(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 June 2022 (23.06.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/126279 A1

(51) International Patent Classification:
F16L 59/02 (2006.01) *B32B 15/02* (2006.01)
B32B 5/30 (2006.01) *B32B 15/16* (2006.01)
B32B 7/027 (2019.01) *F41H 3/02* (2006.01)

(21) International Application Number:
PCT/CA2021/051834

(22) International Filing Date:
17 December 2021 (17.12.2021)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/199,326 18 December 2020 (18.12.2020) US

(71) Applicant: **TEXAVIE TECHNOLOGIES INC.** [CA/CA]; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA).

(72) Inventors: **SERVATI, Peyman**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **YEAP, Rou Yi**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **ZABIHI, Fatemeh**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **NARAYANA, Harishkumar**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **SERVATI, Amir**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **SOLTANIAN, Saeid**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **LE, Katherine Hoang Kieu-linh**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **ARKAZ, Hamdi Harun**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA). **JIANG, Zenan**; 2819 West 13th Avenue, Vancouver, British Columbia V6K 2T6 (CA).

(74) Agent: **LEE, Brian** et al.; Gowling WLG (Canada) LLP, Suite 2300 - 550 Burrard Street, Vancouver, British Columbia V6C 2B5 (CA).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

(54) **Title:** THERMALLY INSULATING SUBSTRATE PRODUCT AND METHOD OF MANUFACTURE

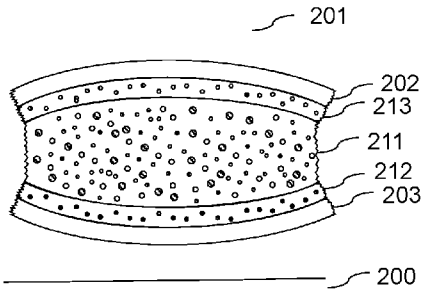


FIG. 3

(57) **Abstract:** This invention relates to a thermally insulating substrate product comprising: a substrate having at least one layer and comprising metallic particles having an average particle size and density selected to block or reflect infrared radiation and aerogel particles having an average pore size and density selected to control conducted and convected thermal energy. The thermally insulating substrate can made as textile and/or film coatings that are light and thin and adapts to external environment conditions for better camouflage as well as improved heat insulation for energy conservation and thermal regulation.

WO 2022/126279 A1

THERMALLY INSULATING SUBSTRATE PRODUCT AND METHOD OF MANUFACTURE

FIELD OF DISCLSOURE

This disclosure relates generally a thermally insulating substrate product, and a method of manufacturing same.

BACKGROUND

Infra-red (IR) spectrum of light carries a large amount of thermal energy and can be emitted from any surface or body. This IR radiation is generated from the atomic and inter-atomic vibrations and can have photon wavelengths in the range of 0.78 to 1,000 micrometers. This emission can be categorized into near-IR (0.78 to 2.5 micrometers), mid-IR (2.5 to 25 micrometers) and far-IR (25 to 1,000 micrometers). This emission leads to heat loss or absorption and transfer of energy in addition to other heat transfer methods such as convection and conduction, and also can be detected by IR cameras and detectors in night vision and night or day surveillance. To improve insulation, comfort and efficiency in a cold environment, it is desirable to suppress this emission to improve comfort and increase energy conservation. This is critical for saving energy for insulation of houses, vehicles, jackets, tents, and sleeping bags that should function for conserving heat in a cold climate. In a hot climate, reflecting the IR radiation coming from sun helps a house, a car or wearer of clothing to stay cooler. As a result, controlled reflection and blocking of IR radiation can be used for both staying hot or cool in different external environments.

In addition, because of the advances in IR cameras and detectors, it is critical to reduce the IR emission over different spectral ranges (near-IR, mid-IR, and far-IR) from bodies of military and security personnel and vehicles for concealing them from external detection and threats. It is therefore desirable that the IR radiation from the body is reduced and matched with that of the surrounding environment to achieve an adaptive camouflage that helps in concealing the personnel and vehicles from IR detectors, cameras and threat in different external environments. For this purpose, it is not only to reduce the IR emission but also match it to that

of the surrounding environment. The IR concealing can also be important in view of privacy concerns caused by the widespread use of IR cameras for monitoring people. Therefore, broad-band IR-shielding materials and technologies are essential for adaptive camouflage and concealing of military personnel, equipment, vehicles, and accessories in different environments as well as providing heat and energy conservation, insulation and comfort for military and emergency personnel as well as general consumers.

Some patents that describe the current state of the art for systems for camouflage, concealing and insulating fabric and textile structures include:

US patent 7,832,018 presents a camouflage suit by using electrically conductive fabric;

US patent 8,916,265 presents a multi-spectral, selectively reflective construct to reduce IR emission; and

US patent 8,918,919 presents an infra-red reflecting covering material.

SUMMARY

Aspects of the invention relate to a thermally insulating substrate product that provides multiple functions including high and controllable thermal insulation, adaptive matching of thermal properties of the fabric with surrounding environment and reducing IR emission from the covered body to achieve energy conservation and adaptive camouflage. Thermal insulation and thermal regulation are provided by nanoporous aerogel particles and phase change material that control thermal conduction, convection, and IR emission in addition to storing heat energy to adapt to the external environmental temperature. The thermally insulating substrate product also includes IR blocking particles that significantly conceal and disperse IR emission. The combination can provide adaptive IR blocking and thermal insulation in a thin, light and flexible form that can be added to existing fabric as coating without adversely impacting the use and function of existing fabrics. In addition, the thermally insulating substrate product can include thicker foams and layers, thus providing insulation as well as spongy cushion and mechanical support for puffy jackets, shoes, or insulation in vehicles and houses. The thermally insulating substrate product can comprise a textile substrate formed from a variety of diameters of yarns

and threads and be integrated in a woven, knitted, braided or unwoven fabric structures for delivery of controllable degree of adaptive IR concealing and thermal insulating and regulating functionality in a variety of apparel forms.

According to one aspect of the invention, there is provided a thermally insulating substrate product comprising: a substrate having at least one layer and comprising metallic particles having an average particle size and density selected to block or reflect infrared radiation and aerogel particles having an average pore size and density selected to control conducted and convected thermal energy. In some embodiments, the substrate can have at least two layers including a first top layer comprising the metallic particles and a second bottom layer comprising the aerogel particles. In some embodiments, the substrate can further comprise at least a third layer comprising a phase change material for absorbing conducted thermal energy. In some embodiments, the first layer can further comprise a phase change material for absorbing conducted thermal energy. The aerogel particles can be selected from a group consisting of softwood kraft lignin, nanocellulose, algae, moss, silica, alumina, titania, zirconia, cadmium sulfide, and iron oxide. The aerogel particle layer can have a density from 0.0001 to 900 g/cm^3 and an average pore size from 1 to 100,000 nm. The phase change material can be polyethylene glycol or encapsulated paraffin. The metallic particles are selected from a group consisting of: Ag, Cu, antimony tin oxide, magnesium oxide, silicon dioxide, zirconium dioxide, indium tin oxide, atimony trioxide, zinc oxide, and antimony zinc. The metallic particles can have a density from 0.1% wt. to 90% wt. and an average particle size from 1 nm to 200 µm.

The first layer can comprise non-woven electrospun nanofibers or wet-spun fibers embedded with the metallic particles. The first layer can have a polymer matrix composed of a biodegradable polymer or co-polymer, wherein the polymer matrix has a composition comprising polyethylene glycol-based polyurethane. The first layer can further comprise at least one colouring dye.

The thermally insulating substrate product can further comprise a top fabric layer attached to a top surface of the substrate, and a bottom fabric layer attached to a bottom surface of the substrate. Alternatively, the product can the comprise a fabric layer in between the first and second layers.

The substrate can comprise fluid flow channels configured to pass fluid such as a gas through the substrate.

The substrate can have a textile layer formed from threads embedded with the metal particles. Further, the substrate can have a textile layer woven from a first set of threads embedded with the metallic particles and a second set of threads embedded with a phase change material. Alternatively, the substrate can have a textile layer woven from a first set of threads embedded with the metallic particles and a second set of threads embedded with the aerogel particles. Alternatively, the substrate can have a textile layer woven from a combination of a first set of threads embedded with metallic particles, a second set of threads embedded with the aerogel particles, and a third set embedded with a phase change material.

