SILK PERFORMANCE APPAREL AND PRODUCTS AND METHODS OF PREPARING THE SAME

FIELD OF THE INVENTION

In some embodiments, the present invention relates to silk performance apparel and products, such as fabrics coated with pure silk fibroin-based proteins or protein fragments.

BACKGROUND OF THE INVENTION

Silk is a natural polymer produced by a variety of insects and spiders, and comprises a filament core protein, silk fibroin, and a glue-like coating consisting of a non-filamentous protein, sericin. Silk fibers are light weight, breathable, and hypoallergenic. Silk is comfortable when worn next to the skin and insulates very well; keeping the wearer warm in cold temperatures and is cooler than many other fabrics in warm temperatures.

SUMMARY OF THE INVENTION

Silk performance apparel and methods of preparing the same are disclosed herein. According to aspects illustrated herein, the present disclosure relates to a product, including, but not limited to, apparel, padding, shoes, gloves, luggage, furs, jewelry and bags, configured to be worn or carried on the body, that is at least partially surface treated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating on the product. In an embodiment, the product is manufactured from a textile material. In an embodiment, the product is manufactured from a non-textile material. In an embodiment, desired additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating having desired additives.

According to aspects illustrated herein, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is available in a spray can for spraying on a product, including, but not limited to, apparel, padding, shoes, gloves, luggage, furs, jewelry and bags, or for directly spraying on the body of a consumer, to impart desired

properties to the product. In an embodiment, the product is manufactured from a textile material. In an embodiment, the product is manufactured from a non-textile material. In an embodiment, desired additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating having desired additives.

In an embodiment, a textile comprising a silk coating of the present disclosure is sold to a consumer. In an embodiment, a textile of the present disclosure is used in constructing action sportswear apparel. In an embodiment, a textile of the present disclosure is used in constructing fitness apparel. In an embodiment, a textile of the present disclosure is used in constructing performance apparel. In an embodiment, a textile of the present disclosure is used in constructing golf apparel. In an embodiment, a textile of the present disclosure is used in constructing lingerie. In an embodiment, a silk coating of the present disclosure is positioned on the underlining of action sportswear/apparel. In an embodiment, a silk coating of the present disclosure is positioned on the shell, the lining, or the interlining of action sportswear/apparel. In an embodiment, action sportswear/apparel is partially made from a silk coated textile of the present disclosure and partially made from an uncoated textile. In an embodiment, action sportswear/apparel partially made from a silk coated textile and partially made from an uncoated textile combines an uncoated inert synthetic material with a silk coated inert synthetic material. Examples of inert synthetic material include, but are not limited to, polyester, polyamide, polyaramid, polytetrafluorethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethylenglycol, ultrahigh molecular weight polyethylene, high-performance polyethylene, nylon, LYCRA (polyester-polyurethane copolymer, also known as SPANDEX and elastomer), and mixtures thereof. In an embodiment, action sportswear/apparel partially made from a silk coated textile and partially made from an uncoated textile combines an elastomeric material at least partially covered with a silk coating of the present disclosure. In an embodiment, the percentage of silk to elastomeric material can be varied to achieve desired shrink or wrinkle resistant properties and desired moisture content against the skin surface. In an embodiment, a silk coating of the present disclosure is positioned on an internal layer of a shoe (textile or non-textile based). In an embodiment, a silk coating

of the present disclosure positioned on an internal layer of a shoe helps maintain optimal feet microenvironment, such as temperature and humidity while reducing any excessive perspiration.

In an embodiment, a silk coating of the present disclosure is visible. In an embodiment, a silk coating of the present disclosure is transparent. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel helps control skin temperature of a person wearing the apparel. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel helps control fluid transfer away from the skin of a person wearing the apparel. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel has a soft feel against the skin decreasing abrasions from fabric on the skin. In an embodiment, a silk coating of the present disclosure positioned on a textile has properties that confer at least one of wrinkle resistance, shrinkage resistance, or machine washability to the textile. In an embodiment, a silk coated textile of the present disclosure is 100% machine washable and dry cleanable. In an embodiment, a silk coated textile of the present disclosure is 100% waterproof. In an embodiment, a silk coated textile of the present disclosure is wrinkle resistant. In an embodiment, a silk coated textile of the present disclosure is shrink resistant. In an embodiment, a silk coated fabric improves the health of the skin. In an embodiment, healthy skin can be determined by visibly seeing an even skin tone. In an embodiment, healthy skin can be determined by visibly seeing a smooth, glowing complexion. In an embodiment, a silk coated fabric decreases irritation of the skin. In an embodiment, a decrease in irritation of the skin can result in a decrease in skin bumps or sores. In an embodiment, a decrease in irritation of the skin can result in a decrease in scaly or red skin. In an embodiment, a decrease in irritation of the skin can result in a decrease in itchiness or burning. In an embodiment, a silk coated fabric decreases inflammation of the skin. In an embodiment, a silk coated textile of the present disclosure has the qualities of being waterproof, breathable, and elastic and possess a number of other qualities which are highly desirable in action sportswear. In an embodiment, a silk coated textile of the present disclosure manufactured from a silk fabric of the present disclosure further includes LYCRA brand spandex fibers (polyester-polyurethane copolymer).

In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a breathable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a water-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a shrink-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a machine-washable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a wrinkle resistant fabric. In an embodiment, textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure provides moisture and vitamins to the skin.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an accumulative one-way transport index of greater than 140. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an accumulative one-way transport index of greater than 120. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an accumulative one-way transport index of greater than 100. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an accumulative one-way transport index of greater than 80.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an overall moisture management capability of greater than 0.4. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an overall moisture management capability of greater than 0.35. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an overall moisture management capability of greater than 0.3. In an embodiment, the textile at least

partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has an overall moisture management capability of greater than 0.25.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a wetting time of at least 3 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a wetting time of at least 2.5 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a wetting time of at least 2 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a wetting time of at least 1.5 seconds.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a top absorption time of at least 50 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a top absorption time of at least 40 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a top absorption time of at least 30 seconds.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a bottom absorption time of at least 80 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a bottom absorption time of at least 70 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a bottom absorption time of at least 60 seconds. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a bottom absorption time of at least 50 seconds. In an embodiment, the textile at least

partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a bottom absorption time of at least 40 seconds.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a spreading speed of at least 1.6 mm/second. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a spreading speed of at least 1.4 mm/second. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a spreading speed of at least 1.2 mm/second. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a spreading speed of at least 1.0 mm/second. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure has a spreading speed of at least 0.8 mm/second.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% microbial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% microbial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% microbial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% microbial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% microbial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% microbial growth over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% bacterial growth over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% fungal growth over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least

partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% growth of *Staphylococcus aureus* over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% growth of *Klebsiella pneumoniae* over 24 hours.

In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is used to coat a textile. In an embodiment, the

concentration of silk in the solution ranges from about 0.1% to about 20.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.1% to about 15.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.5% to about 10.0%. In an embodiment, the concentration of silk in the solution ranges from about 1.0% to about 5.0%. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is applied directly to a fabric. Alternatively, silk microsphere and any additives may be used for coating a fabric. In an embodiment, additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure before coating (e.g., alcohols) to further enhance material properties. In an embodiment, a silk coating of the present disclosure can have a pattern to optimize properties of the silk on the fabric. In an embodiment, a coating is applied to a fabric under tension and/or lax to vary penetration in to the fabric.

In an embodiment, a silk coating of the present disclosure can be applied at the yarn level, followed by creation of a fabric once the yarn is coated. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure can be spun into fibers to make a silk fabric and/or silk fabric blend with other materials known in the apparel industry.

In an embodiment, a method for silk coating a fabric includes immersion of the fabric in any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure. In an embodiment, a method for silk coating a fabric includes spraying. In an embodiment, a method for silk coating a fabric includes chemical vapor deposition. In an embodiment, a method for silk coating a fabric includes electrochemical coating. In an embodiment, a method for silk coating a fabric includes knife coating to spread any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure onto the fabric. The coated fabric may then be air dried, dried under heat/air flow, or cross-linked to the fabric surface. In an embodiment, a drying process includes curing with additives and/or ambient condition.

According to aspects illustrated herein, methods for preparing aqueous solutions of pure silk fibroin-based protein fragments are disclosed. In an embodiment, at least one pure silk fibroin-based protein fragment (SPF) mixture solution having a specific average

weight average molecular weight (MW) range and polydispersity is created. In an embodiment, at least SPF mixture solution having a MW range between about 6 kDa and 16 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a MW between about 17 kDa and 38 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a MW range between about 39 kDa and 80 kDa and a polydispersity range between about 1.5 and about 3.0 is created.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt% to about 30.0 wt% pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth

factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt% to about 30.0 wt% pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment,

the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10

ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt% to about 30.0 wt% pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a gel that includes pure silk fibroin-based protein fragments substantially devoid of sericin and comprising: an

average weight average molecular weight ranging from about 17 kDa to about 38 kDa; and a polydispersity of between about 1.5 and about 3.0; and water from about 20 wt. % to about 99.9 wt. %, wherein the gel includes between 0 ppm and 500 ppm of inorganic residuals, and wherein the gel includes between 0 ppm and 500 ppm of organic residuals. In an embodiment, the gel includes between about 1.0% and about 50.0% crystalline protein domains. In an embodiment, the gel includes from about 0.1 wt. % to about 6.0 wt. % of pure silk fibroin-based protein fragments. In an embodiment, the gel has a pH from about 1.0 to about 7.0. In an embodiment, the gel further includes from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. In an embodiment, the vitamin C or a derivative thereof remains stable within the gel for a period of from about 5 days to about 5 years. In an embodiment, the vitamin C or a derivative thereof is stable within the gel so as to result in release of the vitamin C in a biologically active form. In an embodiment, the gel further includes an additive selected from the group consisting of vitamin E, rosemary oil, rose oil, lemon juice, lemon grass oil and caffeine. In an embodiment, the gel is packaged in an airtight container. In an embodiment, the pure silk fibroin-based protein fragments are hypoallergenic. In an embodiment, the gel has less than 10 colony forming units per milliliter.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, the method including the steps of: degumming a silk source by adding the silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about

16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, the method including the steps of: adding a silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium

bromide solution that ranges from about 80°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60°C to about 100°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, the method including the steps of: adding a silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60°C to about 100°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the

method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, a method is disclosed for producing silk gels having entrapped molecules or therapeutic agents such as those listed in the following paragraphs. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure during processing into aqueous gels. An aqueous silk gel of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

According to aspects illustrated herein, pure silk fibroin-based protein fragments from aqueous solutions of the present disclosure can be formed into yarns and fabrics including for example, woven or weaved fabrics, and these fabrics can be used in textiles, as described above.

According to aspects illustrated herein, silk fabric manufactured from SPF mixture solutions of the present disclosure are disclosed. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure. A silk film of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently disclosed embodiments will be further explained with reference to the attached drawings. The drawings shown are not necessarily to scale, with emphasis instead generally being placed upon illustrating the principles of the presently disclosed embodiments.

Fig. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure.

Fig. 2 is a flow chart showing various parameters that can be modified during the process of producing SPFs of the present disclosure during the extraction and the dissolution steps.

Fig. 3 is a photograph showing dry extracted silk fibroin.

Fig. 4 is a photograph showing an embodiment of a SPF in the form of a solution of the present disclosure.

Figs. 5A-5D are photographs showing dissolved silk in room temperature lithium bromide (LiBr) solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 6A-6D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 7A-7D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60°C oven for 8 hours (sericin extraction temperature and time were varied).

Figs. 8A-8D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60°C oven for 12 hours (sericin extraction temperature and time were varied).

Figs. 9A-9D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60°C oven for 24 hours (sericin extraction temperature and time were varied).

Figs. 10A-10C are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60°C oven for 168/192 hours (sericin extraction temperature and time were varied).

Figs. 11A-11C are photographs showing dissolved silk in room temperature LiBr solutions dissolved in 60°C oven for 1, 4, and 6 hours, where sericin extraction was completed at 100°C for 60 min.

Figs. 12A-12D are photographs showing dissolved silk in 60°C LiBr solutions dissolved in a 60°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 13A-13D are photographs showing dissolved silk in 60°C LiBr solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 14A-14D are photographs showing dissolved silk in 60°C LiBr solutions dissolved in a 60°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 15A-15D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 60°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 16A-16D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 17A-17D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 18A-18D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 60°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 19A-19D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 20A-20D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 60°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 21A-21D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 60°C oven for 1 hour (sericin extraction temperature and time were varied time).

Figs. 22A-22D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 60°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 23A-23D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 60°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 24A-24D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 80°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 25A-25D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 80°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 26A-26D are photographs showing dissolved silk in 80°C LiBr solutions dissolved in a 80°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 27A-27D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 100°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 28A-28D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 100°C oven for 4 hours (sericin extraction temperature and time were varied).

Figs. 29A-29D are photographs showing dissolved silk in 100°C LiBr solutions dissolved in a 100°C oven for 6 hours (sericin extraction temperature and time were varied).

Figs. 30A-30D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 120°C oven for 1 hour (sericin extraction temperature and time were varied).

Figs. 31A-31D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 120°C oven for 4 hours (sericin extraction temperature and time were varied).

Fig. 32A-32D are photographs showing dissolved silk in 140°C (boiling point for LiBr) LiBr solutions dissolved in a 120°C oven for 6 hours (sericin extraction temperature and time were varied).

Fig. 33 shows HPLC chromatograms from samples comprising vitamin C. **Fig. 33** shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible.

Fig. 34 is a table summarizing the LiBr and Sodium Carbonate (Na_2CO_3) concentration in silk protein solutions of the present disclosure.

Fig. 35 is a table summarizing the LiBr and Na_2CO_3 concentration in silk protein solutions of the present disclosure.

Fig. 36 is a table summarizing the stability of vitamin C in chemically stabilized solutions.

Fig. 37 is a table summarizing the Molecular Weights of silk protein solutions of the present disclosure.

Figs. 38A and **38B** are graphs representing the effect of extraction volume on % mass loss.

Fig. 39 is a table summarizing the Molecular Weights of silk dissolved from different concentrations of LiBr and from different extraction and dissolution sizes.

Fig. 40 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 100°C LiBr and 100°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 41 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, boiling LiBr and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 42 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 60°C LiBr and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 43 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 80°C LiBr and 80°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 44 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 80°C LiBr and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 45 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 100°C LiBr and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 46 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 140°C LiBr and 140°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 47 is a graph summarizing the effect of Extraction Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100°C LiBr and 100°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 48 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100°C Extraction Temperature and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 49 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 30 minute Extraction Time, 100°C Extraction Temperature and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Fig. 50 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 30 minute Extraction Time, and 100°C Lithium Bromide (Oven/Dissolution Time was varied).

Fig. 51 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 60 minute Extraction Time, and 100°C Lithium Bromide. (Oven/Dissolution Time was varied).

Fig. 52 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 60 minute Extraction Time, and 140°C Lithium Bromide (Oven/Dissolution Time was varied).

Fig. 53 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 30 minute Extraction Time, and 140°C Lithium Bromide (Oven/Dissolution Time was varied).

Fig. 54 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100°C Extraction Temperature, 60 minute Extraction Time, and 80°C Lithium Bromide (Oven/Dissolution Time was varied).

Fig. 55 is a graph summarizing the Molecular Weights of silk processed under varying conditions including Extraction Time, Extraction Temperature, Lithium Bromide (LiBr) Temperature, Oven Temperature for Dissolution, Oven Time for Dissolution.

Fig. 56 is a graph summarizing the Molecular Weights of silk processed under conditions in which Oven/Dissolution Temperature is equal to LiBr Temperature.

Fig. 57A is a graph illustrating wetting time with spray coating.

Fig. 57B is a graph illustrating wetting time with stencil coating.

Fig. 57C is a graph illustrating wetting time with bath coating.

Fig. 57D is a graph illustrating wetting time with screen coating.

Fig. 58A is a graph illustrating absorption time with spray coating.

Fig. 58B is a graph illustrating absorption time with stencil coating.

Fig. 58C is a graph illustrating absorption time with bath coating.

Fig. 58D is a graph illustrating absorption time with screen coating.

Fig. 59A is a graph illustrating spreading speed with spray coating.

Fig. 59B is a graph illustrating spreading speed with stencil coating.

Fig. 59C is a graph illustrating spreading speed with bath coating.

Fig. 59D is a graph illustrating spreading speed with screen coating.

Fig. 60A is a graph illustrating accumulative one way transport index with spray coating.

Fig. 60B is a graph illustrating accumulative one way transport index with stencil coating.

Fig. 60C is a graph illustrating accumulative one way transport index with bath coating.

Fig. 60D is a graph illustrating accumulative one way transport index with screen coating.

Fig. 61A is a graph illustrating overall moisture management capability with spray coating.

