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(54) Title: POLYMERIC FIBER COMPOSITION AND METHOD

(57) **Abstract:** The present invention generally relates to specific combinations of active particles, forming a powder, that may be combined with carrier materials such as resins to produce fibers for textiles, films, coatings, and/or protective or insulating materials. The specific mixture of particles and materials may be carefully engineered to impart unique and valuable properties to end products including integration with optical energies, heat, and other electromagnetic energies. Resultant compositions may interact with light in the visible spectrum and optical and electromagnetic energy beyond the visible spectrum.

POLYMERIC FIBER COMPOSITION AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of United States provisional patent application Serial No. 60/366,237 filed 03/22/02 and United States provisional patent application Serial No. 60/415,532 filed 10/02/02.

FIELD OF THE INVENTION

[0002] The present invention generally relates to specific combinations of active particles, forming a powder, that may be combined with carrier materials such as resins to produce fibers or filaments for textiles, films, coatings, and/or protective or insulating materials. The specific mixture of particles and materials may be engineered to impart unique and valuable properties to end products, including integration with optical energies, heat, and other electromagnetic energies. Resultant compositions may interact with light in the visible spectrum, as well as optical and electromagnetic energy beyond the visible spectrum.

[0003] The powder may be added to a carrier material, such as, for example, a polymer, which may then be extruded to form a fiber or filament or formed into a membrane, or film, which may be used to create a fabric or coating useful in a variety of applications. Such applications may include hosiery, footwear, active wear, sports wear, sports wraps, base layer, gloves, and bandages. These items may also have certain properties such as controlling odor, regulating heat, providing protection from fire, providing protection from harmful light, insulation, wound healing, and preserving food. The powder may be designed to interact in a benign manner with the human body, its needs, requirements, and homeostatic stabilization.

BACKGROUND OF THE INVENTION

[0004] Human bodies, as well as other organisms and substances, produce electromagnetic radiation in the form of, for example, heat or infrared radiation. In certain circumstances it may be desirable to retain this radiation, such as, for example, applications in which maintaining body heat or food temperature is desired. For example, once a food product is cooked, it may reach a certain temperature; however, this heat is often lost by exposure to cooler temperatures such as ambient air. In another example, a human body may be exposed to cooler temperatures, and infrared radiation may be lost through the epidermis. Retaining this infrared radiation, may have certain beneficial properties including maintaining a particular temperature, evading detection by infrared sensors, insulating pipes and other construction materials to prevent heat transfer, and providing heat to prevent joint stiffness. Known fibers do not completely solve the escape of radiation from a heat-emitting object, without also creating moisture or other undesirable side effects.

Summary of the Invention

[0005] This invention seeks to correct the problems and meet the needs of the industry as detailed above. Therefore, it is a specific objective of the present invention to provide methods and compositions that will provide a biologically benign composition that is optically responsive.

According to a first aspect, there is provided a wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, comprising:

a plurality of different types of optically active particles responsive to both ambient light and radiation emitted from the user; and

a carrier material combined with the optically active particles for retaining the particles and forming an end material;

wherein the plurality of different types of optically active particles have staggered refractive indices with respect to each other and are selected in accordance with the refractive index of the carrier material to generate an overlapping series of passbands that encompass a desired wavelength distribution of about 0.5 to 2 microns to enable the end material to absorb the ambient light and the radiation emitted from the user and re-emit light to the user having wavelengths of about 0.5 to 2 microns.

According to a second aspect, there is provided a method of making a wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, comprising:

selecting a plurality of different types of optically active particles responsive to both ambient light and radiation emitted from the user; and

suspending the selected plurality of different types of optically active particles in a carrier material to form an end material;

wherein the plurality of different types of optically active particles have staggered refractive indices with respect to each other and are selected in accordance with the refractive index of the carrier material to generate an overlapping series of passbands

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that encompass a desired wavelength distribution of about 0.5 to 2 microns to enable the end material to absorb the ambient light and the radiation emitted from the user and re-emit light to the user having wavelengths of about 0.5 to 2 microns.

According to a third aspect, there is provided a wearable active material made by the method of the second aspect.

[0006] One embodiment of the invention relates to a composition comprising titanium dioxide, quartz, aluminum oxide, and a resin. The resin composition is a polymer. The aluminum oxide, titanium dioxide, and quartz may be dispersed within the resin. In addition, the titanium dioxide, quartz and aluminum oxide may be present in a dry weight ratio of 10:10:2, respectively. In this embodiment, the titanium dioxide, quartz, and aluminum oxide may comprise about 1 to about 2 percent of the total weight of the composition, and the composition may be biologically benign.

[0007] In another embodiment of the present invention, the titanium dioxide within the composition may comprise an average grain size of about 2.0 microns or less and the grains may be substantially triangular. The aluminium oxide within the composition may comprise an average grain size of about 1.4 microns or less and the grains may be scalloped-shaped. Additionally, the quartz within the composition may comprise an average grain size of about 1.5 microns or less and the grains may be rounded in shape. The titanium dioxide, aluminium oxide, and quartz composition may be homogenized within this embodiment of the present invention. In addition, the composition may shift the wavelength of incident light, by both shortening and lengthening the wavelength of the incident light that is exposed to the composition.

[0008] The invention herein also relates to methods for creating an optically responsive yarn comprising the steps of extruding the composition of the above mentioned embodiments into a plurality of fibers and spinning those fibers into yarn. The present invention may consist of woven fibers comprising the aforementioned composition. In an alternative embodiment, the composition may also be woven with fibers comprising one or more additional natural fibers such as wool, cotton, silk, linen, hemp, ramie, and jute. In yet another embodiment, the composition may also include woven fibers comprising one or more synthetic fibers such as acrylic, acetate, lycra, spandex, polyester, nylon, and rayon. The present invention may also consist of non-woven fibers comprising the aforementioned composition. The non-woven fibers may be spun with woven natural fibers such as wool, cotton, silk, linen, hemp, ramie, and jute, or synthetic fibers such as acrylic, acetate, lycra, spandex, polyester, nylon, and rayon. The optically responsive yarn can be produced by these methods to create a fabric comprising either the woven or non-woven fibers of the aforementioned composition, spun together with a plurality of natural, synthetic or both natural and synthetic fibers.

[0009] Yet another embodiment of the present invention herein also relates to methods of retaining source radiation emitted from a subject or object comprising covering or surrounding an object bodily area with one of the above mentioned fabrics. In this embodiment, the fabric may be comprised of woven fibers consisting of the aforementioned composition. The composition spun with the woven fibers may be either natural or synthetic. The radiation may also be infrared radiation.

[0010] The present invention also relates to methods of retaining source radiation emitted from an object and may be achieved by covering or surrounding the object with one of the above mentioned fabrics.

[0011] BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a graph of hand data from transcutaneous oxygen measurements.

[0013] Fig. 2 is a graph of foot data from transcutaneous oxygen measurements.