The first layer of the substrate can be a first textile layer woven from threads embedded with the metallic particles, and the third layer of the substrate can be a textile layer woven from threads embedded with the phase change material. The first and second set of threads can be functional weft and warp yarns interwoven together orthogonally. The first and second set of threads can have a woven structure selected from a group consisting of: single jersey, in-lay, rib, interlock, and plaited.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1(a) - (d) are schematic sectional side views of a thermally insulating substrate product according to embodiments of the invention, wherein FIG. 1(a) shows a thermally insulating substrate product having a surface layer with no pattern, FIG. 1(b) shows a thermally insulating substrate having a patterned surface layer, FIG. 1(c) shows a thermally insulating substrate attached to an exterior fabric layer having a pattern, and FIG. 1(d) shows a thermally insulating substrate having an integrated fabric layer.

FIGS. 2(a) – (e) are infrared images of a square sample of the thermally insulating substrate product in various applications, wherein FIG. 2(a) shows the square sample held in a hand and located indoors, FIG. 2(b) shows the square sample attached to a military uniform overlaid on an optical image and located indoors, FIGS. 2(c) shows the square sample attached to a military uniform and located indoors, FIG. 2(d) shows the square sample attached to a military

uniform and located outdoors, and FIGS. 2(e) shows the square sample attached to a painted hot metal plate and located indoors.

FIG. 3 is a schematic sectional side view of an insulating cushion comprising the thermally insulating substrate product, according to another embodiment.

FIG. 4 is a schematic sectional side view of thermally insulating materials of the thermally insulating substrate product, including IR blocking particles, aerogel material and phase change material having fiber, foam or particulate structure with controlled breathability.

FIGS. 5(a) to (i) are schematic views and a microscope image of textile embodiments of the thermally insulating substrate product, comprising woven yarn threads in different configurations, wherein FIG. 5(a) shows a single hollow yarn thread, FIG.5(b) is a microscope image of the yarn thread of FIG. 5(b), FIG. 5(c) shows a woven layer of two yarn threads having different thermally insulating properties, FIG. 5(d) shows the textile having two woven layers encapsulating an aerogel-containing layer, wherein the two woven layers comprises a top IR blocking layer and a bottom phase change layer, and FIGS. 5(e) - (l) show different weave or knit configurations of the yarn threads.

FIGS. 6(a) – (i) are schematic diagrams showing the thermally insulating substrate product used in different applications, wherein FIG. 6(a) shows the thermally insulating substrate product used in a helmet, FIG. 6(b) shows the thermally insulating substrate product used in a tent, FIG. 6(c) shows the thermally insulating substrate product used in base layer clothing, FIG. 6(d) shows the thermally insulating substrate product used in a glove, FIG. 6(e) shows the thermally insulating substrate product used on a vehicle structure, FIG. 6(f) shows the thermally insulating substrate product used in a seat structure, FIG. 6(g) shows the thermally insulating substrate product used in a sleeping bag, FIG. 6(h) shows the thermally insulating substrate product used in a jacket, and FIG. 6(i) shows the thermally insulating substrate product used in a sock.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments described herein relate to a thermally insulating substrate product and a method for manufacturing same, suitable for applications to reduce heat loss or exposure to external heat or radiation, regulate body temperature, and/or provide thermal camouflage.

The term “substrate” in this description means a base material on or in which processing is conducted, and includes textiles and films. The term “thermally insulating” in this description means selectively containing or controlling the passage of thermal energy by one or more of IR radiation, thermal convection and thermal conduction.

Embodiments of the thermally insulating substrate product comprise a base material containing metallic (i.e. metal or metal oxide) particles having an average particle size and density selected to reflect and block IR radiation, and a nanoporous aerogel material that have a selected porosity and density to control or block thermally-convected and thermally-conducted energy. “Nanoporous” in this description means a material with either open or closed pores with at least one dimension in nanometer range, and typically between one and a few hundred nm, for example between 1-200 nm. In some embodiments, the thermally insulating substrate product also comprises a phase change material to absorb thermal energy.

In some embodiments, the thermally insulating substrate product is a coating wherein the substrate is a film. The term “film” as used in this description means a thin layer having a non-woven structure. The film substrate can be composed of non-woven electrospun nanofibers or wet-spun fibers. In some other embodiments, the thermally insulating substrate product is a textile wherein the substrate comprises woven threads. The term “textile” as used in this description means a flexible material made by creating an interlocking bundle of yarns or threads. The thermally insulating textile can be produced as a flexible, light and thin fabric for use in external environmental conditions for thermal camouflage as well for thermal insulation, energy conservation and/or thermal regulation. In some embodiments, the thermally insulating textile can be added to an existing fabric without adversely impacting the use and function of the existing fabric. In some other embodiments, the thermally insulating textile can comprise one or more foam layers, to provide thermal insulation as well as a spongy cushion and mechanical support for various clothing products such as puffy jackets and shoes, and for other applications such as vehicles and buildings. The substrate of the thermally insulating textile can be formed

from yarns and threads of varying diameters and be integrated in a woven, knitted, braided or unwoven fabric structures.

Referring now to **FIG. 1(a)** and according to a first embodiment, a thermally insulating substrate product **110** is shown covering a thermally emissive object **100** such as a human or a vehicle in an external environment **101**. The external environment can be hot or cold, day or night, outside or inside, at high or low altitude, different weather conditions including but not limited to rainy, snowy, windy, stormy, in a city, a desert, an icy field, a terrain, or a forest. The thermally insulating substrate product **110** comprises multiple layers including a first layer **111** comprising a nanoporous material containing aerogel particles **120** and pores **121** ("aerogel layer"), a second layer **112** comprising a phase change material **140** ("phase change layer") and a third layer **113** comprising IR blocking particles **130** ("IR blocking layer"). In some embodiments, the phase change layer 112 and IR blocking layer 113 can each comprise a textile base material. In another embodiment, the aerogel layer 111 and IR blocking layer 113 can each comprise a textile base material. The function of this embodiment is not only to block heat loss from body in a cold environment but also serves to block external IR radiation from heating up a body in a hot environment.

The aerogel layer **111** has a light foam or sponge-like structure that can provide exceptional heat insulation. A characteristic feature of aerogels which makes them suitable as efficient thermal insulations is their nanoporosity, wherein pore diameters within the aerogel structure in the nanometer range limit the mean free path of air molecules. Even at ambient air pressure the gaseous thermal conductivity within the aerogel is thus considerably lower than the conductivity of free air. The aerogel layer **111** provides a nanoporous structure that helps in creating low thermal conductance and air pockets for reduced thermal convection. The nanoporous aerogel layer **111** can provide thermally insulating properties while having a very light weight and thin profile. The aerogel material can provide other desired properties such as fire retardation and protection from heat. Some natural sources of the aerogel material are low cost, renewable, sustainable, have a low carbon footprint, and are disposable and recyclable.

The aerogel particles **120** of the aerogel layer **111** provide thermal insulation against conductive and convective heat transfers as well some scattering of IR emissions. Suitable examples of aerogel particles include: organic materials such as softwood kraft lignin, nanocellulose, algae and moss; natural materials such as silica, alumina, titania, zirconia, cadmium sulfide (CdS),

and iron oxide; and carbon allotropes and polymers known in art used to form aerogel. The aerogel layer **111** can be a film made entirely of aerogel particles (not shown) or a foam matrix having embedded aerogel particles **120** and air gaps and bubbles **121** that can form closed pores of open pores. The foam matrix can be formed as an open pore porous structure (e.g. having interconnected bubbles) when it is desired to control thermal convection (rather than block thermal convection altogether); the pores can be nanoscale pores having a selected density and pore size to provide a desired convective heat transfer through the aerogel layer **111**. A suitable density is in the range of 0.0001 to 900 g/cm^3 and a suitable pores size is between 1 and 100,000 nanometers.

