

Description

Title of Invention: A Surface Textured Wound Closure Material

Technical Field

The present invention generally relates to a surface textured wound closure material. The present invention also relates to a method of preparing the surface textured wound closure material.

Background Art

Wound closure devices, which can include wound dressings or simply dressings, are often used to close wounds depending on the severity of the wound. Although there are several other methods of closing severe wounds such as sutures and staples, these methods require a trained specialist and are often invasive and painful procedures that frequently require the use of an anaesthetic and leave unsightly scars. Furthermore, simply covering a more severe or deeper wound with bandage such as BAND-AID is often insufficient as these adhesives used are often inadequate to close the wounds without being detached or creep. These adhesive based bandages are usually problematic upon exposure to moisture, and may lead to their premature release from the skin and wound site before closure of the wound and proper healing.

Wound dressings are outlined by different parameters including material composition (e.g., each layer and also the use of polymer coatings), geometry (e.g., size, shape, number of layers and thickness of each layer), conformity to the topography of the skin surface, surface properties (e.g, dimpled, textured etc), moisture management (e.g., hydrophobic, hydrophilic etc), anti-inflammatory properties, anti-bacterial properties, air/vapour permeation, textile properties, medical content (in any), color, ergonomics, various adhesion mechanisms used for holding them in place on the skin, among other considerations. In general, the main concerns when selecting the most suitable wound dressings is often based on the above-mentioned parameters so that the highly diverse group of patients with a highly diverse set of wound conditions are able to recover within the shortest period of time.

Conventionally, wound dressings were usually made of gauze pads or bandages made from synthetic and/or natural materials wherein wound exudate would be absorbed by the dressing to keep the wound dry and perhaps help to prevent bacterial infection. Although in some cases, bacterial infection would still occur as this could be due to the bacteria from the surrounding skin invading the superficial wound tissues. In this regard, bacteria biofilm would retard the wound healing process. Hence, there is a demand for an anti-bacterial wound dressing to minimize the odds of getting a bacterial infection. In addition, inflammation is generally a sign of normal, healthy wound healing but excessive inflammation can lead to scarring. Thus, there is a need to control these inflammatory cellular responses to prevent inflammation during wound healing.

Moisture management as mentioned above is one of the most important parameters as this parameter will dictate the wound healing process. If a wound is kept dry and clean, the recovery process might be faster as there will be a lower possibility of bacterial infection. However, more recently, it has been shown that wounds heal faster and more efficiently when they are kept moist. Hence, there is a demand for wound dressing that has an appropriate degree of hydrophobicity such that the wound may be kept dry and clean for faster healing process.

During the final phase of optimal wound healing process, where the ultimate goal is to allow the tissues to heal effectively without formation of scars, the initial extracellular matrix (ECM) organisation reciprocally interacts with the fibroblasts, such that the ECM is continuously remodelled by fibroblasts and guided by the fibroblast migration. Thus, this initial organisation would significantly affect the resulting matrix since the ECM and fibroblasts interact with each other constantly. Hence, if there is a wound dressing product that can influence fibroblast migration and ECM organisation such that the tissues can heal effectively, thus would be an ideal wound dressing product to satisfy the possible demands from the diverse group of patients.

Accordingly, there is a need to provide a surface textured wound closure material that overcomes, or at least ameliorates, one or more of the disadvantages described above. There is also a need to provide a method of preparing a surface textured wound closure material that ameliorates one or more disadvantages mentioned above.

Summary of Invention

According to a first aspect, there is provided a surface textured wound closure material comprising at least one polymeric layer and an absorbent layer, wherein said polymeric layer is disposed on at least one surface of said absorbent layer and having a plurality of imprints thereon to form a textured surface on said wound closure material.

According to another aspect, there is provided a method of preparing a surface textured wound closure device comprising the step of providing at least one surface textured polymeric layer on at least one surface of an absorbent layer to form the surface textured wound closure material.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "wound closure device" or "wound closure material" as used herein includes wound dressing products that utilized gauze dressings or typical bandages such as the adhesive-type of bandages.

The terms "liquidphobic" and "liquidphobicity" when referring to a surface are to be interpreted broadly to include any property of a surface that does not cause a liquid droplet to substantially spread across it. Generally, if the contact angle between a liquid droplet and the surface is greater than 90°, the surface is liquidphobic or exhibits liquidphobicity. Likewise, the terms "hydrophobic" and "hydrophobicity" mean that the surface is liquidphobic or exhibits liquidphobicity when water is the liquid placed thereon. If the

contact angle between a water droplet and the surface is greater than 150° , the surface is defined as superhydrophobic.