[0014] Fig. 3 is a graph of a spectral distribution pattern of alumina.

[0015] Fig. 4 is a graph of a spectral distribution pattern of titanium dioxide.

[0016] Fig. 5 is a flow chart of a process for making filaments with particles added.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] It is understood that the present invention is not limited to the particular methodology, protocols, and reagents, etc., described herein, as these may vary. It is also to be understood that the terminology used herein is used for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention. It must be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural reference unless the context clearly dictates otherwise.

[0018] Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. Preferred methods, devices, and materials are described, although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention. All references cited herein are incorporated by reference in their entirety.

[0019] The present invention focuses on the creation of and methods of use of a biologically benign powder in a resin that has certain beneficial properties such as retaining source infrared radiation and changing the wavelength of light reflected by the powder or passing through the powder. This powder may be combined with a carrier material, such as a resin, specifically a polymer, and/or implemented into a textile fiber, a non-woven membrane, or a similar product. Products that incorporate this powder may provide additional beneficial properties to a subject wearing such a product such as, for example, wound healing, skin fibroblast stimulation, fibroblast growth and proliferation, increased DNA synthesis, increased protein synthesis, increased cell proliferation by changing the optical properties in and around the human system interacting with light, and changing the wavelength, reflecting, or absorbing light in the electromagnetic spectrum. The compositions and fibers of the present invention represent a combination of substances that work together with electromagnetic radiation to provide such beneficial properties.

[0020] Additionally, the compositions of the present invention may be used in a variety of settings to trap source infrared radiation, to provide heat to an object, or to prevent the escape of infrared light. Some uses may include, but are not limited to, insulation of heating and cooling systems, thermal insulation for outdoor recreation, retention of infrared light by military forces to prevent detection, and insulation of perishable items. Other uses of a fabric made from such a composition include hosiery, footwear, active wear, sports wear, sports wraps, base layer, gloves, and bandages. These items may also have certain properties such as controlling odor, regulating heat, providing protection from fire, providing protection from harmful light, insulation, wound healing, and preserving food.

[0021] Electromagnetic light spans a very large spectrum from 10 nm to 1060 nm of wavelength and spans ultraviolet light, visible light, and infrared light. Ultraviolet ("UV") light has wavelengths from 10 nm to 390 nm and is divided in to near (390 to 300 nm), mid (300 to 200 nm), and far (200 to 10 nm) spectra regions. Visible light is a small band in the electromagnetic spectrum with wavelengths between 390 and 770 nm and is divided into violet, blue, green, yellow, orange, and red light. Infrared ("IR") light spans from 770 nm to 1060 nm and includes near (770 to 1.5 X 10^3), mid (1.5X 10^3 to 6 X 10^3), and far (6 X 10^3 to 10^6) regions. The refractive index ("RI") is a measure of a substance's ability to bend light. Light and optical energy that the body is exposed to extends throughout the electromagnetic spectrum. The adult human body, at rest, emits about 100 watts of IR in the mid and far wavelengths. During exercise this level rises sharply and the distribution of wavelengths changes.

[0022] There are many types of materials that interact with optical energy by absorbing, reflecting, refracting, and/or changing the wavelength. When light is absorbed it is changed into molecular motion or heat, or optical energy of a longer wavelength. In one embodiment, the present invention relates to a material, such as a resin, film, polymer or fiber, for example, that is optically responsive to light and electromagnetic spectrums. The end materials created may be used to interact with living or non-living systems. The end material may be created by adding various active materials together to form a powder. The powder may then be combined or mixed with carrier materials that may have their own unique optical properties and may also act as a matrix for the powder and its particles.

[0023] The active materials selected to form the powder are selected based upon several characteristics. One characteristic is that the active materials, in particle form, may be biologically benign, or inert. The material preferably exhibits one of two optical properties: being transparent or having a different refractive index than the carrier material. Specific active materials that may be used in the present invention include silicon, carbon, and various vitreous glasses including oxides of aluminum, titanium, silicon, boron, calcium, sodium, and lithium. In a specific embodiment, the active materials are titanium dioxide, quartz, and aluminum oxide.

[0024] For example, the choice of materials and their optical properties can be selected to effect a certain result, such as, for example, a biological excitation for a range of wavelengths from 1.015 microns to 0.601 microns (601 nm). To target this area of light, an overlapping series of pass-bands that promote excitation and emission in the ranges that bracket the desired wavelength may be created by the materials. These pass bands may be created by using particles of staggered refractive indices with respect to the host, creating a known transparency and if possible concentrating normally blocked or attenuated wavelengths by using particles with high transparency and moderate refractive indices. Additionally, to ensure wide excitation, a material that is transparent to UV light with a high refractive index that is not transmissive at short wave, or harmful, UV regions may be used.

[0025] Specific carrier materials that may be used in the present invention include resins such as rayon, polyester (PET), nylon, acrylic, polyamide, and polyimide. For applications related to infrared light, solid transparent materials with a transmission in the range, of about 0.5 to about 11 microns is preferable, such as, for example, polyethylene and many of its derivatives, polypropylene and many of its derivatives, polymethylpentene, and polystyrene and many of its derivatives. These materials may also exhibit useful transparencies in the ultraviolet. The addition of active particles with varying refractive indices may yield a wide range of filtering effects in the IR and UV ranges. In particular, resinmay serve as a medium to encase and act as a lensing medium for active materials.

[0026] Once the materials are selected, they may be ground or processed to comprise various properties. The grinding or processing helps to determine the particle size of the active material, the concentration of each type of active material, and the physical characteristics of the active material, and is known in the art. The physical characteristics may include the smoothness or shape of the particles. For example, the particles may be smooth, round, triangular, or scalloped.

[0027] The end material may achieve one of two results with respect to wavelength: it may shorten or lengthen wavelength depending the desired effect. In either use, IR light excites atomic and/or molecular structure. The excitation may frequently result in stresses on either atomic or molecular levels. When the stress is released, the electron energy level may change and release energy as photons.

[0028] In some combinations of carrier and active particle materials, particular wavelengths may be selected by the case that a given wavelength may be absorbed and/or emitted. If the active particles are suspended in a matrix that performs a filtering action, i.e., passing optical energy, the active particles may be closer to the wavelength of the carrier material. Conversely, if shorter or longer wavelengths are to be passed, the size of the active particles may be closer to the size of the wavelength of the light passed. For example, in applications in which the desired wavelength is 1 micron, the particle size may be the same, i.e., 1 micron. If carrier material, such as resinfor example, is capable of passing 14 micron to 4 microns it may be desirable to have some particles slightly larger than or equal to those wavelengths. Desired particles sizes may range from about 2 microns to about 0.5 micron and are preferably related to the targeted wavelength.

