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(54) Title: NONWOVEN ARTICLE

(57) Abstract: Nonwoven articles, such as a nonwoven hand tool, can include a body including a plurality of plys. Each ply can include a web including a blend of nonwoven fibers. The plys can bond to one another via a binding material. The nonwoven article can include improved physical and/or mechanical property, hand tool performance, or any combination thereof.

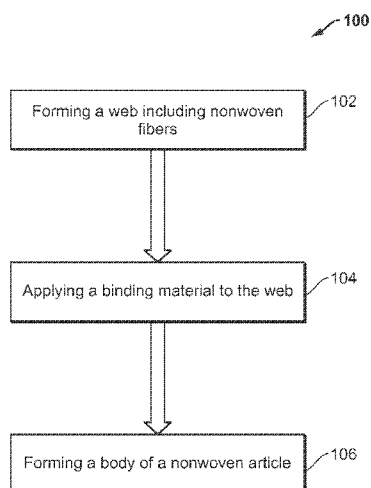


FIG. 1

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NONWOVEN ARTICLE

TECHNICAL FIELD

This disclosure relates, in general, to nonwoven articles and in particular, to articles
5 and methods regarding nonwoven hand tools. The nonwoven hand tools possess physical and performance properties that beneficially exceed the state of the art.

Nonwoven articles having a lofty, open web of fibers are used in various applications and may be employed as a substrate for a wide variety of abrasive articles. Nonwoven articles can often be engineered to provide performance characteristics specific to a particular
10 application that includes workpiece surfaces having complex shapes, delicate surface finishes, and/or deposits or residue that require a combination of performance characteristics to provide satisfactory cleaning and/or finishing. Accordingly, there continues to be a need for improved nonwoven articles having improved performance characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The present disclosure may be better understood, and its numerous features and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. 1 includes a flow diagram illustrating a process for forming a nonwoven article according to an embodiment.

20 FIG. 2 includes an image of an exemplary nonwoven hand tool according to an embodiment.

FIG. 3 includes an illustration of a portion of an exemplary nonwoven article according to an embodiment.

FIG. 4 includes an illustration of a read-out of an FTIR analysis of binding materials.

25 FIGS. 5 and 6 include DSC data of binding materials.

FIG. 7 includes GCMS data of representative binding material according to an embodiment.

Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of
30 some of the elements in the figures can be exaggerated relative to other elements to help improve understanding of embodiments of the invention. The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The following description, in combination with the figures, is provided to assist in understanding the teachings disclosed herein. The following discussion will focus on specific implementations and embodiments of the teachings. This focus is provided to assist in
5 describing the teachings and should not be interpreted as a limitation on the scope or applicability of the teachings.

As used herein, the terms “comprises”, “comprising,” “includes,” “including,” “has,” “having,” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not
10 necessarily limited only to those features but can include other features not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present), and B is false (or not present), A is false (or not present), and B is true (or present), and both A and B are true (or
15 present).

The use of “a” or “an” is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one, or at least one, and the singular also includes the plural, or vice versa, unless it is clear that it is meant otherwise.

20 Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The materials, methods, and examples are illustrative only and not intended to be limiting.

Embodiments herein relate to nonwoven articles, in particular, nonwoven hand tools
25 having improved hand feel and performance. For example, the nonwoven hand tools may have improved mechanical properties, such as improved integrity, resistance against ply separation, peel strength, tensile strength, or any combination thereof, service life, stiffness, or any combination thereof.

Referring to FIG. 1, a process 100 of forming a nonwoven hand tool is illustrated.

30 The process 100 may start at block 102, forming a web including nonwoven fibers. In certain embodiments, forming the web may be accomplished by air laying. Alternate web forming methods can be used. For example, wet laying, dry laying, spun-bonding, melt-blowing, electro-spinning, carding, or any combination thereof, may be used.

The nonwoven fibers can include an organic material, an inorganic material, a natural material, a semisynthetic material, a synthetic material, or any combination thereof. In a particular embodiment, the first type and the second type of fibers may include a thermoplastic material. For example, the web may include fibers including polyamide, polyester, polyolefin, or the like, or any combination thereof. In a particular example, the web may include solid polyester fibers or trilobal polyester or any combination thereof.

In an embodiment, the web may include a blend of a plurality of nonwoven fibers. For example, the web may include a first type of fibers and a second type of fibers, wherein the first type of fibers can be different from the second type of fibers in composition, construction, denier, length, ratio, shape, thickness, type, or any combination thereof. In a particular example, the composition of the first type of fibers may be different from the composition of the second type of fibers.

In an embodiment, the first type of fibers, the second type of fibers, or both may comprise an organic material. For example, the first type of fibers, the second type of fibers, or both may comprise a polymeric material. In another example, the first type of fibers, the second type of fibers, or both may comprise organic fibers. In an exemplary implementation, the blend may include polyamide, such as nylon, and polyester, such as polyethylene terephthalate. A particular example of nylon may include poly[imino(1,6-dioxohexamethylene)iminohexamethylene] fibers ("Nylon 6,6" fibers). In a particular exemplary implementation, the first type of fibers may include polyamide fibers, and the second type of fibers may include solid polyester fibers. In an even more particular implementation, the blend may comprise the first type of fibers consisting of polyamide fibers, such as nylon fibers, and the second type of fibers consisting of solid polyester fibers, such as solid polyethylene terephthalate fibers.

In a particular embodiment, the web may comprise a blend of a plurality of fibers consisting of polyamide fibers and polyester fibers, wherein polyester fibers may consist of solid fibers.

The sizes of fibers can be expressed through denier, a measure of linear density, which is equal to the mass in grams per 9,000 meters of length of a single filament. For instance, a nylon fiber measuring 200 denier means that 9,000 meters of this fiber weighs 200 grams.

In a further embodiment, a difference between a first denier of the first type of fibers and a second denier of the second type of fibers may be within 20% of the bigger of the first and second denier. As used herein, a denier of a type of fibers is intended to refer to the

average denier of the fibers of the same type. For Example, the difference between the first and second denier may be not greater than 15% or not greater than 12% or not greater than 10% or not greater than 8% or not greater than 6% or not greater than 4% or not greater than 2% or not greater than 1% of the bigger of the first and second denier. In a particular embodiment, the first denier of the first type of fibers may be essentially the same as the second denier of the second type of fibers.

In a further embodiment, the first type of fibers may include a particular first denier that may facilitate formation of the nonwoven hand tool with improved properties and/or performance. In an aspect, the first denier may be not greater than 29 or not greater than 25 or not greater than 23 or not greater than 21 or not greater than 19 or not greater than 17 or not greater than 15 or not greater than 13. In a further aspect, the first denier may be at least 10 or at least 11 or at least 12 or at least 13 or at least 14 or at least 15 or at least 16. Moreover, the first denier may be in a range including any of the minimum and maximum values noted herein.

In a further embodiment, the second type of fiber may include a particular second denier that may facilitate formation of the nonwoven hand tool with improved properties and/or performance. In an aspect, the second denier may be not greater than 60 or not greater than 55 or not greater than 50 or not greater than 45 or not greater than 40 or not greater than 35 or not greater than 32 or not greater than 29 or not greater than 25 or not greater than 23 or not greater than 21 or not greater than 19 or not greater than 17 or not greater than 15 or not greater than 13. In another aspect, the second denier may be at least 10 or at least 11 or at least 12 or at least 13 or at least 14 or at least 15 or at least 16 or at least 18 or at least 20 or at least 22 or at least 24 or at least 27 or at least 31 or at least 36 or at least 38 or at least 40 or at least 44. Moreover, the second denier may be in a range including any of the minimum and maximum values noted herein.

In an embodiment, the blend may comprise a particular amount of the first type of fibers that may facilitate formation of the nonwoven hand tool with improved properties and/or performance. In an aspect, the blend may include 5wt% to 95wt% of the first type of fibers, such as 25wt% to 75wt% or 30wt% to 70wt% or 35wt% to 65wt% or 40wt% to 60wt% or 45wt% to 55wt% of the first type of fiber for the total weight of the blend.

In an embodiment, the blend may comprise a particular amount of the second type of fibers that may facilitate formation of the nonwoven hand tool with improved properties and/or performance. In an aspect, the blend may include 5wt% to 95wt% of the second type

of fibers, such as 25wt% to 75wt% or 30wt% to 70wt% or 35wt% to 65wt% or 40wt% to 60wt% or 45wt% to 55wt% of the second type of fibers for the total weight of the blend.

In a particular implementation, the web may include a blend of the first type of fibers and second type of fibers, wherein the first type of fibers are 50wt% of the blend, and the second type of fibers are 50wt% of the blend. In an even more particular implementation, the web may include a blend of polyamide fibers and solid polyester fibers and/or trilobal polyester, wherein the ratio between the polyamide fibers and solid polyester fibers may be 50:50.

In a further embodiment, a plurality of webs may be formed, wherein each web may be formed including a blend of a plurality of nonwoven fibers described in embodiments herein.

In an embodiment, one or more webs of nonwoven fibers may be mechanically bonded. For example, the plurality of nonwoven fibers may be subjected to a needle punching process to at least partially entangle and/or intermingle the plurality of fibers.

In a particular embodiment, the needle punching process may comprise a double needling process. The double needling process may generally comprise two needling boards that operate at different parameters to at least partially entangle and/or intermingle the plurality of fibers 104 to form the nonwoven substrate 10s at various needling depths, strokes, or combinations thereof. In some embodiments, the first needling board of the double needling process may comprise a needling stroke of at least about 75 revolutions / square centimeter (rev/cm^2), such as at least 76 rev/cm^2 , at least 77 rev/cm^2 , at least 78 rev/cm^2 , at least 79 rev/cm^2 , at least 80 rev/cm^2 , at least 81 rev/cm^2 , at least 82 rev/cm^2 , at least 83 rev/cm^2 , at least 84 rev/cm^2 , or even at least about 85 rev/cm^2 . In some embodiments, the first needling board of the double needling process may comprise a needling stroke of not greater than about 120 rev/cm^2 , such as not greater than 110 rev/cm^2 , not greater than 100 rev/cm^2 , not greater than 95 rev/cm^2 , not greater than 90 rev/cm^2 , not greater than 89 rev/cm^2 , not greater than 88 rev/cm^2 , not greater than 87 rev/cm^2 , not greater than 86 rev/cm^2 , or even not greater than 85 rev/cm^2 . Further, it will be appreciated that the first board of the double needling process may comprise a needling stroke between any of these minimum and maximum values, such as at least about 75 rev/cm^2 to not greater than about 120 rev/cm^2 , or even such as at least about 80 rev/cm^2 to not greater than about 85 rev/cm^2 .