Fig. 61B is a graph illustrating overall moisture management capability with stencil coating.

Fig. 61C is a graph illustrating overall moisture management capability with bath coating.

Fig. 61D is a graph illustrating overall moisture management capability with screen coating.

Fig. 62A is a graph illustrating wetting time top.

Fig. 62B is a graph illustrating wetting time bottom.

Fig. 63A is a graph illustrating top absorption rate.

Fig. 63B is a graph illustrating bottom absorption rate.

Fig. 64A is a graph illustrating top max wetted radius.

Fig. 64B is a graph illustrating bottom max wetted radius.

Fig. 65A is a graph illustrating top spreading speed.

Fig. 65B is a graph illustrating bottom spreading speed.

Fig. 66A is a graph illustrating accumulative one-way transport index.

Fig. 66B is a graph illustrating overall moisture management capability.

Fig. 67A is a graph illustrating wetting time of non-wicking finished.

Fig. 67B is a graph illustrating wetting time of semi-finished before final setting.

Fig. 68A is a graph illustrating absorption time of non-wicking finished.

Fig. 68B is a graph illustrating absorption time of semi-finished before final setting.

Fig. 69A is a graph illustrating spreading speed of non-wicking finished.

Fig. 69B is a graph illustrating spreading speed of semi-finished before final setting.

Fig. 70A is a graph illustrating accumulative one way transport index of non-wicking finished.

Fig. 70B is a graph illustrating accumulative one way transport index of semi-finished before final setting.

Fig. 71A is a graph illustrating overall moisture management capability of non-wicking finished.

Fig. 71B is a graph illustrating overall moisture management capability of semi-finished before final setting.

Fig. 72A is a graph illustrating wetting time with spray coating.

Fig. 72B is a graph illustrating wetting time with stencil coating.

Fig. 72C is a graph illustrating wetting time with bath coating.

Fig. 73A is a graph illustrating absorption time with spray coating.

Fig. 73B is a graph illustrating absorption time with stencil coating.

Fig. 73C is a graph illustrating absorption time with bath coating.

Fig. 74A is a graph illustrating spreading speed with spray coating.

Fig. 74B is a graph illustrating spreading speed with stencil coating.

Fig. 74C is a graph illustrating spreading speed with bath coating.

Fig. 75A is a graph illustrating accumulative one way transport index with spray coating.

Fig. 75B is a graph illustrating accumulative one way transport index with stencil coating.

Fig. 75C is a graph illustrating accumulative one way transport index with bath coating.

Fig. 76A is a graph illustrating overall moisture management capability with spray coating.

Fig. 76B is a graph illustrating overall moisture management capability with stencil coating.

Fig. 76C is a graph illustrating overall moisture management capability with bath coating.

Fig. 77A is a graph illustrating wetting time with 1%SFS.

Fig. 77B is a graph illustrating wetting time with 0.1% SFS.

Fig. 78A is a graph illustrating absorption time with 1% SFS.

Fig. 78B is a graph illustrating absorption time with 0.1% SFS.

Fig. 79A is a graph illustrating spreading speed with 1% SFS.

Fig. 79B is a graph illustrating spreading speed with 0.1% SFS.

Fig. 80A is a graph illustrating accumulative one way transport index with 1% SFS.

Fig. 80B is a graph illustrating accumulative one way transport index with 0.1% SFS.

Fig. 81A is a graph illustrating overall moisture management capability with 1% SFS.

Fig. 81B is a graph illustrating overall moisture management capability with 0.1% SFS.

Fig. 82A is a graph illustrating summary of wetting time top.

Fig. 82B is a graph illustrating summary of wetting time bottom.

Fig. 83A is a graph illustrating summary of top absorption rate.

Fig. 83B is a graph illustrating summary of bottom absorption rate.

Fig. 84A is a graph illustrating summary of top max wetted radius.

Fig. 84B is a graph illustrating summary of bottom wetted radius.

Fig. 85A is a graph illustrating summary of top spreading speed.

Fig. 85B is a graph illustrating summary of bottom spreading speed.

Fig. 86A is a graph illustrating summary of accumulative one-way transport index.

Fig. 86B is a graph illustrating summary of overall moisture management capability.

Fig. 87 illustrates bacterial growth results.

Fig. 88 illustrates bacterial growth results.

Fig. 89 illustrates bacterial growth results.

Fig. 90 illustrates bacterial growth results.

Fig. 91 illustrates bacterial growth results.

Fig. 92 illustrates bacterial growth results.

Fig. 93 illustrates accumulative one-way transport index versus fabric washing cycles.

Fig. 94 illustrates overall moisture management capability (OMMC) versus fabric washing cycles.

Fig. 95 illustrates wetting time at the top of the fabric versus fabric washing cycles.

Fig. 96 illustrates wetting time at the bottom of the fabric versus fabric washing cycles.

Fig. 97 illustrates absorption rate at the top of the fabric versus fabric washing cycles.

Fig. 98 illustrates absorption rate at the bottom of the fabric versus fabric washing cycles.

Fig. 99 illustrates spreading speed at the top of the fabric versus fabric washing cycles.

Fig. 100 illustrates spreading speed at the bottom of the fabric versus fabric washing cycles.

Fig. 101 illustrates wetted radius at the top of the fabric versus fabric washing cycles.

Fig. 102 illustrates wetted radius at the bottom of the fabric versus fabric washing cycles.

Fig. 103 illustrates percent reduction in growth of *Staphylococcus aureus* ATCC 6538 versus fabric washing cycles.

Fig. 104 illustrates percent reduction in growth of *Klebisiella pneumoniae* ATCC 4354 versus fabric washing cycles.

Fig. 105 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (first view).

Fig. 106 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (second view).

Fig. 107 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (third view).

Fig. 108 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (fourth view).

Fig. 109 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (first view).

Fig. 110 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (second view).

Fig. 111 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (third view).

Fig. 112 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (fourth view).

Fig. 113 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (fifth view).

Fig. 114 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (sixth view).

Fig. 115 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (seventh view).

Fig. 116 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (first view).

Fig. 117 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (second view).

Fig. 118 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (third view).

Fig. 119 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (fourth view).

Fig. 120 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (fifth view).

Fig. 121 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (first view).

Fig. 122 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (second view).

Fig. 123 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (third view).

Fig. 124 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (fourth view).

Fig. 125 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (fifth view).

Fig. 126 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (sixth view).

Fig. 127 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (seventh view).

Fig. 128 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (eighth view).

Fig. 129 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (ninth view).

Fig. 130 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (first view).

Fig. 131 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (second view).

Fig. 132 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (third view).

Fig. 133 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (fourth view).

Fig. 134 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (fifth view).

Fig. 135 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (sixth view).

Fig. 136 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (seventh view).

Fig. 137 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (first view).

Fig. 138 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (second view).

Fig. 139 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (third view).

Fig. 140 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (fourth view).

Fig. 141 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (fifth view).

Fig. 142 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (sixth view).

Fig. 143 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (seventh view).

Fig. 144 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (eighth view).

Fig. 145 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (ninth view).

Fig. 146 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (first view).

Fig. 147 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (second view).

Fig. 148 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (third view).

Fig. 149 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (fourth view).

Fig. 150 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (fifth view).

Fig. 151 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (sixth view).

Fig. 152 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (seventh view).

Fig. 153 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (eighth view).

Fig. 154 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-B (ninth view).

Fig. 155 illustrates a scanning electron microscopy image of fabric sample FAB-10-SPRAY-C.

Fig. 156 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (first view).

Fig. 157 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (second view).

Fig. 158 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (third view).

Fig. 159 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (fourth view).

Fig. 160 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (fifth view).

Fig. 161 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (sixth view).

Fig. 162 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (seventh view).

Fig. 163 illustrates a scanning electron microscopy image of fabric sample FAB-10-STEN-B (eighth view).

Fig. 164 illustrates a scanning electron microscopy image of a fabric control sample (first view).

Fig. 165 illustrates a scanning electron microscopy image of a fabric control sample (second view).

Fig. 166 illustrates a scanning electron microscopy image of a fabric control sample (third view).

Fig. 167 illustrates a scanning electron microscopy image of a fabric control sample (fourth view).

Fig. 168 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (first view).

Fig. 169 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (second view).

Fig. 170 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (third view).

Fig. 171 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (fourth view).

Fig. 172 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (fifth view).

Fig. 173 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (sixth view).

Fig. 174 illustrates a scanning electron microscopy image of film sample FIL-01-BATH-B-01MYL (seventh view).

Fig. 175 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (first view).

Fig. 176 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (second view).

Fig. 177 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (third view).

Fig. 178 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (fourth view).

Fig. 179 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (fifth view).

Fig. 180 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (sixth view).

Fig. 181 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (seventh view).

Fig. 182 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-01MYL (eighth view).

Fig. 183 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-007MYL (first view).

Fig. 184 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-007MYL (second view).

Fig. 185 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-007MYL (third view).

Fig. 186 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-007MYL (fourth view).

Fig. 187 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-007MYL (fifth view).

Fig. 188 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section (first view).

Fig. 189 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section (second view).

Fig. 190 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section (third view).

Fig. 191 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section (fourth view).

Fig. 192 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-C-01MYL (first view).

Fig. 193 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-C-01MYL (second view).

Fig. 194 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-C-01MYL (third view).

Fig. 195 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-C-01MYL (fourth view).

Fig. 196 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-C-01MYL (fifth view).

Fig. 197 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-B-01-MYL (first view).

Fig. 198 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-B-01-MYL (second view).

Fig. 199 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-B-01-MYL (third view).

Fig. 200 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-B-01-MYL (fourth view).

Fig. 201 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (first view).

Fig. 202 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (second view).

Fig. 203 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (third view).

Fig. 204 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (fourth view).

Fig. 205 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (fifth view).

Fig. 206 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (sixth view).

Fig. 207 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (first view).

Fig. 208 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (second view).

Fig. 209 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (third view).

Fig. 210 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (fourth view).

Fig. 211 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (fifth view).

Fig. 212 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (sixth view).

Fig. 213 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (seventh view).

Fig. 214 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (first view).

Fig. 215 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (second view).

Fig. 216 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (third view).

Fig. 217 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (fourth view).

Fig. 218 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (fifth view).

Fig. 219 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-C-01MYL_cross-section (first view).

Fig. 220 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (first view).

Fig. 221 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (second view).

Fig. 222 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (third view).

Fig. 223 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (fourth view).

Fig. 224 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (fifth view).

Fig. 225 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (sixth view).

Fig. 226 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (first view).

Fig. 227 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (second view).

Fig. 228 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (third view).

Fig. 229 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (fourth view).

Fig. 230 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (fifth view).

Fig. 231 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (sixth view).

Fig. 232 illustrates a scanning electron microscopy image of film sample Melinex Control (first view).

Fig. 233 illustrates a scanning electron microscopy image of film sample Melinex Control (second view).

Fig. 234 illustrates a scanning electron microscopy image of film sample Melinex Control (third view).

Fig. 235 illustrates a scanning electron microscopy image of film sample Melinex Control (fourth view).

Fig. 236 illustrates a scanning electron microscopy image of film sample Mylar Control (first view).

Fig. 237 illustrates a scanning electron microscopy image of film sample Mylar Control (second view).

Fig. 238 illustrates a scanning electron microscopy image of film sample Mylar Control (third view).

Fig. 239 illustrates a scanning electron microscopy image of film sample Mylar Control (fourth view).

Fig. 240 illustrates a scanning electron microscopy image of film sample Mylar Control (fifth view).

Fig. 241 shows results from optical profiling measurements on the Mylar Control sample taken at the top, location 1 (shiny side).

Fig. 242 shows results from optical profiling measurements on the Mylar Control sample taken at the bottom, location 2 (more matte side).

Fig. 243 shows results from optical profiling measurements on the Melinex Control sample taken at the top, location 1.

Fig. 244 shows results from optical profiling measurements on the Melinex Control sample taken at the bottom, location 2.

Fig. 245 shows results from optical profiling measurements on sample FIL-10-SPRAY-B-01MYL taken at the top, location 1.

Fig. 246 shows results from optical profiling measurements on sample FIL-10-SPRAY-B-01MYL taken at the bottom, location 2.

Fig. 247 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-01MYL taken at the top, location 1.

Fig. 248 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-01MYL taken at the bottom, location 2.

Fig. 249 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-007MEL taken the top, location 1.

Fig. 250 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-007MEL taken at the bottom, location 2.

Fig. 251 shows results from optical profiling measurements on sample FIL-01-SPRAY-C-01MYL taken at the top, location 1.

Fig. 252 shows results from optical profiling measurements on sample FIL-01-SPRAY-C-01MYL taken at bottom, location 2

Fig. 253 shows results from optical profiling measurements on sample FIL-01-STEN-B-01MYL taken at the top, location 1.

Fig. 254 shows results from optical profiling measurements on sample FIL-01-STEN-B-01MYL taken at the bottom, location 2.

Fig. 255 shows results from optical profiling measurements on sample FIL-01-STEN-C-01MYL taken at the top, location 1.

Fig. 256 shows results from optical profiling measurements on sample FIL-01-STEN-C-01MYL taken at the bottom, location 2.

Fig. 257 shows results from optical profiling measurements on sample FIL-10-BATH-B-01MYL taken at the top, location 1.

Fig. 258 shows results from optical profiling measurements on sample FIL-10-BATH-B-01MYL taken at the bottom, Location 2.

Fig. 259 shows results from optical profiling measurements on sample FIL-10-BATH-B-007MEL taken at the top, location 1.

Fig. 260 shows results from optical profiling measurements on sample FIL-10-BATH-B-007MEL taken at the bottom, location 2.

Fig. 261 shows results from optical profiling measurements on sample FIL-10-BATH-C-01MYL taken at top, location 1.

Fig. 262 shows results from optical profiling measurements on sample FIL-10-BATH-C-01MYL taken at the bottom, location 2.

Fig. 263 shows results from optical profiling measurements on sample FIL-01-BATH-B-01MYL taken at the top, location 1.

Fig. 264 shows results from optical profiling measurements on sample FIL-01-BATH-B-01MYL taken at the bottom, location 2.

Fig. 265 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section.

Fig. 266 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section.

Fig. 267 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL_cross-section.

Fig. 268 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-C-01MYL_cross-section.

Fig. 269 illustrates accumulative one-way transport index results for natural fibers.

Fig. 270 illustrates overall moisture management capability for natural fibers.

While the above-identified drawings set forth presently disclosed embodiments, other embodiments are also contemplated, as noted in the discussion. This disclosure presents illustrative embodiments by way of representation and not limitation. Numerous other modifications and embodiments can be devised by those skilled in the art which fall within the scope and spirit of the principles of the presently disclosed embodiments.

DETAILED DESCRIPTION OF THE INVENTION

Provided herein are methods for producing pure and highly scalable silk protein fragment (SPF) mixture solutions that may be used to coat at least a portion of textiles or

may be formed into usable fibers for weaving into yarn. The solutions are generated from raw pure intact silk protein material and processed in order to remove any sericin and achieve the desired weight average molecular weight (MW) and polydispersity of the fragment mixture. Select method parameters may be altered to achieve distinct final silk protein fragment characteristics depending upon the intended use. The resulting final fragment solution is pure silk protein fragments and water with PPM to non-detectable levels of process contaminants. The concentration, size and polydispersity of silk protein fragments in the solution may further be altered depending upon the desired use and performance requirements. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the solutions may be used to generate articles, such as silk gels of varying gel and liquid consistencies by varying water content/concentration, or sold as a raw ingredient into the consumer market.

As used herein, the terms “substantially sericin free” or “substantially devoid of sericin” refer to silk fibers in which a majority of the sericin protein has been removed. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 10.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 9.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 8.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 7.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk

fibroin having between about 0.01% (w/w) and about 6.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 5.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.05% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.1% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content between about 0.01% (w/w) and about 0.1 % (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.1 % (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.05 % (w/w). In an embodiment, when a silk source is added to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes, a degumming loss of about 26 wt. % to about 31 wt.% is obtained.

As used herein, the term “substantially homogeneous” may refer to pure silk fibroin-based protein fragments that are distributed in a normal distribution about an identified molecular weight. As used herein, the term “substantially homogeneous” may refer to an even distribution of additive, for example vitamin C, throughout a composition of the present disclosure.

As used herein, the term "substantially free of inorganic residuals" means that the composition exhibits residuals of 0.1 % (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of inorganic residuals is between 0 ppm ("non-detectable" or "ND") and 1000 ppm. In an embodiment, the amount of inorganic residuals is ND to about 500 ppm. In an embodiment, the amount of inorganic residuals is ND to about 400 ppm. In an embodiment, the amount of inorganic residuals is ND to about 300 ppm. In an embodiment, the amount of inorganic residuals is ND to about 200 ppm. In an embodiment, the amount of inorganic residuals is ND to about 100 ppm. In an embodiment, the amount of inorganic residuals is between 10 ppm and 1000 ppm.

