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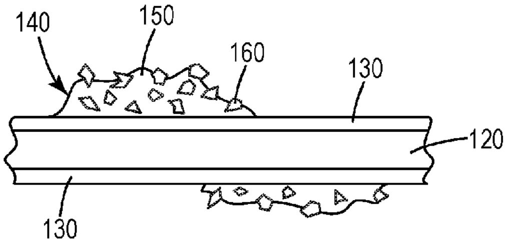

FIG. 2

(57) Abstract: A nonwoven abrasive article includes a prebond composition disposed on a lofty open nonwoven fiber web, an abrasive layer disposed on and secured to at least a portion of the prebond composition. The abrasive layer comprises a binder composition retaining abrasive particles. At least one of the prebond composition and the binder composition comprises a reaction product of a polymer having a plurality of oxazolinyl groups. Methods of making the nonwoven abrasive article are also disclosed.

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NONWOVEN ABRASIVE ARTICLE AND METHODS OF MAKING THE SAME

TECHNICAL FIELD

The present disclosure broadly relates to nonwoven abrasive articles, and methods of their manufacture and use.

BACKGROUND

Nonwoven abrasive articles are known and have been described, for example, in U.S. Pat. No. 2,958,593 (Hoover et al.), and generally comprise fibers formed into a nonwoven web provided as a foraminous three-dimensional integrated network structure with an abrasive layer attached thereto. The abrasive layer typically includes abrasive particles retained in a crosslinked binder.

Often, the fibers are formed into a lofty open nonwoven fiber web, e.g., as described in U.S. Pat. No. 5,591,239 (Larson). A prebond coating of a curable prebond precursor solution without containing abrasive particles, which includes one or more of the above-named resins, is coated on the web and cured (e.g., by exposure to heat) in order to impart sufficient strength to the nonwoven web for further processing.

Such nonwoven abrasive articles are useful in discrete sheet form as well as in various converted forms, such as wheels, discs, and flap brushes, for example. In these converted forms, the resulting articles are useful to scour, clean, condition, and/or decorate the surfaces of such materials as metal, wood, plastics, glass, ceramics, and composites.

One known type of nonwoven abrasive product includes polyamide fibers and an abrasive layer containing a binder retaining abrasive particles. However, the different physical properties of phenolic binder and polyamide fiber, for example, with respect to flexibility and composition can lead to debonding of the polyamide fibers and the abrasive layer during use, thereby causing fraying of the fibers and resulting in shortened product life.

SUMMARY

Various technical solutions have been tried, but to date there remains a need for a solution to the problem of poor wear performance leading to shortened product life. Advantageously, the present disclosure provides such new nonwoven abrasive articles that exhibit improved wear performance.

In one aspect the present disclosure provides a nonwoven abrasive article comprising a lofty open nonwoven fiber web; a prebond composition disposed on at least a portion of the lofty open nonwoven fiber web, an abrasive layer disposed on and secured to at least a portion of the prebond composition, wherein the abrasive layer comprises a binder composition retaining abrasive particles, wherein at least one of the prebond composition and the binder composition comprises a reaction product of a polymer having a plurality of oxazolinyl groups.

In another aspect, the present disclosure provides a method of making a nonwoven abrasive article, the method comprising disposing a curable prebond precursor composition on at least a portion of a lofty open nonwoven fiber web, at least partially curing the curable prebond precursor composition to provide a prebond composition; disposing an abrasive layer precursor composition onto at least a portion of the prebond composition, wherein the abrasive layer precursor composition comprises phenolic resin and abrasive particles; wherein at least one of the curable prebond precursor composition and the abrasive layer precursor composition comprises a polymer having a plurality of oxazolinyl groups; and at least partially curing the abrasive layer precursor composition.

In yet another aspect, the present disclosure provides a method of making a nonwoven abrasive article, the method comprising disposing a curable prebond precursor composition on at least a portion of a lofty open nonwoven fiber web, at least partially curing the curable prebond precursor composition to provide a prebond composition; disposing a curable make layer precursor composition onto at least a portion of the prebond composition, wherein the curable make layer precursor composition comprises phenolic resin; wherein at least one of the curable prebond precursor composition and the curable make layer precursor composition comprises a polymer having a plurality of oxazolinyl groups; at least partially embedding abrasive particles into the curable make layer precursor composition; and at least partially curing the curable make layer precursor composition to provide an at least partially cured make layer composition.

In some embodiments, methods according to the present disclosure further comprise disposing a curable size layer precursor composition on the at least partially cured make layer composition; and at least partially curing the curable size layer precursor composition.

As used herein:

"nonwoven" refers to any fiber web held together by interlocking or bonding (as by chemical or thermal means) and not woven, knitted, or felted;

"acrylic polymer" refers to any polymer comprising one or monomer units corresponding to a residue of (meth)acrylic acid, a (meth)acrylate ester, (meth)acrylonitrile, or an optionally substituted (meth)acrylamide.

"polyurethane" refers to a polymer having a plurality of carbamylene (i.e., –OC(=O)NH–) groups.

"(meth)acryl" refers to either or both of acryl or methacryl.

Features and advantages of the present disclosure will be further understood upon consideration of the detailed description as well as the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic perspective view of exemplary nonwoven abrasive article 100.

FIG. 2 is a schematic enlarged view of an individual coated fiber within nonwoven abrasive article 100 shown in FIG. 1. for convenience

Repeated use of reference characters in the specification and drawings is intended to represent the same or analogous features or elements of the disclosure. It should be understood that 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 disclosure. The figures may not be drawn to scale.