In some embodiments, the first needling board of the double needling process may comprise a needling depth (i.e., penetration into the nonwoven substrate 102) of at least about 3.0 millimeters (mm), such as at least 3.2 mm, at least 3.4 mm, at least 3.6 mm, at least 3.8

mm, at least 4.0 mm, at least 4.2 mm, at least 4.4 mm, at least 4.6 mm, at least 4.8 mm, at least 5.0 mm, at least 5.2 mm, at least 5.4 mm, at least 5.6 mm, at least 5.8 mm, at least 6.0 mm, at least 6.2 mm, at least 6.4 mm, at least 6.6 mm, at least 6.8 mm, at least 7.0 mm, at least 7.2 mm, at least 7.4 mm, at least 7.6 mm, at least 7.8 mm, at least 8.0 mm, at least 8.2 mm, at least 8.4 mm, at least 8.6 mm, at least 8.8 mm, at least 9.0 mm, at least 9.2 mm, at least 9.4 mm, at least 9.6 mm, at least 9.8 mm, or even at least about 10.0 mm. In some embodiments, the first needling board of the double needling process may comprise a needling depth of not greater than about 15 mm, such as not greater than 14.5 mm, not greater than 14 mm, mm, not greater than 13.5 mm, not greater than 13 mm, not greater than 12.5 mm, not greater than 12 mm, not greater than 11.5 mm, or even not greater than about 11 mm. Further, it will be appreciated that the first needling board of the double needling process may comprise a needling depth between any of these minimum and maximum values, such as at least about 3.0 mm to not greater than about 15 mm, or even such as at least about 3.4 mm to not greater than 11 mm.

In some embodiments, the second needling board of the double needling process may comprise a needling stroke of at least about 90 revolutions / square centimeter (rev/cm^2), such as at least 100 rev/cm^2 , at least 105 rev/cm^2 , at least 110 rev/cm^2 , at least 115 rev/cm^2 , at least 116 rev/cm^2 , at least 117 rev/cm^2 , at least 118 rev/cm^2 , at least 119 rev/cm^2 , or even at least about 120 rev/cm^2 . In some embodiments, the second needling board of the double needling process may comprise a needling stroke of not greater than about 150 rev/cm^2 , such as not greater than 140 rev/cm^2 , not greater than 130 rev/cm^2 , not greater than 125 rev/cm^2 , or even not greater than 120 rev/cm^2 . Further, it will be appreciated that the first board of the double needling process may comprise a needling stroke between any of these minimum and maximum values, such as at least about 90 rev/cm^2 to not greater than about 150 rev/cm^2 , or even such as at least about 95 rev/cm^2 to not greater than about 120 rev/cm^2 .

In some embodiments, the second needling board of the double needling process may comprise a needling depth (i.e., penetration into the nonwoven substrate 102) of at least about 1.0 millimeters (mm), such as at least 1.5 mm, at least 2.0 mm, at least 2.5 mm, at least 3.0 mm, at least 3.1 mm, at least 3.2 mm, at least 3.3 mm, at least 3.4 mm, at least 3.5 mm, at least 3.6 mm, at least 3.8 mm, at least 4.0 mm, at least 4.2 mm, at least 4.4 mm, at least 4.6 mm, at least 4.8 mm, at least 5.0 mm, at least 5.2 mm, at least 5.4 mm, at least 5.6 mm, at least 5.8 mm, at least 6.0 mm, at least 6.2 mm, at least 6.4 mm, at least 6.6 mm, at least 6.8 mm, at least 7.0 mm, at least 7.2 mm, at least 7.4 mm, at least 7.6 mm, at least 7.8 mm, at least 8.0 mm, at least 8.2 mm, at least 8.4 mm, at least 8.6 mm, at least 8.8 mm, at least 9.0

mm, at least 9.2 mm, at least 9.4 mm, at least 9.6 mm, at least 9.8 mm, or even at least about 10.0 mm. In some embodiments, the second needling board of the double needling process may comprise a needling depth of not greater than about 15 mm, such as not greater than 14.5 mm, not greater than 14 mm, not greater than 13.5 mm, not greater than 13 mm, not greater than 12.5 mm, not greater than 12 mm, not greater than 11.5 mm, not greater than 11 mm, not greater than 10.5 mm, or even not greater than about 10.12 mm. Further, it will be appreciated that the first needling board of the double needling process may comprise a needling depth between any of these minimum and maximum values, such as at least about 1.0 mm to not greater than about 15 mm, or even such as at least about 3.2 mm to not greater than 10.12 mm.

In an embodiment, the web of non-woven fibers may comprise a particular weight that may facilitate formation of nonwoven hand tools with improved properties and/or performance. For example, the web of non-woven fibers may comprise a fiber weight of at least 190GSM or at least 200GSM or at least 210GSM or at least 220GSM or at least 230GSM or at least 240GSM or at least 250GSM. In another example, the fiber weight may be not greater than 290GSM or not greater than 280GSM or not greater than 270GSM or not greater than 260GSM or not greater than 250GSM or not greater than 240GSM or not greater than 230GSM. Moreover, the web of nonwoven fibers may include a fiber weight including any of the minimum and maximum values noted herein.

The process 100 may continue to block 104, applying a binding material to the web. In an embodiment, applying a binding material can include spraying and dip coating the web. In particular, the web may be sprayed on and then dip coated with a binding material. In a further embodiment, a binding material may be applied to both sides of one or more needled webs by spray coating, which may facilitate improved bonding of the nonwoven fibers, bonding between the webs, or both. In a further embodiment, dip coating may be performed by dipping the webs in the binding material and squeezing through rolls to allow the binding material to penetrate and saturate the fibers through-out the product.

In a particular embodiment, the binding material may include a material that may facilitate improved properties and/or performance of the nonwoven hand tool, such as hand feel, stiffness, peel strength, tensile strength, or any combination thereof. The binding material may include precursor binding material that can form the finally formed binding material. For example, the binding material may include resins that may cure or crosslink under curing or crosslinking conditions to form the finally formed binding material.

In an embodiment, the binding material may comprise a particular coating density that may facilitate formation of nonwoven hand tools with improved properties and/or performance. In an aspect, the coating density may be at least 260GSM or at least 280GSM or at least 300GSM or at least 320GSM or at least 350GSM or at least 370GSM or at least 395GSM or at least 410GSM or at least 440GSM or at least 460GSM or at least 480GSM or at least 500GSM. In another aspect, the binding material may comprise a coating density of less than 690GSM or not greater than 600GSM or no greater than 550GSM or no greater than 530GSM or no greater than 510GSM or no greater than 480GSM or no greater than 460GSM. Moreover, the binding material may include a coating density including any of the minimum and maximum values noted herein.

In an embodiment, the binding material may include a particular glass transition temperature that may facilitate formation of nonwoven hand tools with improved properties and performance. In an aspect, the binding material comprises a glass transition temperature T_g of not greater than 99°C or not greater than 90°C or not greater than 80°C or not greater than 70°C or not greater than 60°C or not greater than 50°C or not greater than 40°C or not greater than 35°C or not greater than 34°C or not greater than 31°C or not greater than 28°C or not greater than 25°C or not greater than 20°C. In another aspect, the binding material may comprise a glass transition temperature T_g of at least -26°C or at least -20°C or at least -15°C or at least -10°C or at least -5°C or at least 1°C or at least 5°C or at least 10°C or at least 15°C or at least 18°C or at least 20°C or at least 24°C or at least 28°C or at least 30°C. In a particular aspect, the binding material may include a glass transition temperature T_g in a range including any of the minimum and maximum values noted herein. For example, the glass transition temperature may be in a range from -15°C to 60°C, such as in a range from 5°C to 50°C or in a range from 10°C to 40°C or in a range from 15°C to 35°C or even in a range from 18°C to 28°C.

In an embodiment, the binding material may include a particular peak of absorbance analyzed by Fourier Transform Infrared Spectroscopy (also referred to as “FTIR”) that may facilitate formation of nonwoven hand tools with improved properties and performance. Briefly turning to FIG. 4, an overlay of FTIR absorbance peaks is provided, including FTIR absorbance of a representative binding material referred to as D-2B and another binding material referred to as D-7B. The binding material D-2B may include a distinct FTIR absorbance profile comparing to D-7B including height of absorbance peaks at same wavenumbers, wavenumber of absorbance peaks, or any combination thereof. More details of the binding materials D-2B and D-7B are discussed in Examples.

In an aspect, the binding material D-2B can have a absorbance peak between 1320cm^{-1} to 1410cm^{-1} . In certain instances, the absorbance may be greater than 0.052 or at least 0.055 or at least 0.058 or at least 0.061 or at least 0.063 or at least 0.065 or at least 0.068 or at least 0.070; and/or the absorbance may be not greater than 0.121 or not greater than 0.113 or not greater than 0.106 or not greater than 0.103 or not greater than 0.098 or not greater than 0.097 or not greater than 0.095 or not greater than 0.092.

In a further aspect, the binding material D-2B can have a absorbance peak between 1200cm^{-1} to 1300cm^{-1} . In certain instances, the absorbance may be greater than 0.097 or at least 0.100 or at least 0.105 or at least 0.108 or at least 0.110 or at least 0.115 or at least 0.118 or at least 0.120 or at least 0.121 or at least 0.123 or at least 0.125; and/or the absorbance may be not greater than 0.150 or not greater than 0.147 or not greater than 0.145 or not greater than 0.143 or not greater than 0.141 or not greater than 0.137 or not greater than 0.135 or not greater than 0.132 or not greater than 0.130 or not greater than 0.128 or not greater than 0.126 or not greater than 0.124.

In an aspect, the binding material may comprise an FTIR peak of absorbance at a wavenumber from 900cm^{-1} to 1100cm^{-1} . In certain instances, the absorbance may be of greater than 0.07 or greater than 0.08 or at least 0.1 or at least 0.12 at a wavenumber from 900cm^{-1} to 1100cm^{-1} . Alternatively or additionally, the binding material may include an FTIR peak of absorbance of not greater than 0.2 or not greater than 0.18 or not greater than 0.15 at a wavenumber from 900cm^{-1} to 1100cm^{-1} . Moreover, the binding material may include an FTIR peak of absorbance at a wavenumber from 900cm^{-1} to 1100cm^{-1} in a range including any of the minimum and maximum values noted herein.

In an aspect, the binding material may comprise an FTIR peak of absorbance at a wavenumber from 1600cm^{-1} to 1700cm^{-1} . In certain instances, the absorbance may be greater than 0.05 or greater than 0.143 or at least 0.144 or at least 0.145 or at least 0.146 or at least 0.148 or at least 0.149 or at least 0.150 or at least 0.152 at a wavenumber from 1600cm^{-1} to 1700cm^{-1} . Alternatively or additionally, the binding material may include an FTIR peak of absorbance of not greater than 0.201 or not greater than 0.190 or not greater than 0.185 or not greater than 0.180 or not greater than 0.175 or not greater than 0.172 or not greater than 0.170 or not greater than 0.168 at a wavenumber from 1600cm^{-1} to 1700cm^{-1} . Moreover, the binding material may include an FTIR peak of absorbance at a wavenumber from 1600cm^{-1} to 1700cm^{-1} in a range including any of the minimum and maximum values noted herein.

