is an adipate prepared from adipic acid and a mixture of 1,4-butanediol and 1,6-hexandiol.*

**[0106]** Each of the documents referred to above is incorporated herein by reference. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." Unless otherwise indicated, all percent values, ppm values and parts values are on a weight basis. Unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers,

by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade. However, the amount of each chemical component is presented exclusive of any solvent or diluent oil, which may be customarily present in the commercial material, unless otherwise indicated. It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the invention can be used together with ranges or amounts for any of the other elements. As used herein, the expression "consisting essentially of" permits the inclusion of substances that do not materially affect the basic and novel characteristics of the composition under consideration.

We claim:

1. A fiber prepared from a composition comprising the reaction product of:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate; and

(iii) a linear alkylene glycol chain extender.

2. The fiber of claim 1 wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C.

3. The fiber of any of the claims 1 to 2 wherein (i) the hydroxyl terminated intermediate is substantially free of polyether block amide copolymers.

4. The fiber of any of the claims 1 to 3 wherein the fiber has a percent elongation of 200% to 300%.

5. The fiber of any of the claims 1 to 4 wherein the fiber has an effective cooling power of at least 49 watts per square meter, measured at 30% relative humidity and a 3 m/s wind speed.

6. The fiber of claim 1 wherein the fiber is substantially free of inorganic fillers.

7. The fiber of any of the claims 1 to 6 wherein (i) the hydroxyl terminated intermediate comprises polyethylene glycol, (ii) the diisocyanate comprises methylene diphenyl diisocyanate; and (iii) the linear alkylene glycol chain extender comprises 1,4-butanediol, 1,6-hexanediol, or combinations thereof.

8. The fiber of any of the claims 1 to 7 wherein the composition from which the fiber is prepared is a polymer alloy comprising:

(a) a multiphase copolymer prepared by reacting a polymer and/or copolymer segment with at least one other polymer and/or copolymer segment;

(b) a polymer blend prepared mixing a polymer and/or copolymer with at least one other polymer and/or copolymer, wherein each of the polymers and/or copolymers is compatible and/or miscible in one another; or

(c) combinations thereof.

9. The fiber of claim 8 wherein said polymer alloy is derived from the reaction of: (i)(a) a polyol; (i)(b) a polyester intermediate derived from a polyol and a dicarboxylic acid; (ii) at least one diisocyanate; and (iii) at least one chain extender.

10. A fabric comprising the fiber of claim 1.

11. The fabric of claim 10 wherein said fabric further comprises one or more additional fibers, other than the fiber of claim 1, wherein the fabric is 10 to 80 percent by weight of these additional fibers.

12. The fabric of claim 11 wherein the additional fibers are selected from the group consisting of nylon fibers, polyester fibers, rayon fibers, acrylic fibers, and combinations thereof.

13. An article comprising the fabric of claim 10.

14. The article of claim 13, wherein the article is a garment and wherein the fibers of the fabric are arranged in said garment to be in direct contact with the skin of a wearer of said garment.

15. A method of providing a cooling effect in an article that comes into direct contact with human skin, comprising the steps of:

I. preparing a fabric comprising the fiber of claim 1;

II. preparing an article that comprises said fabric;

III. bringing said article into direct contact with human skin.

16. A method of making a fiber comprising the steps of:

I. preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate and

(iii) a linear alkylene glycol chain extender;

II. melt-spinning said elastomer resin into a monofilament or multifilament fiber.

17. A method of making a fabric comprising the steps of:

I. preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate and

(iii) a linear alkylene glycol chain extender;

III. melt-spinning said elastomer resin into a monofilament or multifilament fiber;

IV. processing said fiber, optionally in combination with one or more other fibers, into a fabric.

# TITLE

# ELASTOMER FIBERS AND METHODS OF MAKING AND USING THEREOF

## BACKGROUND OF THE INVENTION

**[0001]** The invention relates to a fiber excellent in cool contact feeling which is excellent in hand and skin touch and capable of preventing unpleasant feeling in the wet state while also having excellent elasticity. The invention also relates to fabric, clothing, and underwear excellent in cool contact feeling and obtainable by using said fiber as well as the methods of making the fibers and articles thereof.

**[0002]** There is a continuing, never-ending desire for more comfortable feeling articles and garments, particularly in the areas of underwear and sports and/or exercise-related apparel. Users and/or wearers of such articles and garments want them to be as comfortable and refreshing feeling as possible, including after prolonged periods of use and adverse conditions. The fibers used to make such items, specifically their composition, can have a significant impact on the performance of the items in these areas.

**[0003]** There is also a desire for such fibers, in addition to being more comfortable, to retain or even increase their elasticity.

**[0004]** US 5,167,899 discloses a melt-blowing process for producing a fiber of an extrudable polyurethane having a large amount of hard segment.

**[0005]** EP 2 292 822 discloses a mixed fiber spun bonded nonwoven fabric suitable for use in absorbent articles such as sanitary napkins, pantry liners, incontinence pads and disposable diapers.

## SUMMARY OF THE INVENTION

**[0006]** The present invention provides an elastic cooling fiber with a Tg of no more than 22 degrees C and more specifically a fiber prepared from a composition comprising the reaction product of: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate: and (iii) a chain extender comprising a linear alkylene glycol wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C.

**[0007]** The invention provides a fabric that is made from the fibers described herein, which in some embodiments are mixed with other fibers. The invention provides an article that is made from the fabric described here.

**[0008]** The invention provides a method of providing a cooling effect in an article that comes into close proximity with, in some embodiments even direct contact with, human skin, including the steps of: (1) preparing a fabric comprising the fibers described herein; (2) preparing an article that comprises said fabric; (3)

bringing said article into close proximity with, in some embodiments even direct contact with, human skin.

**[0009]** The invention provides a method of making a fiber including the steps of: (1) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate; and (iii) a chain extender comprising a linear alkylene glycol; wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C; and (2) melt-spinning said elastomer resin into a monofilament or multifilament fiber.

**[0010]** The invention provides a method of making a fabric including the steps of: (1) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting: (i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C; (ii) a diisocyanate; and (iii) a chain extender comprising a linear alkylene glycol; wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C; (2) melt-spinning said elastomer resin into a fiber, in some embodiments a monofilament or multifilament fiber; and (3) processing said fiber, optionally in combination with one or more other fibers, into a fabric.

## DETAILED DESCRIPTION OF THE INVENTION

**[0011]** Various features and embodiments of the invention will be described below by way of non-limiting illustration.

### *The Cooling Effect*

**[0012]** The invention provides a fiber excellent in cool contact feeling and also excellent in elasticity. While this cooling effect is generally observed in fabrics and/or articles made from the fiber, it is believed that the cooling effect is due to the properties of the fiber and so not dependent on the type and/or construction of the fabric and/or article involved, though these parameters may of course have a relative impact on the observed cooling effect. In other words, it is believed that the cooling effect is provided by the fiber, and more specifically, fibers having specific properties and/or chemical compositions. In this application, we often note that the fiber can give a cooling contact feeling when in contact with the skin, or even close to human skin, say on top of a layer or even two layers of clothing

between the fiber of the invention and the human skin. In some embodiments, the fiber is in direct contact with human skin. It is understood that the evaluation of the cooling effect may be done with fibers themselves, fabrics made from such fibers, any article made from such fibers and/or fabrics, or various combinations thereof.

**[0013]** The key factors considered responsible for the cooling effect provided by the invention are described below, primarily in the fiber section.

*The Fibers*

**[0014]** The invention provides a fiber excellent in cool contact feeling and also excellent in elasticity. The fiber can give a cooling contact feeling when in contact with the skin. The effect can be strong enough to be sensed in a sensory test.

**[0015]** The fiber may include a thermoplastic elastomer and may also include inorganic fillers, however, in certain embodiments; the composition is free of any inorganic filler.

**[0016]** The fibers of the invention may have a Tg of no more than 22 degrees C and are, as well as article made from them, exceptionally elastic and are also excellent in providing a cool contact feeling when using the fiber for clothing.

**[0017]** "Elastic" and "Elasticity" as used herein means that a fiber will recover at least 50 percent of its stretched length after the first pull and after the fourth to 100% strain (doubled the length). Elasticity can also be described by the "permanent set" of the fiber. "Permanent Set" is the converse of elasticity. A fiber is stretched to a certain point, in some embodiments 50% of the fiber's known percent elongation at break, and subsequently released to the original position before stretch, and then stretched again. The point at which the fiber begins to pull a load is designated as the percent permanent set. "Elastic materials" are also referred to in the art as "elastomers" and "elastomeric".

**[0018]** The fibers of the present invention can provide this balance of benefits while also avoiding any sticky or inferior skin touch feelings, in the wet state owing to sweat and the like and therefore, which often leads to unpleasant feelings for the wearer when the fiber is used in a garment. The fibers of this invention balance all of these factors and provide superior performance in any one or any combination of these factors.

**[0019]** In some embodiments, the thermoplastic elastomer utilized in the preparation of the fibers described herein is substantially free of, or even free of, a polyamide type elastomer and/or a polyester type elastomer. More specifically, the present invention may be free of polyether block amide copolymers, polyether amide copolymers, and polyester amide copolymers, or any combination thereof. More specifically, the compositions involved in the present invention may be substantially free of, or even completely free of, Pebax (manufactured by Arkema). As used herein, the term polyamide elastomer, or polyamide block within an elastomer, is considered in its chemical sense to be different and distinct from a polyurethane elastomer, or a urethane block within an elastomer. In some embodiments, polyamide links and/or block refer to -N(R)-C(O)-R- units and/or linkages in the elastomer while polyurethane links and/or blocks refer to -N(R)-C(O)-O-R- units and/or linkages in the elastomer.