DETAILED DESCRIPTION

Referring now to FIG. 1, exemplary nonwoven abrasive article 100 comprising a lofty open nonwoven fiber web 110 comprising fibers 120. Referring now to FIG. 2 prebond composition 130 is disposed on fibers 120. Abrasive layer 140 is disposed on and secured to at least a portion of the prebond composition 130. The abrasive layer 140 comprises a phenolic binder 150 retaining abrasive particles 160.

Lofty open nonwoven fiber webs (for convenience hereinafter "nonwoven fiber webs") suitable for use are known in the abrasives art. The fibers may comprise continuous fiber, staple fiber, or a combination thereof. For example, the fiber web may comprise staple fibers having a length of at least about 20 millimeters (mm), at least about 30 mm, or at least about 40 mm, and less than about 110 mm, less than about 85 mm, or less than about 65 mm, although shorter and longer fibers (e.g., continuous filaments) may also be useful. The fibers may have a fineness or linear density of at least about 1.7 decitex (dtex, i.e., grams/10000 meters), at least about 6 dtex, or at least about 17 dtex, and less than about 560 dtex, less than about 280 dtex, or less than about 120 dtex, although fibers having lesser and/or greater linear densities may also be useful. Mixtures of fibers with differing linear densities may be useful, for example, to provide an abrasive article that upon use will result in a specifically preferred surface finish.

The nonwoven fiber web may be made, for example, by conventional air laid, carded, stitch bonded, spun bonded, wet laid, and/or melt blown procedures. Air laid fiber webs may be prepared using equipment such as, for example, that available under the trade designation RANDO WEBBER from Rando Machine Company of Macedon, New York.

Nonwoven fiber webs are typically selected to be compatible with adhering binders and abrasive particles while also being compatible with other components of the article, and typically can withstand processing conditions (e.g., temperatures) such as those employed during application and curing of the curable binder precursor. While many types of fibers can be included, at least some of the fibers in the nonwoven fiber web comprise polyamide, preferably aliphatic polyamide. Blends of polyamide and other polymer(s) may be used. Preferably, at least 50 percent, at least 60 percent, at least 70 percent, at least 80 percent, at least 90 percent, at least 99 percent, or even 100 percent of the fibers, on a weight basis, comprise at least one polyamide. Exemplary polyamides include aliphatic polyamides such as poly(caprolactam) (i.e., nylon 6), poly(hexamethylene/adipic acid) amide (i.e., nylon 6,6), poly(hexamethylene/sebacic acid) amide (i.e., nylon 6,10), and aliphatic polyamide copolymers; semiaromatic polyamides such as polyphthalamides (e.g., PPA); and aromatic polyamides such as p-phenylenediamine/terephthalic acid polymers (e.g., as available under the trade designations Kevlar and Nomex).

Other fibers may be included, for example, to affect properties of the nonwoven abrasive article such as, for example, flexibility, elasticity, durability or longevity, abrasiveness, and finishing properties. Examples of other fibers that may be suitable include natural fibers, synthetic fibers, and mixtures of natural and/or synthetic fibers. Examples of synthetic fibers include those made from polyester (e.g., polyethylene terephthalate), polypropylene, acrylonitrile (i.e., acrylic), rayon, cellulose acetate, polyvinylidene chloride-vinyl chloride copolymers, and vinyl chloride-acrylonitrile copolymers. Examples of suitable natural fibers include cotton, jute, and hemp. The fiber may be of virgin material or of recycled or waste material, for example, reclaimed from garment cuttings, carpet manufacturing, fiber manufacturing, or textile processing. The fiber may be homogenous or a composite such as a bicomponent fiber (e.g., a co-spun sheath-core fiber). The fibers may be tensilized and crimped, but may also be continuous filaments such as those formed by an extrusion process. Combinations of fibers may also be used.

Prior to coating with the prebond precursor composition, the nonwoven fiber web typically has a weight per unit area (i.e., basis weight) of at least about 50 grams per square meter (gsm), at least about 100 gsm, or at least about 150 gsm; and/or less than about 600 gsm, less than about 500 gsm, or less than about 400 gsm, as measured prior to any coating (e.g., with the curable binder precursor or optional pre-bond resin), although greater and lesser basis weights may also be used. In addition, Prior to coating with the prebond precursor composition, the fiber web typically has a thickness of at least about 3 mm, at least about 6 mm, or even at least about 10 mm; and/or less than about 100 mm, less than about 50 mm, or less than about 25 mm, in any subcombination, although greater and lesser thicknesses may also be useful.

It is useful to apply a prebond composition to the nonwoven fiber web prior to coating with the curable binder precursor. The prebond composition serves, for example, to help maintain the nonwoven fiber web integrity during handling, and may also facilitate bonding of the urethane binder to the nonwoven fiber web. Examples of prebond resins include phenolic resins, urethane resins, hide glue, acrylic resins, urea-formaldehyde resins, melamine-formaldehyde resins, epoxy resins, and combinations thereof. The amount of pre-bond resin used in this manner is typically adjusted toward the minimum amount consistent with bonding the fibers together at their points of crossing contact. In those cases, wherein the nonwoven fiber web includes thermally bondable fibers, thermal bonding of the nonwoven fiber web may also be helpful to maintain web integrity during processing. The prebond composition is formed by at least partially curing, preferably at least substantially curing a curable prebond precursor composition.