In an aspect, the binding material may comprise an FTIR peak of absorbance at a wavenumber from 960cm^{-1} to 1050cm^{-1} . In certain instances the absorbance may be greater

than 0.05 or greater than 0.07 or at least 0.09 or at least 0.10 or at least 0.12 at a wavenumber from 960cm^{-1} to 1050cm^{-1} . Alternatively or additionally, the binding material may include an FTIR peak of absorbance of not greater than 0.2 or not greater than 0.18 or not greater than 0.15 at a wavenumber from 960cm^{-1} to 1050cm^{-1} . Moreover, the binding material may include an FTIR peak of absorbance at a wavenumber from 960cm^{-1} to 1050cm^{-1} in a range including any of the minimum and maximum values noted herein.

In another aspect, the binding material may comprises a FTIR peak of absorbance at a wavenumber from 2979cm^{-1} to 3016cm^{-1} . In certain instances, the absorbance may be at least 0.055 or at least 0.058 or at least 0.060 or at least 0.062 or at least 0.065 or at least 0.068 or at least 0.070 or at least 0.072 at a wavenumber from 2979cm^{-1} to 3016cm^{-1} . Alternatively or additionally, the binding material may include a FTIR peak of absorbance of not greater than 0.12 or not greater than 0.10 or not greater than 0.08 or not greater than 0.075 at a wavenumber from 2979cm^{-1} to 3016cm^{-1} . Moreover, the binding material may include an FTIR peak of absorbance at a wavenumber from 2979cm^{-1} to 3016cm^{-1} in a range including any of the minimum and maximum values noted herein.

In a further embodiment, the binding material may include an organic material including a thermoset or thermoplastic, an inorganic material, or any combination thereof. In a particular example, the binding material may include an organic material including a glass transition temperature and/or FTIR peak of absorbance described in embodiments herein.

In a particular embodiment, the binding material may include an acrylic resin. An exemplary acrylic resin may include the glass transition temperature noted in embodiments herein. In a particular instance, the binding material may include an acrylic resin having a glass transition temperature in a range from 5°C to 50°C or in a range from 10°C to 40°C or in a range from 15°C to 35°C or even in a range from 18°C to 28°C . A further example an acrylic resin may include methyl methacrylate. More particularly, the binding material may include an acrylic emulsion in water.

In a further embodiment, the binding material can comprise a self-crosslinkable resin, a non-self-crosslinkable resin, or a combination thereof. In a particular implementation, the binding material can include a self-crosslinkable acrylic resin. A self-cross linkable resin is a resin with polymer chains that can crosslink with each other without the need of any additional compound. In another more particular example, the binding material may include a self-crosslinkable methyl methacrylate latex. Even more particularly, the binding material may include a self-crosslinkable methyl methacrylate emulsion in water.

In another embodiment, the binding material may include a major amount of acrylic resin and a minor amount of one or more of a phenyl resin, melamine formaldehyde, epoxy, alkyd, starch, and urea-formaldehyde. In a particular example, the binding material may include an acrylic resin and melamine formaldehyde.

Furthermore, in some embodiments, the binding material may comprise one or more additives. Suitable additives, may include grinding aids, fillers, lubricants, wetting agents, thixotropic materials, surfactants, thickening agents, pigments, dyes, antistatic agents, coupling agents, plasticizers, suspending agents, pH modifiers, adhesion promoters, lubricants, bactericides, fungicides, flame retardants, degassing agents, anti-dusting agents, dual function materials, initiators, chain transfer agents, stabilizers, dispersants, reaction mediators, colorants, and defoamers.

A particular example of the binding material may include an acrylic resin, one or more of a phenyl resin, melamine formaldehyde, epoxy, alkyd, starch, and urea-formaldehyde, and optionally one or more additives including filler.

In a further embodiment, the process 100 may include drying the one or more webs after the binding material is sprayed on. Drying may include heating the one or more webs and/or curing the binding material. In a further embodiment, heating can be applied for the binding material to cure after dip coating. In a particular implementation, the one or more wet webs may be heated to a temperature from 130°C to 210°C or from 140°C to 165°C. In another particular implementation, heating may be performed for minutes to hours to facilitate curing of the binding material. In an exemplary curing step, heating may be applied for up to 0.5hours, such as 1 min to 25 minutes or 2 to 15 minutes.

In a particular embodiment, the binding material may include filler. Exemplary filler may include hydrophobic filler, semi-reinforcing filler, or any combination thereof. In another example, the binding material may include filler particles, wherein the particles may include average particle size, D50, from 1nm to 100 microns or in a range from 10 microns to 100 microns. In a further example, filler may include an inorganic material. A particular example may include a calcium carbonate filler, aluminium silicas, a silica filler, or a mixture thereof. More particularly, filler may include silica particles, fumed silica, precipitated silica, colloidal silica, or any combination thereof.

In an embodiment, filler may be included in the binding material for at least one of the steps of spray coating or dip coating. In a particular embodiment, dip coating may be performed with a binding material including filler. More particularly, silica particles may be used.

In an embodiment, the binding material may include a particular content of filler that may facilitate improved property and/or performance of nonwoven hand tools. For example, the binding material may include at least 0.3wt% of filler for the total weight of the binding material, such as at least 0.5wt%, at least 0.7wt%, at least 0.8wt%, at least 1.0wt%, at least 1.1wt%, at least 1.5wt%, or at least 1.9wt% of filler for the total weight of the binding material. Alternatively or additionally, the binding material may include not greater than 8wt% of filler, such as not greater than 6wt%, not greater than 5wt%, not greater than 3wt%, not greater than 2.5wt%, not greater than 2.1wt%, not greater than 1.8wt%, not greater than 1.5wt%, or not greater than 1.3wt% for the total weight of the binding material. In a particular implementation, the binding material may include silica particles in a content noted herein.

In a particular embodiment, the process 100 may include spraying a plurality of webs with a first binding material and dip coating the webs with a second binding material that may be different from the first binding material. For example, the first and second binding material may differ in composition, curing temperature, curing time, or any combination thereof. In a particular example, the first and second binding material may include the same components in different contents. In a particular example, each of the first and second binding materials may include the same resins, such as acrylic resin, melamine formaldehyde, and/or another resin noted in embodiments herein, wherein the ratio between acrylic resin and one other resin may be different between the first and second binding materials. In a further example, the first and the second binding material may include different additive and/or the amount thereof. In a more particular example, each of the first and the second binding materials may include acrylic latex and melamine formaldehyde.

In certain embodiments, spray-coating and dip-coating may be performed with the same binding material.

In a further embodiment, after drying the dip-coated webs, a body of a nonwoven hand tool may be formed at block 106. In an embodiment, after curing, the binding material may include an acrylic-based material. In another embodiment, the body may include a binding material including cross-linked acrylic, melamine formaldehyde cross-linked acrylic, poly (methyl methacrylate), melamine formaldehyde cross-linked methyl methacrylate, or the like, or any combination thereof.

After curing, the dried body may include a particular GSM. In an embodiment, the body comprises a weight of at least 320GSM, at least 350GSM, at least 380GSM, at least 400GSM, at least 430GSM, at least 450GSM, at least 480GSM, or at least 530GSM.

Additionally or alternatively, the weight may be not greater than 620GSM, not greater than 600GSM, not greater than 580GSM, not greater than 540GSM, not greater than 510GSM, not greater than 480GSM, not greater than 450GSM, not greater than 430GSM, not greater than 410GSM, or not greater than 380GSM.

5 In a particular embodiment, the body may include a plurality of plies that are bound to one another via the binding material, wherein each ply can include a web, wherein at least a portion of at least some webs may be coated with a binding material. In another particular embodiment, each of the webs may be coated with a binding material. In particular, an exterior surface of the body may include a binding material. In still another particular
10 embodiment, at least some, a majority, or essentially all of the nonwoven fibers may be coated with a binding material.

Optionally, the body may be shaped and/or sized. For example, the body may be cut into handheld sizes and/or desired shapes. For instance, the body may be formed into a shape including a rectangular shape, a pentagonal shape, a diamond shape circular, a round shape,
15 or another geometric shape, or a non-geometric shape as desired.

FIG. 2 includes an image of an exemplary nonwoven hand tool 202 according to an embodiment. As illustrated, the nonwoven hand tool 202 comprises a body 206 comprising plies 204 and 210. Each ply comprises a lofty, open web of fibers.

FIG. 3 includes an illustration of a portion of an exemplary nonwoven article 302. A
20 plurality of nonwoven fibers 304 are coated with a binding material 310 and 314. In a particular implementation, the binding material 310 may be sprayed on, and the binding material 314 may be dip coated over the binding material 310 and the fibers 304. As illustrated, the plurality of fibers 314 may be entirely coated with the binder material 310, the binding material 314, or both. The binding material 310 and 314 may include filler 312. In
25 another example, the binding material 314 may include filler 312 and the binding material 310 may be essentially free of filler. Alternatively, the binding material 310 may include filler 312 and the binding material 314 may be essentially free of filler 312. In a further example, filler 312 may be in a same or different amount when present in the binding material 310 and 314.

30 The binding material 310 may be directly coated over the fibers 304 such that the binding material 310 abuts the fibers 304 and may be an inner coating overlying at least a majority or essentially all of the fibers 304. The binding material 314 may be an outer coating overlying at least the majority of the binding material 310 and/or some of the fibers 304. In particular examples, the binding material 314 may form at least a portion of the

exterior surface of the body of the nonwoven article 302. In more particular examples, the binding material 314 may overlie essentially all of the binding material 310. The binding material 310 and 314 may include any of the features described in embodiments herein with respect to binding materials. For example, the binding material 310 may be the first binding material noted in embodiments herein and the binding material 314 may be the second binding material noted in embodiments herein.

It is noteworthy that the nonwoven hand tool of embodiments herein can comprise a one or more of beneficial physical and abrasive properties. In certain embodiments, the nonwoven hand tool can comprise a particular combination of two or more of stiffness, a peel strength, a loft, an elongation %, a tensile strength, a Toughness, a mean pore size, an air permeability, a Machine Direction Orientation Index, a wear rate, service life, and a Burnt Food Removal Rating.