As used herein, the term "substantially free of organic residuals" means that the composition exhibits residuals of 0.1 % (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of organic residuals is between 0 ppm ("non-detectable" or "ND") and 1000 ppm. In an embodiment, the amount of organic residuals is ND to about 500 ppm. In an embodiment, the amount of organic residuals is ND to about 400 ppm. In an embodiment, the amount of organic residuals is ND to about 300 ppm. In an embodiment, the amount of organic residuals is ND to about 200 ppm. In an embodiment, the amount of organic residuals is ND to about 100 ppm. In an embodiment, the amount of organic residuals is between 10 ppm and 1000 ppm.

Compositions of the present disclosure exhibit "biocompatibility" meaning that the compositions are compatible with living tissue or a living system by not being toxic, injurious, or physiologically reactive and not causing immunological rejection. Such biocompatibility can be evidenced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an

embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely.

Compositions of the present disclosure are "hypoallergenic" meaning that they are relatively unlikely to cause an allergic reaction. Such hypoallergenicity can be evidenced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely.

As used herein, the term "washable" and "exhibiting washability" means that a silk coated fabric of the present disclosure is capable of being washed without shrinking, fading, or the like.

As used herein, the term "textile" refers to a flexible woven material consisting of a network of natural or artificial fibers often referred to as thread or yarn. In an embodiment, textiles can be used to fabricate clothing, shoes and bags. In an embodiment, textiles can be used to fabricate carpeting, upholstered furnishings, window shades, towels, and coverings for tables, beds, and other flat surfaces. In an embodiment, textiles can be used to fabricate flags, backpacks, tents, nets, handkerchiefs, balloons, kites, sails, and parachutes.

As used herein, the term "hand" refers to the feel of a fabric, which may be further described as the feeling of softness, crispness, dryness, silkiness, and combinations thereof. Fabric hand is also referred to as "drape." A fabric with a hard hand is coarse, rough, and generally less comfortable for the wearer. A fabric with a soft

hand is fluid and smooth, such as fine silk or wool, and generally more comfortable for the wearer. Fabric hand can be determined by comparison to collections of fabric samples, or by use of methods such as the Kawabata Evaluation System (KES) or the Fabric Assurance by Simple Testing (FAST) methods. Behera and Hari, *Ind. J. Fibre & Textile Res.*, **1994,** *19,* 168-71.

As used herein, the term "yarn" refers to a single or multi-fiber construct.

As used herein, the term "bath coating" encompasses coating a fabric in a batch, immersing a fabric in a bath, and submerging a fabric in a bath.

In an embodiment, the silk coating is applied using a bath process, a screen (or stencil) process, a spray process, a silk-foam based process, and a roller based process.

In an embodiment, a fiber or a yarn comprises a synthetic fiber or yarn, including polyester, Mylar, cotton, nylon, polyester-polyurethane copolymer, rayon, acetate, aramid (aromatic polyamide), acrylic, ingeo (polylactide), lurex (polyamide-polyester), olefin (polyethylene-polypropylene), and combinations thereof.

In an embodiment, a fiber or a yarn comprises a natural fiber or yarn, including alpaca fiber, alpaca fleece, alpaca wool, lama fiber, lama fleece, lama wool, cotton, cashmere and sheep fiber, sheep fleece, and sheep wool.

In an embodiment, a water-soluble silk coating may be used as an adhesive or binder for binding particles to fabrics or for binding fabrics. In an embodiment, an article comprises a fabric bound to another fabric using a silk coating. In an embodiment, an article comprises a fabric with particles bound to the fabric using a silk adhesive.

In an embodiment, the coating is applied to an article including a fabric at the yarn level. In an embodiment, the coating is applied at the fabric level. In an embodiment, the coating has a thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 μm, about 5 μm, about 10 μm, and about 20 μm. In an embodiment, the coating has a thickness range selected from the group consisting of about 5 nm to about 100 nm, about 100 nm to about 200 nm, about 200 nm to about

500 nm, about 1 μm to about 2 μm, about 2 μm to about 5 μm, about 5 μm to about 10 μm, and about 10 μm to about 20 μm.

In an embodiment, a fiber or a yarn is treated with a polymer, such as polyglycolide (PGA), polyethylene glycols, copolymers of glycolide, glycolide/L-lactide copolymers (PGA/PLLA), glycolide/trimethylene carbonate copolymers (PGA/TMC), polylactides (PLA), stereocopolymers of PLA, poly-L-lactide (PLLA), poly-DL-lactide (PDLLA), L-lactide/DL-lactide copolymers, co-polymers of PLA, lactide/tetramethylglycolide copolymers, lactide/trimethylene carbonate copolymers, lactide/δ-valerolactone copolymers, lactide/ε-caprolactone copolymers, polydepsipeptides, PLA/polyethylene oxide copolymers, unsymmetrically 3,6-substituted poly-1,4-dioxane-2,5-diones, poly-β-hydroxybutyrate (PHBA), PHBA/β-hydroxyvalerate copolymers (PHBA/HVA), poly-β-hydroxypropionate (PHPA), poly-p-dioxanone (PDS), poly-δ-valerolactone, poly-ε-caprolactone, methylmethacrylate-N-vinyl pyrrolidine copolymers, polyesteramides, polyesters of oxalic acid, polydihydropyrans, polyalkyl-2-cyanoacrylates, polyurethanes (PU), polyvinylalcohols (PVA), polypeptides, poly-β-malic acid (PMLA), poly-β-alkanoic acids, polyvinylalcohol (PVA), polyethyleneoxide (PEO), chitine polymers, polyethylene, polypropylene. polyasetal, polyamides, polyesters, polysulphone, polyether ether ketone, polyethylene terephthalate, polycarbonate, polyaryl ether ketone, and polyether ketone ketone.

In an embodiment, the silk coating surface can be modified silk crystals that range in size from nm to μm.

The criterion for "visibility" is satisfied by any one of the following: a change in the surface character of the textile; the silk coating fills the interstices where the yarns intersect; or the silk coating blurs or obscures the weave.

In an embodiment, a silk based protein or fragment solution may be utilized to coat at least a portion of a fabric which can be used to create a textile. In an embodiment, a silk based protein or fragment solution may be weaved into yarn that can be used as a fabric in a textile. In an embodiment, a silk based protein or fragment solution may be used to coat a fiber. In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating at least a portion of a fabric or a textile.

In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating a yarn. In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating a fiber.

In an embodiment, a solution of the present disclosure is contacted with an additive, such as a therapeutic agent and/or a molecule. In an embodiment, molecules include, but are not limited to, antioxidants and enzymes. In an embodiment, molecules include, but are not limited to, ceramics, ceramic particles, metals, metal particles, polymer particles, inorganic particles, organic particles, selenium, ubiquinone derivatives, thiol-based antioxidants, saccharide-containing antioxidants, polyphenols, botanical extracts, caffeic acid, apigenin, pycnogenol, resveratrol, folic acid, vitamin B12, vitamin B6, vitamin B3, vitamin E, vitamin C and derivatives thereof, vitamin D, vitamin A, astaxathin, Lutein, lycopene, essential fatty acids (omegas 3 and 6), iron, zinc, magnesium, flavonoids (soy, Curcumin, Silymarin, Pycnongeol), growth factors, aloe, hyaluronic acid, extracellular matrix proteins, cells, nucleic acids, biomarkers, biological reagents, zinc oxide, benzyol peroxide, retnoids, titanium, allergens in a known dose (for sensitization treatment), essential oils including, but not limited to, lemongrass or rosemary oil, and fragrances. Therapeutic agents include, but are not limited to, small molecules, drugs, proteins, peptides and nucleic acids. In an embodiment, a solution of the present disclosure is contacted with an allergen of known quantity prior to forming the article. Allergens include but are not limited to milk, eggs, peanuts, tree nuts, fish, shellfish, soy and wheat. Known doses of allergen loaded within a silk article can be released at a known rate for controlled exposure allergy study, tests and sensitization treatment.

In an embodiment, a solution of the present disclosure is used to create an article with microneedles by standard methods known to one in the art for controlled delivery of molecules or therapeutic agents to or through the skin.

As used herein, the term “fibroin” includes silkworm fibroin and insect or spider silk protein. In an embodiment, fibroin is obtained from *Bombyx mori*. In an embodiment, the spider silk protein is selected from the group consisting of swathing silk (Achniform gland silk), egg sac silk (Cylindriform gland silk), egg case silk (Tubuliform

silk), non-sticky dragline silk (Ampullate gland silk), attaching thread silk (Pyriform gland silk), sticky silk core fibers (Flagelliform gland silk), and sticky silk outer fibers (Aggregate gland silk).

Fig. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure. As illustrated in **Fig. 1**, **step A**, cocoons (heat-treated or non-heat-treated), silk fibers, silk powder or spider silk can be used as the silk source. If starting from raw silk cocoons from *Bombyx mori*, the cocoons can be cut into small pieces, for example pieces of approximately equal size, **step B1**. The raw silk is then extracted and rinsed to remove any sericin, **step C1a**. This results in substantially sericin free raw silk. In an embodiment, water is heated to a temperature between 84°C and 100°C (ideally boiling) and then Na_2CO_3 (sodium carbonate) is added to the boiling water until the Na_2CO_3 is completely dissolved. The raw silk is added to the boiling water/Na_2CO_3 (100°C) and submerged for approximately 15 - 90 minutes, where boiling for a longer time results in smaller silk protein fragments. In an embodiment, the water volume equals about 0.4 x raw silk weight and the Na_2CO_3 volume equals about 0.848 x raw silk weight. In an embodiment, the water volume equals 0.1 x raw silk weight and the Na_2CO_3 volume is maintained at 2.12g/L. This is demonstrated in **Fig. 38A** and **Fig. 38B** silk mass (x-axis) was varied in the same volume of extraction solution (i.e., the same volume of water and concentration of Na_2CO_3) achieving sericin removal (substantially sericin free) as demonstrated by an overall silk mass loss of 26 to 31 percent (y-axis). Subsequently, the water dissolved Na_2CO_3 solution is drained and excess water/Na_2CO_3 is removed from the silk fibroin fibers (e.g., ring out the fibroin extract by hand, spin cycle using a machine, etc.). The resulting silk fibroin extract is rinsed with warm to hot water to remove any remaining adsorbed sericin or contaminate, typically at a temperature range of about 40°C to about 80°C, changing the volume of water at least once (repeated for as many times as required). The resulting silk fibroin extract is a substantially sericin-depleted silk fibroin. In an embodiment, the resulting silk fibroin extract is rinsed with water at a temperature of about 60°C. In an embodiment, the volume of rinse water for each cycle equals 0.1 L to 0.2 L x raw silk weight. It may

be advantageous to agitate, turn or circulate the rinse water to maximize the rinse effect. After rinsing, excess water is removed from the extracted silk fibroin fibers (e.g., ring out fibroin extract by hand or using a machine). Alternatively, methods known to one skilled in the art such as pressure, temperature, or other reagents or combinations thereof may be used for the purpose of sericin extraction. Alternatively, the silk gland (100% sericin free silk protein) can be removed directly from a worm. This would result in liquid silk protein, without any alteration of the protein structure, free of sericin.

The extracted fibroin fibers are then allowed to dry completely. **Fig. 3** is a photograph showing dry extracted silk fibroin. Once dry, the extracted silk fibroin is dissolved using a solvent added to the silk fibroin at a temperature between ambient and boiling, **step C1b**. In an embodiment, the solvent is a solution of Lithium bromide (LiBr) (boiling for LiBr is 140°C). Alternatively, the extracted fibroin fibers are not dried but wet and placed in the solvent; solvent concentration can then be varied to achieve similar concentrations as to when adding dried silk to the solvent. The final concentration of LiBr solvent can range from 0.1M to 9.3M. **Fig. 39** is a table summarizing the Molecular Weights of silk dissolved from different concentrations of Lithium Bromide (LiBr) and from different extraction and dissolution sizes. Complete dissolution of the extracted fibroin fibers can be achieved by varying the treatment time and temperature along with the concentration of dissolving solvent. Other solvents may be used including, but not limited to, phosphate phosphoric acid, calcium nitrate, calcium chloride solution or other concentrated aqueous solutions of inorganic salts. To ensure complete dissolution, the silk fibers should be fully immersed within the already heated solvent solution and then maintained at a temperature ranging from about 60°C to about 140°C for 1-168 hrs. In an embodiment, the silk fibers should be fully immersed within the solvent solution and then placed into a dry oven at a temperature of about 100°C for about 1 hour.

The temperature at which the silk fibroin extract is added to the LiBr solution (or vice versa) has an effect on the time required to completely dissolve the fibroin and on the resulting molecular weight and polydispersity of the final SPF mixture solution. In an embodiment, silk solvent solution concentration is less than or equal to 20% w/v. In addition, agitation during introduction or dissolution may be used to facilitate dissolution at varying temperatures and concentrations. The temperature of the LiBr solution will

provide control over the silk protein fragment mixture molecular weight and polydispersity created. In an embodiment, a higher temperature will more quickly dissolve the silk offering enhanced process scalability and mass production of silk solution. In an embodiment, using a LiBr solution heated to a temperature between 80°C - 140°C reduces the time required in an oven in order to achieve full dissolution. Varying time and temperature at or above 60°C of the dissolution solvent will alter and control the MW and polydispersity of the SPF mixture solutions formed from the original molecular weight of the native silk fibroin protein.

Alternatively, whole cocoons may be placed directly into a solvent, such as LiBr, bypassing extraction, **step B2**. This requires subsequent filtration of silk worm particles from the silk and solvent solution and sericin removal using methods know in the art for separating hydrophobic and hydrophilic proteins such as a column separation and/or chromatography, ion exchange, chemical precipitation with salt and/or pH, and or enzymatic digestion and filtration or extraction, all methods are common examples and without limitation for standard protein separation methods, **step C2**. Non-heat treated cocoons with the silkworm removed, may alternatively be placed into a solvent such as LiBr, bypassing extraction. The methods described above may be used for sericin separation, with the advantage that non-heat treated cocoons will contain significantly less worm debris.

Dialysis may be used to remove the dissolution solvent from the resulting dissolved fibroin protein fragment solution by dialyzing the solution against a volume of water, **step E1**. Pre-filtration prior to dialysis is helpful to remove any debris (i.e., silk worm remnants) from the silk and LiBr solution, **step D**. In one example, a 3μm or 5μm filter is used with a flow-rate of 200-300mL/min to filter a 0.1% to 1.0% silk-LiBr solution prior to dialysis and potential concentration if desired. A method disclosed herein, as described above, is to use time and/or temperature to decrease the concentration from 9.3M LiBr to a range from 0.1M to 9.3M to facilitate filtration and downstream dialysis, particularly when considering creating a scalable process method. Alternatively, without the use of additional time or temperate, a 9.3M LiBr-silk protein fragment solution may be diluted with water to facilitate debris filtration and dialysis.

The result of dissolution at the desired time and temperate filtration is a translucent particle-free room temperature shelf-stable silk protein fragment-LiBr solution of a known MW and polydispersity. It is advantageous to change the dialysis water regularly until the solvent has been removed (e.g., change water after 1 hour, 4 hours, and then every 12 hours for a total of 6 water changes). The total number of water volume changes may be varied based on the resulting concentration of solvent used for silk protein dissolution and fragmentation. After dialysis, the final silk solution maybe further filtered to remove any remaining debris (i.e., silk worm remnants).

Alternatively, Tangential Flow Filtration (TFF), which is a rapid and efficient method for the separation and purification of biomolecules, may be used to remove the solvent from the resulting dissolved fibroin solution, **step E2**. TFF offers a highly pure aqueous silk protein fragment solution and enables scalability of the process in order to produce large volumes of the solution in a controlled and repeatable manner. The silk and LiBr solution may be diluted prior to TFF (20% down to 0.1% silk in either water or LiBr). Pre-filtration as described above prior to TFF processing may maintain filter efficiency and potentially avoids the creation of silk gel boundary layers on the filter's surface as the result of the presence of debris particles. Pre-filtration prior to TFF is also helpful to remove any remaining debris (i.e., silk worm remnants) from the silk and LiBr solution that may cause spontaneous or long-term gelation of the resulting water only solution, **step D**. TFF, recirculating or single pass, may be used for the creation of water-silk protein fragment solutions ranging from 0.1% silk to 30.0% silk (more preferably, 0.1% - 6.0% silk). Different cutoff size TFF membranes may be required based upon the desired concentration, molecular weight and polydispersity of the silk protein fragment mixture in solution. Membranes ranging from 1-100 kDa may be necessary for varying molecular weight silk solutions created for example by varying the length of extraction boil time or the time and temperate in dissolution solvent (e.g., LiBr). In an embodiment, a TFF 5 or 10 kDa membrane is used to purify the silk protein fragment mixture solution and to create the final desired silk-to-water ratio. As well, TFF single pass, TFF, and other methods known in the art, such as a falling film evaporator, may be used to concentrate the solution following removal of the dissolution solvent (e.g., LiBr) (with resulting desired concentration ranging from 0.1% to 30% silk). This can be used as an

alternative to standard HFIP concentration methods known in the art to create a water-based solution. A larger pore membrane could also be utilized to filter out small silk protein fragments and to create a solution of higher molecular weight silk with and/or without tighter polydispersity values. **Fig. 37** is a table summarizing Molecular Weights for some embodiments of silk protein solutions of the present disclosure. Silk protein solution processing conditions were as follows: 100°C extraction for 20 min, room temperature rinse, LiBr in 60°C oven for 4-6 hours. **Figs. 40-49** further demonstrate manipulation of extraction time, LiBr dissolution conditions, and TFF processing and resultant example molecular weights and polydispersities. These examples are not intended to be limiting, but rather to demonstrate the potential of specifying parameters for specific molecular weight silk fragment solutions.