In one embodiment, the prebond precursor composition comprises a polymer having a plurality of oxazolinyl groups and a polyurethane having a plurality of carboxyl groups. On a solids basis, the polymer having a plurality of oxazolinyl groups and polyurethane are present in a weight ratio of from 1:99 to 8:92 (preferably 1:99 to 7:93). Preferably, at least one of the polymer having a plurality of oxazolinyl groups, the polyurethane, and the prebond precursor composition, more preferably all of them, is water-based; however, this is not a requirement.

Useful polymers having a plurality of oxazolinyl groups can include an acrylic polymer, for example, a methacrylic polymer. Useful (meth)acrylic polymers having a plurality of oxazolinyl groups can be copolymers of a free-radically polymerizable oxazoline-functional monomer with one or more (meth)acrylic monomers.

Exemplary free-radically polymerizable oxazoline-functional monomers include 2-isopropenyl-2-oxazoline, 2-vinyl-2-oxazoline and various substituted derivatives described in U.S. Pat. No. 3,839350 (Hunsucker).

Exemplary (meth)acrylic monomers include (meth)acrylic acid, (meth)acrylonitrile, (meth)acrylamides, (meth)acrylate esters (e.g., methyl (meth)acrylate, ethyl methacrylate, 2-hydroxyethyl (meth)acrylate, propyl (meth)acrylate, n-butyl (meth)acrylate), isobutyl (meth)acrylate), tetrahydrofurfuryl (meth)acrylate), isobornyl (meth(acrylate), (meth)acrylonitrile, or an optionally substituted (meth)acrylamide, 2-phenoxyethyl (meth)acrylate, cyclohexyl (meth)acrylate, benzyl (meth)acrylate, phenyl (meth)acrylate, allyl (meth)acrylate, lauryl (meth)acrylate. In some embodiments, the (meth)acrylic monomer(s) is an alkyl (meth)acrylate having from 1 to 8 carbon atoms.

In some embodiments, additional non-acrylic free-radically polymerizable monomers can be included in the (meth)acrylic polymer having a plurality of oxazolinyl groups. Exemplary such monomers include styrene and substituted styrenes.

Commercially available suitable (meth)acrylic polymers having a plurality of oxazolinyl groups include those marketed by Nippon Shokubai Co. Ltd., Osaka, Japan, under the trade designation EPOCROS. Examples may include WS series polymers such as WS-300, WS-500, and WS-700 which are acrylic water-soluble polymers having a plurality of oxazolinyl groups. Examples may also include K-2000 series polymers such as K-2010E, K-2020E, and K-2035E which are styrene/acrylic emulsion polymers having a plurality of oxazolinyl groups.

The amount of oxazolinyl-containing polymer contained in a composition (either a curable precursor composition or a cured composition) can be shown as Part per Hundred parts of Resin (PHR). Herein, PHR is calculated based on the nonvolatile content in oxazolinyl-containing polymer divided by the nonvolatile content in non-oxazolinyl resin in the precursor composition, and PHR is expressed as part per hundred parts. For example, when a precursor composition includes 6.01 grams oxazolinyl-containing polymer solution with 25% nonvolatile content and 71.66 grams non-oxazolinyl resin solution with 70% nonvolatile content, a PHR of 3 is obtained.

In some embodiments, the prebond precursor composition can include the polymer having a plurality of oxazolinyl groups at an amount of at least 0.5 PHR, 1 PHR, 3 PHR, or 5 PHR. In some embodiments, the prebond precursor composition can includes the polymer having a plurality of oxazolinyl groups at an amount of no more than 20 PHR, 15 PHR, or 10 PHR. Advantageously, the nonwoven abrasive articles according to the disclosure provide good cut and finishing performance, while exhibit less wear of abrasive articles and longer abrasive life.

Methods of making carboxylated polyurethanes are well-know and described in, for example, Liu et al. "Continuous Production of Water-Borne Polyurethanes: A Review" *Polymers* 2020, 12, pp. 2875. There are many techniques for making aqueous carboxylated polyurethane dispersions, including the incorporation of a carboxylic acid moiety in the polyurethane backbone to serve as an internal emulsifier. This internal emulsifier can be achieved by using a carboxylated diol such as, for example, dimethylolpropionic acid (DMPA), which is co-reacted with a polyol and isocyanate and then neutralized with base, facilitating the dispersion of the polyurethane particles in water. DMPA levels vary in the range of 4-8 weight percent of the prepolymer weight.

Many carboxylated polyurethane dispersions are commercially available. Examples include those available under the trade designations ADEKA BONTIGHTER HUX-386 from Adeka Corporation, Tokyo, Japan; HYDRAN HW-110, HYDRAN HW-131, HYDRAN HW-135, HYDRAN HW-320, HYDRAN HW-311, HYDRAN HW-337, HYDRAN 340, HYDRAN WLS-201, and BONDIC 72070 all from DIC Corporation, Tokyo, Japan; NEOSTECKER 400 and NEOSTECKER 700 from NICCA CHEMICAL CO., LTD., Fukui, Japan; and VYLONAL MD-1200, VYLONAL MD-1400, and VYLONAL MD-1930 from TOYOBO CO., LTD., Osaka, Japan. Combinations of carboxylated polyurethanes may also be used.