In an embodiment, the body of the nonwoven hand tool may have particular stiffness that may facilitate improved properties of the nonwoven hand tool, such as hand feel, mechanical strength, longevity, or any combination thereof. In an aspect, the stiffness may be not greater than 40000mg, such as not greater than 38000mg or not greater than 35000mg or not greater than 33000mg or not greater than 31000mg or not greater than 30000mg or not greater than 28500mg or not greater than 28000mg or not greater than 27000mg or not greater than 26000mg or not greater than 25500mg or not greater than 25000mg or not greater than 24500mg or not greater than 23500mg or not greater than 23000mg or not greater than 22500mg or not greater than 22000mg or not greater than 21500mg or not greater than 21000mg or not greater than 20000mg or not greater than 19000mg or not greater than 18000mg or not greater than 17000mg or not greater than 16000mg or not greater than 15500mg or not greater than 15000mg. In another aspect, the stiffness may be at least or greater than 10000mg or at least or greater than 10100mg or at least or greater than 10200mg or at least or greater than 10300mg or at least or greater than 10400mg or at least or greater than 10500mg or at least or greater than 10600mg or at least or greater than 10700mg or at least or greater than 10800mg or at least or greater than 10900mg or at least or greater than 11000mg or at least or greater than 11230mg or at least or greater than 12541mg or at least 12550mg or at least 12600mg or at least 12800gm or at least 13000mg or at least 13100mg or at least 13180mg or at least 13200mg or at least 13500mg or at least 13800mg or at least 14000mg or at least 14200mg or at least 14400mg or at least 14600mg or at least 14800mg or at least 15000mg or at least 15200mg or at least 15320mg or at least 15400mg or at least 15670mg or at least 16000mg or at least 16500mg or at least 17000mg or at least

17500mg or at least 17750mg or at least 18000mg or at least 18030mg or at least 18100mg.

In a particular aspect, the stiffness may be in a range including any of the minimum and maximum values noted herein. In this disclosure, stiffness can be measured using a Gurley type bending resistance machine according to ASTM D6125 – 97, Standard Test Method for Bending Resistance of Paper and Paperboard (Gurley Type Tester), as measured in the machine direction.

In an embodiment, the nonwoven hand tool may include a body having a particular peel strength that may facilitate improved performance of the nonwoven hand tool. As described herein, peel strength is in reference to 180° peel strength tested using Peeling Strength Universal Testing Machine according to ASTM D903.

In an aspect, the body may comprise peel strength greater than 2.06kgf. In an aspect, the body may include peel strength of greater than 2.06kgf, such as greater than 2.45kgf or greater than 2.49kgf or greater than 2.68kgf or at least 2.70kgf or at least 2.72kgf or at least 2.74kgf or at least 2.76kgf or at least 2.78kgf or at least 2.80kgf or at least 2.82kgf or at least 2.84kgf or at least 2.86kgf or at least 2.88kgf or at least 2.90kgf or at least 2.92kgf or at least 2.94kgf or at least 2.96kgf or at least 2.98kgf or at least 3.00kgf or at least 3.02kgf or at least 3.24kgf or at least 3.06kgf or at least 3.08kgf or at least 3.10kgf or at least 3.12kgf or at least 3.15kgf or at least 3.20kgf or at least 3.25kgf or at least 3.30kgf or at least 3.40kgf or at least 3.50kgf or at least 3.60kgf or at least 3.70kgf or at least 3.75kgf or at least 3.80kgf or at least 3.93kgf or at least 3.96kgf or at least 3.98kgf. In another aspect, the peel strength may be not greater than 8.10kgf or not greater than 8.05kgf or not greater than 8.00kgf or not greater than 7.85kgf or not greater than 7.55kgf or not greater than 7.35kgf or not greater than 7.25kgf or not greater than 7.12kgf or not greater than 7.00kgf or not greater than 6.85kgf or not greater than 6.60kgf or not greater than 6.50kgf or not greater than 6.30kgf or not greater than 6.20kgf or not greater than 6.10kgf or not greater than 5.90kgf or not greater than 5.80kgf or not greater than 5.70kgf or not greater than 5.65kgf or not greater than 5.50kgf or not greater than 5.30kgf or not greater than 5.20kgf or not greater than 5.10kgf or not greater than 4.90kgf or not greater than 4.80kgf or not greater than 4.70kgf or not greater than 4.65kgf or not greater than 4.50kgf or not greater than 4.50kgf or not greater than 4.35kgf or not greater than 4.25kgf or not greater than 4.20kgf or not greater than 4.15kgf. In a particular aspect, the body may include peel strength in a range including any of the minimum and maximum values noted herein.

In an embodiment, the nonwoven hand tool may include a body having a particular tensile strength that may facilitate improved performance of the nonwoven hand tool. In an

aspect, the body may comprise tensile strength of at least 14.6kgf or at least 15.5kgf or at least 16.5kgf or at least 17.5kgf or at least 18.1kgf or at least 18.3kgf or at least 18.4kgf or at least 18.6kgf or at least 18.8kgf or at least 19.0kgf or at least 19.2kgf or at least 19.4kgf or at least 19.6kgf or at least 19.8kgf or at least 20.0kgf or at least 20.2kgf or at least 20.4kgf or at least 20.6kgf or at least 20.8kgf or at least 20.9kgf or at least 21.1kgf or at least 21.2kgf or at least 21.3kgf. In another aspect, the body may comprise tensile strength of not greater than 40.0kgf or not greater than 38.5kgf or not greater than 33.5kgf or not greater than 31.5kgf or not greater than 28.8kgf or not greater than 26.5kgf or not greater than 27.6kgf or not greater than 25.8kgf or not greater than 24.5kgf or not greater than 22.2kgf. In a particular aspect, the body may include tensile strength in a range including any of the minimum and maximum values noted herein. Tensile strength can be measured according to ASTM D5034 - 09(2017), Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test), as measured in the machine direction.

In an embodiment, the body of the nonwoven hand tool can comprise a particular air permeability. The air permeability can be measured according to ASTM D737, Standard Test Method for Air Permeability of Textile Fabrics.

In an embodiment, the body of the nonwoven hand tool can comprise a particular pore size (i.e., mean pore size). The pore size can be measured according to ASTM D6767 – 16, Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test.

In another embodiment, the body can comprise a particular density, a particular loft (i.e., thickness), or any combination thereof that may facilitate improved property and performance of the nonwoven hand tool. In an example, the body may include a loft thickness of 2mm to 15mm, such as 5mm to 12mm. The loft thickness can be tested using a loft meter. In another embodiment, the body of the nonwoven hand tool may comprise a particular Toughness (or Work of Rupture), which is a measure or calculation of the area under the curve of a plot of stress vs. strain, based on values measured during tensile strength testing.

In an embodiment, the body of the nonwoven hand tool can comprise a beneficial Machine Direction Orientation Index as measured according to NWSP 407.0.R0(15), “Fiber Orientation Distribution of Nonwoven Fabrics.”

In an embodiment, the body of the nonwoven hand tool may comprise a particular elongation percentage in the machine direction (i.e., percentage of elongation before breakage and/or separation of fibers 104). In an embodiment, the body may comprise an elongation percentage of at least 5%, such as at least 10%; additionally or alternatively, the elongation

percentage may be not greater than 60%, such as not greater than 50% or not greater than 40%. Elongation can be measured according to ASTM D5034 - 09(2017), Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test), as measured in the machine direction.

5 In certain embodiments, the web may be coated with the binding material containing an antimicrobial and/or antiviral agent. In an implementation the binding material may include a particular antimicrobial agent that that may facilitate improved performance and/or manufacturing of the scrubbing article. In an embodiment, the antimicrobial agent can include silver or zinc or a combination thereof. In a particular embodiment the antimicrobial agent can include zinc. In a more particular embodiment, the antimicrobial agent can include zinc pyrithione (hereinafter "ZPT"). In an embodiment the antimicrobial agent can consist of ZPT. In an embodiment, the antimicrobial may comprise powdered ZPT. In an embodiment, the antimicrobial may comprise a ZPT emulsion.

15 In an embodiment, the binding material can have a particular concentration of antimicrobial agent that may facilitate improved performance and/or manufacturing of the scrubbing article. In an embodiment, the concentration of antimicrobial agent in the binding material can be at least 1wt% for a total weight of the binder, or at least 1.2wt% or at least 1.4wt% or at least 1.6wt% or at least 1.8wt% or at least 2.0wt% or at least 2.2wt% or at least 2.4wt% or at least 2.6wt% or at least 2.8wt% or at least 3.0wt% or at least 3.2wt% or at least 3.4wt% or at least 3.6wt% or at least 3.8wt%. In another embodiment, the concentration of antimicrobial agent in the binder can be no greater than 10wt% for a total weight of the binder, or no greater than 9.6wt% or no greater 9.2wt% or no greater than 8.8wt% or no greater than 8.4wt% or no greater than 8.0wt% or no greater than 7.6wt% or no greater than 7.2wt% or no greater than 6.8wt% or no greater than 6.4wt% or no greater than 6.0wt% or no greater than 5.6wt% or no greater than 5.2wt% or no greater than 4.8wt% or no greater than 4.4wt%. It will be appreciated that the concentration of antimicrobial agent may be between any of the minimum and maximum values noted above, including for example, but not limited to, at least 1wt% and not greater than 10wt%, at least 2.0wt% and not greater than 5.6wt%, or at least 1.8wt% and not greater than 4.4wt% or no greater than 4.2wt% or no greater than 4.0wt% or no greater than 3.8wt% or no greater than 3.2wt% or no greater than 3.0wt% or no greater than 2.8wt% or no greater than 2.6wt% or no greater than 2.4wt% or no greater than 2.2wt% or no greater than 2.0wt%.

In an embodiment, the nonwoven hand tool may have a particular antimicrobial effectiveness that may facilitate improved performance and/or manufacturing of the abrasive

article. Antimicrobial effectiveness can be measured as detailed in the examples according to ASTM 2149-13a.

In an embodiment, the nonwoven hand tool may have a bacterial reduction against *Staphylococcus aureus* of at least 95% according to ASTM 2149-13a of at least 96% or at least 97% or at least 98% or at least 99% or at least 99.5%. In an embodiment, the nonwoven hand tool may have a bacterial reduction against *Staphylococcus aureus* of no greater than 99.999%. It will be appreciated that the bacterial reduction may be between any of the minimum and maximum values noted above.

In an embodiment, the nonwoven hand tool may have a bacterial reduction against *Escherichia coli* of at least 95% according to ASTM 2149-13a of at least 96% or at least 97% or at least 98% or at least 99% or at least 99.5%. In an embodiment, the nonwoven hand tool may have a bacterial reduction against *Escherichia coli* of no greater than 99.999%. It will be appreciated that the bacterial reduction may be between any of the minimum and maximum values noted above.

In an embodiment, the nonwoven hand tool may have a bacterial reduction against *Klebsiella pneumonia* of at least 95% according to ASTM 2149-13a of at least 96% or at least 97% or at least 98% or at least 99% or at least 99.5%. In an embodiment, the abrasive article may have a bacterial reduction against *Klebsiella pneumonia* of no greater than 99.999%. It will be appreciated that the bacterial reduction may be between any of the minimum and maximum values noted above.

In an embodiment, the binding material may include a fragrance. For example, fragrances used in liquid detergent can be added to the binding material.

In a further embodiment, the web may be impregnated with abrasive particles. In at least one embodiment, the nonwoven hand tool may include a body that may be free of abrasive particles.

Many different aspects and embodiments are possible. Some of those aspects and embodiments are described herein. After reading this specification, skilled artisans will appreciate that those aspects and embodiments are only illustrative and do not limit the scope of the present invention. Embodiments may be in accordance with any one or more of the embodiments as listed below.