**[0020]** In other embodiments, the thermoplastic elastomer utilized in the preparation of the fibers described herein may include polyether block amide copolymers, polyether amide copolymers, polyester amide copolymers, or any combination thereof.

**[0021]** The polyester type elastomer is not particularly limited and examples are polyether ester copolymers and polyester ester copolymers. They may be used alone or two or more of them may be used in combination.

**[0022]** Commercialized polyester type elastomers among them are Grilux (manufactured by Dainippon Ink and Chemicals, Inc.), Nouvelan (manufactured by Teijin Chemicals Ltd.), Pelprene (manufactured by Toyobo Co., Ltd.), Hytrel (manufactured by DuPont-Toray Co., Ltd.), and Primalloy (manufactured by Mitsubishi Chemical Corporation).

**[0023]** The resin component contained in the fibers of the invention provides the excellent cool contact feeling of the invention, and so the thermoplastic elastomers alone may be used. Another benefit of the invention is that the fibers described here, when they contain only a thermoplastic elastomer as the resin component, generally have no sticky feeling and so do not become difficult for spinning. While additional resins may be used in combination with the resin described here, it is not required to address any stickiness or unpleasant feeling that may otherwise accompany more conventional fibers. In some embodiments, an additional resin is used. While inorganic fillers resins may be used in combination with the resin described here, it is not required to address any stickiness or unpleasant feeling that may otherwise

accompany more conventional fibers.

**[0024]** In some embodiments, the fiber, and/or the resin from which it is prepared is substantially free, to free of, any inorganic filler. When an inorganic filler is used, it is not particularly limited and examples may include mineral type pigments, such as calcium carbonate such as light calcium carbonate and heavy calcium carbonate, barium carbonate, magnesium carbonate such as basic magnesium carbonate, calcium sulfate, barium sulfate, titanium dioxide, iron oxide, tin oxide, titanium oxide, zinc oxide, magnesium oxide, ferrite powder, zinc sulfide, zinc carbonate, aluminum nitride, silicon nitride, Satin White, diatomaceous earth such as fired diatomaceous earth, calcium silicate, aluminum silicate, magnesium silicate, silica such as amorphous silica, amorphous synthesized silica, and colloidal silica, colloidal alumina, pseudo boehmite, aluminum hydroxide, magnesium hydroxide, alumina, hydrated alumina, litopon, zeolite, hydrated halloysite, clay, hydrotalcite, aluminosilicate, talc, pyrophyllite, smectite such as saponite, hectorite, sauconite, stevensite, montmorillonite, beidellite and nontromite, vermiculite, mica such as phologopite, biotie, zinnwaldite, muscovite, paragonite, celadonite and glauconite, clinochlore, chamosite, nimite, pennantite, sudoite, donbasite, clintonite, margarite, thulite, antigorite, lizardite, chrysotile, mesite, cronstedite, berthierine, greenalite, garnierite, kaolin such as kaolinite, dickite, nacrite and hallosite, delaminated kaolin, calcined kaolin, sepiolite, palygorskite, imogolite, allophane, hisingerite, penwithite, activated earth, bentonite, and sericite. They may be used alone or two or more kinds of them may be used in combination. In some embodiments, the filler is titanium oxide, zinc oxide, barium oxide, silica, or some combination thereof. The form of the inorganic fillers is not particularly limited and examples are finite forms such as spherical, needle-like, plate type forms and the like, or nonfinite forms.

**[0025]** When present, the lower limit of the content of the inorganic filler may be 1%, 2% or 7% by weight, and the upper limit of that is 30% by weight.

**[0026]** The fiber of the present invention may further comprise one or more additional additives, and in some embodiments must contain at least one or more additional additives (beyond the thermoplastic elastomer and any inorganic filler, of present). In addition, the fiber may be twisted and/or covered with another fiber for improving the factors required for underwear such as skin touch within an extent that the aim of the invention is not inhibited. Such another fiber is not particularly limited and examples are polyamide type resins such as nylon 6 and nylon 12; polyesters, cotton, and rayon.

**[0027]** In some embodiments, the fibers of the invention may be described by a $q_{max}$ value. The lower limit of a $q_{max}$ value of the fiber may be 0.20, 0.21 or 0.22 J/sec/cm$^2$. If the $q_{max}$ value is less than 0.20 J/sec/cm$^2$, subjects may not feel any cool contact feeling even if a sensory test is performed. In other embodiments, the $q_{max}$ value of the fiber may be less than 0.20 or even more than 0.22 J/sec/cm$^2$.

**[0028]** In this description, the $q_{max}$ value is defined as a peak value of the heat flow quantity of stored heat transferring to a sample at a lower temperature in the case a prescribed heat is stored in a heat plate with a specified surface area and a specified weight and immediately after the heat plate is brought into contact with the sample surface. It is supposed that the $q_{max}$ value simulates the body heat removed from the body by the sample when clothing is put on and it is supposed that as the $q_{max}$ value is higher, the body heat removed from the body is higher and the cool contact feeling is more excellent when the clothing is put on.

**[0029]** In some embodiments, the lower limit of the heat conductivity of the fiber of the invention may be 1x10$^{-3}$ degrees C/Wm$^2$. The heat conductivity is also considered to be one of the important parameters to which the cool contact feeling is corresponding. If the heat conductivity is less than 1x10" degrees C./Wm2, most subjects may not feel any cool contact feeling even if a sensory test is performed.

**[0030]** In this description, the heat conductivity can be calculated by measuring the heat loss speed after a heat plate is layered on a sample put on a sample stand and the temperature of the heat plate is stabilized at a prescribed temperature and performing calculation by the following formula (2).

Heat conductivity(W/cm$^2$/degrees C.)=WD/A/$\Delta$T (2)

Where: W: heat flow quantity (J/sec)

D: thickness of a sample (cm)

A: heat plate surface area ($cm^2$)

ΔT: temperature difference (°C) between the sample stand and the heat plate

**[0031]** The fiber of the invention may be used in the form of a composite fiber comprising the thermoplastic elastomer and another resin and may have a core-sheath structure and comprises a core part containing a dyeable resin and a sheath part containing a thermoplastic elastomer resin, a thickness of the sheath part being 20 micrometers or thinner (hereinafter referred to as a core-sheath type composite yarn in some cases). The fiber excellent in cool contact feeling of the invention can be a fiber having the core-sheath structure having good dyeability, keeping excellent properties of the thermoplastic elastomer such as cool contact feeling by using such a dyeable resin for the core part and the thermoplastic elastomer having the cool contact feeling and excellent in the flexibility for the sheath part.

**[0032]** The form of the core-sheath type composite yarn is not particularly limited and the cross-sectional shape formed in the case the fiber is cut perpendicularly to the longitudinal direction of the fiber may be true round, elliptical and the like. Also, the fiber may have a concentric core-sheath type structure in which the core part and sheath part are formed concentrically or an eccentric core-sheath type structure in which the core part and sheath part are formed eccentrically. Also, the fiber may have a structure in which multiple core parts exist in the case the fiber is cut perpendicularly to the longitudinal direction of the fiber.

**[0033]** In some embodiments, the fiber of the invention is an elastic cooling fiber that has a Tg of no more than 22°C.

**[0034]** In some of these embodiments, the Tg of the fiber may be no more than 22, 15, 10, 0, -10, -20, -30 or even -40 degrees C. These Tg limits may apply to the fiber itself, the composition from which the fiber is made (before the composition is spun or otherwise processed into fibers), the intermediate from which the composition is prepared, or any combination thereof.

**[0035]** In some of these embodiments, the percent elongation achieved by the fiber may be from 200% to 300%.

**[0036]** The fibers of the invention are prepared from a composition that includes a reaction product of (i) a hydroxyl terminated intermediate, (ii) a diisocyanate and (iii) a linear alkylene glycol chain extender. The hydroxyl terminated intermediate m ay include a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C. In some embodiments, the intermediate is derived from polyethylene glycol. The diisocyanate may include diphenyl methane-4,4'-diisocyanate. The linear alkylene glycol may include 1, 6-butanediol and similar materials. In some embodiments, the hydroxyl terminated intermediate used in the invention is substantially free of, or even free of, polyether block amide copolymers and/or units of the same.

**[0037]** In still other embodiments, the fibers of the invention are prepared from a composition itself prepared from (i) an intermediate that includes and/or is derived from polyethylene glycol or an adipate derived from one or more alkylene diols and adipic acid, (ii) a diisocyanate that includes methylene diphenyl diisocyanate; and (iii) a linear alkylene glycol chain extender that may include 1, 4-butanediol, 1, 6-hexanediol, or a combination thereof. In some of these embodiments, the chain extender includes 1, 4-butanediol, and the adipate is prepared from 1, 4-butanediol, 1, 6-hexanediol, or a combination thereof. In some of these embodiments, the adipate is prepared from a mixture of 1, 4-butanediol and 1, 6-hexanediol. Further, in some of these embodiments, the compositions used to prepare the fiber are: from 40 to 80, 40 to 70, 50 to 60, or even 55 to 58 or 56 to 57 percent by weight intermediate; from 20 to 50, 30 to 40, 30 to 35, or even 31 to 34 or 32 to 33 percent by weight diisocyanate; and from 4 to 25, 5 to 20, 5 to 15, or even from 8 to 1 1, or 9 to 10 percent by weight chain extender. The fibers of the invention may be made from compositions that contain the material described above and which may also contain one or more polymer additives, including any of the additional additives described below. In some embodiments, the compositions may further include an antioxidant, a lubricant and/or processing aid, and may even have a metal containing catalyst.