Useful compositions of the curable prebond precursor composition may comprise 3-85 wt. %, 30-85 wt. %, 51-85 wt. %, and 70-85 wt. % solids aqueous dispersions, although higher and lower amounts may also be used. The curable prebond precursor composition may be applied to the nonwoven fiber web by any suitable means such as, for example, roll coating, spray coating, or saturation coating. In some embodiments, the curable prebond precursor composition can also include, for example, additional additives such as wetting agents, levelling agents, colorant, biocide, fungicide, thixotropes, and antioxidants.

After the curable prebond precursor composition is applied to the nonwoven fiber web is then at least partially cured, preferably at least substantially cured, for example by heating in an oven at elevated temperature. This imparts strength to the nonwoven fiber web and helps maintain a lofty open structure. The choice of temperature may depend on factors such as the specific composition of the curable prebond precursor composition, and or the fibers, and is within the capabilities of those having ordinary skill in the art.

Next, an abrasive layer is disposed on and secured to at least a portion of the prebond composition. The abrasive layer includes a binder composition retaining abrasive particles. This can be accomplished in at least two ways.

In a first way, an abrasive layer precursor composition (typically a slurry) containing a curable binder precursor composition and abrasive particles is impregnated into the nonwoven fiber web, or otherwise coated on at least a portion of the prebond layer (e.g., by roll coating or spray coating).

In some embodiments according to the present disclosure, the abrasive layer precursor composition comprises a polymer having a plurality of oxazolinyl groups. Useful polymers having a plurality of oxazolinyl groups can include an acrylic polymer, for example, a methacrylic polymer. Useful (meth)acrylic polymers having a plurality of oxazolinyl groups can be copolymers of a free-radically polymerizable oxazoline-functional monomer with one or more (meth)acrylic monomers. Exemplary free-radically polymerizable oxazoline-functional monomers include 2-isopropenyl-2-oxazoline, 2-vinyl-2-oxazoline and various substituted derivatives described in U.S. Pat. No. 3,839350 (Hunsucker). Additional non-acrylic free-radically polymerizable monomers can be included in the (meth)acrylic polymer having a plurality of oxazolinyl groups. Exemplary such monomers include styrene and substituted styrenes.

In some embodiments, the curable binder precursors can include the polymer having a plurality of oxazolinyl groups at an amount of at least 0.5 PHR, 1 PHR, 3 PHR, or 5 PHR. In some embodiments, the prebond precursor composition can includes the polymer having a plurality of oxazolinyl groups at an amount of no more than 20 PHR, 15 PHR, 10 PHR or 5 PHR. Advantageously, the nonwoven abrasive articles according to the disclosure provide good cut and finishing performance, while exhibit less wear of abrasive articles and longer abrasive life.

Examples of suitable curable binder precursors can include resole phenolic resins, novolac phenolic resins, epoxy resins, polymerizable acrylic monomers oligomers and polymers, alkyd resins, cyanate resins, aminoplast resins, urea-formaldehyde resins, urethane resins (one-part and two-part), and combinations thereof. Depending on the curable binder precursor system selected, an appropriate curative (e.g., a crosslinker, catalyst, or initiator) may also be present. Selection and amounts of suitable such curatives are well known in the abrasives art.

Exemplary curable phenolic resins include novolac and resole phenolic resins. Novolac phenolic resins are characterized by being acid-catalyzed and having a ratio of formaldehyde to phenol of less than one, typically between 0.5:1 and 0.8:1. Resole phenolic resins are characterized by being alkaline catalyzed and having a ratio of formaldehyde to phenol of greater than or equal to one, typically from 1:1 to 3:1. Novolac and resole phenolic resins may be chemically modified (e.g., by reaction with epoxy compounds), or they may be unmodified. Exemplary acidic catalysts suitable for curing phenolic resins include sulfuric, hydrochloric, phosphoric, oxalic, and p-toluenesulfonic acids. Alkaline catalysts suitable for curing phenolic resins include sodium hydroxide, barium hydroxide, potassium hydroxide, calcium hydroxide, organic amines, and/or sodium carbonate.

Examples of commercial phenolic resins include those known by the trade designations DUREZ and VARCUM from Durez Corporation, Novi, Michigan; RESINOX from Monsanto Corp., Saint Louis, Missouri; AROFENE and AROTAP from Ashland Chemical Co., Columbus, Ohio; and RUTAPHEN by Momentive, Columbus, Ohio; and PHENOLITE by Kangnam Chemical Company Ltd. of Seoul, South Korea. Examples of commercially available novolac resins include those marketed as DUREZ 1364 and VARCUM 29302 from Durez Corporation. Examples of commercially available resole phenolic resins include VARCUM resoles in grades 29217, 29306, 29318, 29338, and 29353; AEROFENE 295; and PHENOLITE TD-2207.

In some embodiments, the curable binder precursor is a urethane prepolymer. Examples of useful urethane prepolymers include polyisocyanates and blocked versions thereof. Typically, blocked polyisocyanates are substantially unreactive to isocyanate reactive compounds (e.g., amines, alcohols, thiols) under ambient conditions (e.g., temperatures in a range of from about 20° C. to about 25° C.), but upon application of sufficient thermal energy the blocking agent is released, thereby generating isocyanate functionality that reacts with the amine curative to form a covalent bond.