An assay for LiBr and Na_2CO_3 detection was performed using an HPLC system equipped with evaporative light scattering detector (ELSD). The calculation was performed by linear regression of the resulting peak areas for the analyte plotted against concentration. More than one sample of a number of formulations of the present disclosure was used for sample preparation and analysis. Generally, four samples of different formulations were weighed directly in a 10 mL volumetric flask.

The analytical method developed for the quantitation of Na_2CO_3 and LiBr in silk protein formulations was found to be linear in the range 10 - 165 μg/mL, with RSD for injection precision as 2% and 1% for area and 0.38% and 0.19% for retention time for sodium carbonate and lithium bromide respectively. The analytical method can be applied for the quantitative determination of sodium carbonate and lithium bromide in silk protein formulations.

The final silk protein fragment solution, as shown in **Fig. 4**, is pure silk protein fragments and water with PPM to undetectable levels of particulate debris and/or process contaminants, including LiBr and Na_2CO_3. **Fig. 34** and **Fig. 35** are tables summarizing LiBr and Na_2CO_3 concentrations in solutions of the present disclosure. In **Fig. 34**, the processing conditions included 100°C extraction for 60 min, 60°C rinse, 100°C LiBr in 100°C oven for 60 min. TFF conditions including pressure differential and number of dia-filtration volumes were varied. In **Fig. 35**, the processing conditions included

100°C boil for 60 min, 60°C rinse, LiBr in 60°C oven for 4-6 hours. In an embodiment, a SPF composition of the present disclosure is not soluble in an aqueous solution due to the crystallinity of the protein. In an embodiment, a SPF composition of the present disclosure is soluble in an aqueous solution. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about two-thirds and an amorphous region of about one-third. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about one-half and an amorphous region of about one-half. In an embodiment, the SPFs of a composition of the present disclosure include a 99% crystalline portion and a 1% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 95% crystalline portion and a 5% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 90% crystalline portion and a 10% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 85% crystalline portion and a 15% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 80% crystalline portion and a 20% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 75% crystalline portion and a 25% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 70% crystalline portion and a 30% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 65% crystalline portion and a 35% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 60% crystalline portion and a 40% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 50% crystalline portion and a 50% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 40% crystalline portion and a 60% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 35% crystalline portion and a 65% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 30% crystalline portion and a 70% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 25% crystalline portion and a 75% amorphous region. In an embodiment, the SPFs of a

composition of the present disclosure include a 20% crystalline portion and a 80% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 15% crystalline portion and a 85% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 10% crystalline portion and a 90% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 5% crystalline portion and a 90% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 1% crystalline portion and a 99% amorphous region.

A unique feature of the SPF compositions of the present disclosure are shelf stability (they will not slowly or spontaneously gel when stored in an aqueous solution and there is no aggregation of fragments and therefore no increase in molecular weight over time), from 10 days to 3 years depending on storage conditions, percent silk, and number of shipments and shipment conditions. Additionally pH may be altered to extend shelf-life and/or support shipping conditions by preventing premature folding and aggregation of the silk. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 2 weeks at room temperature (RT). In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 4 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 6 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 8 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 10 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 12 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability ranging from about 4 weeks to about 52 weeks at RT. **Table 1** below shows shelf stability test results for embodiments of SPF compositions of the present disclosure.

Table 1. Shelf Stability of SPF Compositions of the Present Disclosure

% Silk	Temperature	Time to Gelation
2	RT	4 weeks
2	4C	>9 weeks

4	RT	4 weeks
4	4C	>9 weeks
6	RT	2 weeks
6	4C	>9 weeks

A silk fragment-water solution of the present disclosure can be sterilized following standard methods in the art not limited to filtration, heat, radiation or e-beam. It is anticipated that the silk protein fragment mixture, because of its shorter protein polymer length, will withstand sterilization better than intact silk protein solutions described in the art. Additionally, silk articles created from the SPF mixtures described herein may be sterilized as appropriate to application.

Fig. 2 is a flow chart showing various parameters that can be modified during the process of producing a silk protein fragment solution of the present disclosure during the extraction and the dissolution steps. Select method parameters may be altered to achieve distinct final solution characteristics depending upon the intended use, e.g., molecular weight and polydispersity. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure.

In an embodiment, a process for producing a silk protein fragment solution of the present disclosure includes forming pieces of silk cocoons from the *Bombyx mori* silk worm; extracting the pieces at about 100°C in a solution of water and Na_2CO_3 for about 60 minutes, wherein a volume of the water equals about 0.4 x raw silk weight and the amount of Na_2CO_3 is about 0.848 x the weight of the pieces to form a silk fibroin extract; triple rinsing the silk fibroin extract at about 60°C for about 20 minutes per rinse in a volume of rinse water, wherein the rinse water for each cycle equals about 0.2 L x the weight of the pieces; removing excess water from the silk fibroin extract; drying the silk fibroin extract; dissolving the dry silk fibroin extract in a LiBr solution, wherein the LiBr solution is first heated to about 100°C to create a silk and LiBr solution and maintained; placing the silk and LiBr solution in a dry oven at about 100°C for about 60 minutes to achieve complete dissolution and further fragmentation of the native silk protein structure into mixture with desired molecular weight and polydispersity; filtering the solution to remove any remaining debris from the silkworm; diluting the solution with water to result

in a 1% silk solution; and removing solvent from the solution using Tangential Flow Filtration (TFF). In an embodiment, a 10 kDa membrane is utilized to purify the silk solution and create the final desired silk-to-water ratio. TFF can then be used to further concentrate the pure silk solution to a concentration of 2% silk to water.

Each process step from raw cocoons to dialysis is scalable to increase efficiency in manufacturing. Whole cocoons are currently purchased as the raw material, but pre-cleaned cocoons or non-heat treated cocoons, where worm removal leaves minimal debris, have also been used. Cutting and cleaning the cocoons is a manual process, however for scalability this process could be made less labor intensive by, for example, using an automated machine in combination with compressed air to remove the worm and any particulates, or using a cutting mill to cut the cocoons into smaller pieces. The extraction step, currently performed in small batches, could be completed in a larger vessel, for example an industrial washing machine where temperatures at or in between 60°C to 100°C can be maintained. The rinsing step could also be completed in the industrial washing machine, eliminating the manual rinse cycles. Dissolution of the silk in LiBr solution could occur in a vessel other than a convection oven, for example a stirred tank reactor. Dialyzing the silk through a series of water changes is a manual and time intensive process, which could be accelerated by changing certain parameters, for example diluting the silk solution prior to dialysis. The dialysis process could be scaled for manufacturing by using semi-automated equipment, for example a tangential flow filtration system.

Varying extraction (i.e., time and temperature), LiBr (i.e., temperature of LiBr solution when added to silk fibroin extract or vice versa) and dissolution (i.e., time and temperature) parameters results in solvent and silk solutions with different viscosities, homogeneities, and colors (see **Figs. 5-32**). Increasing the temperature for extraction, lengthening the extraction time, using a higher temperature LiBr solution at emersion and over time when dissolving the silk and increasing the time at temperature (e.g., in an oven as shown here, or an alternative heat source) all resulted in less viscous and more homogeneous solvent and silk solutions. While almost all parameters resulted in a viable silk solution, methods that allow complete dissolution to be achieved in fewer than 4 to 6 hours are preferred for process scalability.

Figs. 5-10 show photographs of four different silk extraction combinations tested: 90°C 30 min, 90°C 60 min, 100°C 30 min, and 100°C 60 min. Briefly, 9.3 M LiBr was prepared and allowed to sit at room temperature for at least 30 minutes. 5 mL of LiBr solution was added to 1.25 g of silk and placed in the 60°C oven. Samples from each set were removed at 4, 6, 8, 12, 24, 168 and 192 hours. The remaining sample was photographed.

Figs. 11-23 show photographs of four different silk extraction combinations tested: 90°C 30 min, 90°C 60 min, 100°C 30 min, and 100°C 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60°C, 80°C, 100°C or boiling. 5 mL of hot LiBr solution was added to 1.25 g of silk and placed in the 60°C oven. Samples from each set were removed at 1, 4 and 6 hours. The remaining sample was photographed.

Figs. 24-32 show photographs of four different silk extraction combinations tested: Four different silk extraction combinations were used: 90°C 30 min, 90°C 60 min, 100°C 30 min, and 100°C 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60°C, 80°C, 100°C or boiling. 5 mL of hot LiBr solution was added to 1.25 g of silk and placed in the oven at the same temperature of the LiBr. Samples from each set were removed at 1, 4 and 6 hours. 1 mL of each sample was added to 7.5 mL of 9.3 M LiBr and refrigerated for viscosity testing. The remaining sample was photographed.

Molecular weight of the silk protein fragments may be controlled based upon the specific parameters utilized during the extraction step, including extraction time and temperature; specific parameters utilized during the dissolution step, including the LiBr temperature at the time of submersion of the silk in to the lithium bromide and time that the solution is maintained at specific temperatures; and specific parameters utilized during the filtration step. By controlling process parameters using the disclosed methods, it is possible to create SPF mixture solutions with polydispersity equal to or lower than 2.5 at a variety of different molecular weight ranging from 5 kDa to 200 kDa, more preferably between 10 kDa and 80 kDA. By altering process parameters to achieve silk solutions with different molecular weights, a range of fragment mixture end products,

with desired polydispersity of equal to or less than 2.5 may be targeted based upon the desired performance requirements. Additionally, SPF mixture solutions with a polydispersity of greater than 2.5 can be achieved. Further, two solutions with different average molecular weights and polydispersities can be mixed to create combination solutions. Alternatively, a liquid silk gland (100% sericin free silk protein) that has been removed directly from a worm could be used in combination with any of the SPF mixture solutions of the present disclosure. Molecular weight of the pure silk fibroin-based protein fragment composition was determined using High Pressure Liquid Chromatography (HPLC) with a Refractive Index Detector (RID). Polydispersity was calculated using Cirrus GPC Online GPC/SEC Software Version 3.3 (Agilent).

Parameters were varied during the processing of raw silk cocoons into silk solution. Varying these parameters affected the MW of the resulting silk solution. Parameters manipulated included (i) time and temperature of extraction, (ii) temperature of LiBr, (iii) temperature of dissolution oven, and (iv) dissolution time. Molecular weight was determined with mass spec as shown in **Figs. 40-54**.

Experiments were carried out to determine the effect of varying the extraction time. **Figs. 40-46** are graphs showing these results, and **Tables 2-8** summarize the results. Below is a summary:

- A sericin extraction time of 30 minutes resulted in larger MW than a sericin extraction time of 60 minutes
- MW decreases with time in the oven
- 140°C LiBr and oven resulted in the low end of the confidence interval to be below a MW of 9500 Da
- 30 min extraction at the 1 hour and 4 hour time points have undigested silk
- 30 min extraction at the 1 hour time point resulted in a significantly high molecular weight with the low end of the confidence interval being 35,000 Da
- The range of MW reached for the high end of the confidence interval was 18000 to 216000 Da (important for offering solutions with specified upper limit)
-

Table 2. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 100°C Lithium Bromide (LiBr) and 100°C Oven Dissolution (Oven/Dissolution Time was varied).

Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30	1	57247	12780	35093	93387	1.63
60	1	31520	1387	11633	85407	2.71
30	4	40973	2632	14268	117658	2.87
60	4	25082	1248	10520	59803	2.38
30	6	25604	1405	10252	63943	2.50
60	6	20980	1262	10073	43695	2.08

Table 3. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, boiling Lithium Bromide (LiBr) and 60°C Oven Dissolution for 4 hr.

Sample	Boil Time	Average Mw	Std dev	Confidence Interval		PD
30 min, 4 hr	30	49656	4580	17306	142478	2.87
60 min, 4 hr	60	30042	1536	11183	80705	2.69

Table 4. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 60°C Lithium Bromide (LiBr) and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30 min, 1 hr	30	1	58436		22201	153809	2.63
60 min, 1 hr	60	1	31700		11931	84224	2.66
30 min, 4 hr	30	4	61956.5	13337	21463	178847	2.89
60 min, 4 hr	60	4	25578.5	2446	9979	65564	2.56

Table 5. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 80°C Lithium Bromide (LiBr) and 80°C Oven Dissolution for 6 hr.

Sample	Boil Time	Average Mw	Std dev	Confidence Interval	PD

30 min, 6 hr	30	63510		18693	215775	3.40
60 min, 6 hr	60	25164	238	9637	65706	2.61

Table 6. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 80°C Lithium Bromide (LiBr) and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30 min, 4 hr	30	4	59202	14028	19073	183760	3.10
60 min, 4 hr	60	4	26312.5	637	10266	67442	2.56
30 min, 6 hr	30	6	46824		18076	121293	2.59
60 min, 6 hr	60	6	26353		10168	68302	2.59

Table 7. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 100°C Lithium Bromide (LiBr) and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30 min, 4 hr	30	4	47853		19758	115900	2.42
60 min, 4 hr	60	4	25082	1248	10520	59804	2.38
30 min, 6 hr	30	6	55421	8992	19153	160366	2.89
60 min, 6 hr	60	6	20980	1262	10073	43694	2.08

Table 8. The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 140°C Lithium Bromide (LiBr) and 140°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30 min, 4 hr	30	4	9024.5	1102	4493	18127	2.00865
60 min, 4 hr	60	4	15548		6954	34762	2.2358
30 min, 6 hr	30	6	13021		5987	28319	2.1749
60 min, 6 hr	60	6	10888		5364	22100	2.0298

Experiments were carried out to determine the effect of varying the extraction temperature. **Fig. 47** is a graph showing these results, and **Table 9** summarizes the results. Below is a summary:

- Sericin extraction at 90°C resulted in higher MW than sericin extraction at 100°C extraction
- Both 90°C and 100°C show decreasing MW over time in the oven

Table 9. The effect of extraction temperature (90°C vs. 100°C) on molecular weight of silk processed under the conditions of 60 min. Extraction Temperature, 100°C Lithium Bromide (LiBr) and 100°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
90C, 4 hr	60	4	37308	4204	13368	104119	2.79
100C, 4 hr	60	4	25082	1248	10520	59804	2.38
90C, 6 hr	60	6	34224	1135	12717	92100	2.69
100C, 6 hr	60	6	20980	1262	10073	43694	2.08

Experiments were carried out to determine the effect of varying the Lithium Bromide (LiBr) temperature when added to silk. **Figs. 48-49** are graphs showing these results, and **Tables 10-11** summarize the results. Below is a summary:

- No impact on MW or confidence interval (all CI ~10500-6500 Da)
- Studies illustrated that the temperature of LiBr-silk dissolution, as LiBr is added and begins dissolving, rapidly drops below the original LiBr temperature due to the majority of the mass being silk at room temp

Table 10. The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 60 min. Extraction Time., 100°C Extraction Temperature and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
60C LiBr, 1hr	60	1	31700		11931	84223	2.66
100C LiBr, 1hr	100	1	27907	200	10735	72552	2.60
RT LiBr, 4hr	RT	4	29217	1082	10789	79119	2.71
60C LiBr, 4hr	60	4	25578	2445	9978	65564	2.56

80C LiBr, 4hr	80	4	26312	637	10265	67441	2.56
100C LiBr, 4hr	100	4	27681	1729	11279	67931	2.45
Boil LiBr, 4hr	Boil	4	30042	1535	11183	80704	2.69
RT LiBr, 6hr	RT	6	26543	1893	10783	65332	2.46
80C LiBr, 6hr	80	6	26353		10167	68301	2.59
100C LiBr, 6hr	100	6	27150	916	11020	66889	2.46