**[0038]** In some embodiments, the fibers of the invention are prepared from a composition itself prepared from (i) an intermediate that includes and/or is derived from polyethylene glycol, (ii) a diisocyanate that includes methylene diphenyl

diisocyanate; and (iii) a linear alkylene glycol chain extender that includes 1, 4-butanediol, 1, 6-hexanediol, or a combination thereof. In some of these embodiments, the chain extender includes 1, 4-butanediol. Further, in some of these embodiments, the compositions used to prepare the fiber are: from 40 to 80, 40 to 70, 40 to 60, or even 46 to 49 or 47 to 48 percent by weight intermediate; from 20 to 50, 30 to 50, 35 to 45, or even 40 to 43 or 41 to 42 percent by weight diisocyanate; and from 4 to 25, 5 to 20, 5 to 15, or even from 9 to 12, or 10 to 1 1 percent by weight chain extender.

**[0039]** In addition, the composition from which the fiber is prepared may be a polymer alloy that includes: (a) a multiphase copolymer prepared by reacting a polymer and/or copolymer segment with at least one other polymer and/or copolymer segment; (b) a polymer blend prepared mixing a polymer and/or copolymer with at least one other polymer and/or copolymer, wherein each of the polymers and/or copolymers is compatible and/or miscible in one another; or (c) combinations thereof. The polymer alloy may be derived from the reaction of: (i)(a) a polyol; (i)(b) a polyester intermediate itself derived from a polyol and a dicarboxylic acid; (ii) at least one diisocyanate; and (iii) at least one chain extender.

**[0040]** In general, the TPU polymer type used in this invention can be any conventional TPU polymer that is known to the art and in the literature as long as it (meaning the fiber itself, the composition from which the fiber is made, and/or the intermediate used to prepare the composition) exhibits the Tg, percent elongation, and/or elasticity described above. While not wishing to be bound by theory, Applicants consider that compositions which meet these requirements are expected to provide the same cooling effect demonstrated by the specific examples included in this application, or in the alternative, when at least one or more of the additional parameters described herein is met.

**[0041]** Suitable TPU polymers are generally prepared by reacting a polyisocyanate with an intermediate such as a hydroxyl terminated polyester, a hydroxyl terminated polyether, a hydroxyl terminated polycarbonate or mixtures thereof, with one or more chain extenders, all of which are well known to those skilled in the art.

**[0042]** The hydroxyl terminated polyester intermediate is generally a linear polyester having a number average molecular weight (Mn) of from 500 to 10,000, from 700 to 5,000, or from 700 to 4,000, an acid number generally less than 1.3 and preferably less than 0.8. The molecular weight is determined by assay of the terminal functional groups and is related to the number average molecular weight. The polymers are produced by (1) an esterification reaction of one or more glycols with one or more dicarboxylic acids or anhydrides or (2) by transesterification reaction, i.e., the reaction of one or more glycols with esters of dicarboxylic acids. Mole ratios generally in excess of more than one mole of glycol to acid are preferred so as to obtain linear chains having a preponderance of terminal hydroxyl groups. Suitable polyester intermediates also include various lactones such as polycaprolactone typically made from ε-caprolactone and a bi-functional initiator such as diethylene glycol. The dicarboxylic acids of the desired polyester can be aliphatic, cycloaliphatic, aromatic, or combinations thereof. Suitable dicarboxylic acids which may be used alone or in mixtures generally have a total of from 4 to 15 carbon atoms and include: succinic, glutaric, adipic, pimelic, suberic, azelaic, sebacic, dodecanedioic, isophthalic, terephthalic, cyclohexane dicarboxylic, and the like. Anhydrides of the above dicarboxylic acids such as phthalic anhydride, tetrahydrophthalic anhydride, or the like, can also be used. Adipic acid is a preferred acid. The glycols which are reacted to form a desirable polyester intermediate can be aliphatic, aromatic, or combinations thereof, and have a total of from 2 to 12 carbon atoms, and include ethylene glycol, 1, 2-propanediol, 1, 3-propanediol, 1, 3-butanediol, 1, 4-butanediol, 1, 5-pentanediol, 1, 6-hexanediol, 2,2-dimethyl-l, 3-propanediol, 1, 4-cyclohexanedimethanol, decamethylene glycol, dodecamethylene glycol, and the like, 1, 4-butanediol is a preferred glycol.

**[0043]** Hydroxyl terminated polyether intermediates are polyether polyols derived from a diol or polyol having a total of from 2 to 15 carbon atoms, in some embodiments an alkyl diol or glycol which is reacted with an ether (or an epoxide) which comprises an alkylene oxide group having from 2 to 6 carbon atoms, typically ethylene oxide or propylene oxide or mixtures thereof. For example, hydroxyl functional polyether can be produced by first reacting propylene glycol

with propylene oxide followed by subsequent reaction with ethylene oxide. Primary hydroxyl groups resulting from ethylene oxide are more reactive than secondary hydroxyl groups and thus are preferred. Useful commercial polyether polyols include poly(ethylene glycol) comprising ethylene oxide reacted with ethylene glycol, poly(propylene glycol) comprising propylene oxide reacted with propylene glycol, poly(tetramethylene glycol) comprising water reacted with tetrahydrofuran (PTMEG). PTMEG is the preferred polyether intermediate. Polyether polyols further include polyamide adducts of an alkylene oxide and can include, for example, ethylenediamine adduct comprising the reaction product of ethylenediamine and propylene oxide, diethylenetriamine adduct comprising the reaction product of diethylenetriamine with propylene oxide, and similar polyamide type polyether polyols. Copolyethers can also be utilized in the current invention. Typical copolyethers include the reaction product of THF and ethylene oxide or THF and propylene oxide. These are available from BASF as Poly THF B, a block copolymer, and poly THF R, a random copolymer. The various polyether intermediates generally have a number average molecular weight (Mn) as determined by assay of the terminal functional groups which is an average molecular weight greater than 700, such as from 700 to 10,000, from 1000 to 5000, or from 1000 to 2500. A particular desirable polyether intermediate is a blend of two or more different molecular weight polyethers, such as a blend of 2000 $M_n$ and 1000 $M_n$ PTMEG.

**[0044]** In some embodiments, the compositions of the present invention are prepared from polyethleneglycol (PEG). In other embodiments, the intermediate is a polyester made from the reaction of adipic acid with a 50/50 blend of 1, 4-butanediol and 1, 6-hexanediol.

**[0045]** The polycarbonate-based polyurethane resin of this invention may be prepared by reacting a diisocyanate with a blend of a hydroxyl terminated polycarbonate and a chain extender. The hydroxyl terminated polycarbonate can be prepared by reacting a glycol with a carbonate.

**[0046]** U.S. Patent No. 4, 131, 731 discloses of hydroxyl terminated polycarbonates and their preparation. Such polycarbonates are linear and have terminal hydroxyl groups with essential

exclusion of other terminal groups. The essential reactants are glycols and carbonates. Suitable glycols are selected from cycloaliphatic and aliphatic diols containing 4 to 40, and or even 4 to 12 carbon atoms, and from polyoxyalkylene glycols containing 2 to 20 alkoxy groups per molecule with each alkoxy group containing 2 to 4 carbon atoms. Diols suitable for use in the present invention include aliphatic diols containing 4 to 12 carbon atoms such as butanediol-1, 4, pentanediol-1, 4, neopentyl glycol, hexanediol-1, 6, 2,2,4-trimethylhexanediol-l, 6, decanediol-1, 10, hydrogenated dilinoleylglycol, hydrogenated dioleylglycol; and cycloaliphatic diols such as cyclohexanediol-1, 3, dimethylolcyclohexane-1, 4, cyclohexanediol-1, 4, dimethylolcyclohexane-1, 3, 1, 4-endo methylene-2-hydroxy-5-hydroxymethyl cyclohexane, and polyalkylene glycols. The diols used in the reaction may be a single diol or a mixture of diols depending on the properties desired in the finished product. Polycarbonate intermediates which are hydroxyl terminated are generally those known to the art and in the literature. Suitable carbonates are selected from alkylene carbonates composed of a 5 to 7 member ring. Suitable carbonates for use herein include ethylene carbonate, trimethylene carbonate, tetramethylene carbonate, 1, 2-propylene carbonate, 1, 2-butylene carbonate, 2,3-butylene carbonate, 1, 2-ethylene carbonate, 1, 3-pentylene carbonate, 1, 4-pentylene carbonate, 2,3-pentylene carbonate, and 2,4-pentylene carbonate.

**[0047]** Also, suitable herein are dialkylcarbonates, cycloaliphatic carbonates, and diarylcarbonates. The dialkylcarbonates can contain 2 to 5 carbon atoms in each alkyl group and specific examples thereof are diethylcarbonate and dipropylcarbonate. Cycloaliphatic carbonates, especially dicycloaliphatic carbonates, can contain 4 to 7 carbon atoms in each cyclic structure, and there can be one or two of such structures. When one group is cycloaliphatic, the other can be either alkyl or aryl. On the other hand, if one group is aryl, the other can be alkyl or cycloaliphatic. Examples of suitable diarylcarbonates, which can contain 6 to 20 carbon atoms in each aryl group, are diphenylcarbonate, ditolylcarbonate, and dinaphthylcarbonate.