The term “nanoimprinting lithography” is to be interpreted broadly to include any method for printing or creating a pattern or structure on the micro/nanoscale on the surface of a substrate by applying a mold with the defined pattern or structure on the surface at certain temperatures and pressures. A method of nanoimprinting lithography can be referred from US Patent Number 5,772,905.

The term “microscale” is to be interpreted to include any dimensions that are in the range of about 1 (μm) to about 100 μm . The term “microstructures” as used herein, refers to structures comprising “microscale” features.

The term “nanoscale” is to be interpreted to include any dimensions that are below about 1 μm . The term “nanostructures” as used herein, are structures comprising “nanoscale” or “submicron” features.

The term “three dimensional” is to be interpreted broadly to include any structures, structural features, imprints or patterns that have both lateral variations (thickness) as well as variations with depth.

The term “hierarchical” is to be interpreted broadly to include any relevant steps that are carried out in a serial manner. For example, the term “hierarchical nanoimprinting” refers to the sequential application of nano-sized imprints on a surface of a polymer substrate. In one embodiment, hierarchical nanoimprinting is carried out using two molds that are applied to the surface of the substrate separately one after the other. In other embodiments, more than two molds can be used to create a complex hierarchical structure. Typically, the subsequent imprints have smaller dimensions when compared to the preceding imprint so that the hierarchical structure exhibits a variation in size along the height of the imprint, that is, along the z-direction.

The term “glass transition temperature” (T_g) is to be interpreted to include any temperature of a polymer at which the polymer lies between the rubbery and glass states. This means that above the T_g , the polymer becomes rubbery and can undergo elastic or plastic deformation without fracture. Above this temperature, such polymers can be induced to flow under pressure. When the temperature of the polymer falls below the T_g , generally, the polymer will become inflexible and brittle such that it will break when a stress is applied to the polymer. It should be noted that the T_g is not a sharp transition temperature but a gradual transition and is subject to some variation depending on the experimental conditions (e.g., film thickness, tacticity of the polymer, etc.). The actual T_g of a polymer film will vary as a function of film thickness. The T_g will be defined herein as being the bulk glass-transition temperature of the polymer substrate. The bulk glass transition temperature is a specific value that is widely agreed upon in the literature.

The word “substantially” does not exclude “completely” e.g. a composition which is “substantially free” from Y may be completely free from Y. Where necessary, the word “substantially” may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Certain embodiments may also be described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the disclosure. This includes the generic description of the embodiments with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

Detailed Disclosure of Embodiments

Exemplary, non-limiting embodiments of a surface textured wound closure material shall now be disclosed. The surface textured wound closure material comprises at least one polymeric layer and an absorbent layer, wherein the polymeric layer is disposed on at least one surface of the absorbent layer and having a plurality of imprints thereon to form a textured surface on the wound closure material.

The surface textured wound closure material may comprise a surface topography that is responsible for hydrophobicity properties. The surface topography may be selected from square pillar array, circular pillar array, oval-shape pillar array, triangle pillar array or rectangular pillar array. The size of each of the surface topography may be in the range of 500 nm to 10 μm , 500 nm to 1 μm , 1 to 9 μm , 1 to 8 μm , 1 to 7 μm , 1 to 6 μm , 1 to 5 μm , 1 to 4 μm , 1 to 3 μm , 1 to 2 μm , 2 to 10 μm , 3 to 10 μm , 4 to 10 μm , 5 to 10 μm , 6 to 10 μm , 7 to 10 μm , 8 to 10 μm or 9 to 10 μm . The spacing between each of the surface topography may be in the range of 1 to 10 μm , 1 to 9 μm , 1 to 8 μm , 1 to 7 μm , 1 to 6 μm , 1 to 5 μm , 1 to 4 μm , 1 to 3 μm , 1 to 2 μm , 2 to 10 μm , 3 to 10 μm , 4 to 10 μm , 5 to 10 μm , 6 to 10 μm , 7 to 10 μm , 8 to 10 μm or 9 to 10 μm . Advantageously, the water contact angle of the surface topography may be in the range of 100° to 150° , 100° to 140° , 100° to 130° , 100° to 120° , 100° to 110° , 110° to 150° , 120° to 150° , 130° to 150° or 140° to 150° . The surface topography of the surface textured wound closure material may be a square pillar array, which may be responsible for the hydrophobicity properties. Hence, when a particular

shaped pillar array is selected for the surface topography, the selected pillar array may be the size, spacing and water contact angle as mentioned below. The surface topography may be a square pillar array, which may be used to alter or increase the hydrophobicity of the surface.