EMBODIMENTS

Embodiment 1. A non-woven hand tool, comprising:

a body defining a length, width and thickness, wherein the body comprises a plurality of plys bound to each other, wherein each ply comprises a web of non-woven fibers; and

wherein the body comprises peel strength greater than 2.06kgf and stiffness not greater than 40000mg.

Embodiment 2. The non-woven hand tool of embodiment 1, wherein the body comprises the peel strength of greater than 2.45kgf or greater than 2.68kgf or at least 2.70kgf or at least 2.72kgf or at least 2.74kgf or at least 2.76kgf or at least 2.78kgf or at least 2.80kgf or at least 2.82kgf or at least 2.84kgf or at least 2.86kgf or at least 2.88kgf or at least 2.90kgf or at least 2.92kgf or at least 2.94kgf or at least 2.96kgf or at least 2.98kgf or at least 3.00kgf or at least 3.02kgf or at least 3.24kgf or at least 3.06kgf or at least 3.08kgf or at least 3.10kgf or at least 3.12kgf or at least 3.15kgf or at least 3.20kgf or at least 3.25kgf or at least 3.30kgf or at least 3.40kgf or at least 3.50kgf or at least 3.60kgf or at least 3.70kgf or at least 3.75kgf or at least 3.80kgf or at least 3.93kgf or at least 3.96kgf or at least 3.98kgf.

Embodiment 3. The non-woven hand tool of embodiment 1 or 2, wherein the body comprises the peel strength of not greater than 8.10kgf or not greater than 8.05kgf or not greater than 8.00kgf or not greater than 7.85kgf or not greater than 7.55kgf or not greater than 7.35kgf or not greater than 7.25kgf or not greater than 7.12kgf or not greater than 7.00kgf or not greater than 6.85kgf or not greater than 6.60kgf or not greater than 6.50kgf or not greater than 6.30kgf or not greater than 6.20kgf or not greater than 6.10kgf or not greater than 5.90kgf or not greater than 5.80kgf or not greater than 5.70kgf or not greater than 5.65kgf or not greater than 5.50kgf or not greater than 5.30kgf or not greater than 5.20kgf or not greater than 5.10kgf or not greater than 4.90kgf or not greater than 4.80kgf or not greater than 4.70kgf or not greater than 4.65kgf or not greater than 4.50kgf or not greater than 4.50kgf or not greater than 4.35kgf or not greater than 4.25kgf or not greater than 4.20kgf or not greater than 4.15kgf.

Embodiment 4. The non-woven hand tool of any one of embodiments 1 to 3, wherein the body comprises the stiffness of not greater than 38000mg or not greater than 35000mg or not greater than 33000mg or not greater than 31000mg or not greater than 30000mg or not greater than 28500mg or not greater than 28000mg or not greater than 27000mg or not greater than 26000mg or not greater than 25500mg or not greater than 25000mg or not greater than 24500mg or not greater than 23500mg or not greater than 23000mg or not greater than 21000mg or not greater than 20000mg or not greater than 19000mg or not greater than 18000mg or not greater than 17000mg or not greater than 16000mg or not greater than 15500mg or not greater than 15000mg.

Embodiment 5. The non-woven hand tool of any one of embodiments 1 to 4, wherein the body comprises the stiffness of greater than 11230mg or greater than 12541mg or at least

12550mg or at least 12600mg or at least 12800gm or at least 13000mg or at least 13100mg or
at least 13180mg or at least 13200mg or at least 13500mg or at least 13800mg or at least
14000mg or at least 14200mg or at least 14400mg or at least 14600mg or at least 14800mg or
at least 15000mg or at least 15200mg or at least 15320mg or at least 15400mg or at least
5 15670mg or at least 16000mg or at least 16500mg or at least 17000mg or at least 17500mg or
at least 17750mg or at least 18000mg or at least 18030mg or at least 18100mg.

Embodiment 6. The non-woven hand tool of any one of embodiments 1 to 5, wherein
the body comprises tensile strength of at least 14.6kgf or at least 18.1kgf or at least 18.3kgf or
at least 18.4kgf or at least 18.6kgf or at least 18.8kgf or at least 19.0kgf or at least 19.2kgf or
10 at least 19.4kgf or at least 19.6kgf or at least 19.8kgf or at least 20.0kgf or at least 20.2kgf or
at least 20.4kgf or at least 20.6kgf or at least 20.8kgf or at least 20.9kgf or at least 21.1kgf or
at least 21.2kgf or at least 21.3kgf.

Embodiment 7. The non-woven hand tool of any one of embodiments 1 to 6, wherein
the body comprises tensile strength of not greater than 40.0kgf or not greater than 38.5kgf or
15 not greater than 33.5kgf or not greater than 31.5kgf or not greater than 28.8kgf or not greater
than 26.5kgf or not greater than 27.6kgf or not greater than 25.8kgf or not greater than
24.5kgf or not greater than 22.2kgf.

Embodiment 8. The non-woven hand tool of any one of embodiments 1 to 7, wherein
the web comprises a blend of a plurality of fibers comprising a first type of fibers and a
20 second type of fibers, and wherein the first type of fibers is different from the second type of
fibers in composition, construction, denier, length, ratio, shape, thickness, type, or any
combination thereof.

Embodiment 9. The non-woven hand tool of embodiment 8, wherein the first type
fiber is different from the second type of fibers in composition, wherein the first type fibers,
25 the second type of fibers, or both comprise organic fibers.

Embodiment 10. The non-woven hand tool of embodiment 8 or 9, wherein the first
type of fibers, the second type of fibers, or both comprise a polymeric material.

Embodiment 11. The non-woven hand tool of any one of embodiments 8 to 10,
wherein the first type of fibers comprise polyamide, wherein the second type of fibers
30 comprise polyester and/or trilobal polyester.

Embodiment 12. The non-woven hand tool of any one of embodiments 8 to 11,
wherein the plurality of fibers comprises the first type of fibers consisting of polyamide fibers
and the second type of fibers consisting of solid polyester fibers and/or trilobal polyester.

Embodiment 13. The non-woven hand tool of any one of embodiments 8 to 12, wherein the first type of fibers comprise nylon, wherein the second type of fibers comprise polyethylene terephthalate and/or trilobal polyester.

5 Embodiment 14. The non-woven hand tool of any one of embodiments 1 to 7, wherein the web comprises a blend of a plurality of fibers comprising solid polyester fibers and/or trilobal polyester.

Embodiment 15. The non-woven hand tool of embodiment 14, wherein the blend of the plurality of fibers comprises solid polyethylene terephthalate fibers and/or trilobal polyester.

10 Embodiment 16. The non-woven hand tool of any one of embodiments 1 to 7 and 14 to 15, wherein the web comprises a blend of a plurality of fibers consisting of polyamide fibers and polyester fibers and/or trilobal polyester, wherein polyester fibers consist of solid fibers and/or trilobal polyester.

Embodiment 17. The non-woven hand tool of any one of embodiments 8 to 16, wherein a difference between a first denier of the first type of fibers and a second denier of the second type of fibers is within 20% of the bigger of the first and second denier or not greater than 15% or not greater than 12% or not greater than 10% or not greater than 8% or not greater than 6% or not greater than 4% or not greater than 2% or not greater than 1% of the bigger of the first and second denier.

20 Embodiment 18. The non-woven hand tool of any one of embodiments 8 to 17, wherein a first denier of the first type of fibers is essentially same as a second denier of the second type of fibers.

Embodiment 19. The non-woven hand tool of any one of embodiments 8 to 18, wherein a first denier of the first type of fiber and a second denier of the second type of fiber is independently not greater than 60 or not greater than 55 or not greater than 53 or not greater than 51 or not greater than 49 or not greater than 46 or not greater than 42 or not greater than 40 or not greater than 36 or not greater than 33 or not greater than 29 or not greater than 25 or not greater than 23 or not greater than 21 or not greater than 19 or not greater than 17 or not greater than 15 or not greater than 13.

30 Embodiment 20. The non-woven hand tool of any one of embodiments 8 to 19, wherein a first denier of the first type of fiber and a second denier of the second type of fiber is independently at least 12 or at least 13 or at least 14 or at least 15 or at least 16 or at least 18 or at least 20 or at least 22 or at least 24 or at least 27 or at least 31 or at least 36 or at least 38 or at least 40 or at least 44.

Embodiment 21. The non-woven hand tool of any one of embodiments 8 to 20, wherein the plurality of fibers comprises: 5 to 95wt% of the first type of fibers for a total weight of the blend; and 5 to 95wt% of the second type of fibers for a total weight of the blend.

5 Embodiment 22. The non-woven hand tool of any one of embodiments 8 to 21, wherein the plurality of fibers comprises 25wt% to 75wt% of the first type of fiber or 30wt% to 70wt% or 35wt% to 65wt% or 40wt% to 60wt% or 45wt% to 55wt% of the first type of fiber for a total weight of the blend; and 25wt% to 75wt% of the second type of fiber or 30wt% to 70wt% or 35wt% to 65wt% or 40wt% to 60wt% or 45wt% to 55wt% of the second
10 type of fiber for a total weight of the blend.

Embodiment 23. The non-woven hand tool of any one of embodiments 8 to 22, wherein the plurality of fibers comprises 50% of the first type of fiber and 50% of the second type of fiber.

Embodiment 24. The non-woven hand tool of any one of embodiments 1 to 23,
15 wherein the body comprises a binding material, wherein at least some of the non-woven fibers are coated with the binding material.

Embodiment 25. The non-woven hand tool of embodiment 24, wherein at least some of the plurality of plies are bound to one another via the binding material.

Embodiment 26. The non-woven hand tool of embodiment 24 or 25, wherein the
20 binding material comprises an organic material, an inorganic material, or a combination thereof, wherein the binding material comprises a thermoplastic, a thermoset, or any combination thereof.

Embodiment 27. The non-woven hand tool of any one of embodiments 24 to 26, wherein the binding material comprise an FTIR peak of absorbance at a wavenumber from
25 960cm⁻¹ to 1050cm⁻¹, at a wavenumber between 1200cm⁻¹ to 1300cm⁻¹, at a wavenumber between 1320cm⁻¹ to 1410cm⁻¹, at a wavenumber from 1600cm⁻¹ to 1700cm⁻¹, or any combination thereof.

Embodiment 28. The non-woven hand tool of any one of embodiments 24 to 27, the binding material may comprises a FTIR peak of absorbance at a wavenumber from 2979cm⁻¹
30 to 3016cm⁻¹.

Embodiment 29. The non-woven hand tool of any one of embodiments 24 to 28, wherein the binding material comprises a glass transition temperature T_g of not greater than 99°C or not greater than 90°C or not greater than 80°C or not greater than 70°C or not greater

than 60°C or not greater than 50°C or not greater than 40°C or not greater than 35°C or not greater than 20°C.

