

Description

Title of Invention: MULTI- FUNCTIONAL TRILAMINAR FABRIC

Technical Field

- [0001] The present invention describes a multi-functional trilaminar fabric simultaneously comprising Waterproof, Hydrophobic and Anti-Microbial / Anti-Viral characteristics.

Background Art

- [0002] The COVID-19 Pandemic has brought microbiological environmental safety to the forefront of healthcare concerns. Currently available solutions to guarantee microbiological protection of multi-functional fabrics, as in the case of bed environments, have proven to be ineffective, particularly in antibacterial bed-linens, that fail to provide adequate protection to the multitude of infectious biological agents usually present in the bed environment, such as viruses and fungi, as well as guarantee that any biofilms and contaminants (biological material, such as urine, sweat and other fluids and non-biological material, such as water, coffee, etc), that can become microbiological breeding grounds, are easily managed by avoiding the absorption by the bed linen, mattress or pillow.
- [0003] Often, available solutions are bactericidal using methods that promote the creation of multi-resistant bacteria, posing significant dangers to the health of the individual and society at large. Also, prior-art solutions are often based on materials that show reduced biocompatibility and are thus unfit for continued contact with human body tissues.
- [0004] Finally, some of the existing solutions also have issues providing adequate gaseous exchanges, not being breathable, which is both uncomfortable and may provide an additional environmental factor for microbiological proliferation. The same issue arises in textile formulations currently used for clothing.

Summary of Invention

- [0005] The present invention solves the problems of the prior-art by providing a Multi-functional trilaminar fabric characterized in that the fabric comprises a substrate layer, superficial mesh and a waterproof membrane, wherein the superficial mesh comprises an antibacterial / antiviral composition and a hydrophobic composition crosslinked to a crosslinking composition, that guarantees that the antibacterial / antiviral and hydrophobic features are not removed from the fabric when the it is washed.
- [0006] In one embodiment of the invention, the crosslinking composition is selected from an isocyanate or a poly-isocyanate.

- [0007] In a preferred embodiment, the multi-functional trilaminar fabric of the invention comprises a substrate layer made of a material selected from a group comprising cotton, polyester, microfiber, bamboo, lyocell, cotton, polyester, microfiber, bamboo, lyocell, or a mixture thereof.
- [0008] In a preferred embodiment of the invention, the multi-functional trilaminar fabric of the invention comprises a waterproof membrane made of a material selected from the group of polyurethane, polyethylene, polypropylene, or other technically suitable.
- [0009] In a preferred embodiment of the invention, the multi-functional trilaminar fabric of the invention comprises an antibacterial / antiviral composition comprising an inorganic salt selected from the group composed of silver ions, copper ions, zinc oxide nanoparticles, or other technically suitable antimicrobial agents.
- [0010] In a preferred embodiment of the invention, the hydrophobic composition comprises a hydrophobic compound selected from the group composed of fluoropolymers, silicones, or other technically suitable hydrophobic agents.
- [0011] In another embodiment of the invention, the multi-functional trilaminar fabric is suitable for using as bed sheets, bed covers, duvet covers, pillow covers, medical gowns and curtains.
- [0012] In another embodiment of the invention, the multi-functional trilaminar fabric is suitable for use in hospitals, clinics, hotels, medical environments, bedridden patients or hospitality industry.
- [0013] The present invention also relates to a method of manufacturing a multi-functional trilaminar fabric as disclosed above, the method comprising the steps of
- [0014] i) Impregnating an antibacterial / antiviral composition onto a substrate layer;
- [0015] ii) Impregnating a mixture of a hydrophobic composition and a crosslinking composition onto the substrate layer of step i); and
- [0016] iii) laminate a waterproof membrane onto one of the surfaces of the substrate layer of step ii).
- [0017] In one embodiment of the invention, the method of manufacturing the multi-functional trilaminar fabric comprises a crosslinking composition selected from a isocyanate or a poly-isocyanate.
- [0018] In another embodiment of the invention, the method of manufacturing the multi-functional trilaminar fabric described above involves the impregnation of an antimicrobial / antiviral composition, an hydrophobic composition and a crosslinking composition which is done by a bath or by spraying.