The surface textured wound closure material may comprise a surface topography that is responsible for anti-microbial properties. The surface topography may be selected from square pillar array, circular pillar array, oval-shape pillar array, triangle pillar array or rectangular pillar array. The size of each of the surface topography may be in the range of 500 nm to 30 μm , 500 nm to 1 μm , 1 to 30 μm , 1 to 10 μm , 10 to 15 μm , 10 to 20 μm , 10 to 25 μm , 10 to 30 μm , 15 to 30 μm , 20 to 30 μm or 25 to 30 μm . The spacing between each of the surface topography may be in the range of 1 to 100 μm , 1 to 10 μm , 10 to 100 μm , 10 to 90 μm , 10 to 80 μm , 10 to 70 μm , 10 to 60 μm , 10 to 50 μm , 10 to 40 μm , 10 to 30 μm , 10 to 20 μm , 20 to 100 μm , 30 to 100 μm , 40 to 100 μm , 50 to 100 μm , 60 to 100 μm or 70 to 100 μm , 80 to 100 μm or 90 to 100 μm . The surface topography of the surface textured wound closure material may be square pillar array, which imparts an anti-microbial property to the wound closure material.

The types of microorganisms that may be inhibited from adhering to the surface textured wound closure material may be a bacteria or a fungi. The bacteria may comprise of *pseudomonas aeruginosa*, *staphylococcus aureus*, *streptococcus pyogenes* or *escherichia coli*. The microorganism may be inhibited from adhering to the surface textured wound closure material due to the presence of the surface topographies as compared to adhesion on a wound closure material without the surface topographies. The amount of microorganism that may be inhibited from adhering to the disclosed surface textured wound closure material may be reduced by 50 % to 80 %, 55 % to 80 %, 60 % to 80 %, 65 % to 80 %, 70 % to 80 %, 75 % to 80 %, 50 % to 55 %, 50 % to 60 %, 50 % to 65 %, 50 % to 70 % or 50 % to 75 %, as compared to adhesion of the same microorganism on another wound closure material (which is made of the same material as the disclosed surface textured wound closure material but without the surface topographies).

Advantageously, the surface topography of the surface textured wound closure material may be a square pillars array that alters or increases the hydrophobicity properties. Advantageously, the surface topography of the surface textured wound closure material may be a square pillars array with different spacing between each pillar that imparts the anti-microbial (such as anti-bacterial) properties to the surface textured wound closure material.

The surface texture of the surface textured wound closure material may be integrally formed with the polymeric layer.

The polymeric layer may be disposed on two surfaces of the absorbent layer such that the surface textured wound closure material has two surfaces with the surface textured structures. Where a plurality of absorbent layers is used, the plurality of absorbent layers may be pressed together in the resultant surface textured wound closure material such that the plurality of absorbent layers is envisaged as one absorbent layer. The two surfaces may then be positioned opposite to each other on the absorbent layer (whether formed from only one absorbent layer or from a plurality of absorbent layers), or may be positioned adjacent

to each other, with a common side that is in contact with each of the two surface. Thus, the resultant surface textured wound closure material is deemed to be one that has more than one surface with the above surface topographies. Where more than one surface is patterned, the type and structure of surface topographies on each surface may be the same or may be different from each other. Where the same type surface topography is used, the spacing or dimension of the surface topography on each surface may be the same or differ from each other.

The polymeric layer may comprise a polymer. The polymer may be a thermoplastic polymer. The monomers of the thermoplastic polymer from the group consisting of acrylates, phthalamides, acrylonitriles, cellulose, styrenes, alkyls, alkyl methacrylates, alkenes, halogenated alkenes, amides, imides, aryletherketones, butadienes, ketones, esters, acetals, carbonates and combinations thereof. The thermoplastic polymer is at least one of a polystyrene, a polymethyl methacrylate and a polycarbonate. Exemplary monomers to form the thermoplastic polymer may be selected from the group consisting of methyls, ethylenes, propylenes, methyl methacrylates, methylpentenes, vinylidene, vinylidene chloride, etherimides, ethylenechlorinates, urethanes, ethylene vinyl alcohols, fluoroplastics, carbonates, acrylonitrile-butadiene-styrenes, etheretherketones, ionomers, butylenes, phenylene oxides, sulphones, ethersulphones, phenylene sulphides, elastomers, ethylene terephthalate, naphthalene terephthalate, ethylene naphthalene and combinations thereof.