In an exemplary embodiment, the aerogel layer **111** is made from softwood kraft lignin by creating a gel which is then freeze-dried to form an aerogel material have highly porous with different pore sizes and structures. The aerogel material can then be made into powder or particles and incorporated in a foam matrix as shown in **Fig. 1(a)**. In another exemplary embodiment, the aerogel particles **120** or films can be made from algae including but not limited to Irish moss, through steps of forming a gel and freeze-drying or any other aerogel formation methods.

The phase change layer **112** comprises a phase change material **140** having an extremely high latent heat due to the phase change process at a specific phase change transition temperature, particularly in the range of 100-200 J/g; as result, the phase change material is highly effective at absorbing and latent release of conducted thermal energy. Suitable example phase change materials include: natural materials such as polyethylene glycol (PEG), and encapsulated paraffin. The phase change material layer **112** can be coated onto the aerogel layer **111** by creating a solution of the phase change materials and spraying on the surface of the aerogel layer **111**. The phase change material can coat the surfaces of the aerogel layer **111** and penetrate onto some of the sub-surfaces, producing an embedded nanocomposite structure. Other deposition methods such as soaking and vacuuming can be used for integration of the phase change material with the aerogel to form an integrated composite. The formation of layers **111** and **112** can be non-continuous and spotty or in form of fibers or textile to achieve breathability as well as insulation.

The IR blocking particles **130** of the IR blocking layer **113** provides thermal insulation by reflecting or scattering IR emissions. Suitable IR blocking particles **130** have the following

optical properties: for metal particles, abundant free electrons and crystal structure leading to a high reflectivity for different parts of IR radiation spectrum; for metal oxide particles, a high band gap, typically in the range of 1.9 to 3.8, a high reflective index, typical value of 1.9, a disordered structure and/or having free electrons (n-type) that make surface plasmonic resonance. Suitable examples of IR blocking particles **130** include metallic (metal and metal oxide) particles that provide strong IR blocking and reflection due to high surface plasmon resonance (SPR) effect, such as Ag, Cu, Al, Au and metal oxides like magnesium oxide (MgO), silicon dioxide (SiO_2), zirconium dioxide (ZrO_2), antimony-tin-oxide (ATO), indium tin oxide (ITO), antimony trioxide (Sb_2O_3), zinc oxide (ZnO) and antimony-zinc (Sb-Zn) or alloys of such metallic particles for increasing IR reflection and durability. The metallic particles can be nanoparticles having an average size range of one to a few hundred nanometers, e.g. 1-1,000 nm or microparticles having an average size range of one to a few hundred micrometers, e.g.1-500 μm.

In some embodiments, the IR blocking layer **113** comprises a thin film nanostructured base layer including non-woven electrospun nanofibers or wet-spun or melt-spun or melt-blown fibers having a composite of polymer and metallic particles as the IR blocking particles **130**. The IR-blocking metallic particles **130** can be embedded in a polymer matrix of nanofibers or wet-spun or melt-blown fibers to provide superior adhesion and binding and can be fabricated from a composite ink in one step. Suitable materials for the polymer matrix include polyurethane, polyethylene glycol or a combination thereof and thermoplastics such as polypropylene. The density of IR blocking metallic nanoparticles **130** can be selected to achieve a desired level of IR blocking as well as a desired visible color of the IR blocking layer **113**. The concentration of IR blocking particles **130** can be in the range of 0.1% wt. to 90% wt. A mixture of different IR blocking particles **130** can be used to achieve desired IR blocking as well as the visible color of the film. The film can be continuous or spotty to achieve breathable construction or desired pattern for IR blocking or visible pattern.

In another embodiment, the polymer matrix of the IR blocking layer **113** can be a biodegradable polymer of co-polymer including but not limited to polyethylene glycol (PEG)-based polyurethane (PU), which improves thermal regulation and insulation due to phase change material properties of PEG and keeps the ATO layer bound, integrated and stable. In yet another embodiment, the IR blocking layer **113** can have an electro-spun polymer base layer containing metallic IR blocking particles **130** with a rough surface with topographic features in the range of nano or micrometer, which contributes to IR scattering and reflection. For example,

the IR blocking layer has a rough surface due to fiber structures as well as polymer (PU) and ATO or metallic nanoparticles.

In another embodiment (not shown), the thermally insulating substrate product **110** can comprise a single layer comprising both phase change material and IR blocking particles **130**.

Referring now to **Fig. 1(b)** and according to a second embodiment, the thermally insulating substrate product **110** has a IR blocking layer **113** comprising a mixture of IR blocking particles **130** and coloring dyes **131** and **132** having distinct visible colors (for example, dark green or brown, …) to create a desired visual print on the top surface of the thermally insulating textile **110**. This can be used for achieving both visual and IR camouflage in the same fabric.

Referring to **Fig. 1(c)** and according to a third embodiment, the thermally insulating substrate product **110** comprises a conventional protective fabric **102** covering the outside of the IR blocking layer **113**, and can be used in a jacket for consumer or military uses or in a tent or vehicle covering. The protective fabric **102** can have a specific visual print, for example a camouflage print that is achieved by printing dyes in regions **131** and **132**. The external environment can be hot or cold, day or night, outside or inside, at high or low altitude, different weather conditions including but not limited to rainy, snowy, windy, stormy, in a city, a desert, an icy field, a terrain, or a forest. The protective fabric **102** can be used in applications including but not limited to: nylon/cotton ripstop military uniform fabric with camouflage prints or internal or external jacket layers, base layers, gloves, sleeves, tights, shorts or socks or other clothing fabric and layers. In this embodiment, the thermally insulating textile **110** is coated on the back of the protective fabric **102** which helps in maintaining the visible external appearance, design and prints of the fabric including visible camouflage patterns and other design prints. This embodiment of the thermally insulating textile **110** is particularly intended for heat storage, thermal insulation and temperature regulation with the temperature of the surrounding environment, and shielding and concealing of heat and IR emission from body, thus providing an adaptive camouflage and insulation. The embodiment can also block exposure to external IR radiation and heating from sun or other heating sources thus keeping the body, house or other objects cool.

Referring to **Fig. 1(d)** and according to a fourth embodiment, the thermally insulating substrate product **110** comprises a conventional protective fabric **102** placed between the IR blocking

layer **113** and the aerogel layer **111.** In this case, the IR blocking layer **113** has a composition selected to have desired visual colors by controlling the density of IR blocking nanoparticles or embedding coloring dyes. The visual coloring pattern can be designed to include any design or desired visual and IR camouflage.

Referring to **Figs. 2(a) – (e)**, a square sample of the thermally insulating substrate product **110** was imaged using an IR camera against a number of surfaces, including a hand (**Fig. 2(a)**). The resulting thermal image indicates that the thermally insulating substrate product **110** provides ~9°C drop to match and hide the emission of the hand (35.8°C) located in an indoor environment at 26.5°C. As shown in **Fig. 2(b)**, the square sample of the thermally insulating substrate product **110** was attached to a military uniform and reduced the thermal emission from the body (30.2°C) located in an indoor environment at 20.3°C. In this image, the optical image overlay shows the visual camouflage pattern of a conventional military fabric. In **Fig. 2(c)**, the square sample of the thermally insulating substrate product **110** was attached to a military uniform located in an indoor environment at 22°C. In **Fig. 2(d)**, the square sample of the thermally insulating substrate product **110** was attached to a military uniform worn on a body (29.8°C) and in an outdoor environment at 8°C; this demonstrates a ~21°C temperature drop and generally matching the environment temperature. In **Fig. 2(e)**, the square sample of the thermally insulating substrate product **110** is shown on a hot colored metallic plate (51.7°C), reducing the measured temperature to 28°C and matching to an external indoors environment.