General Description

- [0019] The present invention describes a multi-functional trilaminar fabric that provides protection and comfort for its users. The disclosed fabric incorporates a simultaneous combination of waterproof, hydrophobic, antibacterial (bacteriostatic or bactericidal),

antiviral, and antifungal properties, enabling its users to use, wear, protect or sleep over a clean, dry, breathable, and hygienically stable cloth.

[0020] The fabric of the invention comprises a set of innovative features of which it is possible to highlight its wash-resistance, ensuring the maintenance of its functional characteristics even after a high number of washes (over 100). With this invention, it is ensured that, after the previously indicated washes, both the sheet and its waterproof characteristics remain unchanged. It is also energy efficient since it allows the washing cycles to occur at a low temperature (between 30°C and 60°C) while still guaranteeing the microbiological inactivation within the fabric. The materials used in the fabric (1) provide a comfortable and soft surface, while maintaining its durability and easy maintenance and avoiding the creation of multi-resistant bacteria to which a flexible, breathable waterproof membrane is laminated on a surface of the substrate.

[0021] The fabric of the present invention comprises a substrate layer composed of linen materials made from either synthetic or natural fibres, a chemical treatment being impregnated within the fibres in a way that forms a superficial mesh on the fabric, conferring to it the antibacterial (bacteriostatic or bactericidal), antiviral, antifungal and hydrophobic properties and a flexible, breathable waterproof membrane that is laminated onto one surface of the substrate fibrous layer. The previously mentioned feature combination confers properties to the fabric that make it ideal for technical uses that require breathable, waterproof, hydrophobic, antibacterial (bacteriostatic or bactericidal), antiviral, and antifungal properties. Examples of such uses are bedding materials for hospitals, uniforms for hospital, healthcare, fire fighters, military staff, and others. The fabric of the invention provides a technically advanced solution for various applications, which may include home use, indoor or outdoor use, general industry, hotels, hospitals, and other environments where hygiene, comfort, and protection are of paramount importance.

Brief Description of Drawings

[0022] For better understanding of the present application, a [Fig.1] representing the fabric of the invention is attached.

Fig.1

[0023] [Fig.1] describes a fabric (1) according to the present invention comprising a substrate layer (2), an antimicrobial and hydrophobic composition impregnated in the substrate layer (2) forming a superficial mesh (3) and a breathable waterproof membrane (4).

Detailed description of the invention

[0024] The present invention concerns a substrate layer composed of linen materials made from either synthetic or natural fibres, a chemical treatment being impregnated within

the fibres in a way that forms a superficial mesh on the fabric, conferring antibacterial (bacteriostatic or bactericidal), antiviral, antifungal and hydrophobic properties to the fabric and a flexible, breathable waterproof membrane that is laminated onto one surface of the substrate layer.

[0025] The substrate layer (2) is composed of a linen material made from synthetic fibres (such as, for example but not limited to rayon, microfiber, nylon, lyocell, polyester or acrylic), natural fibres (such as, for example but not limited to bamboo, cotton, wool or flax) or a combination of synthetic and natural fibres in variable proportion.

[0026] The superficial mesh (3) is formed by impregnating a mixture of three components in the substrate layer (2). The three components comprised in the mixture forming the superficial mesh (3) are: i) an antimicrobial / antiviral composition; ii) a hydrophobic composition; and iii) a crosslinking composition.