Table 11. The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 30 min. Extraction Time, 100°C Extraction Temperature and 60°C Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
60C LiBr, 4hr	60	4	61956	13336	21463	178847	2.89
80C LiBr, 4hr	80	4	59202	14027	19073	183760	3.10
100C LiBr, 4hr	100	4	47853		19757	115899	2.42
80C LiBr, 6hr	80	6	46824		18075	121292	2.59
100C LiBr, 6hr	100	6	55421	8991	19152	160366	2.89

Experiments were carried out to determine the effect of varying the oven/dissolution temperature. **Figs. 50-54** are graphs showing these results, and **Tables 12-16** summarize the results. Below is a summary:

- Oven temperature has less of an effect on 60 min extracted silk than 30 min extracted silk. Without wishing to be bound by theory, it is believed that the 30 min silk is less degraded during extraction and therefore the oven temperature has more of an effect on the larger MW, less degraded portion of the silk.
- For 60°C vs. 140°C oven the 30 min extracted silk showed a very significant effect of lower MW at higher oven temp, while 60 min extracted silk had an effect but much less
- The 140°C oven resulted in a low end in the confidence interval at ~6000 Da

Table 12. The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 30 min. Extraction Time, and 100°C Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
30	60	4	47853		19758	115900	2.42
30	100	4	40973	2632	14268	117658	2.87
30	60	6	55421	8992	19153	160366	2.89
30	100	6	25604	1405	10252	63943	2.50

Table 13. The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 60 min. Extraction Time, and 100°C Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
60	60	1	27908	200	10735	72552	2.60
60	100	1	31520	1387	11633	85407	2.71
60	60	4	27681	1730	11279	72552	2.62
60	100	4	25082	1248	10520	59803	2.38
60	60	6	27150	916	11020	66889	2.46
60	100	6	20980	1262	10073	43695	2.08

Table 14. The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 60 min. Extraction Time, and 140°C Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp(°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
60	60	4	30042	1536	11183	80705	2.69
60	140	4	15548		7255	33322	2.14

Table 15. The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 30 min. Extraction Time, and 140°C Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval	PD

30	60	4	49656	4580	17306	142478	2.87
30	140	4	9025	1102	4493	18127	2.01
30	60	6	59383	11640	17641	199889	3.37
30	140	6	13021		5987	28319	2.17

Table 16. The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100°C Extraction Temperature, 60 min. Extraction Time, and 80°C Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (°C)	Oven Time	Average Mw	Std dev	Confidence Interval		PD
60	60	4	26313	637	10266	67442	2.56
60	80	4	30308	4293	12279	74806	2.47
60	60	6	26353		10168	68302	2.59
60	80	6	25164	238	9637	65706	2.61

In an embodiment, when producing a silk gel, an acid is used to help facilitate gelation. In an embodiment, when producing a silk gel that includes a neutral or a basic molecule and/or therapeutic agent, an acid can be added to facilitate gelation. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) increases the shelf stability of the gel. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) allows for a greater quantity of an acidic molecule to be loaded into the gel.

In an embodiment, natural additives may be added to the silk gel to further stabilize additives. For example, trace elements such as selenium or magnesium or L-methoinine can be used. Further, light-block containers can be added to further increase stability.

In an embodiment, the methods disclosed herein result in a solution with characteristics that can be controlled during manufacturing, including, but not limited to: MW – may be varied by changing extraction and/or dissolution time and temp (e.g., LiBr temperature), pressure, and filtration (e.g., size exclusion chromatography); Structure –

removal or cleavage of heavy or light chain of the fibroin protein polymer; Purity – hot water rinse temperature for improved sericin removal or filter capability for improved particulate removal that adversely affects shelf stability of the silk fragment protein mixture solution; Color – the color of the solution can be controlled with, for example, LiBr temp and time; Viscosity; Clarity; and Stability of solution. The resultant pH of the solution is typically about 7 and can be altered using an acid or base as appropriate to storage requirements.

In an embodiment, the above-described SPF mixture solutions may be utilized to coat at least a portion of a fabric which can be used to create a textile. In an embodiment, the above-described SPF mixture solutions may be weaved into yarn that can be used as a fabric in a textile.

Fig. 33 shows two HPLC chromatograms from samples comprising vitamin C. The chromatogram shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible. **Fig. 36** is a table summarizing the stability of vitamin C in chemically stabilized solutions.

In some embodiments, a composition of the present disclosure can further include skin penetration enhancers, including, but not limited to, sulfoxides (such as dimethylsulfoxide), pyrrolidones (such as 2-pyrrolidone), alcohols (such as ethanol or decanol), azones (such as laurocapram and 1-dodecylazacycloheptan-2-one), surfactants (including alkyl carboxylates and their corresponding acids such as oleic acid, fluoroalkylcarboxylates and their corresponding acids, alkyl sulfates, alkyl ether sulfates, docusates such as dioctyl sodium sulfosuccinate, alkyl benzene sulfonates, alkyl ether phosphates, and alkyl aryl ether phosphates), glycols (such as propylene glycol), terpenes (such as limonene, p-cymene, geraniol, farnesol, eugenol, menthol, terpineol, carveol, carvone, fenchone, and verbenone), and dimethyl isosorbide.

Following are non-limiting examples of suitable ranges for various parameters in and for preparation of the silk solutions of the present disclosure. The silk solutions of the present disclosure may include one or more, but not necessarily all, of these

parameters and may be prepared using various combinations of ranges of such parameters.

In an embodiment, the percent silk in the solution is less than 30%. In an embodiment, the percent silk in the solution is less than 25%. In an embodiment, the percent silk in the solution is less than 20%. In an embodiment, the percent silk in the solution is less than 19%. In an embodiment, the percent silk in the solution is less than 18%. In an embodiment, the percent silk in the solution is less than 17%. In an embodiment, the percent silk in the solution is less than 16%. In an embodiment, the percent silk in the solution is less than 15%. In an embodiment, the percent silk in the solution is less than 14%. In an embodiment, the percent silk in the solution is less than 13%. In an embodiment, the percent silk in the solution is less than 12%. In an embodiment, the percent silk in the solution is less than 11%. In an embodiment, the percent silk in the solution is less than 10%. In an embodiment, the percent silk in the solution is less than 9%. In an embodiment, the percent silk in the solution is less than 8%. In an embodiment, the percent silk in the solution is less than 7%. In an embodiment, the percent silk in the solution is less than 6%. In an embodiment, the percent silk in the solution is less than 5%. In an embodiment, the percent silk in the solution is less than 4%. In an embodiment, the percent silk in the solution is less than 3%. In an embodiment, the percent silk in the solution is less than 2%. In an embodiment, the percent silk in the solution is less than 1%. In an embodiment, the percent silk in the solution is less than 0.9%. In an embodiment, the percent silk in the solution is less than 0.8%. In an embodiment, the percent silk in the solution is less than 0.7%. In an embodiment, the percent silk in the solution is less than 0.6%. In an embodiment, the percent silk in the solution is less than 0.5%. In an embodiment, the percent silk in the solution is less than 0.4%. In an embodiment, the percent silk in the solution is less than 0.3%. In an embodiment, the percent silk in the solution is less than 0.2%. In an embodiment, the percent silk in the solution is less than 0.1%. In an embodiment, the percent silk in the solution is greater than 0.1%. In an embodiment, the percent silk in the solution is greater than 0.2%. In an embodiment, the percent silk in the solution is greater than 0.3%. In an embodiment, the percent silk in the solution is greater than 0.4%. In an embodiment, the percent silk in the solution is greater than

0.5%. In an embodiment, the percent silk in the solution is greater than 0.6%. In an embodiment, the percent silk in the solution is greater than 0.7%. In an embodiment, the percent silk in the solution is greater than 0.8%. In an embodiment, the percent silk in the solution is greater than 0.9%. In an embodiment, the percent silk in the solution is greater than 1%. In an embodiment, the percent silk in the solution is greater than 2%. In an embodiment, the percent silk in the solution is greater than 3%. In an embodiment, the percent silk in the solution is greater than 4%. In an embodiment, the percent silk in the solution is greater than 5%. In an embodiment, the percent silk in the solution is greater than 6%. In an embodiment, the percent silk in the solution is greater than 7%. In an embodiment, the percent silk in the solution is greater than 8%. In an embodiment, the percent silk in the solution is greater than 9%. In an embodiment, the percent silk in the solution is greater than 10%. In an embodiment, the percent silk in the solution is greater than 11%. In an embodiment, the percent silk in the solution is greater than 12%. In an embodiment, the percent silk in the solution is greater than 13%. In an embodiment, the percent silk in the solution is greater than 14%. In an embodiment, the percent silk in the solution is greater than 15%. In an embodiment, the percent silk in the solution is greater than 16%. In an embodiment, the percent silk in the solution is greater than 17%. In an embodiment, the percent silk in the solution is greater than 18%. In an embodiment, the percent silk in the solution is greater than 19%. In an embodiment, the percent silk in the solution is greater than 20%. In an embodiment, the percent silk in the solution is greater than 25%. In an embodiment, the percent silk in the solution is between 0.1% and 30%. In an embodiment, the percent silk in the solution is between 0.1% and 25%. In an embodiment, the percent silk in the solution is between 0.1% and 20%. In an embodiment, the percent silk in the solution is between 0.1% and 15%. In an embodiment, the percent silk in the solution is between 0.1% and 10%. In an embodiment, the percent silk in the solution is between 0.1% and 9%. In an embodiment, the percent silk in the solution is between 0.1% and 8%. In an embodiment, the percent silk in the solution is between 0.1% and 7%. In an embodiment, the percent silk in the solution is between 0.1% and 6.5%. In an embodiment, the percent silk in the solution is between 0.1% and 6%. In an embodiment, the percent silk in the solution is between 0.1% and 5.5%. In an embodiment, the percent silk in the solution is between 0.1% and

5%. In an embodiment, the percent silk in the solution is between 0.1% and 4.5%. In an embodiment, the percent silk in the solution is between 0.1% and 4%. In an embodiment, the percent silk in the solution is between 0.1% and 3.5%. In an embodiment, the percent silk in the solution is between 0.1% and 3%. In an embodiment, the percent silk in the solution is between 0.1% and 2.5%. In an embodiment, the percent silk in the solution is between 0.1% and 2.0%. In an embodiment, the percent silk in the solution is between 0.1% and 2.4%. In an embodiment, the percent silk in the solution is between 0.5% and 5%. In an embodiment, the percent silk in the solution is between 0.5% and 4.5%. In an embodiment, the percent silk in the solution is between 0.5% and 4%. In an embodiment, the percent silk in the solution is between 0.5% and 3.5%. In an embodiment, the percent silk in the solution is between 0.5% and 3%. In an embodiment, the percent silk in the solution is between 0.5% and 2.5%. In an embodiment, the percent silk in the solution is between 1 and 4%. In an embodiment, the percent silk in the solution is between 1 and 3.5%. In an embodiment, the percent silk in the solution is between 1 and 3%. In an embodiment, the percent silk in the solution is between 1 and 2.5%. In an embodiment, the percent silk in the solution is between 1 and 2.4%. In an embodiment, the percent silk in the solution is between 1 and 2%. In an embodiment, the percent silk in the solution is between 20% and 30%. In an embodiment, the percent silk in the solution is between 0.1% and 6%. In an embodiment, the percent silk in the solution is between 6% and 10%. In an embodiment, the percent silk in the solution is between 6% and 8%. In an embodiment, the percent silk in the solution is between 6% and 9%. In an embodiment, the percent silk in the solution is between 10% and 20%. In an embodiment, the percent silk in the solution is between 11% and 19%. In an embodiment, the percent silk in the solution is between 12% and 18%. In an embodiment, the percent silk in the solution is between 13% and 17%. In an embodiment, the percent silk in the solution is between 14% and 16%. In an embodiment, the percent silk in the solution is 2.4%. In an embodiment, the percent silk in the solution is 2.0%.

In an embodiment, the percent sericin in the solution is non-detectable to 30%. In an embodiment, the percent sericin in the solution is non-detectable to 5%. In an embodiment, the percent sericin in the solution is 1%. In an embodiment, the percent sericin in the solution is 2%. In an embodiment, the percent sericin in the solution is 3%.

In an embodiment, the percent sericin in the solution is 4%. In an embodiment, the percent sericin in the solution is 5%. In an embodiment, the percent sericin in the solution is 10%. In an embodiment, the percent sericin in the solution is 30%.

In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 1 year. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 2 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 2 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 3 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 3 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 4 to 5 years.

In an embodiment, the stability of a composition of the present disclosure is 10 days to 6 months. In an embodiment, the stability of a composition of the present disclosure is 6 months to 12 months. In an embodiment, the stability of a composition of the present disclosure is 12 months to 18 months. In an embodiment, the stability of a composition of the present disclosure is 18 months to 24 months. In an embodiment, the stability of a composition of the present disclosure is 24 months to 30 months. In an embodiment, the stability of a composition of the present disclosure is 30 months to 36 months. In an embodiment, the stability of a composition of the present disclosure is 36 months to 48 months. In an embodiment, the stability of a composition of the present disclosure is 48 months to 60 months.

In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight

ranging from 6kDa to 16 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 17 kDa to 38kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 39kDa to 80kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 1 to 5kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 5 to 10kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 10 to 15kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 15 to 20kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 20 to 25kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 25 to 30kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 30 to 35kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 35 to 40kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 40 to 45kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 45 to 50kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 50 to 55kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight

ranging from 55 to 60kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 60 to 65kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 65 to 70kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 70 to 75kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 75 to 80kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 80 to 85kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 85 to 90kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 90 to 95kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 95 to 100kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 100 to 105kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 105 to 110kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 110 to 115kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 115 to 120kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 120 to 125kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 125

to 130kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 130 to 135kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 135 to 140kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 140 to 145kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 145 to 150kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 150 to 155kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 155 to 160kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 160 to 165kDa. I In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 165 to 170kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 170 to 175kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 175 to 180kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 180 to 185kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 185 to 190kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 190 to 195kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 195 to 200kDa. In an

embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 200 to 205kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 205 to 210kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 210 to 215kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 215 to 220kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 220 to 225kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 225 to 230kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 230 to 235kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 235 to 240kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 240 to 245kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 245 to 250kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 250 to 255kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 255 to 260kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 260 to 265kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 265 to 270kDa. In an embodiment, a

composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 270 to 275kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 275 to 280kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 280 to 285kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 285 to 290kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 290 to 295kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 295 to 300kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 300 to 305kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 305 to 310kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 310 to 315kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 315 to 320kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 320 to 325kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 325 to 330kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 330 to 335kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 35 to 340kDa. In an embodiment, a composition of the

present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 340 to 345kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 345 to 350kDa.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1 to about 5.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1.5 to about 3.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1 to about 1.5. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1.5 to about 2.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 2.0 to about 2.5. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has a polydispersity ranging from about is 2.0 to about 3.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has a polydispersity ranging from about is 2.5 to about 3.0.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has non-detectable levels of LiBr residuals. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is between 10 ppm and 1000 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is between 10 ppm and 300 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 25ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 50ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 75ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 100ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 200ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than

300ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 400ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 500ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 600ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 700ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 800ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 900ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 1000ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 500ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 450ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 400 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 350ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 300ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 250ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 200ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 150ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 100ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 100ppm to 200ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 200ppm to 300ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 300ppm to 400ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 400ppm to 500ppm.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has non-detectable levels of Na_2CO_3 residuals. In an

embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 100ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 200ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 300ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 400ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 500ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 600ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 700ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 800ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 900ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is less than 1000ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 500ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 450ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 400ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 350ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 300ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 250ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 200ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 150ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is non-detectable to 100ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is 100ppm to 200ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is 200ppm to 300ppm. In an embodiment, the amount of the Na_2CO_3 residuals

in a composition of the present disclosure is 300ppm to 400ppm. In an embodiment, the amount of the Na_2CO_3 residuals in a composition of the present disclosure is 400ppm to 500ppm.

In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 50 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 60 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 70 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 80 to 100%. In an embodiment, the water solubility is 90 to 100%. In an embodiment, the silk fibroin-based fragments of the present disclosure are non-soluble in aqueous solutions.

In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 50 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 60 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 70 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 80 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 90 to 100%. In an embodiment, the silk fibroin-based fragments of the present disclosure are non-soluble in organic solutions.

In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is greater than 84°C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is less than 100°C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84°C to 100°C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84°C to 94°C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 94°C to 100°C.

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the described embodiments, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g. amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

There is disclosed a textile that is at least partially surface treated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating on the textile. In an embodiment, the silk coating of the present disclosure is available in a spray can and can be sprayed on any textile by a consumer. In an embodiment, a textile comprising a silk coating of the present disclosure is sold to a consumer. In an embodiment, a textile of the present disclosure is used in constructing action sportswear/apparel. In an embodiment, a silk coating of the present disclosure is positioned on the underlining of apparel. In an embodiment, a silk coating of the present disclosure is positioned on the shell, the lining, or the interlining of apparel. In an embodiment, apparel is partially made from a silk coated textile of the present disclosure and partially made from an uncoated textile. In an embodiment, apparel partially made from a silk coated textile and partially made from an uncoated textile combines an uncoated inert synthetic material with a silk coated inert synthetic material. Examples of inert synthetic material include, but are not limited to, polyester, polyamide, polyaramid, polytetrafluorethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethylenglycol, ultrahigh molecular weight polyethylene, high-performance polyethylene, and mixtures thereof. In an embodiment, apparel partially made from a silk coated textile and partially made from an uncoated textile combines an elastomeric material at least partially covered with a silk coating of the present disclosure. In an embodiment, the percentage of silk to elastomeric material can be varied to achieve desired shrink or wrinkle resistant properties.