[0029] In a specific embodiment, the powder may comprise aluminum oxide (Al_2O_3), quartz (SiO_2), and titanium dioxide (TiO_2 - in rutile form). Titanium dioxide may be obtained from any commercially available source, such as from Millennium Chemicals, Inc., Hunt Valley, MD. Quartz may be obtained from any commercially available source, such as Barbera Co., Alameda, CA. Aluminum oxide may be obtained from any commercially available source, such as from Industrial Supply, Loveland, CO.

[0030] Aluminum oxide has a unique property that promotes infrared light bandshifts under certain conditions. When aluminum oxide is combined with other materials, such as those described herein, interaction with IR light occurs. For example, the IR light emission of the human body is absorbed and excites electron energy levels in the atoms and molecules of the components of the compositions of the present invention. As the electrons return to their previous energy levels they release energy in the IR range but at a different wavelength, i.e., a longer wavelength. The compositions of the present application, when used in a body covering, such as a compression wrap or sleeve, utilize these bandshifting properties of aluminum oxide to reflect longer infrared wavelengths back into the human body. The longer infrared wavelength, for example, allows capillaries to relax and be less constricted, resulting in greater blood flow where required, which results in improved body circulation.

[0031] Quartz, or silicon dioxide, is biologically benign if it is incorporated into a carrier material in solid bulk form. Quartz is also capable of non-linear frequency multiplication, and, in proper combination with a particular wavelength and a carrier, may emit ultraviolet (UV) light. UV light is known to inhibit bacterial growth and the creation of ozone. UV that has a wavelength that is too short can be detrimental to the human system. Quartz may be used to absorb the shorter wavelength UV light if its physical particle size is close to the wavelength of light that should be excluded. In the present invention, quartz may be used to increase frequency or shorten wavelength.

[0032] In addition to being optically active, quartz may exhibit piezoelectric properties. When quartz is stressed, the distribution of charges may become unequal and an electric field may be established along one face and an opposite field may be established along the other face. If the stressing effect, such as pressure, for example, is constant, the charges may redistribute themselves in an equal and neutral manner. If the stress is removed once the charges are redistributed, a charge of opposite polarity and equal magnitude to the initial charge may be established. This charge redistribution results in nonlinear behavior, which may be manifested as frequency doubling.

[0033] Titanium dioxide is unique because it has a high refractive index and also has a high degree of transparency in the visible region of the spectrum. It is used as a sunblock in sunscreens because it reflects, absorbs, and scatters light and does not irritate the skin. Only diamonds have a higher refractive index than titanium dioxide. For these reasons, titanium dioxide is ideal for applications that are close to skin surfaces.

[0034] If the optical properties of titanium are used in conjunction with quartz and an appropriate carrier material, such as PET, for example, a greenhouse effect may be created. Infrared wavelengths of one size may pass back through the resinand may be reflected. This reflection creates longer wavelengths that prevent passage back through the PET. In a specific embodiment of the present invention this property may be used to reflect longer wavelengths into the human system while directing shorter, more harmful wavelengths away from the human system.

[0035] Particle size and shape of the active materials in the powder may also affect the end product by controlling the wavelength of light that is allowed to pass through the particles. In a specific embodiment, a particle size of about 1.4 microns or smaller is used for aluminum oxide. The particle shape may be scalloped. The particle size of quartz may be about 1.5 microns or smaller. The quartz particles may be spherical or substantially spherical. The titanium dioxide particles may be about 2 microns or smaller and triangular with rounded edges.

[0036] The specific properties and characteristics of the active particles and carrier materials may be combined to produce a specific effect such as wound healing, skin fibroblast stimulation, fibroblast growth and proliferation, increased DNA synthesis, increased protein synthesis, and increased cell proliferation by changing the optical properties in and around the human system. These properties are related to specific wavelengths of light and the interaction of that light with the compositions of the present invention.

[0037] In one embodiment of the present invention wavelengths may be selected to provoke melanin excitement, which occurs at about 15 nm. To achieve this excitement an energy range from a band about 10 nm to about 2.5 microns from the human metabolic action may be used. Daylight from either an outdoor broadband or an indoor lamp ranges from about 1.1

microns, with a "hump" around 900 nm and a broad general peak around 700-800 nm, and also includes lesser wavelengths such as 400 to 700 nm. Some of the general properties and desirable filtering and changes include but are not limited to having band pass in the 600 to 900 nm band range. Also, a carrier material may be selected to have a transparency from 200-900 nm. resinhas a known transparency in the 8 to 14 micron range. An active particle may also be selected to have a wavelength between about 950 and 550 nm. This may be accomplished by using particles with a general size distribution of 2 microns and lower.

[0038] Muscle and bone atrophy are well-documented in astronauts, and various minor injuries occurring in space have been reported not to heal until landing on Earth. Spectra taken from the wrist flexor muscles in the human forearm, and muscles in the calf of the leg, demonstrate that most of the light photons at wavelengths between 630-800 nm travel 23 cm through the surface tissue and muscle between input and exit at the photon detector. The light is absorbed by mitochondria where it stimulates energy metabolism in muscle and bone, as well as skin and subcutaneous tissue. Evidence suggests that using LED light therapy at 680, 730 and 880 nm simultaneously in conjunction with hyperbaric oxygen therapy accelerates the healing process in Space Station missions, where prolonged exposure to microgravity may otherwise retard healing. Tissues stimulate the basic energy processes in the mitochondria (energy compartments) of each cell, particularly when near-infrared light is used to activate the color sensitive chemicals (chromophores, cytochrome systems) inside each cell. Optimal LED wavelengths may include 680, 730, and 880 nm. Whelan et al., 552 SPACE TECH. & APP. INT'L FORUM 35-35 (2001). Whelan et al., 458 SPACE TECH. & APP. INT'L FORUM 3-15 (1999). Whelan et al., 504 SPACE TECH. & APP. INT'L FORUM 37-43 (2000). Near-infrared light at wavelengths of 680, 730 and 880 nm stimulate wound healing in laboratory animals, and near-infrared light has been shown to quintuple the growth of fibroblasts and muscle cells in tissue culture. Hence, the particle size of the compositions of the present invention may be selected to provide reflective or pass through beneficial wavelengths of light.

[0039] The active particles of the present invention may be ground to reach an approximate particle size of about 0.5 to about 2.0 microns. For example, titanium dioxide may be ground to a grain size of between 1 and 2 microns and may be triangular with rounded edges.

Aluminum oxide may be ground to a grain size of between 1.4 and 1 microns and may be scalloped-shaped. Quartz is preferably ground to a grain size of about 1.5 to 1 microns and is generally rounded. All particles are reduced in size and shaped by processes known in the art, such as grinding, polishing, or tumbling, for example. In a preferred embodiment, the dry weight ratio of the active materials titanium dioxide, quartz, and aluminum oxide in the powder is 10:10:2, respectively.