[0027] i) Antimicrobial / antiviral composition

[0028] The antimicrobial / antiviral composition is an anionic preparation comprising inorganic salts and surfactants. Inorganic salts known in the art to have antimicrobial / antiviral activity are, for example but not limited to the group comprising silver ions, copper ions, zinc oxide nanoparticles, or other technically suitable antimicrobial agents. For example, inorganic salts known in the art to have antimicrobial / antiviral activity are silver salts in an amount within the range of 0,00035% (w/v) to 0,035% (w/v). Surfactants known in the art to be suitable for antimicrobial compositions are for example linear alkylbenzene sulfonate (LAS) and sodium lauryl sulfate (SLS). An antimicrobial composition comprising a mixture of LAS and SLS is preferred because it has been demonstrated that LAS and SLS have the capacity to deactivate viruses while SLS has been known to have denaturing proteins. Also, LAS is known as a food contact sanitizer and has shown to have antimicrobial efficacy in laundry.

[0029] The antimicrobial / antiviral composition has antibacterial (bacteriostatic or bactericidal), antiviral, and antifungal properties that prevents the development of microorganisms, such as bacteria, viruses, and fungi in the fabric (1). The antimicrobial / antiviral composition also prevents the development of naturally evolved multi-resistant bacteria.

[0030] ii) Hydrophobic composition

[0031] The hydrophobic composition comprises a polymer, linear or branched, conferring hydrophobic characteristics to fabrics. Compounds known to be suitable as hydrophobic components to confer hydrophobicity to fabrics are esters, sorbitol, derivatives of hydroxycarboxylic acids, ethoxylated fatty acids, nitrogen-containing compounds, derivatives of alkylimideazoline, metal complexes, compounds of aluminum salts with paraffin or wax, compounds of zirconium salts with wax, a combination of chromium and fatty acids, perfluorinated compounds of chromium

and fatty acids, fatty acids, polycarboxylic acids, esters of phosphoric acid, alkyladipic acid derivatives, silicates, silazanes, organosilanes, polyalkylhydrosiloxanes, oligodimethyl-siloxanes, polydimethylsiloxane rubbers, fluorocarbon resins or sodium alkyl siliconates. Typically, the hydrophobic effect is obtained by impregnating the substrate layer in the hydrophobic solution, thereby forming a polymolecular layer onto the surface of the fiber. This layer provides the hydrophobic properties due to its high adhesion to fiber.

[0032] The hydrophobic composition causes liquids and other fluids to bead up and roll off the surface of the fabric, preventing for example the formation of stains due to deposition. This feature is particularly important, for example, to ensure and maintain the cleanliness and freshness of a bed sheet or cover in a hospital environment or of a bedridden patient. The hydrophobic features of the fabric also enable the easy cleaning and quick drying after washing the fabric (1).

[0033] iii) Crosslinking composition

[0034] The crosslinking composition comprises a blocked isocyanate or poly-isocyanate compound. Blocked isocyanates are the result of synthesizing the reaction between an isocyanate and a protection or blocking agent to produce an isocyanate adduct with no free -NCO groups, which is stable in resin preparations with temperatures up to almost 60° Celsius. Increasing the medium temperature above 60° Celsius causes the thermal dissociation of the blocked isocyanates which produces a variety of linking mechanisms that engage and link to other reactive elements present in the medium. Once the isocyanate group -NCO is unprotected it readily reacts with compounds having hydrogen atoms such as water or aqueous conditions, alcohols, amines, etc.

[0035] In the case of the present invention the isocyanates present in the crosslinking composition link to the polymers present in the hydrophobic composition.

[0036] The crosslinking composition guarantees that the hydrophobic composition is not removed from the substrate layer (2) when the fabric (1) is washed. Also, the establishment of a link between the crosslinking composition and the hydrophobic composition entraps the antimicrobial / antiviral composition impregnated in the fibers of the substrate layer (2).

[0037] The waterproof membrane (4) is made of a breathable waterproof material such as, for example but not limited to polyurethane, polyethylene, polypropylene, or other technically suitable, providing the waterproof characteristics while retaining adequate gaseous exchanges and breathability. The waterproof membrane is laminated onto one surface of the substrate layer. This membrane effectively prevents the generation of moisture and liquids or fluids from seeping through the fabric within its several proposed applications.