**[0048]** The reaction is carried out by reacting a glycol with a carbonate, for example an alkylene carbonate in the molar range of 10: 1 to 1: 10, but preferably 3: 1 to 1:3 at a temperature of 100°C to 300°C and at a pressure in the range of 0.1

to 300 mm of mercury in the presence or absence of an ester interchange catalyst, and may also be carried out while removing low boiling glycols by distillation.

**[0049]** More specifically, the hydroxyl terminated polycarbonates are prepared in two stages. In the first stage, a glycol is reacted with an alkylene carbonate to form a low molecular weight hydroxyl terminated polycarbonate. The lower boiling point glycol is removed by distillation at 100°C to 300°C, preferably at 150°C to 250°C, under a reduced pressure of 10 to 30 mm Hg, preferably 50 to 200 mm Hg. A fractionating column may be used to separate the by-product glycol from the reaction mixture. The by-product glycol can be taken off the top of the column and the unreacted alkylene carbonate and glycol reactant may be returned to the reaction vessel as reflux. A current of inert gas or an inert solvent can be used to facilitate removal of by-product glycol as it is formed. When amount of byproduct glycol obtained indicates that degree of polymerization of the hydroxyl terminated polycarbonate is in the range of 2 to 10, the pressure is gradually reduced to 0.1 to 10 mm Hg and the unreacted glycol and alkylene carbonate are removed. This marks the beginning of the second stage of reaction during which the low molecular weight hydroxyl terminated polycarbonate is reacted by distilling off glycol as it is formed at 100°C to 300°C, preferably 150°C to 250°C and at a pressure of 0.1 to 10 mm Hg until the desired molecular weight of the hydroxyl terminated polycarbonate is attained. Molecular weight (Mn) of the hydroxyl terminated polycarbonates can vary from 500 to 10,000 but in a preferred embodiment, it will be in the range of 500 to 2500.

**[0050]** The second necessary ingredient to make the TPU polymer of this invention is a polyisocyanate. The polyisocyanates of the present invention generally have the formula R(NCO)n where n is generally from 2 to 4 with 2 being highly preferred inasmuch as the composition is a thermoplastic. Thus, polyisocyanates having a functionality of 3 or 4 are utilized in very small amounts, for example, less than 5% and desirably less than 2% by weight based upon the total weight of all polyisocyanates, inasmuch as they cause crosslinking. R can be aromatic, cycloaliphatic, and aliphatic, or combinations thereof generally having a total of from 2 to 20 carbon atoms. Examples of suitable aromatic diisocyanates include diphenyl methane-4, 4'-diisocyanate (MDI), Hi2 MDI, m-

xylylene diisocyanate (XDI), m-tetramethyl xylylene diisocyanate (TMXDI), phenylene-1, 4-diisocyanate (PPDI), 1, 5 -na hthalene diisocyanate (NDI), and diphenylmethane-3, 3'-dimethoxy-4, 4'-diisocyanate (TODI). Examples of suitable aliphatic diisocyanates include isophorone diisocyanate (IPDI), 1, 4-cyclohexyl diisocyanate (CHDI), hexamethylene diisocyanate (HDI), l, 6-diisocyanato-2, 2,4,4-tetramethyl hexane (TMDI), 1, 10-decane diisocyanate, and trans-dicyclohexylmethane diisocyanate (HMDI). A highly preferred diisocyanate is MDI containing less than 3% by weight of ortho-para (2,4) isomer.

**[0051]** The third necessary ingredient to make the TPU polymer of this invention is the chain extender. Suitable chain extenders are lower aliphatic or short chain glycols having from 2 to 10 carbon atoms and include for instance ethylene glycol, diethylene glycol, propylene glycol, dipropylene glycol, tripropylene glycol, triethylene glycol, cis-trans-isomers of cyclohexyl dimethylol, neopentyl glycol, 1, 4-butanediol, 1, 6-hexandiol, 1, 3-butanediol, and 1, 5-pentanediol. The present invention requires a linear alkylene glycol chain extender, but in some embodiments additional chain extenders may be used in combination with the linear alkylene glycol chain extender. In such embodiments, aromatic glycols can be used as the chain extender. Benzene glycol (HQEE) and xylylene glycols are suitable chain extenders for use in making the TPU of this invention. Xylylene glycol is a mixture of l, 4-di(hydroxymethyl) benzene and 1, 2-di(hydroxymethyl) benzene. Benzene glycol is the preferred aromatic chain extender and specifically includes hydroquinone, bis(beta-hydroxyethyl) ether also known as l, 4-di(2-hydroxyethoxy) benzene; resorcinol, bis(beta-hydroxyethyl) ether also known as l, 3-di(2-hydroxyethyl) benzene; catechol, i.e., bis(beta-hydroxyethyl) ether also known as l, 2-di(2-hydroxyethoxy) benzene; and combinations thereof. The preferred chain extender is 1, 4-butanediol.

**[0052]** The above three necessary ingredients (hydroxyl terminated intermediate, polyisocyanate, and chain extender) may be reacted in the presence of a catalyst.

**[0053]** Generally, any conventional catalyst can be utilized to react the diisocyanate with the hydroxyl terminated intermediate or the chain extender and the same is well known to the art and to the literature. Examples of suitable catalysts include the various oragno compounds, such as carbonates, of bismuth or

tin wherein the alkyl portion has from 1 to 20 carbon atoms with specific examples including bismuth octoate, bismuth laurate, and the like. Preferred catalysts include the various tin catalysts such as stannous octoate, dibutyltin dioctoate, dibutyltin dilaurate, and the like. The amount of such catalyst is generally small such as from 20 to 200 parts per million based upon the total weight of the polyurethane forming monomers.

**[0054]** The TPU polymers of this invention can be made by any of the conventional polymerization methods well known in the art and literature.

**[0055]** In some embodiments, the polyurethanes of the invention are made via a "one shot" process wherein all the components are added together simultaneously or substantially simultaneously to a heated extruder and reacted to form the polyurethane. The equivalent ratio of the diisocyanate to the total equivalents of the hydroxyl terminated intermediate and the diol chain extender is generally from 0.95 to 1.10, desirably from 0.97 to 1.03, and preferably from 0.97 to 1.00. In some embodiments, the Shore A hardness of the TPU formed will typically be from less than 80A, 85A or even 95A. Reaction temperatures utilizing urethane catalyst may be from 175°C to 245°C or even from 180°C to 220°C. The molecular weight (Mw) of the thermoplastic polyurethane may be from 100,000 to 800,000 Daltons or from 150,000 to 400,000 or even from 150,000 to 350,000 as measured by GPC relative to polystyrene standards.

**[0056]** Useful additives can be utilized in suitable amounts in the TPU's described herein, where such additives may be added either before, during, or after the preparation of the TPU. Such additional additives include opacifying pigments, colorants, mineral fillers, stabilizers, lubricants, UV absorbers, processing aids, and other additives as desired. Useful opacifying pigments include titanium dioxide, zinc oxide, and titanate yellow, while useful tinting pigments include carbon black, yellow oxides, brown oxides, raw and burnt sienna or umber, chromium oxide green, cadmium pigments, chromium pigments, and other mixed metal oxide and organic pigments. Useful fillers include diatomaceous earth (superfloss) clay, silica, talc, mica, wallastonite, barium sulfate, and calcium carbonate. If desired, useful stabilizers such as antioxidants can be used and include phenolic

antioxidants, while useful photostabilizers include organic phosphates, and organotin thiolates (mercaptides). Useful antioxidants also include stearically hindered phenolic antioxidants. Useful lubricants include metal stearates, paraffin oils and amide waxes, for example, alkylene bisstearamides such as N,N' ethylene bisstearamide and esters of nonanic esters. Useful UV absorbers include 2-(2'-hydroxyphenol) benzotriazoles and 2-hydroxybenzophenones. Typical TPU flame retardants can also be added.

**[0057]** Plasticizer additives can also be utilized advantageously to reduce hardness without affecting properties, if they are used in small amounts. In some embodiments, no plasticizers are used.

**[0058]** In some embodiments, the cooling effect of the fiber may be expressed in terms of effective cooling power. While there are various means of measuring the cooling effect provided by the invention, this application includes details on two approaches to measure this effect. The first looks at the cooling effect provided by fabrics made from the fibers described herein, where the fabric and the area of "skin" in contact with the fabric, in this case a test surface taking the place of a person's skin, are both and where a constant wind is blowing across the fabric. While the specific conditions involved are considered to be important primarily for the purposes of comparing results, these type of evaluations can be of course be done at various ambient temperatures, levels of humidity, wind speed, starting temperature of the "skin", whether the "skin" heat source is left on or removed, and various other variables. In addition, this parameter is of course measured with respect to a specific area. Another approach follows the basic test methodology described above but adds the additional variable of sweat, various rates of moisture release from the "skin" over the course of the test. Using these types of tests, one can measure the amount of energy it takes to maintain the temperature of the "skin" under various conditions, or in the alternative, measure the rate at which the "skin" temperature drops if no heat source is applied, thus giving an indication of the cooling power of the fabric involved. Specific test conditions and results are provided in the examples section of this specification. It is important to note that regardless of the testing approach used, and the specific conditions selected, all testing conducted to date has shown that fabrics made from the fibers described

herein exhibit significantly higher cooling powers and allow for faster and greater temperature drops than the comparative materials also tested.