Embodiment 30. The non-woven hand tool of any one of embodiments 24 to 29, wherein the binding material comprises a glass transition temperature T_g of at least -26°C or
5 at least -20°C or at least -15°C or at least -10°C or at least -5°C or at least 1°C or at least 5°C or at least 10°C or at least 15°C or at least 20°C or at least 24°C or at least 28°C or at least 30°C or at least 35°C.

Embodiment 31. The non-woven hand tool of any one of embodiments 24 to 30, wherein the binding material comprises an acrylic, wherein the binding material comprises an
10 acrylic-based material, wherein the binding material comprises poly(methyl methacrylate).

Embodiment 32. The non-woven hand tool of any one of embodiments 24 to 31, wherein the binding material comprises melamine formaldehyde and cross-linked acrylic.

Embodiment 33. The non-woven hand tool of any one of embodiments 1 to 32, wherein the body comprises a first coating overlying at least some of the non-woven fibers
15 and a second coating overlying at least a portion of the first coating, at least some of the non-woven fibers, or both, wherein the first coating comprises a different material than the second coating.

Embodiment 34. The non-woven hand tool of embodiment 33, wherein the first coating is applied by spray-coating and the second coating is applied by dip coating after the
20 first coating is applied.

Embodiment 35. The non-woven hand tool of embodiment 33 or 34, wherein the first coating, the second coating, or both comprises a binding material comprising acrylic, wherein the acrylic comprises poly(methyl methacrylate); and/or wherein the first coating, the second coating, or both comprises a binding material comprising acrylic cross-linked with another
25 resin, wherein the other resin comprises phenyl resin, melamine formaldehyde, epoxy, alkyd, starch, urea-formaldehyde, or any combination thereof.

Embodiment 36. The non-woven hand tool of any one of embodiments 24 to 35, wherein the binding material comprises a coating density of at least 210GSM or at least 220GSM or at least 230GSM or at least 240GSM or at least 250GSM at least 260GSM or at
30 least 280GSM or at least 300GSM or at least 320GSM or at least 350GSM or at least 370GSM or at least 395GSM or at least 410GSM or at least 440GSM or at least 460GSM or at least 480GSM or at least 500GSM.

Embodiment 37. The non-woven hand tool of any one of embodiments 24 to 35, wherein the binding material comprises a coating density of not greater than 600GSM or no

greater than 550GSM or no greater than 530GSM or no greater than 510GSM or no greater than 480GSM or no greater than 460GSM or no greater than 410GSM or no greater than 390GSM or no greater than 350GSM or no greater than 310GSM or no greater than 290GSM or no greater than 260GSM.

5 Embodiment 38. The non-woven hand tool of any one of embodiments 24 to 37, wherein the binding material comprises filler, wherein the filler comprises hydrophilic or partial hydrophobic filler, wherein the filler comprises particles, wherein the particles have an average diameter from 1nm to 100microns; wherein the particles are nanoparticles.

 Embodiment 39. The non-woven hand tool of embodiment 38, wherein the filler
10 comprises a calcium carbonate filler, a silica filler, silicates, e.g., aluminum silicates or a mixture thereof.

 Embodiment 40. The non-woven hand tool of embodiment 38 or 39, wherein the filler comprises silica, wherein the filler comprises fumed silica, precipitated silica, colloidal silica or any combination thereof.

15 Embodiment 41. The non-woven hand tool of any one of embodiments 1 to 40, wherein the non-woven fibers comprises a weight of at least 150GSM or at least 170GSM or at least 190GSM or at least 210GSM or at least 230GSM or at least 250GSM.

 Embodiment 42. The non-woven hand tool of any one of embodiments 1 to 41, wherein the non-woven fibers comprises a weight of not greater than 320GSM or not greater
20 than 305GSM or not greater than 385GSM or not greater than 270GSM or not greater than 250GSM or not greater than 230GSM or not greater than 220GSM.

 Embodiment 43. The non-woven hand tool of any one of embodiments 1 to 42, wherein the non-woven is essentially free of abrasive particles.

 Embodiment 44. The non-woven hand tool of any one of embodiments 1 to 42,
25 wherein the body comprises a weight of at least 320GSM, at least 350GSM, at least 380GSM, at least 400GSM, at least 430GSM, at least 450GSM, at least 480GSM, or at least 530GSM; and/or wherein weight is not greater than 620GSM, not greater than 600GSM, not greater than 580GSM, not greater than 540GSM, not greater than 510GSM, not greater than 480GSM, not greater than 450GSM, not greater than 430GSM, not greater than 410GSM, or
30 not greater than 380GSM.

Example 1

Nonwoven Samples B1-B5 are formed. Loose webs are prepared using air-laid technology and different kinds of staple fibers made out of Nylon and polyester and needled to give fiber entanglement. Details of the fibers are included in Table 2. The webs are

sprayed with the first binding material, an emulsion latex based formulation included in Table 1, on both sides to improve mechanical strength. RHOPLEX™ TR-407 Emulsion is a self crosslinkable acrylic emulsion in water including Methyl methacrylate. Wet webs are cured at 140-150°C to allow coating formation on the fibers.

5 Table 1

RHOPLEX™ TR-407 Emulsion (wt%)	35%
MF resin	3%
CAT 700	0.20%
Aquafil OT	0.10%
Sapco NXZ	0.10%
Blue pigment	0.50%
Water	61.10%

Table 2

Sample	B1	B2	B3	B5
Nylon 6,6 (60D)	75%			
Nylon 6,6 (15D)	25%	50%	50%	50%
Solid Polyester fiber (15D)		50%	50%	
Hollow Polyester fiber (15D)				50%
Fiber weight (GSM)	230-250	230-250	230-250	230-250
Wet Binder concentration on one side (GSM)	230-250	230-250	480-500	230-250

Samples B1, B2, and B5 are used to form Samples D-1, D-2, D-3, D-4, and D-7 by dip coating the webs. Sample B3 failed Taber abrasion test and was believed not suitable for making a nonwoven hand tool and thus not used further. Samples B1, B2, and B5 have a dry
 10 GSM range of 330-350.

Dip coating is performed with Samples B1, B2, and B5 and different latex formulations containing functional additives. Formulations details are included in Table 3. Primal™ NW-1845K Binder is a non-crosslinkable styrene acrylic binder including α -
 15 Methylstyrene and N-butylmethacrylate. Dip coating are performed by dipping the webs and squeezing through rolls to allow the latex formulation to penetrate and saturate the fibers through-out the products. Dip coated webs are then cured at 140-150°C. Details of Samples D-1, D-2, D-3, D-4, and D-7 are included in Table 3. Dry GSM of at least 3 samples of each

of Sample D-1, D-2, D-3, D-4, and D-7 were tested after curing and the average is 430 for all Samples.

Properties of at least 3 samples for each of Samples D-1, D-2, D-3, D-4, and D-7 were tested and the average measurements are included in Table 3.

5 Table 3

	D-1	D-2	D-3	D-4	D-7
Nylon 60 denier (wt%)	75				
Nylon 15 denier (wt%)	25	50	50	50	50
Solid polyester fiber 15 denier (wt%)		50		50	50
Hollow polyester fiber 15 denier (wt%)			50		
Binding material 1 for spraying	Table 1	Table 1	Table 1	Table 1	Table 1
Formulation of Binding material 2 for dip coating	F-1	F-1	F-1	F-2	F-5
Rhoplex TR407, wt%	25	25	25	25	0
Nw1845K latex, wt%	0	0	0	0	25
MF Resin, wt%	5	5	5	5	5
Blue Pigment, wt%	0.5	0.5	0.5	0.5	0.5
Cab-o-sil, wt%	0	0	0	1	0
Water, wt%	69.5	69.5	69.5	68.5	69.5
Stiffness (mg)	12130	14250	10570	16904	15004
180° peel strength (kgf)	2.15	2.99	1.65	3.78	2.49
Tensile (kgf)	17.10	20.46	7.71	19.78	16.31

The data suggests Samples D-2 and D-4 demonstrated improved combined properties of stiffness, peel strength and/or tensile strength compared to Samples D-1, D-3, and D-7.

10 Properties of at least 3 samples for each of Samples B2 and D-2 are tested and the average is included in Table 4. D-2 demonstrated improved stiffness, peel strength and tensile strength compared to B2.

Table 4

	B-2	D-2
Stiffness (mg)	10450	14250
180° peel strength (kgf)	2.06	2.99
Tensile (kgf)	14.55	20.46

FIG. 4 includes a readout of an FTIR analysis of Rhoplex TR407 (referred to as D-2B in FIG. 4) and Nw1845K latex, wt% (referred to as D-7B in FIG. 4). It can be observed D-2B has a distinct FTIR absorbance profile than D-7B. For instance, absorbance peaks of D-2B can be observed at wavenumber from 900cm^{-1} to 1100cm^{-1} , wavenumber from 960cm^{-1} to 1050cm^{-1} , wavenumber from 1320cm^{-1} to 1410cm^{-1} , and/or wavenumber from 2979cm^{-1} to 3016cm^{-1} . FIGs. 5 and 6 include data from differential scanning calorimetry (DSC) analysis of D-7B and D-2B, respectively. It can be observed D-7B has the glass transition temperature of -26.79°C and D-2B includes the glass transition temperature of 24.49°C . FIG. 7 includes data of gas chromatography/mass spectrometry analysis of D-2B, which indicates the presence of methyl methacrylate moiety.

Example 2

Nonwoven Sample B7 was formed in the same manner as D2 except that the binding material for dip coating is replaced with phenolic resin. At least 3 samples of Sample B7 were tested and have an average dry GSM of 180 after curing and average stiffness of 22505mg.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims. Reference herein to a material including one or more components may be interpreted to include at least one embodiment wherein the material consists essentially of the one or more components identified. The term “consisting essentially” will be interpreted to include a composition including those materials identified and excluding all other materials except in minority contents (e.g., impurity contents), which do not significantly alter the properties of the material. Additionally, or in the alternative, in certain non-limiting embodiments, any of the compositions identified herein may be essentially free of materials that are not expressly disclosed. The embodiments herein include range of contents for certain components within a material, and it will be appreciated that the contents of the components within a given material total 100%.

The specification and illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments. The specification and illustrations are not intended to serve as an exhaustive and comprehensive description of all of the elements and features of apparatus and systems that use the structures or methods described herein. Separate embodiments may also be provided in combination in a single embodiment, and conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, reference to values stated in ranges includes each and every value within that range. Many other embodiments may be apparent to skilled artisans only after reading this specification. Other embodiments may be used and derived from the disclosure, such that a structural substitution, logical substitution, or another change may be made without departing from the scope of the disclosure. Accordingly, the disclosure is to be regarded as illustrative rather than restrictive.