[0038] The fabric (1) of the invention is particularly appropriate for medical applications, in particular for bed sheets, bed covers, duvet covers, pillow covers, medical gowns, curtains, or other within this field of application. However, other applications can be considered, particularly which require the technical features provided by the fabric (1). The fabric (1) of the invention is particularly effective when applied on bed sheets because it guarantees the protection of the underlying mattress while keeping the sleep environment dry.

[0039] METHOD OF PRODUCTION

[0040] In a first step of the process an antimicrobial / antiviral composition is applied to the substrate layer (2) by impregnation the composition onto the fibres of the substrate layer (2). The impregnation can be achieved by submerging the fabric or by spraying.

[0041] The antimicrobial / antiviral composition is applied to the substrate layer (2) by an industrial foularding process – pH 5.5; Foulard pressure: 2.4 bar; drying: 160° C at 5 meters/minute. The substrate layer is initially submerged in a bath of the antimicrobial / antiviral composition and dried.

[0042] In a second step of the process, a mixture of the hydrophobic composition and the crosslinking composition is applied to the substrate layer (2) impregnated with the antimicrobial / antiviral composition of the previous step.

[0043] The substrate layer (2) impregnated with the antimicrobial / antiviral composition can be submerged in a bath containing a mixture of the hydrophobic composition and the crosslinking composition and dried.

[0044] Alternatively, the mixture of the hydrophobic composition and the crosslinking composition can be sprayed onto the substrate layer (2) impregnated with the antimicrobial / antiviral composition and dried.

[0045] The waterproof membrane (4) is applied to one of the surfaces of the substrate layer (2) after the formation of the superficial mesh (3) by lamination at 300° C.

[0046] CYTOCOMPATIBILITY

[0047] For evaluation of cytocompatibility of the multi-functional fabric of the invention, tests based on ISO 10993-5:2012 were performed either by direct contact of dermal cells with the fabric (1) samples or by contact with leachates. For the direct contact test, 1 cm² squares were cut from the fabric (1) and contacted with a semi-confluent layer of dermal cells.

[0048] In parallel, fabric (1) samples were immersed in culture medium for 72 hours at 37°C and 5%CO₂. The resulting leachates were placed in contact with a semi-confluent culture of primary neonatal human dermal fibroblast cell line (nHDFs). After 72 hours of direct textile-nHDFs contact and leachate-nHDFs contact, cell morphology and density were assessed and compared to a positive control ("healthy control"). The

results of both experiments is that the multi-functional fabric (1) is cytocompatible as no cytotoxic reaction was observed.

[0049] WASHING CYCLES

[0050] The main problem associated with technical fabrics designed resist becoming vectors for microbial and viral infections is that antimicrobial and antiviral treatments wash away after a few washing cycles, typically less than 10 washes. This requires the fabric to receive another antimicrobial and antiviral treatment which ends up wearing out the fabric. The fabric (1) of the invention overcomes the need to repetitively apply the antimicrobial / antiviral treatment due to the hydrophobic and crosslinking component which are key to retain the antimicrobial / antiviral treatment and protect the substrate by preventing moisture and liquids to impregnate the fibres.

[0051] Two washing tests were conducted followed by a hydrophobicity test.

[0052] The first washing test was conducted according to ISO 6330:2012 with a type A washing machine, at 30° Celsius, total load of 2kg, detergent used comprising a mixture of test grade detergents ECE (phosphate based detergent powder), TAED (tetraacetylenediamine based detergent powder) and sodium perborate, drying process of the tumble dryer type at standard temperature; the fabric (1) samples were subjected to 70 washing and drying cycles. The fabric (1) samples were then tested for their hydrophilicity under AATCC TM79-2010e2(2018)e. After 70 washes the samples only absorbed about 30% or less of water in more than 60 seconds.