**[0059]** In some embodiments, the fibers of the present invention, when evaluated by the methods described above, specifically where the fabric is placed on the test skin surface, with an active heat source working to maintain skin surface temperature, 30% relative humidity, a 3 m/s wind speed, and an ambient temperature of 15 degrees C, provide a cooling power of at least 31 watts for a test are of 629 $cm^2$, or stated differently a cooling power of at least 49 watts per square meter. That is, at least 49 watts of power per square meter of area is required to maintain skin temperature, giving an indication of the cooling effect the fabric would provide to a person where the fabric against their skin, compared to other materials (nylon and polyester, for example, could not break the 31 watt limit under the exact same test conditions). This cooling power may also be at least 34 watts for a test area of 629 $cm^2$, at least 55 watts per square meter, where the fiber is a monofilament and is not semi-dull. The same limits apply to testing conducted at 50% relative humidity and 3 m/s wind speed, as well as at 5 m/s wind speed at 50% relative humidity.

**[0060]** In similar embodiments, the fiber of the present invention when evaluated by the methods described above, specifically where the fabric is placed on the test skin surface, with an active heat source working to maintain skin surface temperature, 50% relative humidity, a 0.3 m/s wind speed, and an ambient temperature of 15 degrees C, provide a cooling power of at least 13 or 14 watts for a test area of 629 $cm^2$, at least 21 or 22 watts per square meter.

**[0061]** A method of producing the fiber excellent in cool contact feeling of the invention is not particularly limited and conventionally known methods such as a method of producing it by producing resin pellets containing the thermoplastic elastomer and the inorganic filler and melting and spinning, using the obtained resin pellets, may be employed.

**[0062]** The core-sheath type composite yarn may also be produced by, for example, loading resin pellets containing the dyeable resin, the thermoplastic elastomer, and the inorganic filler into a composite spinning apparatus and melting and spinning them.

**[0063]** The invention provides a method of making a fiber that includes the steps of: (I) preparing an elastomer resin in an internal mixing device. The elastomer resin is prepared by reacting: (i) a hydro xyl terminated intermediate, (ii) a diisocyanate and (iii) a linear alkylene glycol chain extender. The intermediate may be a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C. The second step, (II) is melt-spinning the elastomer resin into a fiber, for example, a monofilament or multifilament fiber. In some embodiments, the fiber is a monofilament fiber. All of the various features and embodiments discussed above with regards to the fiber and the composition used to prepare it apply here as well.

*The Fabric*

**[0064]** The fiber of the invention may be used in form of a fabric such as a knit, a textile, and a bonded textile. The resulting fabric is excellent in cool contact feeling while also possessing the excellent elasticity of the fiber.

**[0065]** The fabric excellent in cool contact feeling of the invention may solely comprise the fiber excellent in cool contact feeling of the invention and in other embodiments may comprise the fiber and another fiber twisted together for improving the factors required for specific applications. For example, in garments that come into direct contact with skin. Such optional co-fibers are not particularly limited and examples include polyamide type resins such as nylon 6 and nylon 12, polyesters, cotton, and rayon.

**[0066]** The invention includes fabrics made from any of the fibers described herein, including woven fabric, non-woven fabric, knitted fabric, and combinations thereof. In some embodiments, the fabrics of the invention are woven fabrics. In other embodiments, the fabrics of the invention are non-woven fabrics. In still other embodiments, the fabrics of the invention are knitted fabrics. In addition, the invention includes fabrics that further contain one or more additional fibers, other than the fibers of the invention. The fabric may be from 10 to 80 percent by weight of these additional fibers, or no more than 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, or 10% of these additional fibers. In some embodiments, no additional fibers are present. In embodiments where there are one or more additional fibers present

in the fabric, these additional fibers may be nylon fibers, polyester fibers, rayon fibers, acrylic fibers, and combinations thereof.

**[0067]** The invention also includes a method of making a fabric that includes the steps of (I) preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared as described above. The process may optionally include the addition of a cross-linking agent, such as the reaction product of a polyalkylene ether glycol or triol and a diisocyanate. Step (II) is melt-spinning said elastomer resin into a fiber, for example, a monofilament or multifilament fiber. In some embodiments, the fiber, or rather the polymer making up the fiber, has a weight average molecular weight of at least 700,000. Step (III) is processing the fiber, optionally in combination with one or more other fibers, into a fabric.

**[0068]** An additional benefit of the invention is the improved mold-ability of fabrics that contain the fibers described herein. When utilized at suitable levels within the fabric, the fabric of the invention can be successful molded at lower temperatures and/or in less time, thus improving the ability to protect the fabric, dye, etc of the fabric which may be damaged by the high temperatures and/or low exposure time required by more conventional fabrics in order to successfully mold them. In some embodiments, the fabrics of the invention may be molded at temperatures of no more than 150 or even 140 degrees C, and/or where the molding is complete in less than 20, 15 or even 10 seconds. In some embodiments, a minimum level of the fibers of the invention must be present in the fabric for it to provide these benefits. In some embodiments, this lower limit is 40%, 50%, 60% or even 80% where the percentage represent the percent by weight of the fibers in the fabric that must be the fibers of the present invention. However, it is also understood that a much smaller amount of the fibers of the invention in a fabric will improve that fabric's mold-ability. It is noted that Spandex™ and similar materials are not moldable at low temperatures, and that fibers of these materials are not even knittable into fabrics unless a positive feeder is used, an expensive piece of equipment required due to the over-elasticity of Spandex™ fibers.

*The Articles*

**[0069]** The fiber excellent in cool contact feeling of the invention and the fabric excellent in cool contact feeling of the invention may be used for producing articles

including clothing. In the case of articles that come into contact with skin, again for example, clothing, the articles of the invention exhibit excellent elasticity, provide a cooling sensation to the wearer, and have no unpleasant and/or sticky feeling even at times of wetting.

**[0070]** Since the articles, and specifically the clothing, provide excellent cool contact feeling, it can cause sensation of cool feeling at the time of wearing and give refreshing feeling. Also, the present invention does not require the addition of the inorganic filler to make the clothing free from a sticky feeling at the time of wetting, as other fibers used in clothing with similar cooling effects may do. Thus, the present invention is extremely suitable for underwear.

**[0071]** The clothing excellent in cool contact feeling of the invention may be produced using the fiber excellent in cool contact feeling entirely and it is particularly preferable to be clothing excellent in cool feeling comprising a fabric having a reversible structure and excellent in refreshing feeling, 30 to 70% by number of total loops comprising the fiber excellent in cool contact feeling, the loops comprising the fiber excellent in cool contact feeling being arranged in a skin contact side (hereinafter, also referred to as refreshing clothing).

**[0072]** With respect to the clothing comprising a fabric having a reversible structure as clothing excellent in cool contact feeling of the invention, the ratio of the number of loops comprising the fiber excellent in cool contact feeling is controlled within a prescribed range and such loops comprising the fiber excellent in cool contact feeling are arranged only in the skin contact side, so that the clothing can have an effect of preventing unpleasant feeling caused by much sweating.

**[0073]** In recent years, various kinds of clothing having improved functions as underwear to be put on in an occasion of sweating in summer, in the case of exercises, sports and the like, have been developed and proposed, and such functional clothing is suggested, for example, clothing produced from hydrophobic fibers such as polyester. Also, a method of increasing the air permeability by using a hydrophilic fiber in combination with cotton and a method of increasing the air permeability by forming a mesh structure for a cloth or by forming a moss knitting of a derivative weave of a plain knitting and warp knitting, have been investigated,

and Japanese Kokai Publication 2003-155669 discloses a reformed cloth by depositing a hydrophilic chemical substance on the surface of a hydrophobic fiber composing the cloth. However, in the case of clothing comprising such hydrophobic fibers, although the generated heat can efficiently be released, it causes unpleasant feeling due to wet feeling in the case the skin or the clothing is wetted because of sweating and at the same time the fabric tends to be stuck to the skin to cause the problem that the clothing restrains the movement.

**[0074]** On the other hand, with respect to the refreshing clothing comprising the fabric having a reversible structure, it can cause sensation of cool feeling at the time of wearing and give refreshing feeling and simultaneously it can prevent unpleasant feeling due to wet feeling at the time of sweating and prevent sticking of the fabric to the skin due to deterioration of the separation from the skin by controlling the ratio of the number of loops comprising the fiber excellent in cool contact feeling to be within a prescribed range. Also, the loops comprising the fiber excellent in cool contact feeling are arranged only in the skin side, so that the fiber excellent in cool contact feeling can be brought into direct contact with the skin and clothing with further improved refreshing feeling and cool contact feeling can be produced.

**[0075]** In the refreshing articles and clothing of the invention, the lower limit of the ratio of the loops of the fiber excellent in cool contact feeling may be 30% of the total number of loops, and the upper limit may be 70% or even higher, such as 75%, 80%, 90% or even 100% of the total number of loops. If it is less than 30%, the effect to cause refreshing feeling and cool contact feeling may become insufficient in some cases. The high level can be obtained with the present invention without causing any unpleasant feeling due to wet feeling in the case the skin or the clothing is wetted because of sweating.

**[0076]** As noted above, for the fiber and fabric, the refreshing article, for example, the clothing, may contain the thermoplastic elastomer and an inorganic filler, but in other embodiments is substantially free of, to even free of, any inorganic filler.

**[0077]** In the articles of the invention, for example, the clothing, the thickness of the fabric is to be made as thin as possible, the fiber excellent in cool contact feeling may be used in combination with another fiber. The lower limit of the content of the thermoplastic elastomer in the fiber excellent in cool contact

feeling may be 50% by weight. If it is less than 50% by weight, sufficient cool contact feeling may not be caused in some cases. In other embodiments, the content of the fiber of the invention is present in the fabric and articles is at least 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85%, or even 95% by weight. While not wishing to be bound by theory, it is believed that some minimum fiber content in the fabric and/or article in question must be the fiber of the invention for the cooling effect to be noticeable. This minimum required content may vary across the various formulations included in the present invention, but in some embodiments may be fairly consistent across the various formulations. This minimum content may be any of the percentages described above.