[0040] In a specific embodiment of the present invention, the compositions may further comprise a resin, such as a polymer made into a film or fiber. The polymer may initially be in pellet form and dried to remove moisture by using, for example, a desiccant dryer. The powder may then be dispersed into the resin by methods known in the art, such as for example in a rotating drum with paddle-type mixers. In one embodiment of the present invention the polymer used may be polyester. The powder may comprise from about 0.5 to about 20 percent of the mixture. In another embodiment, the powder may comprise from about 1 to about 10 percent of the mixture. In a specific embodiment, the powder may comprise from about 1 to about 2 percent of the total weight of the resin/powder mixture. To produce one half ton of fiber, about 100 pounds of the powder may be combined with about 1000 pounds of PET. In an alternative embodiment, the powder may be introduced to the resin by other processes known in the art such as compounding, for example. In this embodiment, 100 pounds of the powder may be combined with about 250 to about 300 pounds of PET.

[0041] After the resin and powder are combined, the resulting liquid may be extruded into fiber that may be drawn into staple fibers of various lengths. This process of grinding, combining, and extrusion is known in the art, as described in, for example, U.S. Patent Nos. 6,204,317; 6,214,264; and 6,218,007, which are expressly incorporated by reference in their entirety herein.

[0042] The basic techniques for forming polyester fiber by extrusion from commercially available raw materials are well known to those of ordinary skill in this art and will not otherwise be repeated herein. Such conventional techniques are quite suitable for forming the fiber of the invention and are described in U.S. Patent No. 6,067,785, which is herein expressly incorporated by reference in its entirety.

[0043] After extrusion the fibers may be combined together by a spinning process, preferably using a rotary spinning machine, to yield a yarn. The range of the size of the apertures in the rotary spinning machine may be from about 6 microns to about 30 microns.

[0044] In preferred embodiments, the step of spinning the fibers of the present invention into yarn comprises spinning staple having a denier per fiber of between about 1 and about 3; accordingly, the prior step of spinning the melted polyester into fiber likewise comprises forming a fiber of those dimensions. The fiber is typically heat set before being cut into staple with conventional techniques. While the extruded fibers are solidifying, they may be drawn by methods known in the art to impart strength.

[0045] Similarly, the method can further comprise forming fabrics, typically woven or knitted fabrics from the spun yarn in combination with both natural and synthetic fibers. Typical natural fibers may include cotton, wool, hemp, silk, ramie, and jute. Alternatively, typical synthetic fibers may include acrylic, acetate, Lycra, spandex, polyester, nylon, and rayon.

[0046] Because polyester is so often advantageously blended with cotton and other fibers, the present invention also includes spinning a blend of cotton into yarn in which the polyester may include between about 0.5 and 4% by weight of polyethylene glycol into yarn in a rotor spinning machine.

[0047] The method can further comprise spinning the fibers of the present invention. Similarly, the fibers of the present invention may include a woven or knitted fabric from the blended yarn with the yarn being either dyed as spun yarn, or after incorporation into the fabric in which case it is dyed as a fabric.

[0048] The cotton and polyester can be blended in any appropriate proportion, but in the specific embodiments the blend includes between about 35 and 65% by weight of cotton with the remainder polyester. Blends of 50% cotton and 50% polyester ("50/50") are also used.

[0049] The yarn formed according to this embodiment can likewise be incorporated into blends with cotton, and is known to those familiar with such blending processes, the cotton is typically blended with polyester staple fiber before spinning the blend into yarn. As set forth above, the blend may contain between about 35% and 65% by weight cotton with 50/50 blends being typical. Other methods of production of fibers are equally suitable such as those described in U.S. Patent Nos. 3,341,512; 3,377,129; 4,666,454; 4,975,233; 5,008,230; 5,091,504; 5,135,697; 5,272,246; 4,270,913; 4,384,450; 4,466,237; 4,113,794; and 5,694,754, all of which are expressly incorporated by reference in their entirety herein.

[0050] In one embodiment of the present invention, the polyester mixture may be used to create a staple fiber. The staple fiber may then be used to create a non-woven membrane. This membrane may be bonded to another fabric, membrane or material. For example, the non-woven membrane may be used as a lining by being bonded to the inside of a pair of leather gloves or, for example, being bonded to another fabric such as ThinsulateTM by 3M by methods known to those skilled in the art.

EXAMPLES

[0051] Without further elaboration, it is believed that one skilled in the art, using the preceding description, can utilize the present invention to the fullest extent. The following examples are illustrative only, and not limiting of the remainder of the disclosure in any way whatsoever.

Example 1: Thermal homeostasis

[0052] Two batches of wrist bands are prepared: WB1 (woven with fibers comprising the powder composition of the present invention) and WB2 (woven with fibers lacking the powder composition of the present invention).

[0053] Twenty panelists are selected from the general population, and no specific demographic parameters are utilized in recruiting the panelists. Panelists are placed within a climate-controlled area of standard room temperature, standard humidity, and sea-level atmospheric pressure. A measurement of each panelist's middle finger temperature is taken prior to the panelists' donning of any band. Panelists are asked to don a band from WB2. Five minutes later, a measurement of each panelist's middle finger temperature is taken. Panelists are then asked to remove the band from WB2, wait five minutes, and don a band from WB1. Five minutes later, measurements of each panelist's middle finger temperature are taken. Thermographic instruments are used to record the temperatures of the fingers of the panelists throughout the trials. All temperature measurements are averaged.

[0054] There exists a statistically significant difference between the average middle finger temperature of the panelists after their donning of bands from WB1 and the average middle finger temperature of the panelists prior to their donning of any band. Further, there exists no statistically significant difference between the average middle finger temperature of the panelists after their donning of bands from WB2 and the average middle finger temperature of the panelists prior to their donning of any band. The ability of the bands woven with fibers comprising the powder composition of the present invention to serve as agents of thermal homeostasis is demonstrated.

Example 2: Muscle strength

[0055] Two batches of wrist bands are prepared: WB1 (woven with fibers comprising the powder composition of the present invention) and WB2 (woven with fibers lacking the powder composition of the present invention).

[0056] Panelists are selected from the general population, and no specific demographic parameters are utilized in recruiting the panelists. Panelists are placed within a climate-controlled area of standard room temperature, standard humidity, and sea-level atmospheric pressure. A measurement of each panelist's grip strength is taken prior to the panelists' donning of any band. Panelists are asked to don a band from WB2. Five minutes later, a measurement of each panelist's grip strength is taken. Panelists are then asked to remove the band from WB2, wait five minutes, and don a band from WB1. Five minutes later, measurements of each panelist's grip strength are taken. Grip dynamometers are used to record the grip strengths of the panelists throughout the trials. All grip strength measurements are averaged.

[0057] There exists a statistically significant difference between the average grip strength of the panelists after their donning of bands from WB1 and the average grip strength of the panelists prior to their donning of any band. Further, there exists no statistically significant difference between the average grip strength of the panelists after their donning of bands from WB2 and the average middle finger temperature of the panelists prior to their donning of any band. The ability of the bands woven with fibers comprising the powder composition of the present invention to increase muscle strength is demonstrated.