Referring now to **Fig. 3** and according to a fifth embodiment, a thermally insulating substrate product **210** comprises multiple layers including an aerogel layer **211**, a phase change layer **212,** an IR blocking layer **213**, a first conventional protective external fabric **202** covering the outside of the IR blocking layer **213** and a second conventional protective inner fabric **203** covering the outside of the phase change layer **212**. This embodiment can be used as a jacket, a covering, a underlayer for consumer or military uniform or tent or accessories or shoes or vehicle covering, which covers an emissive body **200** that can be a human or a vehicle in an external environment **201**. The external environment can be hot or cold, day or night, outside or inside, at high or low altitude, different weather conditions including but not limited to rainy, snowy, windy, stormy, in a city, a desert, an icy field, a terrain, or a forest. The protective external fabric **202** can used in applications including but not limited to: ripstop military uniform fabric with camouflage prints external jacket layers, shoe or boot external layer or covering, backpack covering, sleeping bag or mat covering, sleeves, tights, shorts or socks or other

clothing fabric and layers. The protective internal fabric **203** can be the internal layer of a military uniform fabric, jacket layer, shoe or boot internal layer or covering, backpack covering, sleeping bag or mat covering, sleeves, tights, shorts or socks or other clothing fabric and layers. In another embodiment, the thermally insulating substrate product **210** can be used as internal insulation and IR blocking layer for any object or structure including but not limited to cars, shoes, houses rooms, doors or accessories.

In this embodiment, the aerogel layer **211**, phase change layer **212,** and IR blocking layer **213** are placed and encapsulated between the external **202** and internal **203** fabric layers and serve to provide conductive and convective thermal insulation and blocking of IR radiation for the purpose of heat preservation or IR concealing. These layers can be sewn together. In addition, the thermally insulating textile **210** has a highly porous structure, which provides a lightweight, "fluffy or puffy" structure that is highly compressible. More particularly, the aerogel layer **211** is configured to have a higher porosity and thickness than other embodiments to provide the desired structure. Additionally or alternatively, the aerogel layer **211** can be embedded with elastic and springy yarns to provide the desired structure. The thermally insulating textile **210** is particularly intended for heat storage, insulation and regulation with the temperature of surrounding environment, and shielding and concealing of heat and IR emission from body, thus providing an adaptive camouflage and insulation, mechanical cushioning, and a soft and compressible feel.

The IR blocking layer **213** can have the same or similar composition and structure as the IR blocking layer **113** of the first to fourth embodiments. The aerogel layer **211** can have the same or similar composition and structure as the aerogel layer **111** of the first to fourth embodiments. The IR blocking layer **213** can have the same or similar composition and structure as the IR blocking layer **113** of the first to fourth embodiments.

Referring to **Fig. 4** and according to a sixth embodiment, a thermally insulating substrate product **310** comprises multiple film layers including a nanoporous aerogel containing layer **311**, a phase change layer **312** and an IR blocking layer **313**. The thermally insulating substrate product **310** covers an emissive body **300** that can be a human or a vehicle or an object located in an external environment **301**. The external environment can be hot or cold, day or night, outside or inside, at high or low altitude, different weather conditions including but not limited to rainy, snowy, windy, stormy, in a city, a desert, an icy field, a terrain, or a forest.

In comparison to the embodiment shown in **Fig. 1(a)**, each of the film layers **311**, **312**, and **313** are comprised of micro-structured and nano-structured particles, nanofibers, microfiber of the desired materials that form a porous packed layer with channels **360** that allows fluid flow (e.g. air, humidity and sweat) to pass through. These film layers **311, 312, 313** can be deposited from inks containing the desired particles of each layer using a 3D printer or roll-to-roll printer, screen printing or lamination processes. These film layers **311, 312, 313** can be electrospun and be in form of non-woven nanofibers whose approximate cross-section are displayed in **Fig. 4**. The IR blocking layer **313** can be configured to block all IR emission despite being highly porous structure by layering the IR blocking particles **330**. Binding fibers or mesh **350** are used in the different layers **311, 312, 313** to hold the particles or nanofibers securely together while maintaining a high porosity. The IR blocking particles **330** and coloring dye particles **331** are used in IR blocking layer **313** to provide IR blocking as well as visible print or camouflage. The aerogel layer **311** is made from particles that contain aerogel particles **320** and air gaps and bubbles **321** like in the other embodiments but additionally with channels **360** that allow fluid flow. The phase change layer **312** comprises a phase change material **340** like in the other embodiments but additionally with channels **360** that allow fluid flow.

Referring now to **Figs. 5(a)-(i)** and according to a seventh embodiment, the thermally insulating substrate product **410** comprises one or more textile layers containing thermally insulating materials. The different textile layers are each formed by spinning the material in form of a solid or hollow yarn whose shell contains the desired nanoparticles. For instance, as shown in **Fig. 5(a)**, a IR blocking layer **413** can be spun from a thin hollow fiber whose shell contain the desired IR blocking nanoparticles **430** such as ATO, Cu, Ag or other IR blocking materials ("IR blocking yarn"). This can be done by wet-spinning, electrospinning or other fiber spinning methods that are used for fabrication of fibers from a source material. The electrospun materials can be in the form of web, having a microstructure made of entangled nanofibers. **Fig. 5(b)** shows an optical microscope image of a hollow Cu-PET fibers wet-spun with a diameter of 100 micrometers. Similarly, a phase change layer **412** can be spun from a fiber incorporating a phase change material ("phase change yarn"). Similarly, an aerogel layer can be spun from a fiber incorporating aerogel particles ("aerogel yarn", not shown). **Fig. 5(c)** illustrates an embodiment comprising a thermally insulating substrate product **410** comprising a single textile base layer comprising interwoven phase change yarn **412** and IR blocking yarn **413** or aerogel yarn. The thermally insulating substrate product **410** provides both thermal convection and conduction insulation and

regulation and IR insulation and concealing due to the presence of both IR blocking and phase change yarns **412, 413** in a woven structure. **Fig. 5(d)** demonstrates another embodiment of the thermally insulating substrate product **410**, comprising two textile layers **412, 413** encapsulating an aerogel layer **411**. The phase change layer **412** comprises a woven fabric of phase change yarns and the IR blocking layer **413** comprises a woven fabric of IR blocking yarns. The aerogel layer **411** comprises a highly particulate or fiber structure of aerogel foam.

Referring to **Fig. 5(e)** to **5(k)**, the textile layers **412, 413** can have functional weft and warp yarns interwoven together orthogonally. The woven structures can be in the form of double cloth or triple cloths with different variations of the principal structural types. The double cloths include self-stitched double cloths, center-stitched double cloths, thread-interchange double cloths (**Fig. 5(h)**), and cloth-interchange double cloths. The double cloths can contain two series of threads/yarns in both warp and weft directions to interweave orthogonally to form separate face and back fabric layers. The separate face and back layers can be the IR blocking yarn **413** and the phase change yarn **412** or aerogel yarn. Interconnection/stitching of each two separate layers can be accomplished by occasionally dropping a face warp under a back weft **417** (**Fig. 5(e)**) or lifting a back warp above the face weft **416** (**Fig. 5(f)**) or by utilizing both methods simultaneously (**Fig. 5(g)**) in the cloth with variable proportions. **Fig. 5(e) and 5(g)** shows the textile woven structures formed by lifting the back layer (**412**) warp **415** above **418** the face layer (**413**) weft **416**. This is based on the design but not limited to 2/2 (two up and two down) twill weave with variable step or move numbers (**Fig. 5(j)**). The fabric structure can be a knitted fabric having phase change yarns **412** and IR blocking yarns **413** at different stitch densities for achieving desired insulation and IR blocking properties. A knitted fabric system may be but not limited to the structures including single jersey, in-lay (**Fig. 5(k)**), rib, interlock, and plaited structure. An embodiment depicted in the **Fig. 5(h)** can include knitted fabric but not limited to the functional low surface emissivity yarns and IR blocking yarns. Low surface emissivity yarns can be but not limited to nylon, polyester or any other synthetic filaments with or without texturing. These yarns may include dopants including but not limited to copper, silver, or any other low emissive particles. The IR blocking yarns may include but not limited to ATO, Cu, Ag, Al, Au reinforced with polymeric materials. All the aforementioned functional yarn systems (**412**, **413** or aerogel yarns) may be fabricated by but not limited to wet spinning, dry spinning, melt spinning, or any other fibre forming methods. The cross-section of these filaments can include but not limited to hollow, solid or any other type of geometry. The hollow filament systems may include any type of phase change materials but not limited only

to this. The fabric structure can be complex three-dimensional braiding and jacquard braiding to achieve desired fabric structure, form and desired heat and IR insulation for a variety of applications including clothing, military accessories, structural components, biomedical applications, implanted components.