**[0078]** In some embodiments, in the articles and/or clothing of the invention, the loops comprising the fiber excellent in cool contact feeling are preferable to be arranged only in the skin side. Arrangement in such a manner makes the loops comprising the fiber excellent in cool contact feeling have mainly contact with the skin and causes the cool contact feeling and refreshing feeling, and as described later, arrangement of loops comprising a hydrophobic fiber in the outside improves the diffusion and evaporating property of the heat and water emitted from the skin.

**[0079]** In the articles and/or clothing of the invention, the loops other than the loops comprising the fiber excellent in cool contact feeling are preferably the loops comprising a hydrophobic fiber. Since the loops comprising the fiber excellent in cool contact feeling are arranged only in the skin side, the loops comprising a hydrophobic fiber are arranged mainly in the outside.

**[0080]** In this description, the hydrophobic fiber means a chemical fiber having a official water percentage of 5.0% or less. Practically, fibers comprising polypropylenes (official water percentage: 0%), polyesters (0.4%), acrylic resins (2.0%), nylon (4.5%), and vinylon (5.0%) can be exemplified. They may be used alone or two or more kinds of them may be used in combination. In this connection, the official water percentage means water percentage at 20 degrees C. and 65% RH.

**[0081]** The articles and/or clothing of the invention may contain natural fibers such as cotton and flax, and semi-synthesized fibers such as rayon and acetate based on the necessity besides the fiber excellent in cool contact feeling and the hydrophobic fiber.

**[0082]** In some embodiments, the articles and/or clothing of the invention has an air permeability of the refreshing clothing from 200 $cm^3/cm^2/sec$ up to 500 $cm^3/cm^2/sec$. If it is less than 200 $cm^3/cm^2/sec$, the air permeability may be deteriorated and the diffusion of heat and evaporation of sweat emitted from the skin may possibly be inhibited and if it is more than 500 $cm^3/cm^2/sec$, transfer of the heat and water through the clothing may not be carried out sufficiently and contrarily the outer air may penetrate. The air permeability can be measured by using a air permeability tester according to JIS L 1096 A method.

**[0083]** In the fabric, articles and/or clothing of the invention, the upper limit of the weight per square-meter may be 120, 100 or even 90 g/m. Unlike other means of providing such cooling feelings, if the weight per square-meter is more than 120, 100 or even 90 g/m, the mechanism at work may be stifled and so the cooling feeling may possibly be deteriorated.

**[0084]** A method of producing the articles and/or clothing of the invention is not particularly limited and for example, conventionally known methods such as a method of producing clothing by weaving the fiber excellent in cool contact feeling of the invention can be employed. These materials may also be produced by the conventionally known methods of sewing, cutting and the like, using the fabrics with the reversible structure obtained by the above-mentioned manner.

**[0085]** Underwear excellent in cool contact feeling can be produced by using the fiber of the invention or the fabric of the invention. Also, the clothing excellent in cool contact feeling of the invention can be used as underwear. In such embodiments, the invention may provide any one or more of the benefits described above for the fiber, fabric, article, and/or clothing.

**[0086]** In addition to the underwear, the present invention includes stockings, gloves, face masks, mufflers and the like that may be produced by using the fiber of the invention or the fabric excellent in cool contact feeling of the invention. They

are brought into direct contact with the skin and therefore, they can cause a particularly excellent effect.

**[0087]** The invention includes an article made from the fabrics described above. For example, various garments can be made with the fabrics of this invention. In some embodiments, the fabric is used in making undergarments or tight fitting garments, for which the fabrics of this invention are well-suited due to the comfort and cooling effect provided by the fiber. Undergarments, such as bras and T-shirts as well as sport garments used for activities such as running, skiing, cycling, or other sports, can benefit from the properties of these fibers. Garments worn next to the body benefit from the elasticity and cooling effect the invention provides. It will be understood by those skilled in the art that any garment can be made from the fabric and fibers of this invention.

**[0088]** In other embodiments, the fibers described herein are used to make one or more of any number of garments and articles including but not limited to: sports apparel, such as shorts, including biking, hiking, running, compression, training, golf, baseball, basketball, cheerleading, dance, soccer and/or hockey shorts; shirts, including any of the specific types listed for shorts above; tights including training tights and compression tights; swimwear including competitive and resort swimwear; bodysuits including wrestling, running and swimming body suits; and footwear. Additional embodiments include work wear such as shirts and uniforms. Additional embodiments include intimates including bras, panties, men's underwear, camisoles, body shapers, nightgowns, panty hose, men's undershirts, tights, socks and corsetry. Additional embodiments include medical garments and articles including: hosiery such as compression hosiery, diabetic socks, static socks, and dynamic socks; therapeutic burn treatment bandages and films; wound care dressings; medical garments. Additional applications include military applications that mirror one or more of the specific articles described above. Additional embodiments include bedding articles including sheets, blankets, comforters, mattress pads, mattress tops, and pillow cases.

**[0089]** In some embodiments, the article of the invention is a garment and the fibers that make up the fabric in the garment are arranged in the garment as to be in

direct contact with the skin of a wearer of said garment. This allows the wearer to gain the full benefit of the cooling effect provided by the invention.

**[0090]** The invention also provides a method of providing a cooling effect in an article, such as a garment, that comes into direct contact with human skin, comprising the steps of: (I) preparing a fabric comprising the fiber of claim 1; (II) preparing an article that comprises said fabric; and (II) bringing said article into direct contact with human skin.

**[0091]** It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) can migrate to other acidic or anionic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included within the scope of the present invention; the present invention encompasses the composition prepared by admixing the components described above.

## EXAMPLES

**[0092]** The invention will be further illustrated by the following examples, which sets forth particularly advantageous embodiments. While the examples are provided to illustrate the present invention, they are not intended to limit it.

*Example Set*

**[0093]** Seven materials were evaluated to demonstrate the benefits of the invention. These materials are summarized in the table below.

**Table 1 - Sample Descriptions and Properties**

| Ex | Sample Description[1] | Fabric Diameter [cm] | Fabric Length [cm] | Fabric Weight [g/m$^2$] |
|---|---|---|---|---|
| 1 | Baseline: No Material (Bare test surface) | NA | NA | NA |
| 2 | Multifilament Red Core Polyester Fiber | 13.9 | 42.0 | 27 |
| 3 | Multifilament Blue Core Nylon Fiber[2] | 14.7 | 43.0 | 25 |
| 4 | Monofilament Fiber A[3] | 5.3 | 37.5 | 90 |
| 5 | Monofilament Fiber B[4] | 8.4 | 35.5 | 65 |
| 6 | Monofilament Fiber C[5] | 9.2 | 29.0 | 66 |
| 7 | Monofilament Fiber D – Semi Dull[6] | 10.8 | 43.0 | 43 |

*1 – Each fabric sample is in the form of a open sock/sleeve. The diameter refers to the diameter of the sleeve the fabric creates while the length is the actual length of the sample. For the fabric weight, each sample was weighed and then, using the other measurements reported, a weight in terms of grams per meter squared was calculated for each fabric.*
*2 – This fiber is commercially available from Invista™.*
*3 – Fiber A is prepared from a polyalkylene glycol, an alkylene diol, and MDI.*
*4 – Fiber B is prepared from alkylene diol adipate, an alkylene diol, and MDI.*
*5 – Fiber C is a multifilament version of Fiber B, and is chemically identical to Fiber B.*
*6 –Fiber D is Fiber B but with a commercially available dulling agent added.*

**[0094]** Comparative Example 1 is a baseline and represents no fiber and/or fabric. Comparative Examples 2 and 3 are comparative materials that do not represent the invention. Examples 4, 5, 6 and 7 represent various embodiments of the invention.

**[0095]** It is noted that the fabrics tested have different diameters and the fabrics obtained for testing are of different weights. To account for these differences, the testing described below has been carried out with the use of clamps to fix the fabric samples in such a way as to provide comparable tension and fabric density over the testing surface, thus allowing for a valid comparison of the materials. Any differences not accounted for by these controls are not expected to have a significant impact on the parameters tested.

*Test Methods and Results*

**[0096]** The examples described above were tested to determine their cooling power. This testing was conducted in a climatic chamber at controlled temperature and humidity using a sweating thermal mannequin as a test surface. The test surface of the mannequin, with a known surface area, is equipped with thermocouples to monitor temperature and heating elements to allow the test surface to be heated to a realistic human skin temperature for the testing. In addition, the power demands of the heating elements could also be monitored to see

the amount energy required to maintain a specific skin temperature at the test surface. The test surface is also capable of moisture release, simulating the sweat release of human skin. A high power fan was used as a wind source. The area of the test surface used for all of this testing is 629 $cm^2$.

**[0097]** For this testing, the sweating thermal mannequin is placed inside the climatic chamber, which is set to 15 degrees C. Testing was carried out at 30% and 50% relative humidity, with winds speeds of 0.3 m/s, 3 m/s and 5 m/s. A wind speed of 0.3 m/s is the normal condition inside the climatic chamber and so indicates the high speed fan is in the off position. Circular knitted, open-ended sock samples of each material, also referred to as sleeves, are placed on the test surface of the sweating thermal mannequin, in this case the forearm of the mannequin. Samples are placed on the test surface for testing and then are removed and replaced with the next sample. As noted above, clamps are used to secure each sample to the forearm of the sweating thermal mannequin and care is taken to ensure the samples are placed with comparable levels of tension and fabric density.