In an embodiment, a silk coating of the present disclosure is visible. In an embodiment, a silk coating of the present disclosure positioned on apparel helps control skin temperature. In an embodiment, a silk coating of the present disclosure positioned on apparel helps control fluid transfer away from the skin. In an embodiment, a silk coating of the present disclosure positioned on apparel has a soft feel against the skin decreasing abrasions from fabric on skin. In an embodiment, a silk coating of the present disclosure positioned on a textile has properties that confer at least one of wrinkle resistance, shrinkage resistance, or machine washability to the textile. In an embodiment, a silk coated textile of the present disclosure is 100% machine washable and dry cleanable. In an embodiment, a silk coated textile of the present disclosure is 100% waterproof. In an embodiment, a silk coated textile of the present disclosure is wrinkle resistant. In an embodiment, a silk coated textile of the present disclosure is shrink resistant. In an embodiment, a silk coated textile of the present disclosure has the qualities of being waterproof, breathable, and elastic and possess a number of other qualities which are highly desirable in action sportswear. In an embodiment, a silk coated textile of the present disclosure manufactured from a silk fabric of the present disclosure further includes LYCRA® brand spandex fibers.

In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a breathable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a water-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a shrink-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a machine-washable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a wrinkle resistant fabric. In an embodiment, textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure provides moisture and vitamins to the skin.

In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is used to coat a textile. In an embodiment, the concentration of silk in the solution ranges from about 0.1% to about 20.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.1% to about 15.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.5% to about 10.0%. In an embodiment, the concentration of silk in the solution ranges from about 1.0% to about 5.0%. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is applied directly to a fabric. Alternatively, silk microsphere and any additives may be used for coating a fabric. In an embodiment, additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure before coating (e.g., alcohols) to further enhance material properties. In an embodiment, a silk coating of the present disclosure can have a pattern to optimize properties of the silk on the fabric. In an embodiment, a coating is applied to a fabric under tension and/or lax to vary penetration in to the fabric.

In an embodiment, a silk coating of the present disclosure can be applied at the yarn level, followed by creation of a fabric once the yarn is coated. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure can be spun into fibers to make a silk fabric and/or silk fabric blend with other materials known in the apparel industry.

In an embodiment, a method for silk coating a fabric includes immersion of the fabric in any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure. In an embodiment, a method for silk coating a fabric includes spraying. In an embodiment, a method for silk coating a fabric includes chemical vapor deposition. In an embodiment, a method for silk coating a fabric includes electrochemical coating. In an embodiment, a method for silk coating a fabric includes knife coating to spread any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure onto the fabric. The coated fabric may then be air dried, dried under heat/air flow, or cross-linked to the fabric surface. In an embodiment, a drying process includes curing with additives and/or ambient condition.

EXAMPLES

Example 1. Tangential Flow Filtration (TFF) to Remove Solvent from Dissolved Silk Solutions

A variety of % silk concentrations have been produced through the use of Tangential Flow Filtration (TFF). In all cases a 1% silk solution was used as the input feed. A range of 750-18,000mL of 1% silk solution was used as the starting volume. Solution is diafiltered in the TFF to remove lithium bromide. Once below a specified level of residual LiBr, solution undergoes ultrafiltration to increase the concentration through removal of water. See examples below.

7.30% Silk Solution: A 7.30% silk solution was produced beginning with 30 minute extraction batches of 100g silk cocoons per batch. Extracted silk fibers were then dissolved using 100C 9.3M LiBr in a 100C oven for 1 hour. 100g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 15,500 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 1300mL. 1262mL of 7.30% silk was then collected. Water was added to the feed to help remove the remaining solution and 547mL of 3.91% silk was then collected.

6.44% Silk Solution: A 6.44% silk solution was produced beginning with 60 minute extraction batches of a mix of 25, 33, 50, 75 and 100g silk cocoons per batch. Extracted silk fibers were then dissolved using 100C 9.3M LiBr in a 100C oven for 1 hour. 35, 42, 50 and 71g per batch of silk fibers were dissolved to create 20% silk in LiBr and combined. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 17,000 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 3000mL. 1490mL of 6.44% silk was then collected. Water was added to the feed to help remove the remaining solution and 1454mL of 4.88% silk was then collected

2.70% Silk Solution: A 2.70% silk solution was produced beginning with 60 minute extraction batches of 25g silk cocoons per batch. Extracted silk fibers were then dissolved using 100C 9.3M LiBr in a 100C oven for 1 hour. 35.48g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 1000 mL of 1%,

filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 300mL. 312mL of 2.7% silk was then collected.

Example 2. Preparation of Silk Gels

Table 17. Gel Samples – Silk gel formulations including additives, concentration of silk and additive, gelation conditions and gelation times.

Sample Name	mL 2% silk solution	Mass Vit C (g)	Ratio silk: VitC	Additive	Amount of additive	Temp/ Treatment	Days to Gelation
1	10	0.04	5:01	None	None	RT	8
2	10	0.08	2.5:1	None	None	RT	8
3	10	0.2	1:01	None	None	RT	8
4	10	0.4	1:02	None	None	RT	14
5	10	0.8	1:04	None	None	RT	None
6	10	0.04	5:01	None	None	Fridge	~39
7	10	0.08	2.5:1	None	None	Fridge	~39
8	10	0.2	1:01	None	None	Fridge	~39
9	10	0.4	1:02	None	None	Fridge	None
10	10	0.8	1:04	None	None	Fridge	None
11	10	0.2	1:01	None	None	RT/Shake vigorously	8
O-1	10	0.04	5:01	None	None	37C Oven	3
O-2	10	0.04	5:01	None	None	50C Oven	2
O-3	10	0.2	1:01	None	None	37C Oven	4
O-4	10	0.2	1:01	None	None	50C Oven	3
M	40	0.16	5:01	None	None	RT	5
D	40	0.16	5:01	None	None	RT	5
E1	10	0.04	5:01	Vit E	1 drop	RT	7
E2	10	0.04	5:01	Vit E	3 drops	RT	7
E3	10	0	None	Vit E	1 drop	RT	None
E4	10	0	None	Vit E	3 drops	RT	None
L1	10	0.04	5:01	Lemon	300 uL	RT	6
L2	10	0.04	5:01	Lemon Juice	300 uL	RT	6
L3	10	0.04	5:01	Lemon Juice	1000 uL	RT	5
L4	10	0	None	Lemon	300 uL	RT	6
L5	10	0	None	Lemon Juice	300 uL	RT	7

Jar 1	20	0.08	5:01	Lemon Juice	2000 uL	RT	5-7
Jar 2	5	0.02	5:01	Lemongrass Oil	1 drop	RT	2-3
R-1	10	0.04	5:01	Rosemary Oil	1 drop	RT	7
T-1	10	0.04	5:01	None	None	RT/Tube	7
RO-1	10	0.04	5:01	Rose Oil	1 drop	RT	6
RO-2	10	None	None	Rose Oil	1 drop	RT	None

Ratio of Silk to Vitamin C

Samples 1-10 were used to examine the effect of silk to vitamin C ratio on serum gelation. Samples 1-3 with less vitamin C gelled quicker than samples 4 and 5. All other conditions were kept constant. Samples 6-8 with less vitamin C gelled quicker than samples 9 and 10. All other conditions were kept constant. It is concluded that decreasing the ratio of silk to vitamin C (increasing the amount of vitamin C), will lengthen the time to gel creation. At ratios with small amounts of vitamin C, days to gel creation did not vary greatly.

Physical Stimulation

Samples 3 and 11 were used to examine the effect of physical stimulation on serum gelation. Each sample was prepared under the same conditions. Sample 11 was vigorously shaken for about 3 minutes after addition of vitamin C. Treatment of 3 and 11 was otherwise the same. The shaking resulted in bubbles but did not significantly change gel creation time.

Temperature Treatment

Samples 1, 3, 6, 8, O-1, O-2, O-3, and O-4 were used to examine the effect of temperature treatment on serum gelation time. Samples 1, 6, O-1, and O-2 were identical other than temperature treatment. Samples 3, 8, O-3, and O-4 were identical other than temperature treatment. The two groups differed in silk to vitamin C ratio. Time to serum gelation was directly related to temperature treatment with a higher temperature resulting in quicker serum gelation.

Solution Volume

Samples 1, M and D were used to examine the effect of solution volume on serum gelation time. Samples M and D varied from sample 1 only by an increased solution

volume. Samples M and D gelled in 5 days while sample 1 gelled in 8 days. Samples M and D were definitively noticed to be gelled on the day of gelling while sample 1 gelled over a weekend.

Additives

Samples E1, E2, E3, E4, L1, L2, L3, L4, L5, Jar 2, R1, RO-1 and RO-2 were used to examine the effect of additives on serum gelation time. Samples E1-4 contained Vitamin E. Only samples E1 and E2 contained vitamin C and only these two samples gelled. Vitamin E can be added to a solution to become a gel but it appears that another additive may be needed to create a gel. Samples L1-5 contained a form of lemon juice. Samples L1 and L4 had juice directly from a lemon while samples L2, L3 and L5 contained lemon juice from a plastic lemon container. Samples L4 and L5 did not have vitamin C while all others did. All samples gelled showing that lemon juice can create gel on its own. Amount of lemon juice and type of lemon juice had little effect on gelation time. Sample Jar 2 contained lemon grass oil which formed an albumen like substance when initially added. This sample also had vitamin C but gelation time was significantly quicker than with other vitamin C samples. Sample R1 contained rosemary oil, which seemed to be soluble, as well as vitamin C. The sample gelled in a similar time frame to other samples with only vitamin C. Samples RO-1 and RO-2 contained rose oil while only RO-1 had vitamin C. Only RO-1 gelled showing that rose oil will not create a gel quickly on its own. In both cases the rose oil was immiscible and visible as yellow bubbles.

Aqueous silk fibroin-based fragment solution and essential oils are immiscible liquids. In an embodiment, to increase the fragrance of the silk fibroin-based fragment solution, without entrapping oils within the solution, the solution is mixed with the essential oil with the use of a stir bar. The stir bar is rotated at a speed such that some turbulence is observed in the mixture, thus causing contact between the fragrant essential oil and the molecules in solution, adding a scent to the solution. Before casting of product from the solution, mixing may be stopped and the oil allowed to separate to the top of the solution. Dispensing from the bottom fraction of the solution into the final product allows for fragrance without visible essential oil within the final product.

Alternatively, the silk fibroin-based solution and essential oil can be combined with or without additional ingredients and/or an emulsifier to create a composition containing both ingredients.

In an embodiment, mixing of the solution as described above can reduce gelation time if the solution is used to create a gel formulation.

Vessel

Samples T1 and Jar 1 were used to examine the effect of casting vessel on serum gelation time. Jar 1 was cast in a glass jar while T1 was cast in an aluminum tube. Both samples gelled and did not affect serum gel time.

Summary

All treatments of silk solution for gel solution were in a conical tube at room temperature unless otherwise stated. The ratio of silk to vitamin C did affect the ability of a solution to gel as ratios above 1:2 did not gel and a 1:2 ratio took twice as long as other lower ratios (5:1, 2.5:1, 1:1). Temperature affected gel creation time with higher temperatures resulting in quicker gel times. 50°C treatment gelled in as quick as 2 days, 37°C treatment gelled in as quick as 3 days, room temperature treatment gelled in 5-8 days and storage in a refrigerator took at least 39 days to gel. The effects of additives on gel creation were dependent on the additive. Vitamin E, Rosemary Oil and Rose Oil all had no effect on gel creation. Each of these additives did not prevent gelation or affect the time to gelation. Each also required the presence of vitamin C to gel. Lemon juice from a fresh lemon, pre-squeezed lemon juice from a plastic lemon container and lemon grass oil did affect gel creation. Without wishing to be bound by theory, it is believed that the lower pH as a result of these additives is the reason the additives had an impact on decreasing gelation time. Both lemon juice types were able to cause gelation without the presence of vitamin C. This occurred in the same number of days as with vitamin C. The lemongrass oil was able to decrease the number of days to gelation to 2-3 days. All additives appeared soluble other than lemongrass oil and rose oil. Rose oil remained in yellow bubbles while the lemongrass oil was partially soluble and formed an albumen like chunk. In an embodiment, oils that are not fully soluble, can still be suspended within the gel as an additive. Physical stimulation by shaking, vessel the solution was cast into and solution volume did not affect gelation time.

Table 18. Concentration of vitamin C in various gel formulations.			
Sample Info	**Sample Weight**	**Concentration of Vitamin C (mg/g)**	
	(mg)	**In Sample**	**Average**
Rosemary (Room Temperature storage)	685.7	3.2511	3.2657
		3.2804	
	638	3.3336	3.3334
		3.3332	
Lemongrass (Room Temperature storage)	646	2.8672	2.877
		2.8868	
	645.5	2.9051	2.9051
		2.9052	
Rosemary (Room Temperature; Foil Covered storage)	645.2	3.9063	3.9147
		3.923	
	649	3.9443	3.9374
		3.9305	
Lemongrass (Room Temperature; Foil Covered storage)	630.1	3.8253	3.8274
		3.8295	
	660.4	3.8283	3.8253
		3.8222	
Rosemary (Fridge, Foil Covered storage)	672.4	5.1616	5.1484
		5.1352	
	616.5	5.1984	5.201
		5.2036	
Lemongrass (Fridge, Foil Covered storage)	640.5	5.1871	5.1824
		5.1776	
	627.7	5.2098	5.2126
		5.2154	

Example 3. Preparation of Silk Gels

Additional gels may be prepared according to Table 19, Table 20, Table 21, and Table 22.

Table 19. Lemongrass Gel	
% Silk Solution	2%
Quantity Vitamin C	100 mg/15 mL solution
Quantity Lemongrass Oil	20 μL/15 mL solution

Table 20. Rosemary Gel

% Silk Solution	2%
Quantity Vitamin C	100 mg/15 mL solution
Quantity Rosemary Oil	20 μL/50 mL solution

Table 21. Lemongrass Gel (50 mL)	
% Silk Solution (60 minute boil, 25kDA)	2%
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)
Quantity Lemongrass Oil	1.33 μL/mL solution
pH	4

Table 22. Rosemary Gel (50 mL)	
% Silk Solution (60 minute boil, 25kDA)	2%
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)
Quantity Rosemary Oil	0.8 μL/mL solution
pH	4

Gels of the present disclosure can be made with about 0.5% to about 8% silk solutions. Gels of the present disclosure can be made with ascorbyl glucoside at concentrations of about 0.67% to about 15% w/v. Gels of the present disclosure be clear/white in color. Gels of the present disclosure can have a consistency that is easily spread and absorbed by the skin. Gels of the present disclosure can produce no visual residue or oily feel after application. Gels of the present disclosure do not brown over time.

Silk gels with essential oils were prepared by diluting a silk solution of the present disclosure to 2%. Vitamin C was added to the solution and allowed to dissolve. The essential oil was added, stirred and dissolved. The solution was aliquot into jars.

Example 4. Coating Fabrics with Aqueous Silk Solutions

Table 23. Silk Solution Characteristics					
	Molecular Weight:	57 kDa			
	Polydispersity:	1.6			
	% Silk	5.0%	3.0%	1.0%	0.5%
Process Parameters					
	Extraction				
	Boil Time:	30 minutes			

	Boil Temperature:	100°C			
	Rinse Temperature:	60°C			
	Dissolution				
	LiBr Temperature:	100°C			
	Oven Temperature:	100°C			
	Oven Time:	60 minutes			
Table 24. Silk Solution Characteristics					
	Molecular Weight:	25 kDa			
	Polydispersity:	2.4			
	% Silk	5.0%	3.0%	1.0%	0.5%
Process Parameters					
	Extraction				
	Boil Time:	60 minutes			
	Boil Temperature:	100°C			
	Rinse Temperature:	60°C			
	Dissolution				
	LiBr Temperature:	100°C			
	Oven Temperature:	100°C			
	Oven Time:	60 minutes			

Silk Solution and Silk Gel Application to Fabric and Yarn Samples

Three 50mm diameter fabric samples from each of three different fabric materials, cotton, polyester, and nylon/LYCRA®, were placed in plastic containers. about 0.3mL of about 5.8% silk fibroin solution was deposited using a 1mL syringe and 18 gauge needle on two samples of each material, and allowed to sit for about 1 minute. About 0.3mL of denatured alcohol (containing methanol and ethanol) was then deposited using a 1mL syringe and 30 gauge needle on one of the silk-coated samples of each material.