Example 3: Insoles

[0058] The powder composition of the present invention is prepared by the processes of the present invention. Two batches of insoles are prepared: INl (woven with fibers comprising the powder composition of the present invention) and IN2 (woven with fibers lacking the powder composition of the present invention).

[0059] Panelists are selected from the general population, and no specific demographic parameters are utilized in recruiting the panelists. Samples, are presented to panelists in a blinded manner (samples are identified only by a random digit label). Each panelist receives two insoles to wear, one within each shoe, and panelists are instructed to randomly place one insole within each shoe. Thus, the shoe (right or left) in which each insole is worn is completely random. In each pair of insoles, one sample is from IN1 and one sample is from IN2. Panelists are asked to record any differences between the two insoles that they notice after wearing them for an eight hour period.

A number of the panelists note a difference between the insoles. A statistically significant number of those panelists noting a difference between the two insoles regard the insole comprising the powder composition of the present invention as providing greater comfort than the insole lacking the powder composition of the present invention. The ability of the insoles woven with the fibers comprising the powder composition of the present invention to provide comfort is demonstrated.

[0060] The following examples further demonstrate that the use of a material as described herein can increase blood flow and enhance muscle strength. The term "proximal" as used herein means close to, abutting, next to, or underneath a material used in the examples. Instances of "proximal" include a wrist to a hand, an elbow to a hand, a wrist to a finger, an ankle to a foot, and an ankle to a toe.

EXAMPLE 4

Studies were performed to evaluate changes in peripheral blood perfusion. This was monitored by changes in peripheral blood flow in the hands and feet of persons with diabetes when gloves and stockings incorporating a material of the invention were worn. Each subject had a history of diabetes and vascular impairment. The study was a double blinded test, monitoring transcutaneous oxygen and laser Doppler flowometry. Data points were taken over the course of one hour. Subjects wore either garments incorporating a material of the invention (test material) or placebo garments. Results were analyzed after unblinding.

Subjects were evaluated for baseline blood flow status. They then had transcutaneous oxygen (Perimed Inc. North Royalton, Ohio, PF5040 transcutaneous module) and laser Doppler flowometry measurements (PF5010 Laser Doppler Perfusion module) with stockings and gloves made with and without the test material. Measurements were made prior to wearing the garments and continuously over a one hour period while wearing the garments. Data was analyzed at ten minute intervals. The tester and subject were blinded to the study garment. Garments were randomly selected and tested from a computer generated randomization list. Measurements were taken of both the hand and foot with the study subjects wearing the test material versus standard fiber gloves and stockings.

The diagnosis of diabetes mellitus was based on World Health Organization criteria. For the purposes of this study, the diagnosis of peripheral vascular disease was a transcutaneous oxygen measurement > 30mm Hg taken at the transmetatarsal level on the day of enrollment. Patients varied in age from 18 to 80 years old.

Patients with the following characteristics were excluded: Patient currently being treated by dialysis, or having serum creatinine greater than or equal to 3.0 mg/dl; patient known to be an active alcohol or substance abuser for the six months prior to the start of the study; patient currently receiving systemic corticosteriods in a dose equivalent to greater than or equal to 10 mg of prednisone per day; patient currently receiving immunosuppressive agents; patient currently receiving radiation therapy; patient currently receiving cytotoxic agents; patient currently receiving antiviral agents; patient having history of widespread malignant or systemically immunocompromising disease; atient is a female who is breast feeding, pregnant, or attempting to become pregnant; atient has other conditions considered by the

investigator to be sound reasons for disqualification (e.g., acute illness or exacerbation of chronic illness, lack of motivation, and history of poor compliance);
amputation proximal toLisfranc's(tarsometatarsal) joint or if amputation/surgical debridement has destroyed the venous plexus of the plantar arch; acute deep venous thrombosis; active congestive heart failure; uncontrolled osteomyelitis; vascular surgery in the past 4 weeks; patient has a full thickness skin ulcer.

The dynamic non-invasive vascular assessment consisted of transcutaneous oxygen pressure ($TcPO_2$) measurement, and laser Doppler flowmetric measurement. The PeriFlux 5000 System was used. It is a multifunctional system that incorporates four functional units that combine transcutansous oxygen and laser Doppler function units.

The transcutaneous oxygen electrodes were warmed to 44°C and allowed to equilibrate on the skin for 5 minutes (until stable values were achieved). The resultant values were measured in mmHg. The laser Doppler monitor was used to continuously measure tissue blood perfusion (PF5010 Laser Doppler Perfusion module). The application was non-invasive. Two stick-on probes similar to standard EKG probes were applied to the skin. In the tissue, the laser light was scattered and Doppler shifted by interaction with the moving blood cells according to the well-known Doppler principle. The sampling depth was on the order of 200-500 micrometers. A fraction of the backscattered light was detected by a remotely positioned photo detector.

We measured transcutaneous oxygen and laser Doppler flowometry measurements continuously during the one hour evaluation period and recorded values for 60 seconds at ten minute intervals on the dorsum of the foot and hand. In addition, we measured a two minute interval at the conclusion of each data collection period to compare the change in blood flow parameters in placebo and test treatment groups.

Results:

We used a paired t-test to compare transcutaneous oxygen (TCOM) and laser Doppler (LD) values on the hand and foot. Treanscutaneous oxygen measures the partial pressure of oxygen at the surface of the skin. As part of the descriptive evaluation of the data, we stratified

TCOM and LD into three levels: increase when comparing test material to placebo, no change, or a decrease when comparing test material to placebo. If there was less than a 4% change when the placebo vs. test material was used, this was determined to represent "no change". TCOM's in the hand showed 10 subjects with an increase, 4 unchanged and 6 with a decrease when using test material compared to the placebo garment. TCOM's in the foot again showed 10 subjects with an increase when using Holofiber, 4 were unchanged and 6 were decreased.

There was a statistically significant change in transcutaneous oxygen or the oxygen delivery to the skin in the hand and foot when using the paired t-test to compare data collected at time periods 40 and 50 minutes after initiation of testing. The Laser Doppler studies did not show a difference in blood flow in placebo versus test material in either the hand or the foot.

Data can be seen in figures 1 and 2. Figure 1 shows that with the use of gloves comprising the test material, transcutaneous oxygen in the patients' hands increased more than twelve percent over that when placebo gloves were used. Likewise, figure 2 shows that transcutaneous oxygen in feet wearing socks comprising the test material was approximately 8 percent higher than in those with the placebo socks. These significant changes are very compelling, as an 8-12% improvement in skin oxygenation could improve marginal circulation enough to improve would healing or eliminate ischemic pain of the legs.