**[0098]** At the start of each test, the chamber is brought up to the desired conditions. The test surface, covered with the sample of fabric being testing, is heated to the desired starting skin temperature of either 31 or 34 degrees C, selected to approximate human skin temperature, and if wind is included in the test conditions, the fan is turned on to the desired setting. Once all of these conditions are set, the test period begins by monitoring the amount of power required by the heating element to maintain the set test surface temperature. This amount of power is measured in Watts and is referred to as the cooling power of the fabric being tested under the given conditions of the test. The reported cooling power the power the system stabilized at under the given test conditions. At the end of each test, the sample fabric was replaced with a different sample and the testing was repeated, changing conditions as needed.

**[0099]** For the Example 1 baseline, the test was carried out with a bare, uncovered test surface, providing the effect one could expect from bare skin. This bare skin baseline was included in the testing for purposes of comparison.

**[0100]** The table below summarizes the test conditions used and the examples tested under each set of conditions:

**Table 2 – Summary of Cooling Power Test Conditions using the Mannequin**

| Condition Set[1] | Chamber Temp [C] | Chamber Humidity [%] | Wind Speed [m/s] | Target Skin Temp[2] [C] | Examples tested at these conditions |
|---|---|---|---|---|---|
| I | 15 | 50 | 3.0 | 34 | 1, 2, 3, 4, 5, 6, 7 |
| II | 15 | 50 | 5.0 | 31 | 1, 2, 3, 4, 5, 6, 7 |
| III | 15 | 30 | 3.0 | 34 | 1, 2, 3, 4, 5, 6, 7 |
| IV | 15 | 50 | 0.3 | 34 | 1, 2, 3, 4, 5, 6, 7 |
| V | 15 | 50 | 0.3 | 34 | 1, 2, 3, 4, 5, 6, 7 |
| VI | 15 | 30 | 0.3 | 34 | 1, 2, 3, 4, 5, 6, 7 |

*1 – These condition sets were carried out in the testing in the following order: IV, I, V, II, VI, III. Condition Sets IV and V are identical, and were not run consecutively, thus providing a duplicate set of data that shows the repeatability of the results and relative difference between samples.*
*2 – The target skin temperature for this testing is always 34 degrees C except for the Condition Set where the wind is at 5 m/s. Under these conditions a 31 degrees C skin temperature is used to ensure the system, which has limited heating capabilities, can maintain the desired temperature.*

**[0101]** The results of this testing are summarized in the table below:

**Table 3 - Summary of Cooling Power Test Results[1]**

| Example | Condition Set I | Condition Set II | Condition Set III | Condition Set IV | Condition Set V | Condition Set VI |
|---|---|---|---|---|---|---|
| 1 – Baseline | 39.65 | 41.36 | 38.92 | 16.02 | 13.16 | 15.40 |
| 2 – Comparative | 28.82 | 29.43 | 27.78 | 11.83 | 9.54 | 10.96 |
| 3 – Comparative | 30.19 | 30.16 | 30.36 | 12.93 | 12.93 | 10.60 |
| 4 – Inventive | 38.18 | 37.03 | 37.19 | 15.42 | 13.10 | 15.14 |
| 5 – Inventive | 36.12 | 34.54 | 34.92 | 15.24 | 13.01 | 15.01 |
| 6 – Inventive | 31.39 | 31.91 | 33.33 | 14.18 | 11.55 | 14.47 |
| 7 – Inventive | 31.98 | 34.18 | 31.36 | 14.08 | 12.43 | 14.32 |

*1 - All reported results in this table are cooling power, measured in Watts [W]. This is the amount of power the heating element in the sweating thermal mannequin required in order to maintain the temperature of the test surface, the surface of the foreman covered with the test fabric, at the set point under the specified conditions. The higher the cooling power reported, the more power was required to maintain the temperature, and so the larger the cooling effect the fabric creates. In other words, the larger the cooling power reported, the larger the cooling effect one would expect to experience when wearing a garment made of the fabric tested. These results are all in relation to a standard test surface area of 629 $cm^2$. A cooling power per square meter may be calculated by dividing the reported result by 0.629.*

**[0102]** The results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, greater than that of conventional synthetic fibers, and more specifically fabric made from conventional synthetic fibers. In addition the results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, comparable to that seen in the baseline, bare skin example. In other words, the

present invention provides fibers, fabrics and various garments, including the means of making such articles

that would give a wearer whose skin comes into contact with said articles, a cooling sensation similar to that felt when no fabric is in contact with the skin that is when the skin is bare.

**[0103]** An additional set of testing is also included that adds the additional variable of moisture release from the test surface during the testing. In these tests, a sweating thermal foot model was used, where the model was equipped with similar controls to the mannequin described above. The moisture releases used in this testing are designed to simulate different sweat rates that a person would experience when wearing a garment made of the test fabric, for example, during exercise, and to see what impact if any this has on the cooling power of the fabric.

**[0104]** The same seven examples listed in Table 1 were tested here. The conditions used in this testing are summarized in the table below. For each test condition, the system was allowed to stabilize for 30 minutes without any wind or moisture release, during which time the cooling power of the fabric was measured. The moisture release was then started and the system was again allowed to stabilize over 30 minutes, during which the cooling power was measured. Finally, the wind condition was added and the system was again allowed to stabilize over 30 minutes, during which the cooling power was measured.

**TABLE 4 – Summary of Cooling Test Power Test Conditions Using the Foot Model**

| Condition Set[1] | Chamber Temp [C] | Chamber Humidity [%] | Wind Speed [m/s] | Target Skin Temp[2] [C] | Examples tested at these conditions |
|---|---|---|---|---|---|
| VII | 15 | 50 | 3.0 | 34 | 2, 3, 4, 5, 6, 7 |
| VIII | 15 | 50 | 3.0 | 34 | 2, 3, 4, 5, 6, 7 |
| IX | 15 | 50 | 3.0 | 34 | 2, 3, 4, 5, 6, 7 |
| X | 15 | 50 | 5.0 | 34 | 2, 3, 4, 5, 6, 7 |
| XI | 15 | 50 | 5.0 | 34 | 2, 3, 4, 5, 6, 7 |

*1 – These condition sets were carried out in the testing in the following order: VII, VIII, IX, X, XI.*

**[0105]** The results of this testing are summarized in the table below. As noted above, each test condition included three distinct measurements of the cooling power, one with no wind or moisture release (A), one with moisture release and no wind (B), and one with both the target moisture release and wind (C). For each condition set, the measured cooling power are present below:

**TABLE 5A – Summary of Cooling Power Test Results[1]**

| Example | Condition Set VII | | | Condition Set VIII | | | Condition Set IX | | |
|---|---|---|---|---|---|---|---|---|---|
| | (A) | (B) | (C) | (A) | (B) | (C) | (A) | (B) | (C) |
| 2 – Comparative | 3.9 | 4.9 | 11.0 | 4.2 | 6.5 | 13.0 | 4.1 | 7.8 | 15.3 |
| 3 – Comparative | 4.3 | 5.3 | 11.6 | 4.3 | 6.9 | 13.4 | 4.7 | 8.6 | 16.2 |
| 4 – Inventive | 5.2 | 6.4 | 15.2 | 5.2 | 8.1 | 16.8 | 4.9 | 8.6 | 19.7 |
| 5 – Inventive | 4.9 | 6.1 | 14.6 | 4.9 | 6.5 | 16.2 | 5.0 | 6.6 | 17.5 |
| 6 – Inventive | 4.6 | 5.5 | 12.6 | 4.8 | 7.6 | 15.5 | 4.7 | 10.9 | 19.5 |
| 7 – Inventive | 4.5 | 5.8 | 13.8 | 4.7 | 7.2 | 15.6 | 4.6 | 7.4 | 18.8 |

*1 – All reported results in this table are cooling power, Watts [W]. See also footnote 1 of table 3.*

**TABLE 5B – Summary of Cooling Power Test Results[1]**

| Example | Condition Set X | | | Condition Set XI | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (A) | (B) | (C) | (A) | (B) | (C) | | | |
| 2 – Comparative | 4.2 | 5.2 | 15.5 | 4.4 | 6.7 | 16.7 | | | |
| 3 – Comparative | 4.3 | 5.7 | 16.9 | 4.8 | 7.0 | 17.9 | | | |
| 4 – Inventive | 5.4 | 6.7 | 21.2 | 5.0 | 8.0 | 22.0 | | | |
| 5 – Inventive | 5.0 | 6.2 | 19.9 | 5.0 | 6.8 | 22.0 | | | |
| 6 – Inventive | 5.2 | 6.3 | 17.9 | 4.8 | 7.8 | 19.7 | | | |
| 7 – Inventive | 4.8 | 6.1 | 18.5 | 4.2 | 6.2 | 21.0 | | | |

*1 – All reported results in this table are cooling power, Watts [W]. See also footnote 1 of table 3.*

**[0106]** The results show that the fibers of the invention, and more specifically fabric made from such fibers, provide a cooling effect, as measured by cooling power, greater than that of conventional synthetic fibers, and more specifically fabric made from conventional synthetic fibers, particularly when the both moisture release and wind conditions are present. As these conditions are common, and indeed expected, when a person is wearing a garment, especially sports apparel and similar clothing, the results reinforce the conclusion that articles made from the fibers of the invention would provide a person wearing said articles, or otherwise bring their skin into contact with said articles, a cooling effect.