The phase change yarns **412** and IR blocking yarns **413** can be incorporated in the compositions of the conventional protective external and internal fabrics such as **102** and **202** and **203** as described above. The integration technique could include fabric production methods such as weaving, knitting, braiding or embroidery.

In another embodiment as shown in **Figs. 6(a) – (i)**, the thermally insulating substrate product **510** comprises the aerogel layer **511**, the phase change layer **512** and IR blocking layer **513,** and can be coated on the surface of or attached to objects having various surface finishes including but not limited to: metal, wood, and concrete. The aerogel layer **511** has a controllable porosity and thickness to provide the desired thickness, for this embodiment of the invention. The aerogel layer **511** can be embedded with elastic and springy yarns or embedded composition to provide springy mechanical feel and support for weight. The aerogel layer **511** can be embedded with a phase change layer **512** to add extreme thermal capacity to absorb heat and regulate temperature by virtue of its latent heat of the material used. The IR blocking layer **513** comprises IR blocking particles with very low IR emissivity, strong IR reflection and scattering.

The object **500** as shown in **Fig. 6(a)** can be a helmet, a military helmet, a hat or any other protective head gear, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(b)** can be a tent, a house (embedded insulation in the walls or subsurfaces), a room, a roof, an awning, a window screen, curtain or shutter, an umbrella or any other temporary or permanent structure or covering, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(c)** can be a uniform including pants, a shirt, a jacket, an undershirt, underpants, shoes, boots, sandals, space suite, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(d)** can be gloves, protective gloves, gaming gloves, surgical gloves, rehabilitation gloves, work gloves, ski gloves, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in

Fig. 6(e) can be a vehicle, a truck, a motorcycle, a tank, a bus, a helicopter, an airplane, an unmanned aerial vehicle (UAV), a drone, an unmanned ground vehicle (UGV), an electric vehicle, an electric truck, an electric bus, a ship, a boat, space shuttle, satellite or any other ground, air, sea and space vehicles, having a visible insulation and camouflage suited for their environment, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(f)** can be a chair, a seat, a child seat, a camping chair, a lounge chair, an inflatable chair or any other seating or lounging chair, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(g)** can be a sleeping bag, a compactable sleeping bag, an insulation mat, a rug, a spacer, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(h)** can be a jacket, a jacket with hat, a fluffy jacket, a compactable jacket, a pillow, a blanket, a mattress, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**. The object **500** as shown in **Fig. 6(i)** can be socks, stockings, compression stockings, compression socks, sleeves, shoe insoles, having a visible camouflage, or another pattern, print or no pattern, which is in an external environment **501**.

The thermally insulating substrate product **510** is specifically designed for heat storage, insulation and regulation with the temperature of surrounding environment, and shielding and concealing of heat and IR emission from body, thus providing an adaptive camouflage and insulation, and mechanical cushion, soft and compressible feel for the fabric. The thermally insulating substrate product **510** is intended to provide superior thermal conductive and convective insulation, and IR radiation blocking for the purpose of heat preservation or IR concealing. The external environment can be hot or cold, day or night, outside or inside, at high or low altitude, different weather conditions including but not limited to rainy, snowy, windy, stormy, in a city, a desert, an icy field, a terrain, or a forest.

Interpretation of Terms

Unless the context clearly requires otherwise, throughout the description and the claims:

- “comprise”, “comprising”, and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”;

- "linked", "connected", "coupled", or any variant thereof, means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can be physical, logical, or a combination thereof;
- "herein", "above", "below", and words of similar import, when used to describe this specification, shall refer to this specification as a whole, and not to any particular portions of this specification;
- "or", in reference to a list of two or more items, covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list;
- the singular forms "a", "an", and "the" also include the meaning of any appropriate plural forms.

Words that indicate directions such as "vertical", "transverse", "horizontal", "upward", "downward", "forward", "backward", "inward", "outward", "vertical", "transverse", "left", "right", "front", "back", "top", "bottom", "below", "above", "under", and the like, used in this description and any accompanying claims (where present), depend on the specific orientation of the apparatus described and illustrated. The subject matter described herein may assume various alternative orientations. Accordingly, these directional terms are not strictly defined and should not be interpreted narrowly.

Where a component (e.g. a substrate, assembly, device, manifold, etc.) is referred to above, unless otherwise indicated, reference to that component (including a reference to a "means") should be interpreted as including as equivalents of that component any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments described herein.

Specific examples of systems, methods, and apparatus have been described herein for purposes of illustration. These are only examples. The technology provided herein can be applied to systems other than the example systems described above. Many alterations, modifications, additions, omissions, and permutations are possible within the practice of this disclosure. This disclosure includes variations on described embodiments that would be apparent to the skilled addressee, including variations obtained by: replacing features, elements and/or acts with equivalent features, elements and/or acts; mixing and matching of features,

elements and/or acts from different embodiments; combining features, elements and/or acts from embodiments as described herein with features, elements and/or acts of other technology; and/or omitting combining features, elements and/or acts from described embodiments.

While particular elements, embodiments and applications of the present disclosure have been shown and described, it will be understood, that the disclosure is not limited thereto since modifications can be made by those skilled in the art without departing from the scope of the present disclosure, particularly in light of the foregoing teachings. It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions, omissions, and sub-combinations as may reasonably be inferred. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

CLAIMS

1. A thermally insulating substrate product comprising:

a substrate having at least one layer and comprising metallic particles having an average particle size and density selected to block or reflect infrared radiation and aerogel particles having an average pore size selected to control conducted and convected thermal energy.

2. The thermally insulating substrate product as claimed in claim 1 wherein the substrate has at least two layers including a first top layer comprising the metallic particles and a second bottom layer comprising the aerogel particles.

3. The thermally insulating substrate product as claimed in claim 2, wherein the substrate further comprises at least a third layer comprising a phase change material for absorbing conducted thermal energy.

4. The thermally insulating substrate product as claimed in claim 2 wherein the first layer further comprises a phase change material for absorbing conducted thermal energy.

5. The thermally insulating substrate product as claimed in any one of claims 1 to 4, wherein the aerogel particles are selected from a group consisting of: softwood kraft lignin, nanocellulose, algae, moss, silica, alumina, titania, zirconia, cadmium sulfide, and iron oxide.

6. The thermally insulating substrate product as claimed in any one of claims 1 to 4, wherein the metallic particles are selected from a group consisting of: Ag, Cu, Al, Au, antimony tin oxide, magnesium oxide, silicon dioxide, zirconium dioxide, indium tin oxide, atimony trioxide, zinc oxide, and antimony zinc.

7. The thermally insulating substrate product as claimed in any one of claims 1 to 4, wherein the phase change material is polyethylene glycol or encapsulated paraffin.

8. The thermally insulating substrate product as claimed in any one of claims 2 to 4 wherein the first layer comprises non-woven electrospun nanofibers or wet-spun fibers embedded with the metallic particles.

9. The thermally insulating substrate product as claimed in claim 8 wherein the first layer is a polymer matrix composed of a biodegradable polymer or co-polymer.

10. The thermally insulating substrate product as claimed in claim 9 wherein the polymer matrix has a composition comprising polyethylene glycol-based polyurethane.

11. The thermally insulating substrate product as claimed in any one of claims 1 to 4 wherein the metallic particles have a density from 0.1% wt. to 90% wt. and an average particle size from 1 nm to 200 µm.

12. The thermally insulating substrate product as claimed in any one of claims 1 to 4 wherein the aerogel particles have a density from 0.0001 to 900 g/cm^3 and an average pore size from 1 to 100,000 nm.

13. The thermally insulating substrate product as claimed in any one of claims 2 to 4 wherein the first top layer further comprises at least one colouring dye.

14. The thermally insulating substrate product as claimed in any one of claims 1 to 4 further comprising a top fabric layer attached to a top surface of the substrate.

15. The thermally insulating substrate product as claimed in any one of claims 2 to 4 wherein the substrate comprises a fabric layer in between the first top and second bottom layers.