[0053] The second washing test was conducted according to ISO 15797:2018 with an industrial washing machine, with a reduced workload program at 30° Celsius, total load of 13kg, standard detergent without whitener, drying process of the tumble dryer type at standard temperature; the fabric (1) samples were subjected to 70 washing and drying cycles. The fabric (1) samples were then tested for their hydrophilicity under AATCC TM79-2010e2(2018)e. After 70 washes the samples only absorbed about 30% or less of water in more than 60 seconds.

[0054] ANTI-BACTERIAL ACTIVITY

[0055] Antibacterial activity was tested with the gram-positive bacterium *Staphylococcus aureus* (ATCC 25923) and the gram-negative *Pseudomonas aeruginosa* (ATCC 9027).

[0056] *S. aureus* is often found on the skin and in nasal cavities of healthy people. However, it can cause disease and is associated with hospital-acquired infections, ranging from a simple infection (acnes, boils and cellulitis) to serious infections (pneumonia, meningitis, endocarditis, toxic shock syndrome, sepsis and others).

[0057] *P. aeruginosa* is a bacterium also found on human skin. However, it is considered an opportunistic pathogen, i.e. it rarely causes disease in a healthy immune system, but threatens any weaknesses in the body by establishing a symptomatic picture of infection. *P. aeruginosa* infects the respiratory tract, urinary tract, burns, and also

causes blood infections. This characteristic, combined with its natural resistance to a large number of antibiotics and antiseptics, makes this bacterium an important cause of hospital-acquired infections. For the evaluation of the antibacterial efficacy of the fabric (1), plaque tests were performed according to ISO 20645:2004. For this purpose, twenty times washed fabric (1) samples were placed in direct contact with bacterial growth on an agar plate. Bacterostatic effect was observed against both gram-positive and gram-negative strains, i.e. inhibition of bacterial growth in direct contact with the fabric (1).

[0058] ANTI-FUNGAL ACTIVITY

[0059] Antifungal activity was tested with *Aspergillus fumigatus* (ATCC 204305) and *Aspergillus brasiliensis* (ATCC 16404). *Aspergillus fumigatus* is the etiological agent of aspergillosis. It is a saprophytic fungus present in the air and inhabiting the mucosa of the respiratory tract. As its spores are persistent and abundant in the atmosphere, a single individual can inhale several hundred spores per day, but they are usually quickly eliminated by the immune system in healthy people. In immunocompromised individuals, such as organ transplant recipients and people with AIDS or leukaemia, the fungus is more likely to become pathogenic, overcoming the host's weakened defences and causing infection. Due to the recent increase in the use of immunosuppressants to treat patients, it is estimated that *A. fumigatus* may be responsible for more than 600,000 deaths annually with a mortality rate of between 25% and 85%, depending on the person infected. *Aspergillus brasiliensis* is one of the most common species of the genus *Aspergillus*. It is a common contaminant of food and is also regularly found in indoor environments such as industrial plants or hospitals. Its spores are the common route of contamination and can spread in hospitals and manufacturing facilities by the hands of healthcare workers or by the use of equipment that is not properly cleaned. *A. brasiliensis* infections are considered opportunistic, meaning that the organism only causes disease when the person's immune system is compromised. When it occurs, it can result in severe pulmonary aspergillosis disease.

[0060] To evaluate the anti-fungal efficacy of the fabric (1), plaque assays were performed. For this purpose, twenty times washed fabric (1) samples were placed in direct contact with the fungal growth.

[0061] Fungostatic effect was observed against both fungi, i.e. inhibition of fungal growth in direct contact with the fabric (1).