The polymer substrate may be a photoresist material. Suitable photoresist materials include epoxy based negative resists such as SU-8TM resist available from MicroChem Corp. of Newton, Massachusetts, United States of America.

The polymer substrate may be a polymer composite whereby particles may be added to or incorporated with the polymer. These particles may be selected from the group consisting of calcium carbonate, carbon filler, glass filler, fibers, glass fibers, carbon fibers, carbon nanotubes and mixtures thereof.

The imprints of the surface textured wound closure material may comprise hierarchical, pillar, lotus-leaf like, ridges, fibrillar or anisotropic structures.

The imprints may have any shape. The imprints may be holes, columns, gratings, trenches, Sharklet topography, or anisotropic patterns. The Sharklet topography may be deemed as, when viewed from the side, having a cylindrical shape with a pyramidal shape on top.

The imprints may have defined heights and widths in the micro/nanoscale. The imprints may be spaced apart from each other. The imprints may comprise gratings and trenches. The gratings and trenches may be placed parallel to each other.

The micro or nano-sized surface textured features may be formed on a hierarchical array. For instance, one or more of the specific regions of a polymeric layer may comprise an array of micro-sized structures that are integrally formed on said polymeric layer, each micro-sized feature in turn being imprinted with nano-sized surface features on its surface thereon. The surface textured features may be hierarchical structures.

The hierarchical structures may refer to surface topological structures that are imprinted sequentially, usually in increasingly smaller dimensions. In the context of the present

invention, a hierarchical structure may refer to the embossing of nano-sized features on the surface of existing micro-sized structures formed by an earlier imprinting step. The micro-sized structures may be integrally formed on the polymeric layer. Each micro-sized feature may comprise a planar surface that extends from the surface of the polymeric layer. Such planar surfaces may refer to a distal end of a cone, a cylinder, or a polygonal (e.g., square, hexagonal) structure extending from the base of the polymeric layer. The nano-sized features may be imprinted or embossed on such a planar surface to thereby form hierarchical structures.

The top polymeric layer may comprise a silicone elastomer. The bottom polymeric layer may comprise a silicone elastomer. The top and bottom polymeric layers may be of the same silicone elastomer or combinations of different silicone elastomers. The silicone elastomer may comprise of synthetic polymers with an alternating Si-O chain backbone. The molecules of the Si-O chain backbone may be crosslinked with the addition of a catalyst. The catalyst may be selected from peroxide or transition metal. The transition metal may be platinum.

The absorbent layer may comprise absorptive fibers. The absorptive fibers may be selected from cotton, cellulose or rayon.

The amorphous oxide layer may comprise an oxide of a metal selected from titanium, zinc, aluminium, cobalt or composites thereof. The metal oxide layer may comprise a composite oxide e.g., iron-doped titanium dioxide composition (Fe/TiO_2), zinc-cobalt composite ($\text{ZnO / Co}_3\text{O}_4$). The amorphous oxide layer is a TiO_2 layer.

The amorphous metal oxide layer may be substantially evenly distributed across the entire or part of the surface of the polymeric layer.