16. The thermally insulating substrate product as claimed in claim 14 further comprising a bottom fabric layer attached to a bottom surface of the substrate.

17. The thermally insulating substrate product as claimed in any one of claims 1 to 4 wherein the substrate comprises fluid flow channels configured to pass fluid through the substrate.

18. The thermally insulating substrate product as claimed in any one of claims 1 to 4 wherein the substrate has a textile layer formed from threads embedded with the metal particles.

19. The thermally insulating substrate product as claimed in claim 1 wherein the substrate has a textile layer woven from a first set of threads embedded with the metallic particles and a second set of threads embedded with a phase change material.

20. The thermally insulating substrate product as claimed in claim 1 wherein the substrate has a textile layer woven from a first set of threads embedded with the metallic particles and a second set of threads embedded with the aerogel particles.

21. The thermally insulating substrate product as claimed in claim 3 wherein the first top layer of the substrate is a first textile layer woven from threads embedded with the metallic particles, and the third layer of the substrate is a textile layer woven from threads embedded with the phase change material.

22. The thermally insulating substrate product as claimed in claim 21 wherein the first and second set of threads are functional weft and warp yarns interwoven together orthogonally.

23. The thermally insulating substrate product as claimed in claim 22 wherein the first and second set of threads have a woven structure selected from a group consisting of: single jersey, in-lay, rib, interlock, and plaited.

24. A thermally insulating and breathable textile product comprising:

at least one textile layer comprising a first set of yarns comprising metallic particles having a density and average particle size selected to block or reflect infrared radiation, and a second set of yarns comprising aerogel particles having a density and average pore size selected to control conducted and convected thermal energy; and

wherein the at least one textile layer has a porous weave to pass fluid including air and water vapour.

25. The textile product as claimed in claim 24 wherein at least some of the yarns are hollow yarns.

26. The textile product as claimed in claims 24 or 25 further comprising a third set of yarns comprising a phase change material for absorbing conducted thermal energy.

27. The textile product as claimed in any one of claims 24 to 26, wherein the density and average particle size of the metallic particles are selected such that the IR emission through the at least one textile layer is in the range of IR emissions of an external environment, thereby providing IR camouflage.

28. The textile product as claimed in any one of claims 24 to 27, wherein the density and average pore size of the aerogel particles are selected such that the temperature of an outer surface of the at least one textile layer is in the range of temperature of an external environment, thereby providing thermal camouflage.

29. The textile product as claimed in any one of claims 24 to 29, wherein at least some of the yarns comprise a colouring dye, thereby providing optical camouflage.

30. A thermally insulating, breathable and camouflaging substrate product, comprising:

(a) a first top layer comprising metallic particles having a selected density and particle size to block or reflect IR radiation thereby providing thermal insulation and IR camouflage;

(b) a second central layer comprising aerogel particles having a selected density and pore size to control conducted and convected thermal energy thereby providing thermal insulation and thermal camouflage; and

(c) a third bottom layer comprising a phase change material for absorbing conducted thermal energy thereby providing thermal insulation and thermal camouflage;

wherein the three layers have a selected porosity to pass fluid including air and water vapour, thereby providing breathability.

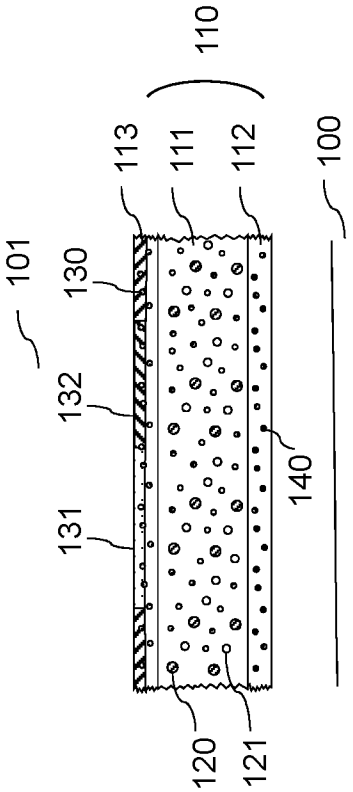


FIG. 1(a)

FIG. 1(b)

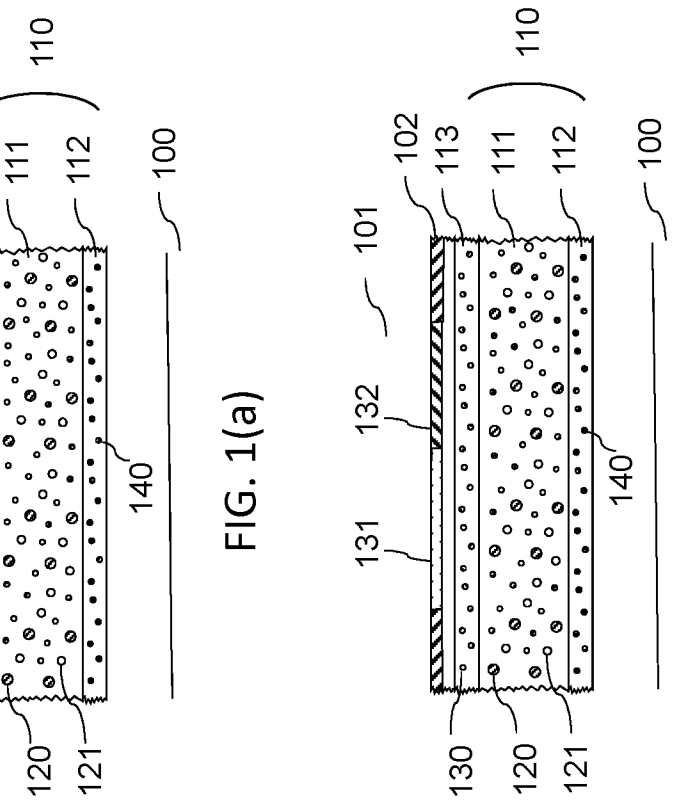


FIG. 1(c)

FIG. 1(d)

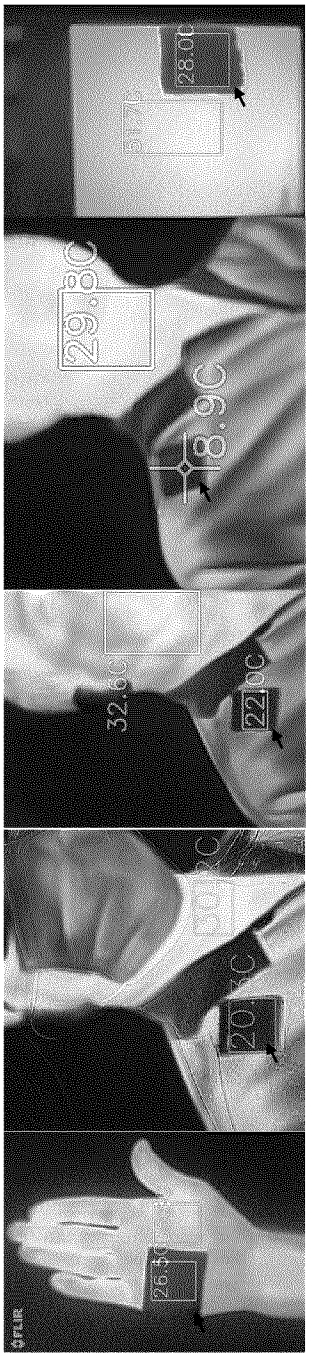


FIG. 2(a) FIG. 2(b) FIG. 2(c) FIG. 2(d) FIG. 2(e)