Curable binder compositions may contain various additives. For example, conventional resin filler(s) (e.g., calcium carbonate or fine fibers), lubricant(s) (e.g., alkali metal salts of stearic acid and light petroleum oils), grinding aid(s) (e.g., potassium fluoroborate), wetting agent(s) or surfactant(s) (e.g., sodium lauryl sulfate), defoamer(s), pigment(s), dye(s), biocide(s), coupling agent(s) (e.g., organosilanes), plasticizer(s) (e.g., polyalkylene polyols or phthalate esters), thickeners, and combinations thereof. Typically, the curable binder precursor will include at least one solvent (e.g., isopropyl alcohol, methyl ethyl ketone, water) to facilitate coating of the curable binder precursor on the nonwoven fiber web, although this is not a requirement.

Examples of useful abrasive particles include any abrasive particles known in the abrasive art. Exemplary useful abrasive particles include fused aluminum oxide, heat-treated aluminum oxide, white fused aluminum oxide, ceramic aluminum oxide materials such as those commercially available as 3M CERAMIC ABRASIVE GRAIN from 3M Company, St. Paul, Minnesota, brown aluminum oxide, blue aluminum oxide, silicon carbide (including green silicon carbide), titanium diboride, boron carbide, tungsten carbide, garnet, titanium carbide, diamond, cubic boron nitride, fused alumina zirconia, iron oxide, chromia, zirconia, titania, tin oxide, quartz, feldspar, flint, emery, sol-gel-derived ceramic (e.g., alpha alumina), and combinations thereof. Examples of sol-gel-derived abrasive particles from which the abrasive particles can be isolated, and methods for their preparation can be found, in U.S. Pat. Nos. 4,314,827 (Leitheiser et al.); 4,623,364 (Cottringer et al.); 4,744,802 (Schwabel), 4,770,671 (Monroe et al.); and 4,881,951 (Monroe et al.). It is also contemplated that the abrasive particles could comprise abrasive agglomerates such, for example, as those described in U.S. Pat. Nos. 4,652,275 (Bloecher et al.) or 4,799,939 (Bloecher et al.). In some embodiments, the abrasive particles may be surface-treated with a coupling agent (e.g., an organosilane coupling agent) or other physical treatment (e.g., iron oxide or titanium oxide) to enhance adhesion of the abrasive particles to phenolic binder, for example.

The abrasive particles may, for example, have an average diameter of at least about 0.1 micrometer, at least about 1 micrometer, or at least about 10 micrometers, and less than about 2000 micrometers, less than about 1300 micrometers, or less than about 1000 micrometers, although larger and smaller abrasive particles may also be used. For example, the abrasive particles may have an abrasives industry specified nominal grade. Such abrasives industry accepted grading standards include those known as the American National Standards Institute, Inc. (ANSI) standards, Federation of European Producers of Abrasive Products (FEPA) standards, and Japanese Industrial Standard (JIS) standards. Exemplary ANSI grade designations (that is, specified nominal grades) include: ANSI 4, ANSI 6, ANSI 8, ANSI 16, ANSI 24, ANSI 36, ANSI 40, ANSI 50, ANSI 60, ANSI 80, ANSI 100, ANSI 120, ANSI 150, ANSI 180, ANSI 220, ANSI 240, ANSI 280, ANSI 320, ANSI 360, ANSI 400, and ANSI 600. Exemplary FEPA grade designations include P8, P12, P16, P24, P36, P40, P50, P60, P80, P100, P120, P150, P180, P220, P320, P400, P500, 600, P800, P1000, and P1200. Exemplary JIS grade designations include HS8, JIS12, JIS16, JIS24, JIS36, JIS46, JIS54, JIS60, JIS80, JIS100, JIS 150, JIS 180, JIS220, JIS 240, JIS280, JIS320, JIS360, JIS400, JIS600, JIS800, JIS1000, JIS1500, JIS2500, JIS4000, JIS6000, JIS8000, and JIS10000.

The abrasive particles may comprise sol-gel-derived polycrystalline alpha alumina particles. Such abrasive particles composed of crystallites of alpha alumina, magnesium alumina spinel, and a rare earth hexagonal aluminate may be prepared using sol-gel precursor alpha alumina particles according to methods described in, for example, U.S. Pat. No. 5,213,591 (Celikkaya et al.) and U.S. Publ. Pat. Appln. Nos. 2009/0165394 A1 (Culler et al.) and 2009/0169816 A1 (Erickson et al.). Further details concerning methods of making sol-gel-derived abrasive particles can be found in, for example, U.S. Pat. Nos. 4,314,827 (Leitheiser); 5,152,917 (Pieper et al.); 5,435,816 (Spurgeon et al.); 5,672,097 (Hoopman et al.); 5,946,991 (Hoopman et al.); 5,975,987 (Hoopman et al.); and 6,129,540 (Hoopman et al.); and in U.S. Publ. Pat. Appln. No. 2009/0165394 Al (Culler et al.).

The abrasive particle may comprise shaped abrasive particles, for example, having the shape of triangular platelets can be found in U.S. Pat. Nos. 5,201,916 (Berg); 5,366,523 (Rowenhorst (Re 35,570)); and 5,984,988 (Berg). In some embodiments, the shaped abrasive particles are precisely-shaped (i.e., the particles have shapes that are at least partially determined by the shapes of mold cavities in a production tool used to make them. Details concerning such abrasive particles and methods for their preparation can be found, for example, in U.S. Pat. Nos. 8,142,531 (Adefris et al.); 8,142,891 (Culler et al.); and 8,142,532 (Erickson et al.); and in U.S. Pat. Appl. Publ. Nos. 2012/0227333 (Adefris et al.); 2013/0040537 (Schwabel et al.); and 2013/0125477 (Adefris). One particularly useful precisely-shaped abrasive particle shape is that of a platelet having three-sidewalls, any of which may be straight or concave, and which may be vertical or sloping with respect to the platelet base; for example, as set forth in U.S. Pat. Nos. 9,771,504 and 10,301,518, both to Adefris.