The amorphous metal oxide layer may be deposited by a chemical vapour deposition process (CVD), which may be undertaken at conditions that would not deform the polymeric layer or adversely affect the topological features imprinted thereon. The amorphous metal oxide layer may be deposited by an Atomic Layer Deposition (ALD) process. Advantageously, the ALD process may afford precise control over the thickness and uniformity of the topological features. The ALD may be performed at considerably mild temperatures in the range of about 15 °C to about 100 °C, about 20 °C to about 100 °C, about 25 °C to about 100 °C, about 30 °C to about 100 °C, about 40 °C to about 100 °C, about 50 °C to about 100 °C, about 60 to about 100 °C, about 15 °C to about 90 °C, about 20 °C to about 90 °C, about 25 °C to about 90 °C, about 30 °C to about 90 °C, about 40 °C to about 90 °C, about 50 °C to about 90 °C, about 60 °C to about 90 °C, about 15 °C to about 80 °C, about 20 °C to about 80 °C, about 25 °C to about 80 °C, about 30 °C to about 80 °C, about 40 °C to about 80 °C, about 50 °C to about 80 °C, about 60 °C to about 80 °C, about 15 °C to about 70 °C, about 20 °C to about 70 °C, about 25 °C to about 70 °C, about 30 °C to about 70 °C, about 40 °C to about 70 °C, about 50 °C to about 70 °C, about 60 °C to about 70 °C, about 70 °C to about 100 °C, about 70 °C to about 90 °C, or about 70 °C to about 80 °C. The ALD may be performed at ambient or room temperature.

The ALD process may be performed with at least two chemicals typically known as precursors. One of the precursors may comprise a titanium derivative selected from titanium tetrachloride, tetrakis(dimethylamino) titanium (TDMAT), tetrakis (diethylamino)

titanium (TDEAT), tetrakis(ethylmethylamino) titanium (TEMAT), PrimeTi™, StarTi™ or TyALD™. The first precursor may be titanium tetrachloride. The second precursor may be an oxidizing agent selected from ozone or water. The second precursor may be water.

The ALD process may comprise a series of sequential, non-overlapping pulses for each of the precursors. In each of these pulses, the precursor molecules react with the surface in a self-limiting way such that all the reactions terminate once all the reactive sites on the surface are consumed. The remaining reactant molecules of either one of the precursors are flushed away and only then the second precursor is inserted into the reaction. The ALD reaction may occur in high vacuum reactor or inert gas reactor. By alternating exposures of the first and second precursors, a thin film may be deposited. The ALD process may refer to both dose times (the time a surface is being exposed to a precursor), also known as the exposure time, and purge times (the time left in-between doses for the precursor to evacuate the chamber) for each precursor. The dose(exposure)-purge-dose(exposure)-purge sequence of a ALD process establishes an ALD cycle.

The pulse for each of the precursors of the ALD process may be in the range of about 0.05 to about 0.5 seconds, about 0.05 to about 0.06 seconds, about 0.05 to about 0.07 seconds, about 0.05 to about 0.08 seconds, about 0.05 to about 0.09 seconds, about 0.05 to about 0.1 seconds, about 0.05 to about 0.2 seconds, about 0.05 to about 0.3 seconds, about 0.05 to about 0.4 seconds, about 0.06 to about 0.5 seconds, about 0.07 to about 0.5 seconds, about 0.08 to about 0.5 seconds, about 0.09 to about 0.5 seconds, about 0.1 to about 0.5 seconds, about 0.2 to about 0.5 seconds, about 0.3 to about 0.5 seconds or about 0.4 to about 0.5 seconds.

The exposure for each of the precursors with the surface is in the range of about 1 to about 10 seconds, about 1 to about 9 seconds, about 1 to about 8 seconds, about 1 to about 7 seconds, about 1 to about 6 seconds, about 1 to about 5 seconds, about 1 to about 4 seconds, about 1 to about 3 seconds, about 1 to about 2 seconds, about 2 to about 10 seconds, about 3 to about 10 seconds, about 4 to about 10 seconds, about 5 to about 10 seconds, about 6 to about 10 seconds, about 7 to about 10 seconds, about 8 to about 10 seconds or about 9 to about 10 seconds. The maximum amount of material deposited on the surface after a single exposure to the two precursors is determined by the nature of the precursor-surface interaction.

The purge time for each precursor may be in the range of 10 to 60 seconds, 10 to 50 seconds, 10 to 40 seconds, 10 to 30 seconds, 10 to 20 seconds, 20 to 60 seconds, 30 to 60 seconds, 40 to 60 seconds or 50 to 60 seconds.

The carrier gas for the ALD process may be selected from the group of inert gas. The group of inert gas may be selected from nitrogen or helium. The carrier gas for the ALD process is nitrogen gas. The gasflow rate of the nitrogen gas may be in the range of 10 to 50 sccm, 10 to 40 sccm, 10 to 30 sccm, 10 to 20 sccm, 20 to 50 sccm, 30 to 50 sccm or 40 to 50 sccm.

The amorphous metal layer may comprise a metal selected from silver, zinc or copper. The metal layer may be selected for anti-bacterial properties.