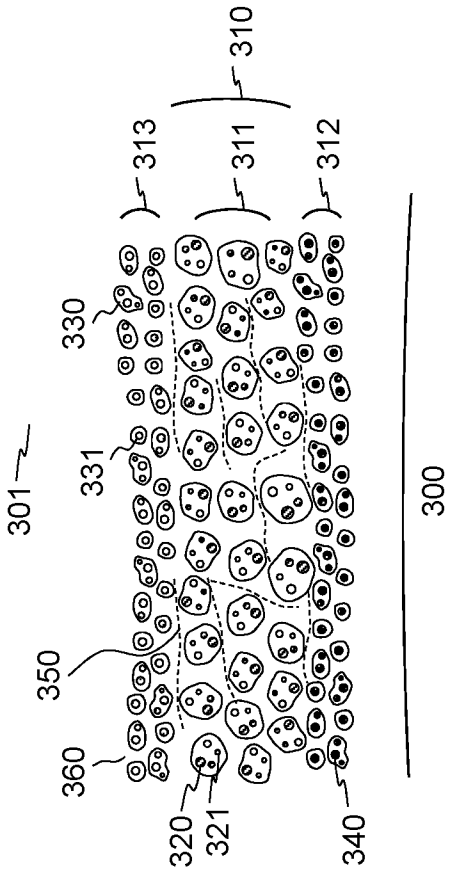

310
313
311
312
330
301
331
300
350
360
320
321
340

FIG. 4

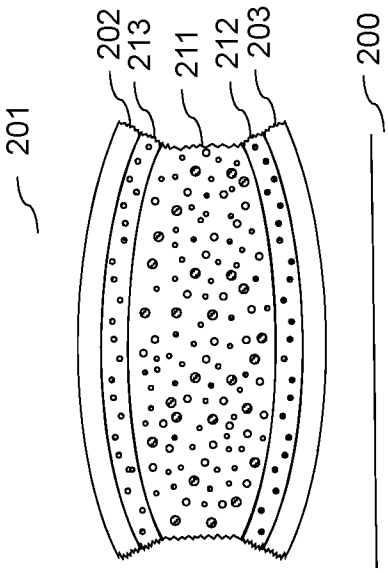

202
213
211
212
203
200
201

FIG. 3

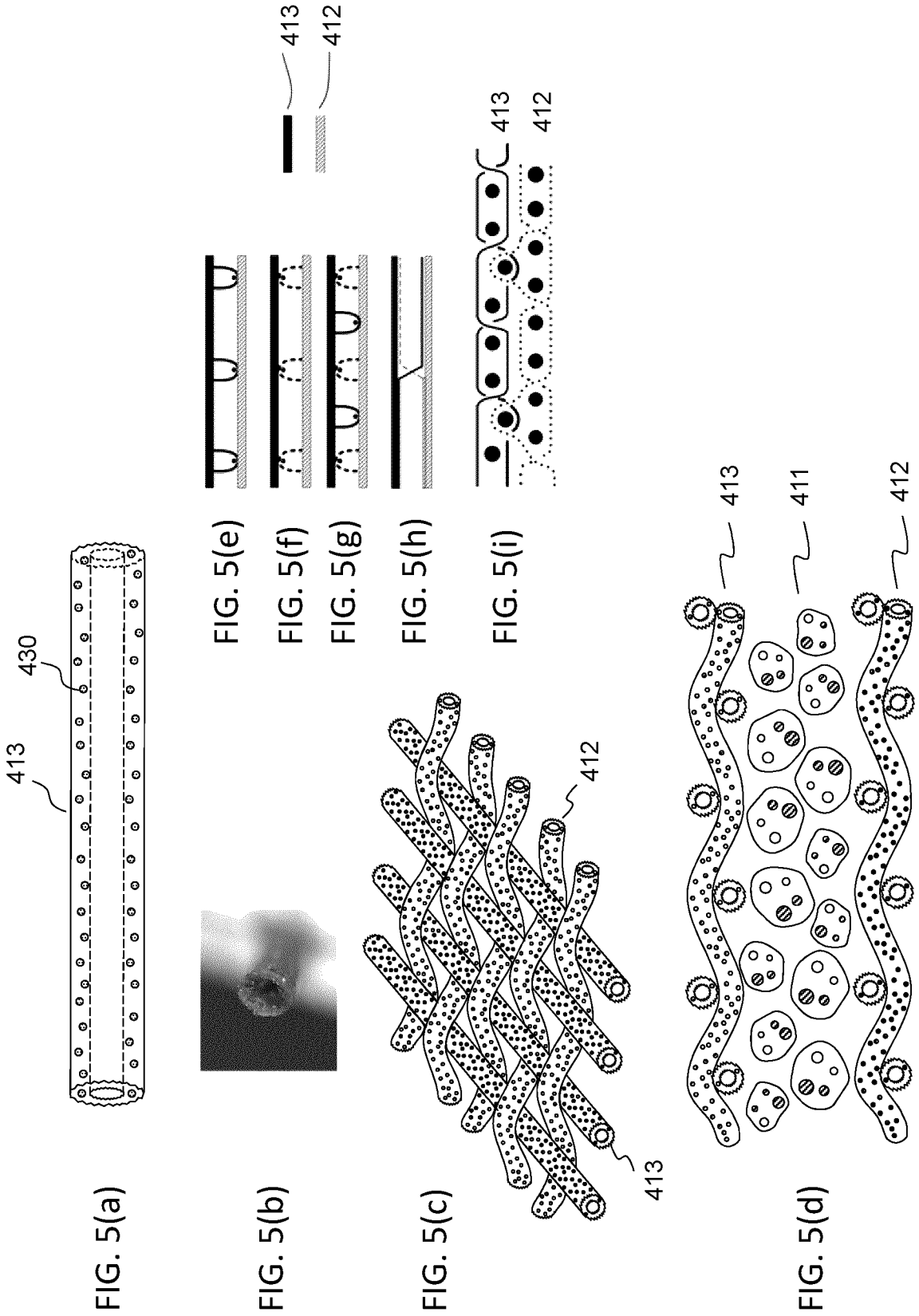


FIG. 5(a) FIG. 5(b) FIG. 5(c) FIG. 5(d) FIG. 5(e) FIG. 5(f) FIG. 5(g) FIG. 5(h) FIG. 5(i)

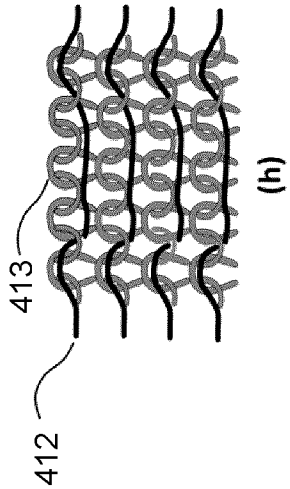


FIG. 5(l)

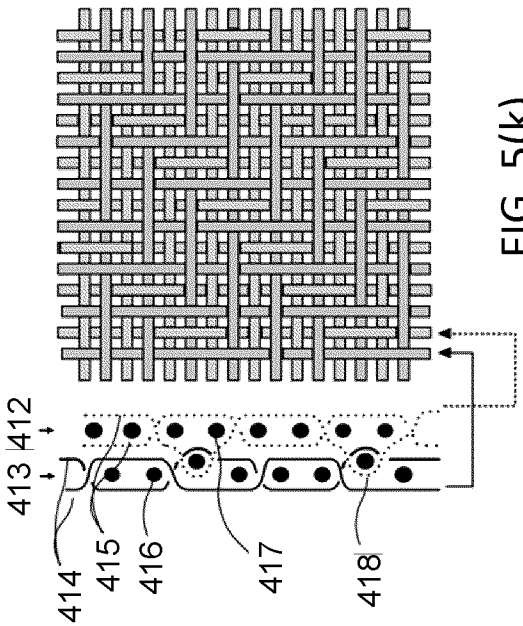


FIG. 5(k)

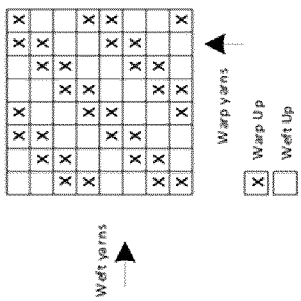


FIG. 5(j)