WHAT IS CLAIMED IS:

1. A non-woven hand tool, comprising:
a body defining a length, width and thickness,
wherein the body comprises a plurality of plies bound to each other, wherein each ply comprises a web of non-woven fibers; and
wherein the body comprises peel strength greater than 2.06kgf and stiffness not greater than 40000mg.
2. The non-woven hand tool of claim 1, wherein the body comprises the peel strength of greater than 2.49kgf.
3. The non-woven hand tool of claim 2, wherein the body comprises the stiffness of not greater than 22500mg.
4. The non-woven hand tool of any one of claims 1 to 3, wherein the body comprises the stiffness of at least 10000mg.
5. The non-woven hand tool of any one of claims 1 to 3, wherein the body comprises tensile strength of at least 14.6kgf or at least 17.5kgf.
6. The non-woven hand tool of any one of claims 1 to 3, wherein the non-woven fibers comprise a blend of a first type of fibers and a second type of fibers that is different from the first type of fibers in composition, wherein the first type of fibers is 5wt% to 95wt% for a total weight of the blend; and wherein the first type of fibers, the second type of fibers, or both comprise organic fibers.
7. The non-woven hand tool of claim 6, wherein the first type of fibers comprise polyamide, wherein the second type of fibers comprise polyester and/or trilobal polyester.
8. The non-woven hand tool of claim 7, wherein the second type of fibers comprise solid fibers.
9. The non-woven hand tool of claim 7, wherein the second type of fibers consist of solid fibers.
10. The non-woven hand tool of claim 6, wherein a difference between a first denier of the first type of fibers and a second denier of the second type of fibers is within 20% of the bigger of the first and second denier.
11. The non-woven hand tool of claim 10, wherein the first denier or the second denier is not greater than 60.
12. The non-woven hand tool of any one of claims 1 to 3, wherein the non-woven fibers comprise a weight of at least 150GSM and not greater than 310GSM.

13. The non-woven hand tool of any one of claims 1 to 3, wherein the body comprises a binding material, wherein at least some of the plurality of plys are bound to one another via the binding material, wherein the binding material comprises a material resulted from curing a composition including poly(methyl methacrylate) and melamine formaldehyde.
14. The non-woven hand tool of any one of claims 1 to 3, wherein at least some of the non-woven fibers are coated with a binding material including a filler, wherein the filler comprises calcium carbonate, silica, silicates, or a mixture thereof.
15. The non-woven hand tool of any one of claims 1 to 3, wherein the body comprises a weight of at least 320GSM and is essentially free of abrasive particles.

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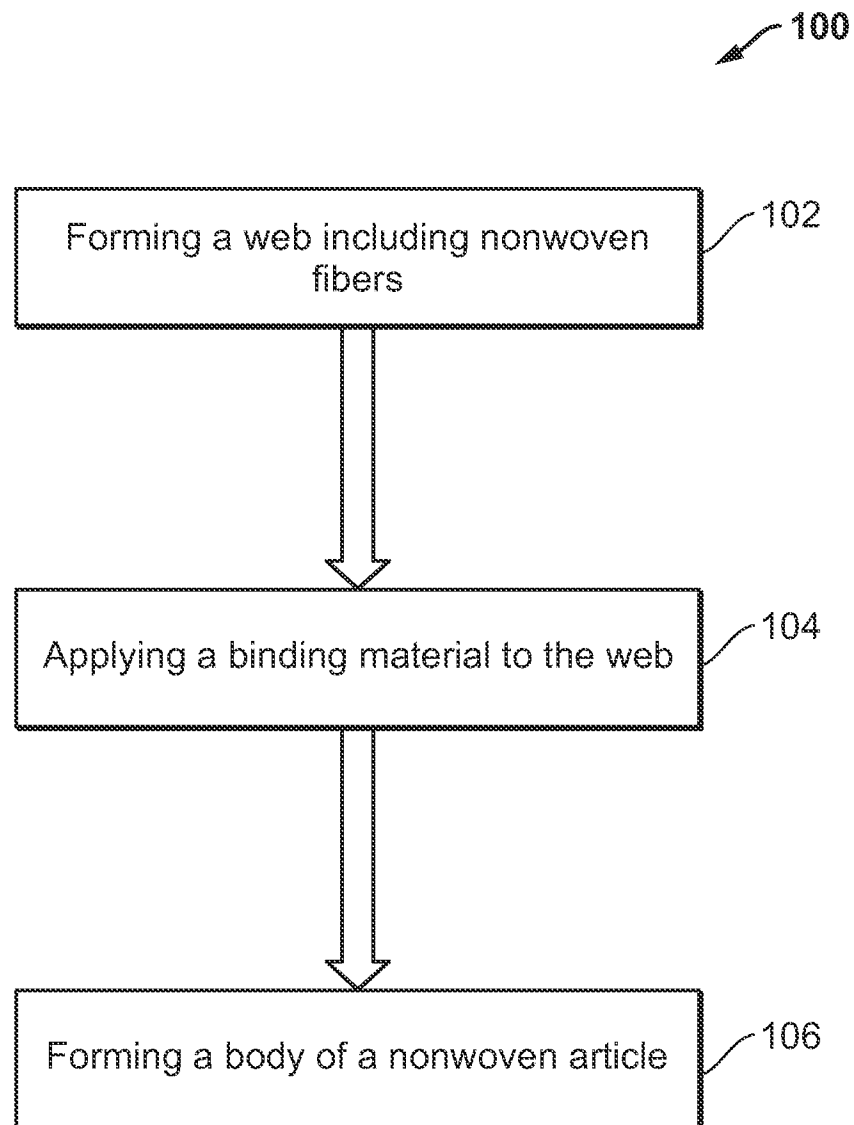


FIG. 1

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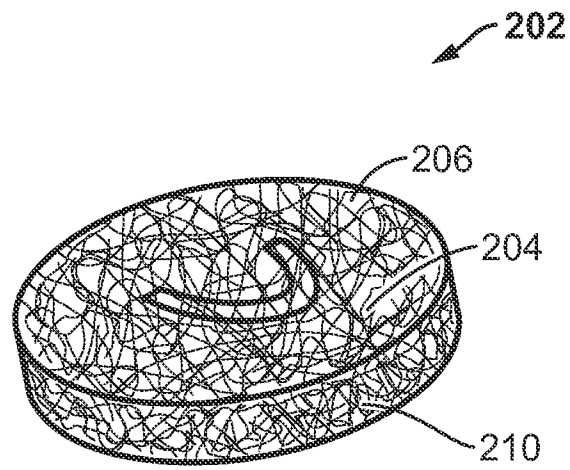