In an additional experiment, silk gel with Rosemary Essential Oil (water, silk, ascorbyl glucoside, rosemary essential oil) was collected on a tip and applied to half the length of 2 pieces of 400um tencel yarn. One sample was then wetted with about 0.3mL alcohol.

Silk Solution Dip Test

Polyester fabric samples were dipped in silk fibroin solutions of varying concentration. Samples were placed in incubator with air flow on foil and allowed to dry at about 22.5°C for about 15.5 hours. Change in mass before and after silk coating was measured.

Table 25. Polyester Fabric Samples with Silk Coatings of the Present Disclosure

Silk Fibroin Concentration (%)	Starting Mass (g)	Mass after coating (g)	Change (%)	Average Change (%)
1	0.25	0.26	+4	-3%
	0.30	0.27	-10	
	0.24	0.24	0	
	0.22	0.21	-5	
3	0.30	0.36	+20	15%
	0.28	0.31	+11	
	0.29	0.33	+14	
	0.29	0.34	+15	
5	0.25	0.29	+16	16%
	0.28	0.33	+18	
	0.31	0.35	+13	
	0.27	0.31	+15	

Silk Solution Spray Test

A spray test was performed to verify the handle impact of silk fibroin solution sprayed on polyester fabric. About 0.5% silk fibroin solution was applied to a 4 inch by 4 inch square of polyester fabric using a spray gun from a distance of about 10 inches. Three passes were completed from left to right and from right to left (six passes total). Samples were placed in a 50°C oven on aluminum foil over a water bath for about 1.5 hours. Methods were repeated with a second polyester fabric sample with an about 5.8% silk fibroin solution spray application. No change in material hand was observed in

samples sprayed with either 0.5% or 5.8% solutions. Perceived increase in materials smoothness was observed for samples sprayed with either the 0.5% and 5.8% solutions.

Example 5. Optimized Fabric Coating Processes

The coating processes described in Table 26 were used to produce multiple fabric samples for performance testing, as described in more detail below.

Table 26. Coating Processes.

1	**Spray**
1.1	Material for coating
1.1.1	cork board 24" × 36" Hobby Lobby part 132894
1.1.2	Covered the cork board with polyester interlock fabric
1.1.3	Saw horse for support
1.1.4	Several clamps for holding cork panel to saw horse
1.1.5	Double filter to remove oil residue from compressor and dehumidificaton salt
1.1.6	Iwata eclipse MP-CS airbrush
1.1.7	Husky 30.3 liter tank compression system
1.1.8	Push pin to hold fabric on cork panel Hobby Lobby part #523456
1.2	Material for preparation
1.2.1	Scissor
1.2.2	Ruler
1.2.3	Balance AWS model Pnx-203
1.3	Material for drying
1.3.1	Wolf stove set up at 150 °F maintaining 71-78 °C with fan system.
1.3.2	Flat baking sheet
1.3.3	Aluminum foil
1.3.4	SC 307T thermometer with probe
1.4	Execution
1.1.1	lay fabric to be coated on top of cork panel covered with polyester fabric
1.1.2	secure fabric with pin to the cork panel
1.1.3	set compressor with oil and humidity filters
1.1.4	set air pressure supply to 55 psi
1.1.5	load solution to airbrush gun
1.1.6	position airbrush gun approximately 10 inches from board
1.1.7	pull the airbrush gun trigger and over spray 2 inches side to side the fabric to be coated
1.1.8	remove pin from cork panel and place coated fabric on aluminum foil
1.1.9	place coated fabric in oven for 30-60 min at 150 °C
2	**Stencil/Spray**
2.1	Material for coating
2.1.1	cork board 24" × 36" Hobby Lobby part 132894
2.1.2	Covered the cork board with polyester interlock fabric

2.1.3 Saw horse for support 2.1.4 Several clamps for holding cork panel to saw horse 2.1.5 Double filter to remove oil residue from compressor and dehumidificaton salt 2.1.6 Iwata eclipse MP-CS airbrush 2.1.7 Husky 30.3 liter tank compression system 2.1.8 Push pin to hold fabric on cork panel Hobby Lobby part #523456 2.1.9 Stencil pattern SKU#75244 Lincaine 12"x 24"x 0.020" Hobby Lobby 2.2 Material for preparation 2.2.1 Scissor 2.2.2 Ruler 2.2.3 Balance AWS model Pnx-203 2.3 Material for drying 2.3.1 Wolf stove set up at 150 °F maintaining 71-78 °C with fan system. 2.3.2 Flat baking sheet 2.3.3 Aluminum foil 2.3.4 SC 307T thermometer with probe 2.4 Execution 2.4.1 lay fabric to be coated on top of cork panel covered with polyester fabric 2.4.2 lay stencil pattern on top of fabric 2.4.3 secure stencil with pin to the cork panel 2.4.4 set compressor with oil and humidity filters 2.4.5 set air pressure supply to 55psi 2.4.6 load solution to airbrush gun 2.4.7 position airbrush gun approximately 10 inches from board 2.4.8 pull the airbrush gun trigger and over spray 2 inches side to side the fabric to be coated 2.4.9 remove pin from cork panel and place coated fabric on aluminum foil 2.4.10 place coated fabric in oven for 30-60 min at 150°C
3 **Screen print** 3.1 Material for coating 3.1.1 cork board 24" × 36" Hobby Lobby part 132894 3.1.2 Covered the cork board with polyester interlock fabric 3.1.3 Saw horse for support 3.1.4 Several clamps for holding cork panel to saw horse 3.1.5 screen print frame 12" × 18" part# 4710 made by Speed Ball 3.1.6 silicon spatula 3.2 Material for preparation 3.2.1 Scissor 3.2.2 Ruler 3.2.3 Balance AWS model Pnx-203 3.3 Material for drying 3.3.1 Wolf stove set up at 150 °F maintaining 71-78 °C with fan system.

3.3.2	Flat baking sheet
3.3.3	Aluminum foil
3.3.4	SC 307T thermometer with probe
3.4	Execution
3.4.1	lay fabric to be coated on top of cork panel covered with polyester fabric
3.4.2	lay screen print frame on top of fabric
3.4.3	load solution to one edge of the screen print frame
3.4.4	with a silicon spatula move solution across the screen print frame until the entire fabric to be coated surface is covered
3.4.5	remove screen print frame and place coated fabric on aluminum foil
3.4.6	place coated fabric in oven for 30-60 min at 150 °C
4	**Bath**
4.1	Material for coating
4.1.1	cork board 24" × 36" Hobby Lobby part 132894
4.1.2	Covered the cork board with polyester interlock fabric
4.1.3	Saw horse for support
4.1.4	Several clamps for holding cork panel to saw horse
4.1.5	Paint tray liner Item #: 170418 Model #: LOWES0-PK170418 at Lowes Hardware
4.1.6	Noodle making machine Imperia model #15-4590
4.2	Material for preparation
4.2.1	Scissor
4.2.2	Ruler
4.2.3	Balance AWS model Pnx-203
4.3	Material for drying
4.3.1	Wolf stove set up at 150 °F maintaining 71-78 °C with fan system.
4.3.2	Flat baking sheet
4.3.3	Aluminum foil
4.3.4	SC 307T thermometer with probe
4.4	Execution
4.4.1	load silk solution inside the paint tray liner well
4.4.2	immerse the fabric sample to be coated inside the silk solution until it is all saturated
4.4.3	pass the saturated fabric between pressure roller (noodle making machine) to remove any excess solution
4.4.4	place coated fabric on aluminum foil
4.4.5	place coated fabric in oven for 30-60 min at 150 °C

The products produced using the coating processes described above were tested for accumulative one way transport capability (or index) and other properties using Association of Textile, Apparel & Materials Professionals (AATCC) test method 195-2012 for the measurement, evaluation, and classification of liquid moisture management

properties of textile fabrics. The details of the test methods are available from AATCC, and a synopsis of the methods and calculations is provided here. The absorption rate (ART) (top surface) and (ARB) (bottom surface) is defined as the average speed of liquid moisture absorption for the top and bottom surfaces of the specimen during the initial change of water content during a test. The accumulative one-way transport capability (R) is defined as the difference between the area of the liquid moisture content curves of the top and bottom surfaces of a specimen with respect to time. The bottom surface (B) is defined for testing purposes as the side of the specimen placed down against the lower electrical sensor which is the side of the fabric that would be the outer exposed surface of a garment when it is worn or product when it is used. The top surface (T) for testing purposes is defined as the side of a specimen that, when the specimen is placed on the lower electrical sensor, is facing the upper sensor. This is the side of the fabric that would come in contact with the skin when a garment is worn or when a product is used. The maximum wetted radius (MWRT) and (MWRB) (mm) is defined as the greatest ring radius measured on the top and bottom surfaces. Moisture management is defined, for liquid moisture management testing, as the engineered or inherent transport of aqueous liquids such as perspiration or water (relates to comfort) and includes both liquid and vapor forms of water. The overall (liquid) moisture management capability (OMMC), an index of the overall capability of a fabric to transport liquid moisture as calculated by combining three measured attributes of performance: the liquid moisture absorption rate on the bottom surface (ARB), the one way liquid transport capability (R), and the maximum liquid moisture spreading speed on the bottom surface (SS_B). The spreading speed (SS_i) is defined as the accumulated rate of surface wetting from the center of the specimen where the test solution is dropped to the maximum wetted radius. The total water content (U) (%) is defined as the sum of the percent water content of the top and bottom surfaces. The wetting time (WTT) (top surface) and (WTB) (bottom surface) is defined as the time in seconds when the top and bottom surfaces of the specimen begin to be wetted after the test is started.

A moisture management tester (MMT) is used to perform the test. The accumulative one way liquid transport capability (R) is calculated as: [Area (U_B) – Area (U_T)]/total testing time. The OMMC is calculated as: $OMMC = C_1^* AR_{B_ndv} + C_2^* R_{nvd} +$

C_3^* SS_{B_ndv}, where C_1, C_2, and C_3 are the weighting values * for AR_{B_ndv}, R_{ndv} and SS_{B_ndv}; (AR_B) = absorption rate; (R) = one-way transport capability, and (SS_B) = spreading speed. Detailed calculations of these parameters, and other parameters of interest, are provided in AATCC test method 195-2012.

A description of the samples used is given in Table 27.

Table 27. Description of samples.

Sample ID	Description
15051201	no coating (polyester)
15051301	1% silk solution spray coating on 15051201
15051302	0.1% silk solution spray coating on 15051201
15051303	0.05% silk solution spray coating on 15051201
15051304	1% silk solution spray stencil coating on 15051201
15051305	0.1% silk solution spray stencil coating on 15051201
15051306	0.05% silk solution spray stencil coating on 15051201
15051401	1% silk solution bath coating on 15051201
15051402	0.1% silk solution bath coating on 15051201
15051403	0.05% silk solution bath coating on 15051201
15051404	PureProC screen print on 15051201
15042001	non wicking finished
15042002	semifinished before final setting
15042003	with wicking finished
15042101	non wicking finished (15042001) 1% silk solution spray coating
15042102	non wicking finished (15042001) 0.1% silk solution spray coating
15061206	non wicking finished (15042001) 1% silk solution stencil coating
15061207	non wicking finished (15042001) 1% silk solution bath coating
15061205	non wicking finished (15042001) 0.1% silk solution stencil coating
15061209	non wicking finished (15042001) 0.1% silk solution bath coating
15061201	semifinished before final setting (15042002) 1% silk solution spray coating
15061203	semifinished before final setting (15042002) 1% silk solution stencil coating
15061208	semifinished before final setting (15042002) 1% silk solution bath coating
15061202	semifinished before final setting (15042002) 0.1% silk solution spray coating
15061204	semifinished before final setting (15042002) 0.1% silk solution stencil coating
15061210	semifinished before final setting (15042002) 0.1% silk solution bath coating

The results of the tests are depicted in **Fig. 57A** through **Fig. 86B** and illustrate the superior performance of silk coated fabric, including superior performance with

respect to accumulative one way transport capability (index) and overall moisture management capability.

Example 6. Antimicrobial Properties of Silk Coatings on Fabrics

The antimicrobial properties of silk coatings were testing on four materials: a cotton/LYCRA jersey (15051201), a cotton/LYCRA jersey with 1% silk fibroin solution (sfs) bath coating (15070701), a polyester/LYCRA finish after final setting (15042003), and a polyester/LYCRA semi-finished 1% sfs bath coating (15070702) (wherein LYCRA is the trade name of a polyester-polyurethane copolymer). AATCC test method 100-2012 for the assessment of antibacterial finishes on textile materials was used. The details of the test method are available from AATCC. Briefly, the tests were performed using tryptic soy broth as a growth medium, a sample size of 4 layers, autoclave sterilization, 100 mL Letheen broth with Tween for neutralization, a target inoculation level of 1-2 $\times$ 10^5 CFU/mL, 5% nutrient broth as an inoculent carrier and dilution medium, a contact time of 18 to 24 hours, and a temperature of 37 +/- 2 °C.

The results of the tests are summarized in Table 28 and are depicted in FIG. 87 to FIG. 92, and illustrate the superior antimicrobial performance of the silk-coated fabrics.

Table 28. Antimicrobial test results.

		Results: cfu/sample		
sample #	bacteria	Zero Contact Time	24hr Contact Time	Percent Reduction
15051201	Staphylococcus aureus ATCC 6538	1.23E+05	4.90E+06	-3883.74%
	Klebsiella pneumoniae ATCC 4352	1.65E+05	4.90E+06	-2869.70%
15070701	Staphylococcus aureus ATCC 6538	1.23E+05	4.90E+06	-3883.74%
	Klebsiella pneumoniae ATCC 4352	1.65E+05	4.90E+06	-2869.70%
15042003	Staphylococcus aureus ATCC 6538	1.23E+05	4.90E+06	-3883.74%
	Klebsiella pneumoniae ATCC 4352	1.65E+05	4.90E+06	-2869.70%
15070702	Staphylococcus aureus ATCC 6538	1.23E+05	1.03E+04	91.63%
	Klebsiella pneumoniae ATCC 4352	1.65E+05	2.33E+05	-40.91%

Example 7. Methods of Preparing Fabrics with Silk Coatings

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa includes the steps of: degumming a silk source by adding the silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may

further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa includes the steps of: adding a silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60°C to about 100°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an

antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, includes the steps of: adding a silk source to a boiling (100°C) aqueous solution of sodium carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80°C to about 140°C; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60°C to about 100°C for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid

chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

Example 8. Characterization of Silk Coatings on Polyester

A summary of the results from studies of silk coatings on polyester are given in Table 29 and Table 30. The results shown in **Fig. 93** and **Fig. 94** illustrate that the accumulative one way transport index and OMMC performance is maintained even at 60 wash cycles. Additional test results are shown in **Fig. 95** to **Fig. 102**. The antimicrobial performance of the silk coated polyester fabrics are maintained to 25 to 50 washing cycles, as shown in **Fig. 103** to **Fig. 104**. The results illustrate the surprising improvement in moisture management properties, as well as the surprising result that the improved properties survive many wash cycles.

Table 29. Test results for semifinished polyester with 1% silk solution coating.

Testing Results: Semifinished polyester with 1% silk solution coating

Number of Washes	Raw Data:	Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%/sec)	Bottom Absorption Rate (%/sec)	Top Max Wetted Radius (mm)	Bottom Max Wetted Radius (mm)	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	Accumulative One-Way Transport Index(%)	Overall Moisture Management Capability OMMC
0 Cycles	Mean	5.63	3.95	7.24	28.73	5	5	0.90	1.22	133.26	0.27
	S. Deviation	1.20	0.38	1.46	8.62	0	0	0.20	0.12	34.81	0.06
	CV	0.21	0.10	0.20	0.30	0	0	0.22	0.09	0.26	0.21
10 Cycles	Mean	23.87	7.96	4.82	8.55	5	5	0.46	0.68	144.84	0.22
	S. Deviation	31.51	3.30	0.84	2.94	0	0	0.28	0.23	27.71	0.03
	CV	1.32	0.41	0.17	0.34	0	0	0.61	0.33	0.19	0.14
25 Cycles	Mean	6.09	4.59	7.36	17.22	5	5	0.83	1.05	124.05	0.22
	S. Deviation	1.61	0.44	2.98	3.28	0	0	0.17	0.09	11.70	0.02
	CV	0.26	0.10	0.40	0.19	0	0	0.20	0.09	0.09	0.09
50 Cycles	Mean	25.20	11.64	6.84	7.80	5	5	0.39	0.53	58.81	0.13
	S. Deviation	28.06	6.36	3.38	5.70	0	0	0.30	0.27	26.56	0.03
	CV	1.11	0.55	0.49	0.73	0	0	0.77	0.51	0.45	0.25

Table 30. Test results for wicking finished polyester without silk coating.