*Example Set 2*

**[0107]** Various materials are prepared so that they may further demonstrate the present invention. These materials are summarized in the tables below.

**Table 6 - Sample Descriptions and Properties**

| Ex | Sample Description[1] | Hydroxyl Terminated Intermediate | Diisocyanate | Linear Alkyelene Glycol |
|---|---|---|---|---|
| 8 | Monofilament Fiber | BDO Adipate[2] | MDI | BDO |
| 9 | Monofilament Fiber | HDO Adipate[3] | MDI | BDO |
| 10 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | BDO |
| 11 | Monofilament Fiber | PTMEG | MDI | BDO |
| 12 | Monofilament Fiber | PEG | MDI | BDO |
| 13 | Monofilament Fiber | BDO Adipate[2] | HDI | BDO |
| 14 | Monofilament Fiber | HDO Adipate[3] | HDI | BDO |
| 15 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | BDO |
| 16 | Monofilament Fiber | PTMEG | HDI | BDO |
| 17 | Monofilament Fiber | PEG | HDI | BDO |
| 18 | Monofilament Fiber | BDO Adipate[2] | HMDI | BDO |
| 19 | Monofilament Fiber | HDO Adipate[3] | HMDI | BDO |
| 20 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | BDO |
| 21 | Monofilament Fiber | PTMEG | HMDI | BDO |
| 22 | Monofilament Fiber | PEG | HMDI | BDO |
| 23 | Monofilament Fiber | BDO Adipate[2] | MDI | HDO |
| 24 | Monofilament Fiber | HDO Adipate[3] | MDI | HDO |
| 25 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | HDO |
| 26 | Monofilament Fiber | PTMEG | MDI | HDO |
| 27 | Monofilament Fiber | PEG | MDI | HDO |
| 28 | Monofilament Fiber | BDO Adipate[2] | HDI | HDO |
| 29 | Monofilament Fiber | HDO Adipate[3] | HDI | HDO |
| 30 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | HDO |
| 31 | Monofilament Fiber | PTMEG | HDI | HDO |
| 32 | Monofilament Fiber | PEG | HDI | HDO |
| 33 | Monofilament Fiber | BDO Adipate[2] | HMDI | HDO |
| 34 | Monofilament Fiber | HDO Adipate[3] | HMDI | HDO |
| 35 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | HDO |
| 36 | Monofilament Fiber | PTMEG | HMDI | HDO |
| 37 | Monofilament Fiber | PEG | HMDI | HDO |

*1 – Each fabric sample is in the form of an open sock/sleeve woven from the described fiber.*

*2 – BDO Adipate is an adipate prepared from 1, 4-butanediol and adipic acid.*

*3 – HDO Adipate is an adipate prepared from 1, 6-hexandiol and adipic acid.*

*4 – BDO/HDO Adipate is an adipate prepared from adipic acid and a mixture of 114-butanedio and 1, 6-hexandiol.*

**Table 7 – Sample Descriptions and Properties**

| Ex | Sample Description[1] | Hydroxyl Terminated Intermediate | Diisocyanate | Linear Alkyelene Glycol |
|---|---|---|---|---|
| 38 | Monofilament Fiber | BDO Adipate[2] | MDI | BDO |
| 39 | Monofilament Fiber | HDO Adipate[3] | MDI | BDO |
| 40 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | BDO |
| 41 | Monofilament Fiber | PTMEG | MDI | BDO |
| 42 | Monofilament Fiber | PEG | MDI | BDO |
| 43 | Monofilament Fiber | BDO Adipate[2] | HDI | BDO |
| 44 | Monofilament Fiber | HDO Adipate[3] | HDI | BDO |
| 45 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | BDO |
| 46 | Monofilament Fiber | PTMEG | HDI | BDO |
| 47 | Monofilament Fiber | PEG | HDI | BDO |
| 48 | Monofilament Fiber | BDO Adipate[2] | HMDI | BDO |
| 49 | Monofilament Fiber | HDO Adipate[3] | HMDI | BDO |
| 50 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | BDO |
| 51 | Monofilament Fiber | PTMEG | HMDI | BDO |
| 52 | Monofilament Fiber | PEG | HMDI | BDO |
| 53 | Monofilament Fiber | BDO Adipate[2] | MDI | HDO |
| 54 | Monofilament Fiber | HDO Adipate[3] | MDI | HDO |
| 55 | Monofilament Fiber | BDO/HDO Adipate[4] | MDI | HDO |
| 56 | Monofilament Fiber | PTMEG | MDI | HDO |
| 57 | Monofilament Fiber | PEG | MDI | HDO |
| 58 | Monofilament Fiber | BDO Adipate[2] | HDI | HDO |
| 59 | Monofilament Fiber | HDO Adipate[3] | HDI | HDO |
| 60 | Monofilament Fiber | BDO/HDO Adipate[4] | HDI | HDO |
| 61 | Monofilament Fiber | PTMEG | HDI | HDO |
| 62 | Monofilament Fiber | PEG | HDI | HDO |
| 63 | Monofilament Fiber | BDO Adipate[2] | HMDI | HDO |
| 64 | Monofilament Fiber | HDO Adipate[3] | HMDI | HDO |
| 65 | Monofilament Fiber | BDO/HDO Adipate[4] | HMDI | HDO |
| 66 | Monofilament Fiber | PTMEG | HMDI | HDO |
| 67 | Monofilament Fiber | PEG | HMDI | HDO |

*1 – Each fabric sample is in the form of an open sock/sleeve woven from the described fiber.*
*2 – BDO Adipate is an adipate prepared from 1, 4-butanediol and adipic acid.*
*3 – HDO Adipate is an adipate prepared from 1, 6-hexandiol and adipic acid.*
*4 – BDO/HDO Adipate is an adipate prepared from adipic acid and a mixture of 114-butanedio and 1, 6-hexandiol.*

**[0108]** Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." Unless otherwise indicated, all percent values, ppm values and parts values are on a weight basis. Unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers,

by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade. However, the amount of each chemical component is presented exclusive of any solvent or diluent oil, which may be customarily present in the commercial material, unless otherwise indicated. It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the invention can be used together with ranges or amounts for any of the other elements. As used herein, the expression "consisting essentially of permits the inclusion of substances that do not materially affect the basic and novel characteristics of the composition under consideration.

We claim:

1. A fiber prepared from a composition comprising the reaction product of:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate; and

(iii) chain extender comprising a linear alkylene glycol, wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C.

2. The fiber of claim 1 wherein (i) the hydroxyl terminated intermediate is substantially free of polyether block amide copolymers.

3. The fiber of any of the claims 1 to 2 wherein the fiber has a percent elongation of 200% to 300%.

4. The fiber of any of the claims 1 to 3 wherein the fiber has an effective cooling power of at least 49 watts per square meter, measured at 30% relative humidity and a 3 m/s wind speed.

5. The fiber of claim 1 wherein the fiber is substantially free of inorganic fillers.

6. The fiber of any of the claims 1 to 5 wherein (i) the hydroxyl terminated intermediate comprises polyethylene glycol, (ii) the diisocyanate comprises methylene diphenyl diisocyanate; and (iii) the linear alkylene glycol chain extender comprises 1, 4-butanediol, 1, 6-hexanediol, or combinations thereof.

7. The fiber of any of the claims 1 to 6 wherein the composition from which the fiber is prepared is a polymer alloy comprising:

(a) a multiphase copolymer prepared by reacting a polymer and/or copolymer segment with at least one other polymer and/or copolymer segment;

(b) a polymer blend prepared mixing a polymer and/or copolymer with at least one other polymer and/or copolymer, wherein each of the polymers and/or copolymers is compatible and/or miscible in one another; or

(c) combinations thereof.

8. The fiber of claim 7 wherein said polymer alloy is derived from the reaction of: (i)(a) a polyol; (i)(b) a polyester intermediate derived from a polyol and a dicarboxylic acid; (ii) at least one diisocyanate; and (iii) at least one chain extender.

9. A fabric comprising the fiber of claim 1.

10. The fabric of claim 9 wherein said fabric further comprises one or more additional fibers, other than the fiber of claim 1, wherein the fabric is 10 to 80 percent by weight of these additional fibers.

11. The fabric of claim 10 wherein the additional fibers are selected from the group consisting of nylon fibers, polyester fibers, rayon fibers, acrylic fibers, and combinations thereof.

12. An article comprising the fabric of claim 9.

13. The article of claim 12, wherein the article is a garment and wherein the fibers of the fabric are arranged in said garment to be in direct contact with the skin of a wearer of said garment.

14. A method of providing a cooling effect in an article that comes into direct contact with human skin, comprising the steps of:

I. preparing a fabric comprising the fiber of claim 1;

II. preparing an article that comprises said fabric;

III. bringing said article into direct contact with human skin.

15. A method of making a fiber comprising the steps of:

I. preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate and

(iii) a linear alkylene glycol chain extender;

II. melt-spinning said elastomer resin into a monofilament or multifilament fiber.

16. A method of making a fabric comprising the steps of:

I. preparing an elastomer resin in an internal mixing device wherein said elastomer resin is prepared by reacting:

(i) a hydroxyl terminated intermediate, comprising a polyester, a polyether, a polycarbonate or a combination thereof, wherein the intermediate has a Tg of no more than 22 degrees C;

(ii) a diisocyanate and

(iii) a chain extender comprising a linear alkylene glycol; wherein the Tg of the composition from which the fiber is prepared is no more than 22 degrees C; and

II. melt-spinning said elastomer resin into a monofilament or multifilament fiber;

III. processing said fiber, optionally in combination with one or more other fibers, into a fabric.