[0062] ANTI-VIRAL ACTIVITY

[0063] Influenzavirus A is a genus of the virus family Orthomyxoviridae. The genus includes the species Influenza A that causes influenza in birds and some mammals, including humans. Some variants of Influenza A cause severe disease in poultry and,

more rarely, in humans. Occasionally the viruses are transmitted from wild waterfowl to domesticated birds and an outbreak can occur or human influenza pandemics can result. The latest example was the 'Spanish Flu', or pneumonic flu pandemic, which killed tens of thousands of people between 1918 and 1919. Testing of the antiviral activity was conducted according to ISO 18184:2019. The virology test was carried out by inoculating Influenza A viral particles on the surface of the multi-functional fabric (1) for 6 and 24 hours, compared to common polystyrene plastic surfaces, which served as a control. Complete elimination of plaque formation from Influenza A viral infection in mammalian cells was observed in fabric (1) samples both at zero and twenty washes.

[0064] Coronavirus belongs to the family Coronaviridae. These viruses are enveloped having an outer corona of embedded envelope spikes. The longest viability of Coronaviridae viruses was observed on stainless steel and plastic; the estimated median half-life of SARS-CoV-2 was approximately 5.6 hours on stainless steel and 6.8 hours on plastic. The fabric (1) of the present invention was tested for antiviral activity against viruses of the Coronaviridae family. Fabric (1) samples, both of 100 % cotton and 100 % polyester substrate layer, demonstrate an immediate effect versus standard fabrics against Feline Coronavirus.

Claims

- [Claim 1] Multi-functional trilaminar fabric (1) characterized in that the fabric comprises a substrate layer (2), a superficial mesh (3) and a waterproof membrane (4), wherein the superficial mesh (3) comprises an antibacterial / antiviral composition and a hydrophobic composition crosslinked to a crosslinking composition.
- [Claim 2] Multi-functional trilaminar fabric (1) according to claim 1, characterized in that the crosslinking composition is a isocyanate or a poly-isocyanate.
- [Claim 3] Multi-functional trilaminar fabric (1) according to previous claim 1, characterized in that the substrate layer (2) is made of a material selected from a group comprising cotton, polyester, microfiber, bamboo, lyocell, cotton, polyester, microfiber, bamboo, lyocell, or a mixture thereof.
- [Claim 4] Multi-functional trilaminar fabric (1) according to previous claim 1, characterized in that the waterproof membrane (4) is made of a material selected from the group of polyurethane, polyethylene, polypropylene, or other technically suitable.
- [Claim 5] Multi-functional trilaminar fabric (1) according to previous claim 1, characterized in that the antibacterial / antiviral composition comprises an inorganic salt selected from the group composed of silver ions, copper ions, zinc oxide nanoparticles, or other technically suitable antimicrobial agents.
- [Claim 6] Multi-functional trilaminar fabric (1) according to previous claim 1, characterized in that the hydrophobic composition comprises a hydrophobic compound selected from the group composed of fluoropolymers or silicones.
- [Claim 7] Use of the multi-functional trilaminar fabric (1) according to any of the previous claims 1 to 6, for bed sheets, bed covers, duvet covers, pillow covers, medical gowns and curtains.
- [Claim 8] Use of the multi-functional trilaminar fabric (1) according to any of the previous claims 1 to 6, in hospitals, clinics, hotels, medical environments, bedridden patients or hospitality industry.
- [Claim 9] Method of manufacturing the multi-functional trilaminar fabric (1) described in any of the claims 1 to 6, characterized by comprises the following steps: i) Impregnating an antibacterial / antiviral

composition onto a substrate layer (2); ii) Impregnating a mixture of a hydrophobic composition and a crosslinking composition comprising a crosslinking composition onto the substrate layer of step i); and iii) laminate a waterproof membrane (4) onto one surface of the substrate layer of step ii).

[Claim 10]

Method of manufacturing a multi-functional trilaminar fabric (1) according to previous claim 9, characterized in that the crosslinking composition is an isocyanate or a poly-isocyanate.

[Claim 11]

Method of manufacturing the multi-functional trilaminar fabric (1) according to previous claims 9 or 10, wherein the impregnation of the antibacterial / antiviral composition, hydrophobic composition and crosslinking composition is done by a bath or by spraying.