EXAMPLE 5

Subjects were analyzed for the effects of a material of the invention (the test material) on strength of proximal muscles. Wrist bands made either with the test material or without it were used. Subjects ranged in age between 20 and 80 years old. Each subject was asked to stand in a relaxed position and to squeeze a dynamometer having an analog readout with his or her preferred hand. The device used is also used to test patients with carpal tunnel syndrome.

The subjects squeezed the device as hard as possible three times, resting between efforts. The amount of pressure applied was measured on the dynamometer, and the highest number for each subject was used as the control level. A wrist band was then placed on the wrist of the hand used to establish the control level. Optionally, a second wrist band was placed on the other wrist. The subjects were then allowed to rest their wrists and hands for between two and ten minutes, after which their strength was again measured on the dynamometer.

For those subjects wearing wrist bands comprising the test material, an increase in strength was recorded in comparison to those wearing wrist bands without the test material. In studies involving well over a thousand subjects, 75 to 80 percent of the subjects had an increase in strength of between 5 and 20 percent over comparable placebo events. Thus, the test material successfully caused an increase in strength in muscles proximal to the location of the wrist bands comprising the test material. It is believed that this increased strength is due to increased blood flow to those muscles, caused by the presence of the test material.

EXAMPLE 6

Subjects were analyzed for the temperature effects of test material on skin and subdermal tissue. An Agema 5500 thermovision camera was employed. Temperature of a location can be read as a number readout on the camera, as well as by a color change. The camera was calibrated regularly to maintain accuracy. Wrist bands made either with the test material or without it were used. All studies were performed in a climate-controlled area at standard room temperature, standard humidity, and sea-level atmospheric pressure.

A subject was seated at a table that was approximately waist high, with his or her hands on the table in a resting position. The camera was used to scan a hand, including the fingers, for approximately ten minutes, to locate the coldest spot. The temperature of this spot was used as the baseline. The subject then put on a wrist band next to the hand being monitored. The temperature of that hand was continuously monitored, and data were recorded at 0 minutes, 3 minutes, 8 minutes and 10 minutes.

When the wrist band used contained no test material, minimal changes in temperature were recorded. However, when the wrist band used contained the test material, exemplary results were as follows:

TABLE 1

	t = 0	t = 3	t = 8	t = 10	total change
A) example of high results	19°C	20°C	26°C	29°C	10°C
B) example of med. results	14°C	18°C	21°C	22°C	8°C
C) example of low results	14.9°C	16°C	19°C	21°C	6.1°C

For example A, the temperature at the coldest spot on the subject's hand increased a degree centigrade within the first 3 minutes, another 6 degrees in the next 5 minutes, and another 3 degrees in the following 2 minutes, for a total of a 10 degrees C increase. In the middle example, an overall increase of 8 degrees C was observed. In the low example, there was more than a 6 degree C increase.

The data show that as early as three minutes after application of the test material to the wrist, the temperature of even the coldest spot on a subject's hand was raised markedly. It is believed that this is caused by increased blood flow to the hand, caused by the presence of the test material.

[0061] In a preferred embodiment, a wearable fabric or material is woven from resin filaments, such as polymers and, preferably from resinfilaments or fibers, including uniformly distributed 0.5 to 1.5 micron, biologically benign particles of titanium dioxide, alumina and silicon oxides. The material may also be formed from non woven filaments. It addition to wearable fabrics, the material may also be used between a user and a source of light, for example, the material may be used for bedding, tents, umbrellas, shades and awnings. Particles having substantially intact crystal lattice structures, and minimal contamination, have improved optical performance when uniformly distributed within the resin filaments beyond what is achievable with substantially or partially amorphous particles and are therefore preferred. The particles may be added in substantially equal weight for a .25% to 15% loading of the PET. A range of 1% to 2% loading of the resinis presently preferred.

[0062] Crystalline particles of titanium dioxide, alumina and silicon oxides, with the desirable properties, may be obtained from the following suppliers.

[0063] Silicon oxide: Alibab.com., 39899 Balentine Dr., Ste 325, Newark, CA 94560

[0064] Alumina: PACE Technologies, 200 Larkin Dr., Wheeling, IL 60090

[0065] Titanium Dioxide: Goodfellow Corporation, 800 Lancaster Ave, Berwyn, PA 19312

[0066] Ambient light incident on the woven material typically includes visible light as well as some infrared (IR) and ultraviolet (UV) radiation. The crystalline particles within the resinfilaments have pass bands in or overlapping the visible spectrum and also translates or converts some portions of UV and IR light into light in specific pass bands in or overlapping the visible light spectrum including the near IR. The light applied to the skin of the wearer of the material therefore has a substantially modified distribution of light in pass bands in or overlapping the visible spectrum.

[0067] The substantially uniform distribution of the particles in the resinresults in interaction and enhancement of these effects so that the spectral distribution of the light applied to the wearer is substantially altered from the spectral distribution that would have been applied under the same conditions without the presence of the particles in the PET. For example, if the ambient light applied to the material had a relatively flat or equal spectrum in the band of interest, the light transmitted through unadulterated resinwould also have a relatively flat spectrum reduced in amplitude generally, but somewhat higher in intensity in the pass band of the unadulterated PET.

[0068] resinis often manufactured from recycled materials including contaminants. The light transmitted through contaminated resinwill also typically have a relatively even or flat distribution of the spectrum of the light applied to the material. However, the light transmitted through the resinincluding the particles, whether or not contaminated, will exhibit the substantially altered spectrum, described below as an altered spectrum distribution pattern.

[0069] Referring now to Fig. 3, an example of the effects on light incident on Alumina particles is provided to aid in the understanding the altered spectral distribution discussed above. Fig. is a graph of the intensities of light emerging from a suspension of alumina particles, from about .25 to 1.75 micron in a fluid having a refractive index of 1.51, similar to the resincarrier. The fluid may be prepared by mixing Agar-Agar, water, propylene glycol and amyl alcohol to form a gel to suspend the particles. A generally broadband relatively flat spectrum of light is applied to the gel suspension and a scanning spectrophotometer is used to detect and measure the light emerging from the gel with suspended particles. The graph shows the results, normalized to a peak intensity of 1.00 at a wavelength of about 300 nm. As can be seen by inspection from the shape of the graph, the emerging light has substantial peaks and valleys, for example, valley "A" occurring just below about 400 nm and twin peaks "B" at just above 400 nm.

[0070] Referring now to Fig. 4, a similar graph of the light emerging from a suspension of titanium dioxide particles in a similar gel is shown for a similar flat spectrum input. The graph shows the results, normalized to a peak intensity of 1.00 at a wavelength of about 425 nm. As can be seen by inspection from the shape of the graph, the emerging light has substantial peaks and valleys, for example, valley "C" occurring just below about 400 nm and peak "D" occurring at about 425 nm.

[0071] The spectral distribution of light emerging from Quartz particles also has peak amplitudes at certain wavelengths and minima or valleys at other wavelengths.