In some embodiments, the shaped abrasive particles may be selected to have a length and/or width in a range of from 0.1 micrometers to 3.5 millimeters (mm), more typically 0.05 mm to 3.0 mm, and more typically 0.1 mm to 2.6 mm, although other lengths and widths may also be used.

In some embodiments, the shaped abrasive particles may be selected to have a thickness in a range of from 0.1 micrometer to 1.6 mm, more typically from 1 micrometer to 1.2 mm, although other thicknesses may be used. In some embodiments, abrasive particles may have an aspect ratio (length to thickness) of at least 2, 3, 4, 5, 6, or more.

Typically, the coating weight for the abrasive particles (independent of other ingredients in the curable composition) may depend, for example, on the particular curable phenolic resin prepolymer used, the process for applying the abrasive particles, and the size of the abrasive particles. For example, the coating weight of the abrasive particles on the nonwoven fiber web may be at least 200 grams per square meter (g/m), at least 600 g/m, or at least 800 g/m; and/or less than 2000 g/m, less than about 1600 g/m, or less than about 1200 g/m, although greater or lesser coating weights may also be used.

Typically, the curable abrasive layer precursor composition, including any optional solvent that may be present, is coated onto the nonwoven fiber web in an amount of from 1120 to 2080 gsm, more typically 1280 - 1920 gsm, and even more typically 1440 - 1760 gsm, although values outside these ranges may also be used.

In a second way, a curable make layer precursor composition comprising phenolic resin is impregnated into the nonwoven fiber web, or otherwise coated on at least a portion of the prebond layer (e.g., by roll coating or spray coating) and then abrasive particles are deposited thereon by electrostatic coating, drop coating or spray coating, for example.

In some embodiments according to the present disclosure, the curable make layer precursor composition comprises a polymer having a plurality of oxazolinyl groups. Useful polymers having a plurality of oxazolinyl groups can include an acrylic polymer, for example, a methacrylic polymer. Useful (meth)acrylic polymers having a plurality of oxazolinyl groups can be copolymers of a free-radically polymerizable oxazoline-functional monomer with one or more (meth)acrylic monomers. Exemplary free-radically polymerizable oxazoline-functional monomers include 2-isopropenyl-2-oxazoline, 2-vinyl-2-oxazoline and various substituted derivatives described in U.S. Pat. No. 3,839350 (Hunsucker). Additional non-acrylic free-radically polymerizable monomers can be included in the (meth)acrylic polymer having a plurality of oxazolinyl groups. Exemplary such monomers include styrene and substituted styrenes. In some embodiments, the curable make layer precursors can include the polymer having a plurality of oxazolinyl groups at an amount of at least 0.5 PHR, 1 PHR, 3 PHR, or 5 PHR.

In either embodiment, the phenolic resin is at least partially cured after the phenolic resin precursor composition is deposited on the prebond layer and optional portions of the nonwoven fiber web. Typically, the phenolic resin is cured by heating (e.g., in an oven or under heat lamps).

Optionally, and preferably in the second embodiment, a curable size layer precursor can be applied over the at least partially cured make layer precursor and abrasive particles. The size layer precursor may comprise the same or different binder precursor used in the make layer (if present) and/or slurry layer (if present). The size layer precursor may comprise, for example, glue, phenolic resin, aminoplast resin, urea-formaldehyde resin, melamine-formaldehyde resin, urethane resin, free-radically polymerizable polyfunctional (meth)acrylate (for example, aminoplast resin having pendant alpha, beta-unsaturated groups, acrylated urethane, acrylated epoxy, acrylated isocyanurate), epoxy resin (including bis-maleimide and fluorene-modified epoxy resins), isocyanurate resin, and mixtures thereof. In preferred embodiments the size layer precursor comprises curable phenolic resin.

The size layer precursor may be applied by any known coating method for applying a size layer to a backing, including roll coating, extrusion die coating, curtain coating, knife coating, gravure coating, spray coating, and the like. If desired, a presize layer precursor or make layer precursor according to the present disclosure may be also used as the size layer precursor.

Likewise, the size layer precursor may be cured by heating (e.g., in an oven or under heat lamps), or by other methods.

The basis weight of the size layer will also necessarily vary depending on the intended use(s), type(s) of abrasive particles, and nature of the coated abrasive article being prepared, but generally will be in the range of from 1 or 5 gsm to 300, 400, or even 500 gsm, or more. The size layer precursor may be applied by any known coating method for applying a size layer precursor (for example, a size coat) to a backing including, for example, roll coating, extrusion die coating, curtain coating, and spray coating.

Optionally a supersize layer may be applied onto at least a portion of the size layer. If present, the supersize typically includes grinding aids and/or anti-loading materials. The optional supersize layer may serve to prevent or reduce the accumulation of swarf (the material abraded from a workpiece) between abrasive particles, which can dramatically reduce the cutting ability of the coated abrasive article. Useful supersize layers typically include a grinding aid (for example, potassium tetrafluoroborate), metal salts of fatty acids (for example, zinc stearate or calcium stearate), salts of phosphate esters (for example, potassium behenyl phosphate), phosphate esters, urea-formaldehyde resins, mineral oils, crosslinked silanes, crosslinked silicones, and/or fluorochemicals. Useful supersize materials are further described, for example, in U.S. Patent No. 5,556,437 (Lee et al.).