Testing Results: Wicking Finished Polyester

Number of Washes	Raw Data:	Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%/sec)	Bottom Absorption Rate (%/sec)	Top Max Wetted Radius (mm)	Bottom Max Wetted Radius (mm)	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	Accumulative One-Way Transport Index(%)	Over all Moisture Management Capability OMMC
0 Cycles	Mean	3.46	3.48	37.30	56.90	5	5	1.37	1.36	62.37	0.29
	S .Deviation	0.07	0.04	12.89	10.24	0	0	0.02	0.02	9.74	0.03
	CV	0.02	0.01	0.35	0.18	0	0	0.02	0.01	0.16	0.12
25 Cycles	Mean	6.69	6.71	7.23	6.89	5	5	0.75	0.76	30.40	0.09
	S. Deviation	1.48	1.92	1.27	2.74	0	0	0.13	0.19	16.22	0.02
	CV	0.22	0.29	0.18	0.40	0	0	0.17	0.25	0.53	0.20
50 Cycles	Mean	11.27	8.46	6.70	9.35	5	5	0.54	0.65	31.21	0.09
	S. Deviation	6.57	3.53	1.45	5.21	0	0	0.23	0.25	18.26	0.03
	CV	0.58	0.42	0.22	0.56	0	0	0.44	0.38	0.59	0.30

Example 9. Characterization of Silk Coatings on Polyester Fabrics

Scanning electron microscopy (SEM) analysis was performed using a Hitachi S-4800 field-emission SEM (FE-SEM) operated at 2 kV accelerating voltage. Pieces from each sample were sectioned using a razor blade and placed on carbon adhesive tape mounted on aluminum SEM stubs. A coating of iridium approximately 2 nm thick was applied via sputter deposition in order to minimize the buildup of surface charge.

The samples used in the SEM study are described in Table 31. SEM micrographs for fabric samples are shown in Fig. 105 to Fig. 167.

Table 31. Fabric samples tested by scanning electron microscopy and optical profilometry.

Sample ID	Fabric	Silk solution for coating/treatment (average molecular weight, Da)	Silk coating/treatment method using silk fibroin solution (sfs)
FAB-10-SPRAY-B	Semi-finished UA R20904012	41,576	spray with 1% sfs
FAB-01-SPRAY-B	Semi-finished UA R20904012	41,576	spray with 0.1% sfs
FAB-10-STEN-B	Semi-finished UA R20904012	41,576	stencil spray with 1% sfs
FAB-10-BATH-B	Semi-finished UA R20904012	41,576	bath with 1% sfs
FAB-01-BATH-B	Semi-finished UA R20904012	41,576	bath with 0.1% sfs
FAB-01-SPRAY-C	Semi-finished UA R20904012	10,939	spray with 0.1% sfs
FAB-01-STEN-C	Semi-finished UA R20904012	10,939	stencil spray with 0.1% sfs
FAB-10-BATH-C	Semi-finished UA R20904012	10,939	bath with 1% sfs

The fabric SEM results show that the silk solution has very clearly been deposited along and between individual polyester fibers. The use of 0.1% silk solution results in less coating than 1.0% silk solution. The use of a bath for 0.1% silk solution, with an average molecular weight of 41 kDa, results in uniform coating along fibers with large, smooth features. The use of a spray with a 0.1% silk solution, with an average molecular weight of 41 kDa, in coating along fibers as well as connected, webbed coating between fibers. The use of a spray for 0.1% silk solution, with an average molecular weight of 11 kDa, results in uniform coating along fibers with small, spotted/ribbed features. The use

of a stencil for 0.1% silk solution, with an average molecular weight of 11 kDa, results in coating along fibers that has clear edges and delineation between coated and non coated sides. The use of a bath for 1.0% silk solution, with an average molecular weight of 41 kDa, results in thick coating along fibers as well as thick connected, webbed coating between fibers. The use of a bath for 1.0% silk solution, with an average molecular weight of 11 kDa, results in coating along all sides of individual fibers. Coating appears uniform on surface with many single point extrusions. The use of a spray for 1.0% silk solution, with an average molecular weight of 41 kDa, results in coating along fibers as well as connected, webbed coating between fibers, which was thicker than that observed using 0.1% silk solution. The use of a stencil for 1.0% silk solution, with an average molecular weight of 41 kDa, results in coating along fibers and between fibers, and the coating appears well organized.

The SEM results demonstrate that the silk coating has been applied as an even, thin, uniform coating to the fibers of the fabric. This illustrates the surprising result that the silk coating was applied to the fibers without the use of any additives or cross-linking, using a water based delivery system.

Example 10. Characterization of Silk Coatings on Polyester Films

The film samples are described in Table 32. The SEM images from these films are shown in **Fig. 168** to **Fig. 237**.

Table 32. Film samples tested by scanning electron microscopy and optical profilometry.

Sample identifier	Polyester substrate material	Silk solution for coating/treatment (average molecular weight, Da)	Silk coating/treatment method using silk fibroin solution (sfs)
FIL-10-SPRAY-B-01MYL	0.01 Mylar	41,576	spray with 1% sfs
FIL-01-SPRAY-B-01MYL	0.01 Mylar	41,576	spray with 0.1% sfs
FIL-01-SPRAY-B-007MEL	0.007 Melinex	41,576	spray with 0.1% sfs
FIL-01-SPRAY-C-01MYL	0.01 Mylar	10,939	spray with 0.1% sfs
FIL-01-STEN-B-01MYL	0.01 Mylar	41,576	stencil spray with 0.1% sfs
FIL-01-STEN-C-01MYL	0.01 Mylar	10,939	stencil spray with 0.1% sfs
FIL-10-BATH-B-01MYL	0.01 Mylar	41,576	bath with 1% sfs

FIL-10-BATH-B-007MEL	0.007 Melinex	41,576	bath with 1% sfs
FIL-10-BATH-C-01MYL	0.01 Mylar	10,939	bath with 1% sfs
FIL-01-BATH-B-01MYL	0.01 Mylar	41,576	bath with 0.1% sfs

The results show that the silk coatings are applied uniformly. Little to no variation is observed in the characteristics or topology of the coated polyester films. Surprisingly, the coating is even, uniform, and thin. Furthermore, surprising, the silk coated the fibers without any additives or cross-linking using a water-based system.

Optical profiling was carried out using a Zygo New View 6200 optical profilometer. Two locations on each sample were randomly selected and measured with 10X magnification. The results are shown in **Fig. 241** to **Fig. 264.** The results indicate that the silk-coated samples have a homogeneous deposition of silk fibroin. Surface roughness features observed in the control are visible after silk coating on Mylar films, which is consistent with the presence of a relatively thin silk film that is forming a conformal coating on Mylar. The results substantiate the uniformity of the coating, and demonstrate that silk can be stenciled into discrete locations.

Contact profilometry was performed and the cross-sectioned samples were examined by SEM. Results are shown in **Fig. 265** to **Fig. 268**. For sample FIL-10-SPRAY-B-10MYL, the thickness ranged from approximately 260 nm to 850 nm in 4 locations analyzed. For sample FIL-10-BATH-B-01MYL, the coating ranged from approximately 140 nm to 400 nm in 4 locations. SEM images from cross-sections show similar trends, with one location on sample FIL-10-SPRAY-B-10MYL having a cross-section that measures approximately 500 nm and one on FIL-10-BATH-B-01MYL measuring approximately 180 nm.

Example 11. Preparation of Silk Fibroin Solutions with Higher Molecular Weights

The preparation of silk fibroin solutions with higher molecular weights is given in Table 33.

Table 33. Preparation and properties of silk fibroin solutions.

Sample Name	Extraction Time (mins)	Extraction Temp (°C)	LiBr Temp (°C)	Oven/Sol'n Temp	Average weight average	Average polydispersity

					molecular weight (kDa)	
Group A TFF	60	100	100	100°C oven	34.7	2.94
Group A DIS	60	100	100	100°C oven	44.7	3.17
Group B TFF	60	100	100	100°C sol'n	41.6	3.07
Group B DIS	60	100	100	100°C sol'n	44.0	3.12
Group C TFF	60	100	140	140°C sol'n	10.9	3.19
Group C DIS	60	100	140	140°C sol'n		
Group D DIS	30	90	60	60°C sol'n	129.7	2.56
Group D FIL	30	90	60	60°C sol'n	144.2	2.73
Group E DIS	15	100	RT	60°C sol'n	108.8	2.78
Group E FIL	15	100	RT	60°C sol'n	94.8	2.62

Example 12. Silk Coatings on Natural Fabrics

The coating of natural fabric with silk fibroin solutions and the resulting properties are illustrated in Table 34, Table 35, **Fig. 269,** and **Fig. 270**. The results demonstrate that silk fibroin solutions can coat cotton-Lyrca natural fabrics including LUON and POWER LUXTREME.

Table 34. Silk fibroin coated fabrics.

Legend	**Fabric**
15072201	Power Luxtreme RT1211362
15072202	Luon RT20602020
15072301	Power Luxtreme RT1211362 (15072201) 1% silk solution spray coating
15072302	Luon RT20602020 (15072202) 1% silk solution spray coating
15072303	Power Luxtreme RT1211362 (15072201) 0.1% silk solution spray coating
15072304	Luon RT20602020 (15072202) 0.1% silk solution spray coating
15072305	Power Luxtreme RT1211362 (15072201) 1% silk solution stencil coating
15072306	Luon RT20602020 (15072202) 1% silk solution stencil coating
15072307	Power Luxtreme RT1211362 (15072201) 0.1% silk solution stencil coating
15072308	Luon RT20602020 (15072202) 0.1% silk solution stencil coating
15072309	Power Luxtreme RT1211362 (15072201) 1% silk solution bath coating
15072310	Luon RT20602020 (15072202) 1% silk solution bath coating
15072311	Power Luxtreme RT1211362 (15072201) 0.1% silk solution bath coating
15072312	Luon RT20602020 (15072202) 0.1% silk solution bath coating

Table 35. Test results for silk fibroin coated fabrics.

		Wetting Time Top	Wetting Time Bottom	Top Absorption Rate	Bottom Absorption Rate	Top Max Wetted Radius	Bottom Max Wetted Radius	Top Spreading Speed	Bottom Spreading Speed	Accumulative One-Way Transport	Over all Mois Manageme Capability
	Raw Data:	(sec)	(sec)	(%/sec)	(%/sec)	(mm)	(mm)	(mm/sec)	(mm/sec)	index(%)	OMMC
15072201	Mean	64.3786	3.4072	8.8123	8.60494	5	5	0.15038	1.41686	151.65248	0.25898
15072202	Mean	25.1786	28.1922	5.4636	6.195	5	5	0.218	0.4244	80.9572	0.1529
15072301	Mean	16.7172	12.2804	21.9859	33.6196	5	5	0.4304	0.4906	143.6659	0.2808
15072302	Mean	25.8898	41.5026	6.16512	8.70282	5	5	0.23336	0.1791	44.06124	0.10704
15072303	Mean	42.152	4.7268	7.9114	19.3725	4	5	0.3261	1.364	370.2757	0.5297
15072304	Mean	78.4746	34.3138	5.01486	6.63212	5	5	0.0661	0.38728	94.97976	0.16848
15072305	Mean	36.1954	17.2038	6.27158	6.25526	5	5	0.18872	0.89046	139.73478	0.23052
15072306	Mean	78.4746	34.3138	5.01486	6.63212	5	5	0.0661	0.38728	94.97976	0.16848
15072307	Mean	36.195	17.2038	6.2716	6.2553	5	5	0.1887	0.8905	139.7348	0.2305
15072308	Mean	57.335	25.7588	5.6432	6.4437	5	5	0.1274	0.6389	117.3573	0.1995
15072309	Mean	54.1384	9.2662	4.01594	9.11064	5	5	0.09398	0.85306	267.0755	0.36724
15072310	Mean	28.4544	13.6658	6.8844	7.8956	5	5	0.3059	0.5111	104.5035	0.1794
15072311	Mean	5.1292	4.4738	8.8047	13.0277	5	5	0.9486	1.1702	246.6729	0.3597
15072312	Mean	6.8516	9.4722	11.0684	11.7268	5	5	0.7394	0.5794	73.4005	0.1461

All patents, patent applications, and published references cited herein are hereby incorporated by reference in their entirety. While the methods of the present disclosure have been described in connection with the specific embodiments thereof, it will be understood that it is capable of further modification. Further, this application is intended to cover any variations, uses, or adaptations of the methods of the present disclosure, including such departures from the present disclosure as come within known or customary practice in the art to which the methods of the present disclosure pertain.

CLAIMS

1. An article comprising a fiber or yarn having a coating, wherein the coating comprises silk-fibroin based proteins or fragments thereof, wherein the silk-fibroin based proteins or fragments thereof have (a) an average weight average molecular weight range of 6 kDa to 80 kDa, (b) a polydispersity from 1.5 to 3.0, and (c) 0.01% (w/w) to 10% (w/w) sericin.

2. The article of Claim 1, wherein the article is a fabric.

3. The article of Claim 1, wherein the silk fibroin based proteins or fragments thereof are selected from the group consisting of natural silk fibroin based proteins or fragments thereof, recombinant silk fibroin based proteins or fragments thereof, and combinations thereof.

4. The article of Claim 3, wherein the silk fibroin based proteins or fragments thereof are natural silk fibroin based proteins or fragments thereof that are selected from the group consisting of spider silk fibroin based proteins or fragments thereof, silkworm silk fibroin based proteins or fragments thereof, and combinations thereof.

5. The article of Claim 4, wherein the natural silk fibroin based proteins or fragments are silkworm silk fibroin based proteins or fragments thereof, and the silkworm silk fibroin based proteins or fragments thereof is *Bombyx mori* silk fibroin based proteins or fragments thereof.

6. The article of Claim 1, wherein the coating further comprises a polymer or copolymer.

7. The article of Claim 1, wherein the silk fibroin based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of 6 kDa to 16 kDa, 17 kDa to 38 kDa, 39 kDa to 80 kDa, and wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or

gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

8. The article of Claim 1, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof.

9. The article of Claim 8, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cashmere, sheep fleece, sheep wool, and combinations thereof.

10. The article of Claim 8, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof.

11. The article of Claim 2, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one-way moisture transport index selected from the group consisting of greater than 40 %, greater than 60 %, greater than 80 %, greater than 100 %, greater than 120 %, greater than 140 %, greater than 160 %, and greater than 180%.

12. The article of Claim 2, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one way transport capability increase relative to uncoated fabric selected from the group consisting of 1.2 fold, 1.5 fold, 2.0 fold, and 3.0 fold.

13. The article of Claim 2, wherein the fabric exhibits an improved property, wherein the improved property is an overall moisture management capability selected from the group consisting of greater than 0.05, greater than 0.10, greater than 0.15, greater than 0.20, greater than 0.25, greater than 0.30, greater than 0.35, greater than 0.40, greater than 0.50, greater than 0.60, greater than 0.70, and greater than 0.80.

14. The article of Claim 13, wherein the improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

15. The article of Claim 2, wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

16. The article of Claim 15, wherein the microbial growth is microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebisiella pneumoniae*, and combinations thereof.

17. The article of Claim 16, wherein the microbial growth is reduced by a percentage selected from the group consisting of 50 %, 100 %, 500 %, 1000 %, 2000 %, and 3000 % compared to an uncoated fabric.

18. The article of Claim 2, wherein the coating is applied to the fabric at the fiber level prior to forming the fabric.

19. The article of Claim 2, wherein the coating is applied to the fabric at the fabric level.

20. The article of Claim 19, wherein the fabric is bath coated.

21. The article of Claim 19, wherein the fabric is spray coated.

22. The article of Claim 19, wherein the fabric is coated with a stencil.

23. The article of Claim 19, wherein the coating is applied to at least one side of the fabric using a method selected from the group consisting of a bath coating process, a spray coating process, a stencil process, a silk-foam based process, and a roller-based process.

24. The article of Claim 1, wherein the coating has a thickness of one nanolayer.

25. The article of Claim 1, wherein the coating has a thickness selected from the group consisting of 5 nm, 10 nm, 15 nm, 20 nm, 25 nm, 50 nm, 100 nm, 200 nm, 500 nm, 1 μm, 5 μm, 10 μm, and 20 μm.

26. The article of Claim 2, wherein the coating is adsorbed on the fabric.

27. The article of Claim 2, wherein the coating is attached to the fabric through chemical, enzymatic, thermal, or irradiative cross-linking.

28. The article of Claim 19, wherein the hand of the coated fabric is improved relative to an uncoated fabric.

29. The article of Claim 28, wherein the hand of the coated fabric that is improved is selected from the group consisting of softness, crispness, dryness, silkiness, and combinations thereof.