[0072] When the titantium dioxide, alumina and quartz are loaded in the resinfilament, the spectral altering characteristics of the particles, shown in Fig.s 1 and 2 for titanium dioxide and alumina, respectively, interact to further alter the spectral distribution of the light emerging from the filament material, that is, the spectral distribution pattern. The resultant pattern becomes quite complex and provides wide and narrow peaks and valleys at many different spectral lines. The characteristics of the PET, and temperature, particle size distribution and other effects may shift or further vary the spectral density pattern.

[0073] It is important to note that the variations in the spectral density pattern from the ambient, that is, the pattern of peaks and valleys is not random but rather intentional and permits selective illumination of the wearer's skin with a somewhat higher intensity light at certain specific wavelengths and ranges of wavelengths surrounded by light at lower intensity at other specific wavelengths and ranges of wavelengths. The selective spectral distribution pattern of illumination can cause various beneficial effects in the wearer by selectively energizing some components of the human body, such as mitochondria.

[0074] With an applied excitation from ambient light, such as excitation from 210 nm to 75 microns, and/or 300 to 1,500 nm, and/or 350 to 1,100, and/or 390 to 750 nm, the spectral distribution pattern of the wearable fiber having titanium dioxide, alumina and quartz particles may include spectral lines, 35 nm wide on each side, for the following sets of spectra, and ranges of spectra (all in nm):

400, 420, 443, 458, 462, 474, 490, 512, 540 to 550, 550 to 565, 570 to 595, 598, 602, 620, 590 to 630, 625 to 648, 633 to 670, 665 to 680, 686 to 703, 710 to 770, 700 to 740, 708 to 734, 737 to 770, 750 to 790, 800, 880, 870 to 910, 920 to 940, 933 to 960, 905 to 950, 940 to 970.

[0075] Distributed harmonic outputs may also be present, 45 nm wide, on either side of (all in nm): 950, 975, 1050, 1070, 1100, 1150, 1190, 1205, 1250, 1285, 1290, 1310, 1350 1370 and 1390.

[0076] The resultant spectral distribution pattern provides selective illumination of the wearer which has been shown to be advantageous to the wearer.

[0077] The human body is known to radiate heat and also, at very low levels, to radiate light in various pass bands. The wearable fiber material will therefore also receive light and heat from wearer's body, which is also subject to the effects of the particles in the PET, the resultant radiation may also be applied to the wearer's skin.

[0078] Polarization of the light in the fiber may be caused by the resinmaterial as well as the particles and further enhances the ability of the resinand particulate system to modify the distribution of wavelengths in the visible and near IR light applied to the wearer.

[0079] The increase in applied visible and near IR radiation may be on the order of 0.01 to .03 percent using wearable materials made from the fiber and particulate system.

[0080] Referring now to Fig. 5, a simple flow chart is provided for the process of creating the filaments of resinfrom which thc wcarable material may be made. In step 10, the sizes of one or more the types of the particlcs may bc adjusted by pre-processing if the particles are not within the desired range of particles sizes. In step 20, the particles may be physically combined by mechanical mixing to provide a powder or other particle mixture.

[0081] In step 30, the particle mixture may be prepared by compounding or fluid suspension or other known mechanisms to permit introduction into the filament forming process in step 40. Conventional compounding techniques include forming a high concentration of the particles in pellets, typically on the order of 1/8 inch diameter rods about 1" long. In the filament forming process step 40, these pellets are combined with additional pellets or chips of resinin order to achieve the desired loading or concentration of particles in the final filament. Conventional fluid suspension techniques include suspending the particles in a liquid, such a propylene glycol, which is compatible with the resinused in filament forming step 40.

[0082] The filament forming process in step 50 is conventional thermal extrusion. Thereafter, depending up the final use of the filaments, end process steps 60 may be applied.

[0083] Various modifications and variations of the described methods and systems of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in materials engineering or related fields are intended to be within the scope of the following claims.

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The claims defining the invention are as follows:

1. A wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, comprising:

a plurality of different types of optically active particles responsive to both ambient light and radiation emitted from the user; and

a carrier material combined with the optically active particles for retaining the particles and forming an end material;

wherein the plurality of different types of optically active particles have staggered refractive indices with respect to each other and are selected in accordance with the refractive index of the carrier material to generate an overlapping series of passbands that encompass a desired wavelength distribution of about 0.5 to 2 microns to enable the end material to absorb the ambient light and the radiation emitted from the user and re-emit light to the user having wavelengths of about 0.5 to 2 microns.

2. The wearable active material as recited in claim 1, wherein each of the different particle types are reduced to a particle size and shape to generate a particular wavelength passband.

3. The wearable active material as recited in claim 2, wherein at least one of the different particle types is reduced in size to substantially scallop shaped particles for bandshifting the wavelengths of received light.

4. The wearable active material as recited in claim 2 or 3, wherein at least one of the different particle types is reduced in size to substantially spherical shaped particles for shortening the wavelengths of the received light.

5. The wearable active material as recited in claim 2, 3 or 4, wherein at least one of the different particle types is reduced in size to substantially triangular shaped particles with rounded edges for reflecting, absorbing and scattering the received light.

6. The wearable active material as recited in any one of claims 1 to 5, wherein the plurality of different types of optically active particles are further selected in accordance with the refractive index of the carrier material to enable the end material to absorb the radiation emitted from the user and re-emit light to the user having wavelengths longer than the wavelengths of the radiation emitted from the user.

7. The wearable active material as recited in any one of claims 1 to 6, wherein the plurality of different types of optically active particles are further selected in accordance with the refractive index of the carrier material to enable the end material to absorb and reflect ambient light having shorter wavelengths away from the user.

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8. A method of making a wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, comprising:

selecting a plurality of different types of optically active particles responsive to both ambient light and radiation emitted from the user; and

suspending the selected plurality of different types of optically active particles in a carrier material to form an end material;

wherein the plurality of different types of optically active particles have staggered refractive indices with respect to each other and are selected in accordance with the refractive index of the carrier material to generate an overlapping series of passbands that encompass a desired wavelength distribution of about 0.5 to 2 microns to enable the end material to absorb the ambient light and the radiation emitted from the user and re-emit light to the user having wavelengths of about 0.5 to 2 microns.

9. The method as recited in claim 8, further comprising reducing each of the different particle types to a particular size and shape to generate a particular wavelength passband.

10. The method as recited in claim 9, further comprising reducing at least one of the different particle types to substantially scallop shaped particles for bandshifting the wavelengths of received light.

11. The method as recited in claim 9 or 10, further comprising reducing at least one of the different particle types to substantially spherical shaped particles for shortening the wavelengths of the received light.

12. The method as recited in any one of claims 9 to 11, further comprising reducing at least one of the different particle types to substantially triangular shaped particles with rounded edges for reflecting, absorbing and scattering the received light.