Typically, the amount of grinding aid incorporated into coated abrasive products is about 50 to about 400 gsm, more typically about 80 to about 300 gsm. The supersize may contain a binder such as for example, those used to prepare the size or make layer, but it need not have any binder.

Exemplary nonwoven abrasive articles including a lofty open nonwoven fiber web include hand pads, surface conditioning discs and belts, flap brushes, and nonwoven abrasive webs used to make unitized or convolute abrasive wheels). In such nonwoven abrasive articles, interstices between adjacent fibers that are substantially unfilled by binder compositions and abrasive particles, resulting in a composite structure of extremely low density having a network on many relatively large intercommunicated voids. The resulting lightweight, lofty, extremely open fibrous construction is essentially non-clogging and non-filling in nature, particularly when used in conjunction with liquids such as water and oils. These structures also can be readily cleaned upon simple flushing with a cleansing liquid, dried, and left for substantial periods of time, and then reused. Towards these ends, the voids in these nonwoven abrasive articles may make up at least about 75 percent, and preferably more, of the total space occupied by the composite structure.

Nonwoven abrasive articles according to the present disclosure are useful, for example, for abrading a workpiece. For example, a method of abrading a workpiece comprises frictionally contacting a nonwoven abrasive article according to the present disclosure with a surface of the workpiece, and moving at least one of the nonwoven abrasive article and the surface of the workpiece relative to the other to abrade at least a portion of the surface of the workpiece.

Abrading may be carried out dry or wet. For wet abrading, the liquid may be introduced supplied in the form of a light mist to complete flood. Examples of commonly used liquids include water, water-soluble oil, organic lubricant, and emulsions. The liquid may serve to reduce the heat associated with abrading and/or act as a lubricant. The liquid may contain minor amounts of additives such as bactericide, antifoaming agents, and the like.

Examples of workpieces include aluminum metal, carbon steels, mild steels (e.g., 1018 mild steel and 1045 mild steel), tool steels, stainless steel, hardened steel, titanium, glass, ceramics, wood, wood-like materials (e.g., plywood and particle board), paint, painted surfaces, organic coated surfaces and the like. The applied force during abrading typically ranges from about 1 to about 100 kilograms (kg), although other pressures can also be used.

Objects and advantages of this disclosure are further illustrated by the following non-limiting examples, but the particular materials and amounts thereof recited in these examples, as well as other conditions and details, should not be construed to unduly limit this disclosure.

EXAMPLES

Unless otherwise noted, all parts, percentages, ratios, etc. in the Examples and the rest of the specification are by weight. Materials used in the Examples are reported in Table 1, below.

TABLE 1

MATERIAL	PRODUCT	SUPPLIER
Carboxylated polyurethane resin dispersion, 30% solids content	ADEKA BONTIGHTER HUX-386	Adeka Corporation, Tokyo, Japan
Phenolic resin, 70% solids content	SHONOR BRL-120Z	Aica Kogyo Co., Ltd., Nagoya, Japan
Oxazoline-containing polymer solution, 25% solids content	EPOCROS WS-700	Nippon Shokubai Co., Ltd., Osaka, Japan
Urethane acrylic resin	HYBRIDUR 870 POLYMER DISPERSION	Evonik Industries AG Deutschland
Silane coupling agent	LS-3150	Shin-Etsu Chemical Co., Ltd. Japan
Abrasive grain 1, aluminum oxide	MORUNDUM IV-10	Showa Denko K.K., Tokyo, Japan
Abrasive grain 2, silicon carbide	DENSIC C #320J	Showa Denko K.K. Japan
Abrasive grain 3	Formed abrasive particles that were prepared according to the disclosure of U.S. Pat. No. 8,142,531 (Adefris et al.). The formed abrasive particles were prepared by molding alumina sol gel in equilateral triangle-shaped polypropylene mold cavities. The draft angle between the sidewall and bottom of the mold was 98 degrees. After drying and firing, the resulting formed abrasive particles were about 0.10 millimeter (side length) × 0.025 millimeter (thickness). The formed abrasive particles made as described above are used, for example, in 3M Cubitron II Hookit Clean Sanding abrasive disc 737U, grade 320+, available from 3M Company (St. Paul, Minnesota, USA).	

Nonwoven abrasive disc preparation:

EXAMPLES 1-5 AND COMPARATIVE EXAMPLES A, B

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 2, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was roll-coated with prebond precursor composition and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were coated with abrasive mix solution by a spray and cured in an oven at 150°C for 5 minutes.