The amorphous metal layer may be deposited in a form of physical vapour deposition (PVD) process, which may be undertaken at conditions that would not deform the polymeric layer or adversely affect the topological features imprinted thereon. The amorphous metal layer may be deposited by an electron beam evaporation process. The electron beam evaporation process system may be in a deposition chamber that must be evacuated to a pressure in the range of about 5×10^{-3} to about 8×10^{-5} Torr, about 5×10^{-3} to about 6×10^{-3} Torr, about 5×10^{-3} to about 7×10^{-3} Torr, about 6×10^{-3} to about 8×10^{-3} Torr or 7×10^{-3} to about 8×10^{-3} Torr to allow passage of electrons from the electron gun to the ingot comprising the metal. The generated electron beam may be accelerated to a high kinetic energy and directed towards the evaporation material which is the metal. Upon striking the evaporation material, the electrons will lose their energy very rapidly. The kinetic energy of the electrons is converted into other forms of energy through interactions with the evaporation material. The thermal energy that is produced heats up the evaporation material causing it to melt or sublime. Once temperature and vacuum level are sufficiently high, vapour will result from the melt or solid. The resulting vapour may then be used to coat on the polymeric material. A high deposition rate may be achievable in the range of about $0.1 \mu\text{m}/\text{min}$ to $10 \mu\text{m}/\text{min}$, at an appropriate low temperature that has very high material utilization efficiency.

Exemplary, non-limiting embodiments of a method of preparing a surface textured wound closure material comprising the step of providing at least one surface textured polymeric layer on at least one surface of an absorbent layer to form said surface textured wound closure material.

The method may comprise, before the providing step, the step of forming the surface textured polymeric layer via nanoimprinting, thermal imprinting, ultraviolet roll-to-roll imprinting, roll-to-plate imprinting, or batch imprinting.

The forming step may comprise the steps of:

- a) coating a first polymeric layer onto a patterned mold;
- b) disposing a second polymeric layer onto said first polymeric layer;
- c) heating the second polymeric layer and the first polymeric layer when in contact with the patterned mold to a temperature above the glass transition temperature of the first polymeric layer to form a textured surface on the first polymeric layer, the textured surface having a pattern that is complementary to the pattern on the mold.

The heating step may be undertaken for a period of time and pressure to ensure that the complementary pattern is formed on the first polymeric layer. When the complementary pattern is formed, the temperature may be reduced to enable the surface textured first polymeric layer to disengage from the patterned mold.

The temperature that is above the glass transition temperature (when referring to the first or second glass transition temperature) may be selected from the group consisting of about 120°C to about 200°C , about 140°C to about 200°C , about 160°C to about 200°C , about 180°C to about 200°C , about 120°C to about 140°C , about 120°C to about 160°C and about 120°C to about 180°C .

The pressure used when nanoimprinting may be selected from the group consisting of about 40 bars to about 50 bars, about 42 bars to about 50 bars, about 44 bars to about 50 bars, about 46 bars to about 50 bars, about 48 bars to about 50 bars, about 40 bars to about 42 bars, about 40 bars to about 44 bars, about 40 bars to about 46 bars and about 40 bars to about 48 bars.

The time period used during nanoimprinting may be in the range of about 4 minutes to 20 minutes.

The method may further comprise the step of contacting the second polymeric layer with a second patterned mold (being the same or different from the patterned mold in contact with the first polymeric layer) to thereby form a textured surface on the second polymeric layer. Similarly to the first polymeric layer, the temperature may be increased to be above the glass transition temperature of the second polymeric layer to ensure that the pattern that is complementary to the second patterned mold is formed on the second polymeric layer, followed by cooling the second polymeric layer to disengage from the second patterned mold.

The textured surface on the second polymeric layer may be different or may be the same as the textured surface on the first polymeric layer. The two textured surfaces may have different types of imprints, at different dimensions or may be made from different polymers. The imprints on the two textured surfaces may be randomly arranged or may be arranged in a specific pattern or orientation. The imprints on the two textured surfaces may cover the entire first or second polymeric layer, or may be only present on certain regions of the first or second polymeric layer.