FIG. 2

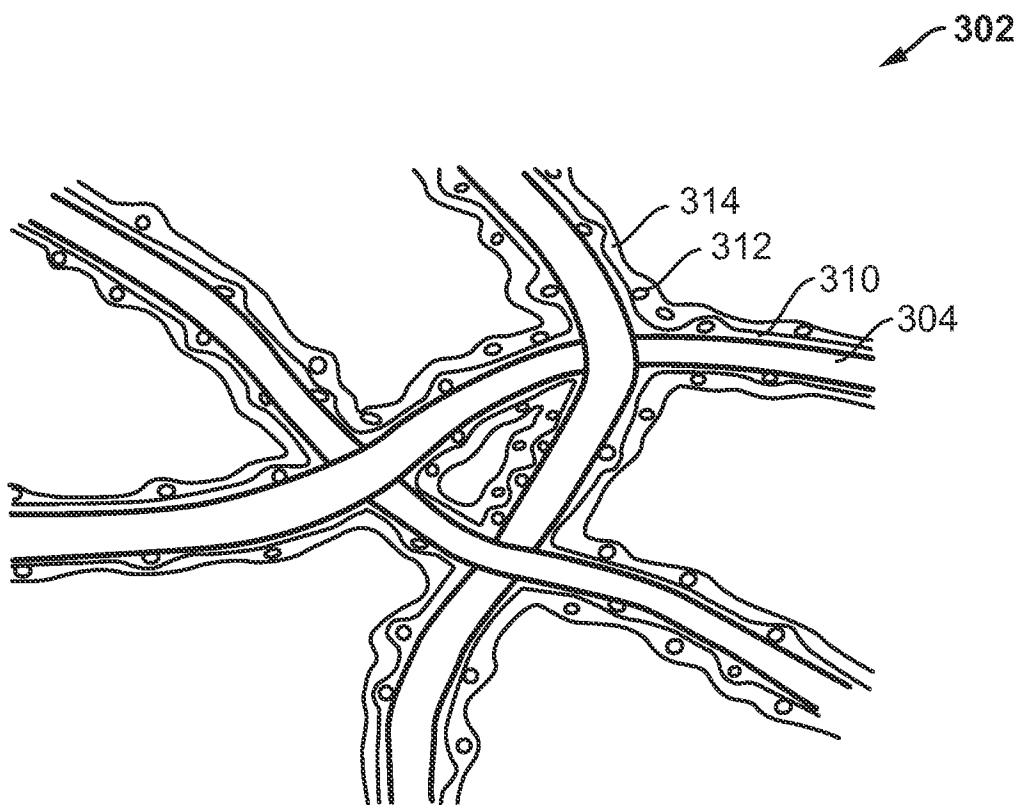


FIG. 3

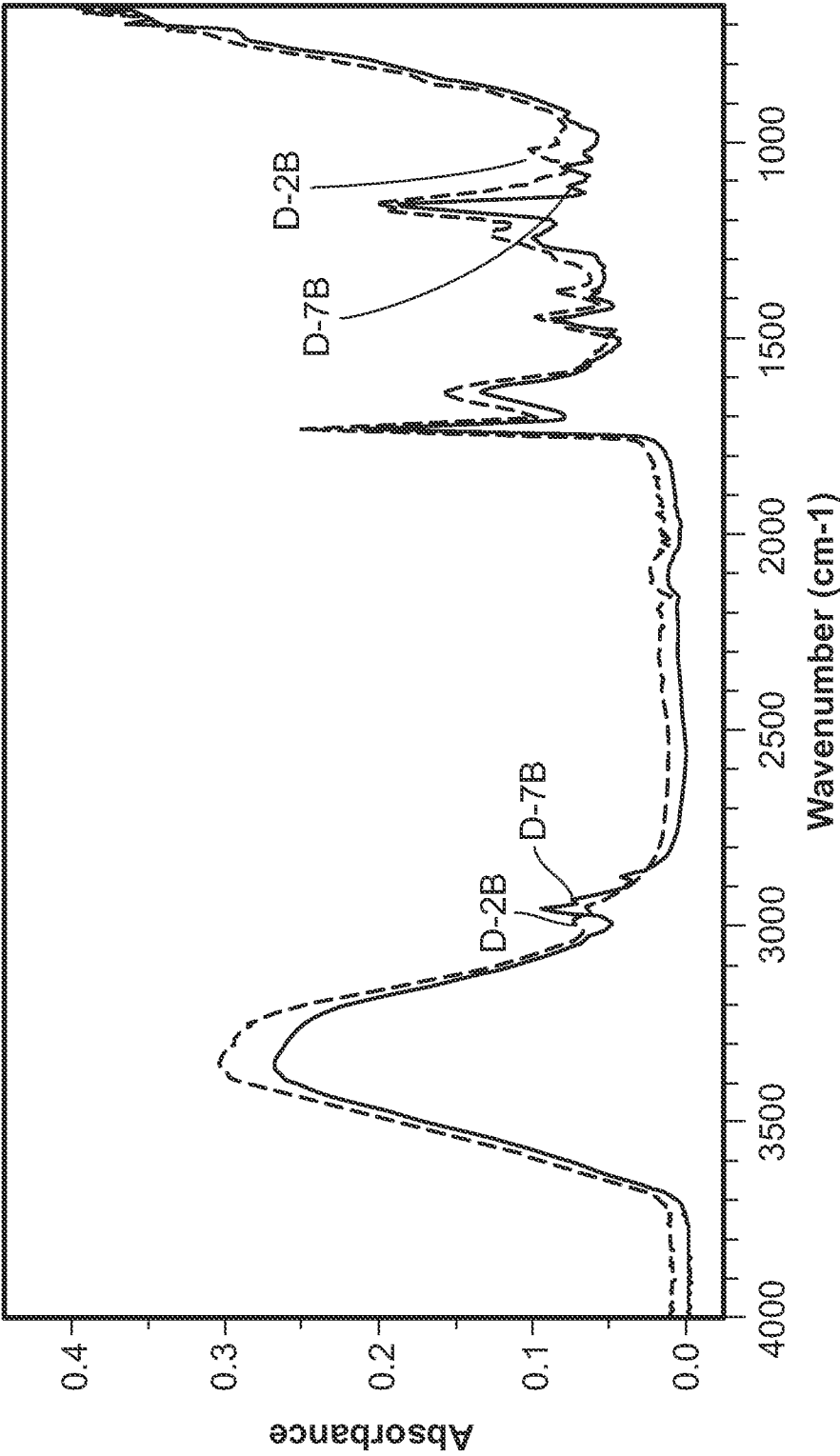


FIG. 4

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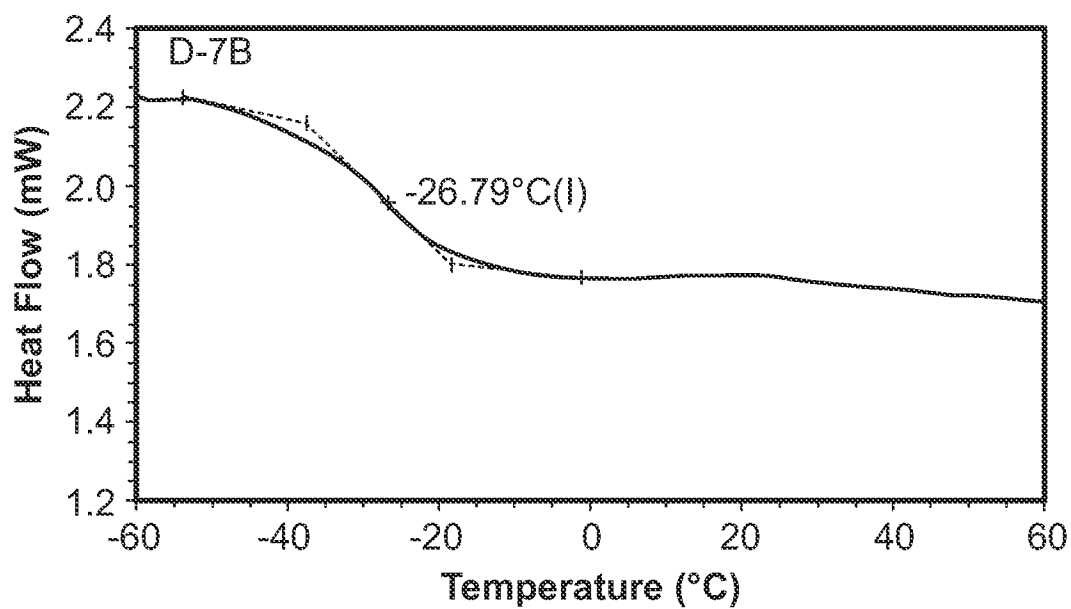


FIG. 5

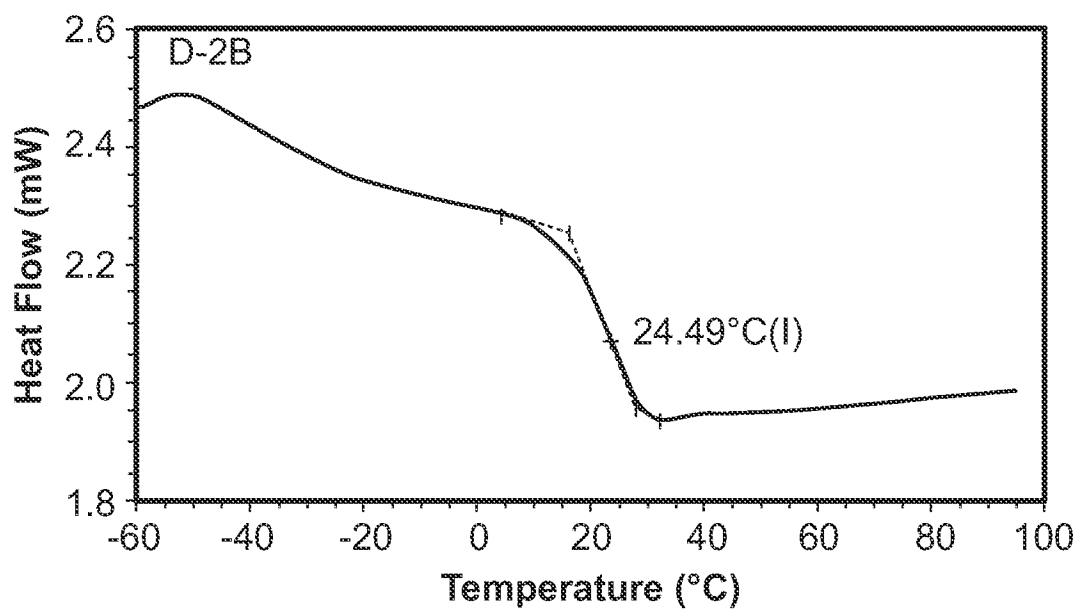


FIG. 6

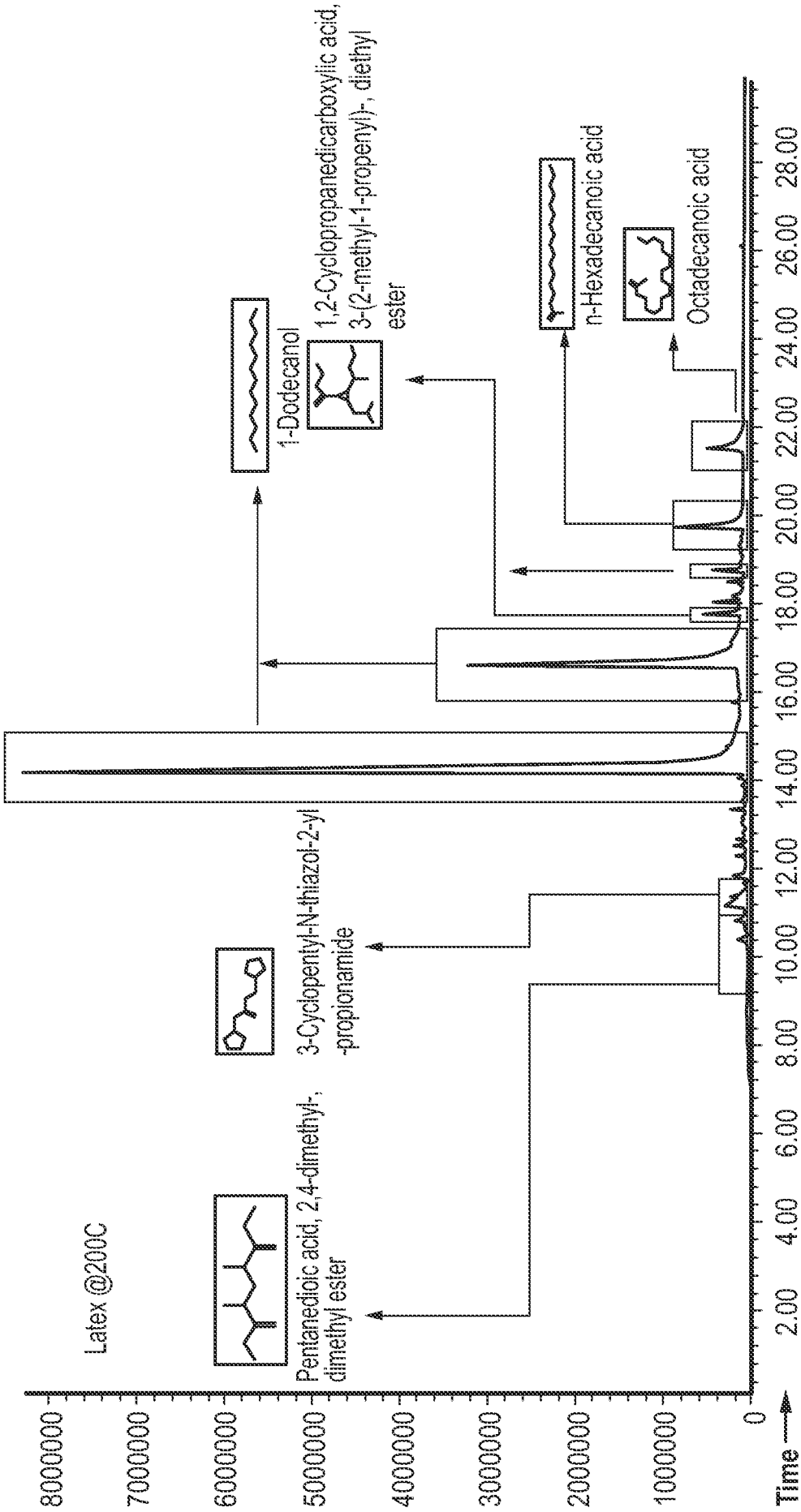


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/079397

A. CLASSIFICATION OF SUBJECT MATTER D04H 1/736(2012.01)i; D04H 1/4382(2012.01)i; D04H 1/4334(2012.01)i; D04H 1/435(2012.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) D04H 1/736(2012.01); B24B 11/00(2006.01); B24D 11/00(2006.01); B24D 18/00(2006.01); B24D 3/14(2006.01); B24D 3/28(2006.01); B24D 3/34(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: non-woven hand tool, non-woven fiber, web, peel strength, stiffness		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2021-124352 A1 (SAINT-GOBAIN ABRASIVES, INC. et al.) 24 June 2021 (2021-06-24) paragraphs [0018]-[0036], [0056]-[0063]; and fig. 1	1-15
Y	US 2020-0139513 A1 (3M INNOVATIVE PROPERTIES COMPANY) 07 May 2020 (2020-05-07) paragraphs [0037]-[0045]	1-15
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 12 March 2024		Date of mailing of the international search report 13 March 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer HEO, Joo Hyung Telephone No. +82-42-481-5373

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/079397

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