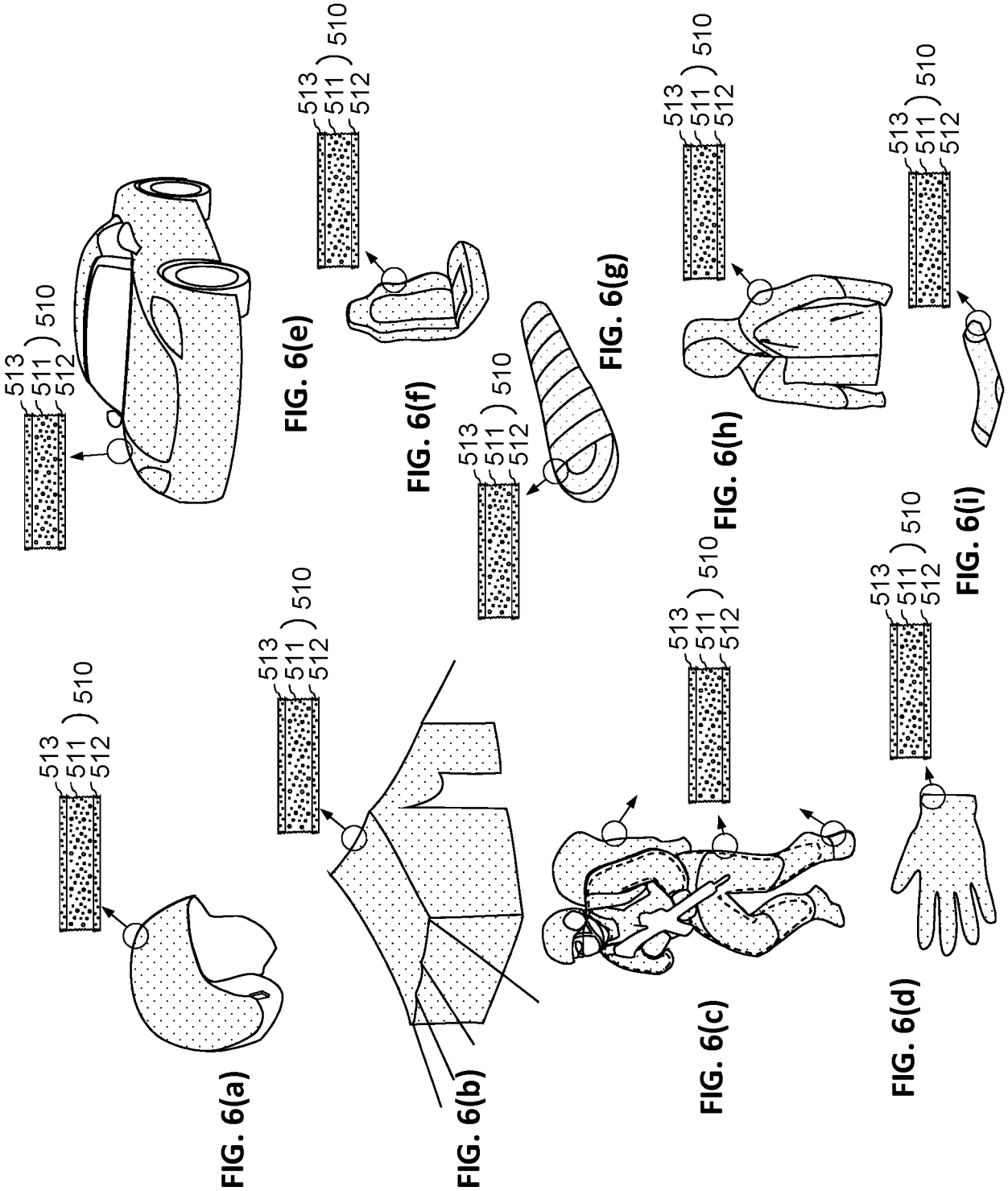


FIG. 6(a) FIG. 6(b) FIG. 6(c) FIG. 6(d) FIG. 6(e) FIG. 6(f) FIG. 6(g) FIG. 6(h) FIG. 6(i)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2021/051834

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***F16L 59/02*** (2006.01) , ***B32B 5/30*** (2006.01) , ***B32B 7/027*** (2019.01) , ***B32B 15/02*** (2006.01) , ***B32B 15/16*** (2006.01) , ***F41H 3/02*** (2006.01)

CPC: **F16L 59/029** (2020.01) , B32B 5/30 (2020.01) , B32B 7/027 (2020.01) , B32B 15/16 (2020.01) , F41H 3/02 (2020.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
CCB / CPC: F16L-059/02, F16L-059/029, B32B-015/02, B32B-015/16, B32B-005/30, B32B-007/027, F41H-003/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Google patents: Camouflage and Aerogel and infrared

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Questel Orbit (fampat); Keywords: metal+, aerogel, (thermal+ heat) , (IR or infrared or signature), yarn, (pore or porosity), Camouflage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US8340358 CINCOTTI et al. 25 December 2012 (2012-12-25) *whole document* 19-20, 24-29	1-2, 5-6, 11-13 3-4, 7-10, 14-18, 21-23, 30
Y	US9668530 MILLER et al. 06 June 2017 (2017-06-06) *whole document*	3, 14-17, 30
Y	CN106120010 LUO et al. 16 November 2016 (2016-11-16) *whole document*	4, 8-10, 18, 21
Y	CN108504006B ZHANG et al. 23 June 2020 (2020-06-23) *whole document*	7

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"D"	document cited by the applicant in the international application
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search 21 March 2022 (21-03-2022)	Date of mailing of the international search report 21 March 2022 (21-03-2022)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Jarret Diggins (819) 639-7846

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR10-2113292 KIM 20 May 2020 (2020-05-20) *whole document*	22-23
A	CN111962296 WANG et al. 20 November 2020 (2020-11-20) *whole document*	1-30
A	CN110820102 XIAO 21 February 2020 (2020-02-21) *whole document*	1-30
A	CN109927386 A DUAN 25 June 2019 (2019-06-25) *whole document*	1-30
A	EP3283576 MAIER et al. 12 June 2019 (2019-06-12) *whole document*	1-30
A	US10000618 ATTIA 19 June 2018 (2018-06-19) *whole document*	1-30

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2021/051834

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US8340358B2	25 December 2012 (25-12-2012)	US2010112316A1	06 May 2010 (06-05-2010)
		CA2699339A1	30 April 2009 (30-04-2009)
		US2018094905A1	05 April 2018 (05-04-2018)
		US11060821B2	13 July 2021 (13-07-2021)
		US2009154777A1	18 June 2009 (18-06-2009)
		US2009252913A1	08 October 2009 (08-10-2009)
		US2010031423A1	11 February 2010 (11-02-2010)
		US2011151191A1	23 June 2011 (23-06-2011)
		US2011272088A1	10 November 2011 (10-11-2011)
		US2021341259A1	04 November 2021 (04-11-2021)
		WO2009054872A2	30 April 2009 (30-04-2009)
		WO2009054872A3	18 March 2010 (18-03-2010)
		WO2009124117A1	08 October 2009 (08-10-2009)
		WO2011063249A1	26 May 2011 (26-05-2011)
		WO2011140498A1	10 November 2011 (10-11-2011)
US9668530B2	06 June 2017 (06-06-2017)	US2015366281A1	24 December 2015 (24-12-2015)
		CL2015002144A1	11 November 2016 (11-11-2016)
		WO2014120867A1	07 August 2014 (07-08-2014)
CN106120010A	16 November 2016 (16-11-2016)	None	
CN108504006A	07 September 2018 (07-09-2018)	CN108504006B	23 June 2020 (23-06-2020)
KR102113292B1	20 May 2020 (20-05-2020)	None	
CN111962296A	20 November 2020 (20-11-2020)	None	
CN110820102A	21 February 2020 (21-02-2020)	None	
CN109927386A	25 June 2019 (25-06-2019)	CN109927386B	05 November 2021 (05-11-2021)
EP3283576A1	21 February 2018 (21-02-2018)	EP3283576B1	12 June 2019 (12-06-2019)
		DE102015105831A1	20 October 2016 (20-10-2016)
		WO2016166074A1	20 October 2016 (20-10-2016)
US10000618B2	19 June 2018 (19-06-2018)	US2017073491A1	16 March 2017 (16-03-2017)
		US9034934B1	19 May 2015 (19-05-2015)
		US2015247016A1	03 September 2015 (03-09-2015)
		US9512286B2	06 December 2016 (06-12-2016)
		US2015259499A1	17 September 2015 (17-09-2015)
		US9540495B2	10 January 2017 (10-01-2017)