The method may further comprise the step of imprinting two surfaces of the absorbent layer with two surface textured polymeric layers via roll-to-roll imprinting. The roll-to-roll imprinting step may be undertaken to imprint the two surfaces at the same time or simultaneously. The method may comprise the step of providing a first polymeric layer having a first glass transition temperature onto a first patterned mold and a second polymeric layer having a second glass transition temperature onto a second patterned mold; contacting the first polymeric layer with the second polymeric layer and subjecting both the polymeric layers (when in contact with their respective patterned molds) to a temperature that is above the higher of the first glass transition temperature and second glass transition temperature. The first polymeric layer contacting with the second polymeric layer in contact with the respective patterned molds may be subjected to a temperature that is above the higher of both of the glass transition temperatures simultaneously. Once the two textured surfaces are formed, the temperature may be reduced to allow disengaging of the first and second polymeric layers from their respective mold. The first and second polymeric layers may form the surface textured wound closure material.

The first polymeric layer may be the same polymer or may be a different polymer compared to the second polymeric layer.

The absorbent layer may be provided between the first and second polymeric layers. The absorbent layer may be in contact with the first polymeric layer and nanoimprinted on the side with the first polymeric layer. The absorbent layer may be in contact with the second polymeric layer and nanoimprinted on the side with the second polymeric layer. The two

polymeric layers with an absorbent layer each may be laminated together such that the absorbent layer may be inserted between the first and second polymeric layers. Alternatively, the absorbent layer may be only one layer but with two polymeric layers on two surfaces of the absorbent layer.

Brief Description of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig.1

[Fig. 1] **A**, is a diagram showing the side view of a wound closure material. **B**, is a diagram showing the top view of the same wound closure material.

[Fig. 2] shows a microscopic image of the surface topography comprising square pillars arrays that are responsible for the hydrophobicity properties at an enlarged view. The insert of Fig. 2 shows the square pillar arrays at a reduced view.

[Fig. 3] shows a number of microscopic images of the surface topographies comprising square pillars arrays that are responsible for the anti-bacterial properties using *pseudomonas aeruginosa* and *staphylococcus aureus* as the test microorganisms.

Detailed Description of Drawings

Referring to Fig. 1, there is shown in A, the side view of a wound closure material 100. Here, the wound closure material 100 having a surface texture 2. The surface textured wound closure material comprises at least one polymeric layer 4 and an absorbent layer 6, wherein the polymeric layer 4 is disposed on at least one surface of the absorbent layer 6 and having a plurality of imprints 2a thereon to form a textured surface 2 on the wound closure material 100. Fig. 1 also shows a second polymeric layer 8 on the opposite side of the polymeric layer 4, where the second polymeric layer 8 also has a plurality of imprints 10a thereon. The wound closure material 100 here is made up of both the polymeric layer 4 and the second polymeric layer 8 with the absorbent layer 6 there between. The textured surface of the wound closure material 100 is thus present on both surfaces of the wound closure material 100, where the two textured surfaces (based on imprints 2a and 10a) are opposite to each other.

Fig. 1B then shows the top view of the same wound closure material 100 based on the polymeric layer 4 on top and the second polymeric layer 8 is below (and is hence not shown in B).

Referring to Fig. 2, the figure shows the microscopic image of the square pillars array that is responsible for the hydrophobicity properties at a higher magnification. The insert of Fig 2 is the same square pillars array but at a lower magnification. The square pillars have a size of 2 μm and spacing of 2 μm . Here, the water contact angle of the square pillar array is about 130°.

Referring to Fig 3, there is shown in A and F control materials at 24 and 96 hours respectively, B and G are the surface textured wound closure materials with a pillar array that has a 10 μm spacing at 24 and 96 hours respectively, C and H are the surface textured wound closure materials with a pillar array that has a 20 μm spacing at 24 and 96 hours respectively, D and I are the surface textured wound closure materials with a pillar array that has a 50 μm spacing at 24 and 96 hours respectively, E and J are the surface textured wound closure materials with a pillar array that has a 100 μm spacing at 24 hours and 96 hours respectively and images A to J are based on *pseudomonas aeruginosa*. Images F to J displayed different amounts of *pseudomonas aeruginosa* adhered to the respective surfaces. Images K and P are the control materials at 24 and 96 hours respectively, L and Q are the surface textured wound closure materials with a pillar array that has a 10 μm spacing at 24 and 96 hours respectively, M and R are the surface textured wound closure materials with a pillar array that has a 20 μm spacing at 24 and 96 hours respectively, N and S are the surface textured wound closure materials with a pillar array that has a 50 μm spacing at 24 and 96 hours respectively, O and T are the surface textured wound closure materials with a pillar array that has a 100 μm spacing at 24 and 96 hours respectively, and images K to T are based on *staphylococcus aureus*. Images P to T displayed different amount of *staphylococcus aureus* adhered to the respective surfaces.