13. The method as recited in any one of claims 8 to 12, further comprising selecting the plurality of different types of optically active particles in accordance with the refractive index of the carrier material to enable the end material to absorb the radiation emitted from the user and re-emit light to the user having wavelengths longer than the wavelengths of the radiation emitted from the user.

14. The method as recited in any one of claims 8 to 14, further comprising selecting the plurality of different types of optically active particles in accordance with the refractive index of the carrier material to enable the end material to absorb and reflect ambient light having shorter wavelengths away from the user.

15. A wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, said material as claimed in claim 1, and substantially as

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hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

16. A method of making a wearable active material for absorbing, altering and re-emitting energy in the form of light to a user, said method as claimed in claim 8 and substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

17. A wearable active material made by the method of any one of claims 8 to 14 or 16.

Dated 17 October, 2005
John H. Schnurer
Robert M. Klein
David D. Horinek

Patent Attorneys for the Applicant/Nominated Person
SPRUSON & FERGUSON

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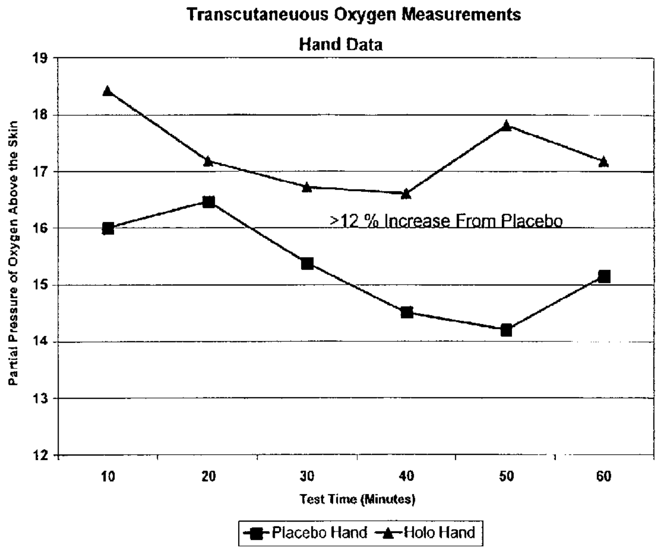
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Partial Pressure of Oxygen Above the Skin
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18
17
16
15
14
13
12
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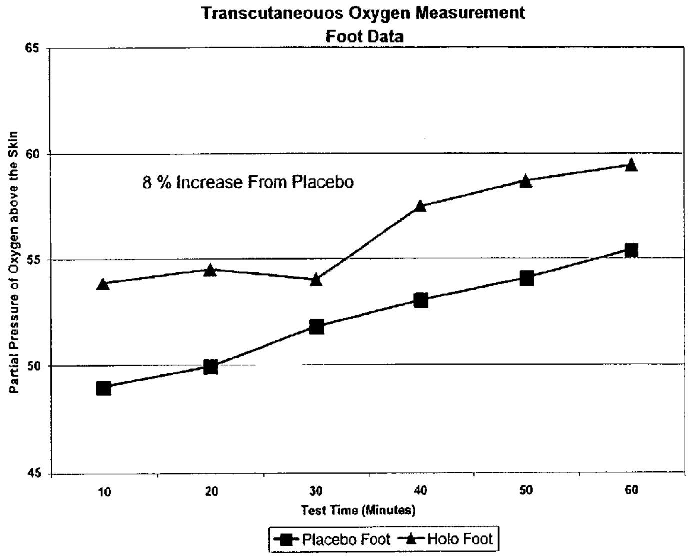
10
20
30
40
50
60
Test Time (Minutes)
Placebo Hand
Holo Hand

Fig. 1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10
20
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40
50
60
Test Time (Minutes)
Placebo Foot
Holo Foot

Fig. 2

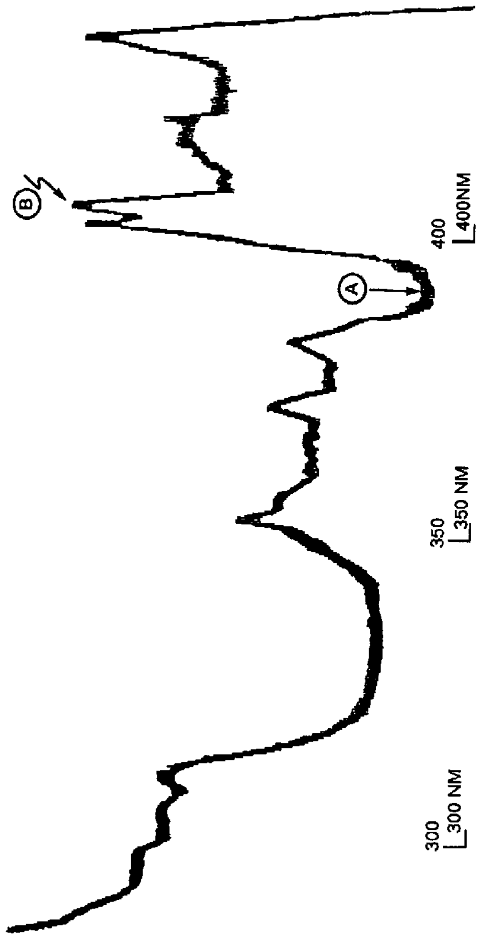

FIG. 3

FIG. 4

SUBSTITUTE SHEET (RULE 26)

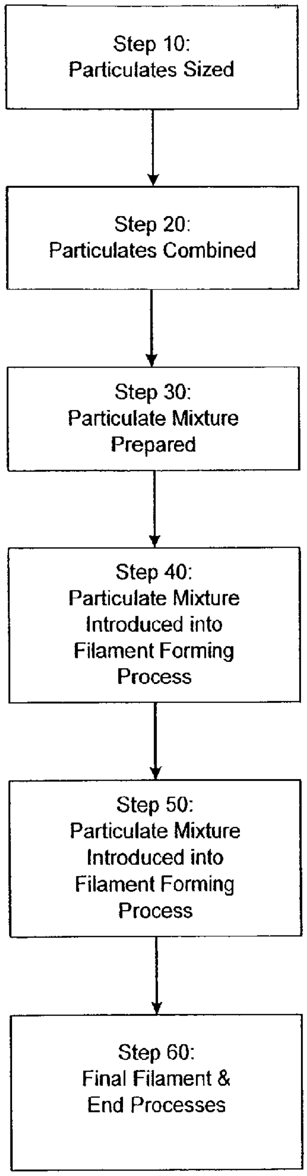
Step 10:
Particulates Sized
Step 20:
Particulates Combined
Step 30:
Particulate Mixture
Prepared
Step 40:
Particulate Mixture
Introduced into
Filament Forming
Process
Step 50:
Particulate Mixture
Introduced into
Filament Forming
Process
Step 60:
Final Filament &
End Processes

Fig. 5