Based on the images in Fig. 3, it can be seen that having square pillar arrays with the stated size and spacing above aid to inhibit the adhesion of the test bacteria on the surface textured wound closure material. Hence, as compared to the control material (that is one without the square pillar array on the surface), the amount of microorganisms on the surface of the surface textured wound closure material is reduced.

In particular, the surface textured wound closure material tested in Fig. 3D and Fig. 3E show about 55 to 67% lesser *P. aeruginosa* adhesion as compared to the control in Fig. 3A. For *S. aureus*, Fig. 3S and Fig. 3T show about 50% lesser adhesion as compared to the control in Fig. 3P. Based on the various images in Fig. 3, it can be seen that an increase in the spacing between the various square pillars result in lesser adhesion of the test bacteria onto the surface.

Industrial Applicability

The wound closure device may be used as a wound dressing product that addresses different phases of wound healing. The wound closure device may be used as a waterproof wound dressing product. The wound closure device may be used as an anti-inflammatory wound dressing product. The wound closure device may be used as an anti-bacterial wound dressing product. The wound closure device may be used as a wound dressing product that influences fibroblast migration and extracellular matrix (ECM) organisation for enhanced skin regeneration.

The method of preparing a surface textured wound closure device may include nanoimprint lithography fabrication techniques, nanoinjection molding process and depositing technologies to provide wound closure device with a combination of desirable properties. The desirable properties may include properties such as waterproof, anti-bacterial, anti-inflammatory and enhanced skin regeneration, suitable for different phases of wound healing. The desirable properties may satisfy different requirements for optimal wound

healing. The method may be used for small-scale production or for large-scale production. The imprinting process may provide a waterproof wound closure device. The imprinting process may provide an anti-bacterial wound closure device. The imprinting process may provide an anti-inflammatory wound closure device. The imprinting and deposition processes may provide the wound closure device an enhanced rate of skin regeneration.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A surface textured wound closure material comprising at least one polymeric layer and an absorbent layer, wherein said polymeric layer is disposed on at least one surface of said absorbent layer and having a plurality of imprints thereon to form a textured surface on said wound closure material.
2. The surface textured wound closure material according to claim 1, wherein said surface textured is integrally formed with the polymeric layer.
3. The surface textured wound closure material according to claim 1 or 2, wherein said polymeric layer is disposed on two surfaces of said absorbent layer.
4. The surface textured wound closure material according to any one of the preceding claims, wherein said surface textured comprises hierarchical, pillar, lotus-leaf like, ridges, fibrillar or anisotropic structures.
5. The surface textured wound closure material according to claim 4, wherein the size of the structure is in the range of 500 nm to 10 μm , or 500 nm to 2 μm .
6. The surface textured wound closure material according to claim 4 or 5, wherein the spacing of the structure is in the range of 500 nm to 100 μm , or 500 nm to 2 μm .
7. The surface textured wound closure material according to any one of the preceding claims, wherein said surface textured wound closure device comprises at least one amorphous metal/metal oxide layer deposited thereon.
8. The surface textured wound closure material according to claim 7, wherein said amorphous oxide layer comprises an oxide of a metal selected from titanium, cobalt, zinc, aluminum and composites thereof.
9. The surface textured wound closure material according to claim 7, wherein said amorphous metal layer comprises of a metal selected from silver, zinc or copper.
10. The surface textured wound closure material according to any one of claims 7 to 9, wherein said amorphous metal oxide layer is deposited by atomic layer deposition.
11. The surface textured wound closure material according to any one of claims 7 to 10, wherein said amorphous metal layer is deposited by electron beam evaporation.
12. The surface textured wound closure material according to any one of claims 7 to 10, wherein said amorphous metal oxide layer comprises amorphous titanium dioxide.
13. A method of preparing a surface textured wound closure material comprising the step of providing at least one surface textured polymeric layer on at least one surface of an absorbent layer to form said surface textured wound closure material.

14. The method according to claim 13, further comprising the step of imprinting two surfaces of the absorbent layer with two surface textured polymeric layers via roll-to-roll imprinting.