TABLE 2

MATERIALS	EXAMPLE					COMPARATIVE EXAMPLE A
	1	2	3	4	5	
PREBOND PRECURSOR COMPOSITION						
Polyurethane resin HUX-386, wt. %	98.8	96.4	94.1	91.9	88.9	100.0
Oxazoline polymer WS-700, wt. %	1.2	3.6	5.9	8.1	11.1	0
Total, wt. %	100.0	100.0	100.0	100.0	100.0	100.0
ABRASIVE LAYER PRECURSOR SLURRY						
Phenol resin BRL-120Z, wt. %	33.4	33.4	33.4	33.4	33.4	33.4
Abrasive grain 1, aluminum oxide, wt. %	62.5	62.5	62.5	62.5	62.5	62.5
water, wt. %	4.1	4.1	4.1	4.1	4.1	4.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

EXAMPLES 6-10 AND COMPARATIVE EXAMPLE B

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 3, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was spray-coated with prebond precursor composition (phenolic resin along with a coloring agent) and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were spray-coated with abrasive slurry using the composition listed in TABLE 3 at an add-on weight 4.2-4.5 g/100 cm^2. The coated nonwoven fiber mat was cured in an oven at 150°C for 5 minutes.

TABLE 3

MATERIALS	EXAMPLE					COMPARATIVE EXAMPLE B
	6	7	8	9	10	
Web weight, polyamide fiber only (grams/square meter, gsm)	145	144	142	145	143	146
Pre-bond coating add-on weight, (gsm)	79	75	72	77	76	80
Web weight after pre-bond, (gsm)	224	219	214	222	219	226
Web thickness after pre-bond, cm	0.89	0.88	0.86	0.89	0.87	0.91
Density, g/cm3	0.025	0.025	0.025	0.025	0.025	0.025
Amount of Oxazoline (PHR)	3	5	7	10	1	none
Abrasive grain 1, aluminum oxide, wt. %	60.0	59.7	57.3	57.6	60.4	62.6
Phenol resin, wt. %	32.1	31.9	30.6	30.7	32.2	33.4
Oxazoline polymer WS-700, wt. %	2.7	4.4	6.0	8.6	0.9	None
Water	5.2	4.0	6.1	3.1	6.5	4.0
Total (wt%)	100.0	100.0	100.0	100.0	100.0	100.0

EXAMPLES 11-13 AND COMPARATIVE EXAMPLES C, D

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 4, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was spray-coated with prebond precursor composition (phenolic resin along with a coloring agent) and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were spray-coated with abrasive slurry using the composition listed in TABLE 4 at an add-on weight 3.4-4.4 g/100 cm^2. For COMPARATIVE EXAMPLE C where the silane coupling agent was used, abrasive grain 1 aluminum oxide were mixed with the silane coupling aqueous solution and treated at 90 degrees C. (194 degrees F.) for 18 hours, then mix the silane-coupled aluminum oxide abrasive grains with the phenolic resin. The coated nonwoven fiber mat was cured in an oven at 150°C for 5 minutes.

TABLE 4

MATERIALS	EXAMPLE			COMPARATIVE EXAMPLE	
	11	12	13	C	D
Web weight, polyamide fiber only (gsm)	142	145	143	145	144
Pre-bond coating add-on weight, (gsm)	74	77	76	77	79
Web weight after pre-bond, (gsm)	216	222	219	221	224
Web thickness after pre-bond, cm	0.86	0.89	0.88	0.88	0.90
Density, g/cm3	0.025	0.025	0.025	0.025	0.025
Amount of Oxazoline (PHR)	3	5	7	none	none
Abrasive grain 1, aluminum oxide, wt. %	60.0	59.7	59.4	50.8	51.2
Phenol resin, wt. %	32.0	31.9	31.7	27.2	27.3
Oxazoline polymer WS-700, wt. %	2.7	4.4	6.2	none	none
Silane coupling agent, wt. %	none	none	none	0.5	none
Water	5.3	4.0	2.7	21.5	21.5
Total (wt%)	100.0	100.0	100.0	100.0	100.0

EXAMPLES 14-18 AND COMPARATIVE EXAMPLE E

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 5, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was spray-coated with prebond precursor composition (phenolic resin along with a coloring agent) and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were spray-coated with abrasive slurry using the composition listed in TABLE 5 at an add-on weight 3.8-4.2 g/100 cm^2. The coated nonwoven fiber mat was cured in an oven at 150°C for 5 minutes.

TABLE 5

MATERIALS	EXAMPLE					COMPARATIVE EXAMPLE E
	14	15	16	17	18	
Web weight, polyamide fiber only, (gsm)	145	144	143	143	145	142
Pre-bond coating add-on weight, (gsm)	74	77	71	74	71	77
Web weight after pre-bond, (gsm)	219	221	214	214	222	216
Web thickness after pre-bond, cm	0.88	0.88	0.87	0.86	0.89	0.86
Density, g/cm3	0.025	0.025	0.025	0.025	0.025	0.025
Amount of Oxazoline (PHR)	5	7	10	1	3	none
Abrasive grain 2, silicon carbide, wt. %	59.7	57.3	57.6	60.4	60.0	62.6
Phenol resin, wt. %	31.9	30.6	30.7	32.2	32.1	33.4
Oxazoline polymer WS-700, wt. %	4.5	6.0	8.6	0.9	2.7	None
Water	3.9	6.1	3.1	6.5	5.2	4.0
Total (wt%)	100.0	100.0	100.0	100.0	100.0	100.0

EXAMPLES 19-22 AND COMPARATIVE EXAMPLE F

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 6, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was spray-coated with prebond precursor composition (phenolic resin along with a coloring agent) and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were spray-coated with abrasive slurry using the composition listed in TABLE 6 at an add-on weight 4.1-4.4 g/100 cm^2. The coated nonwoven fiber mat was cured in an oven at 150°C for 5 minutes.

TABLE 6

MATERIALS	EXAMPLE				COMPARATIVE EXAMPLE F
	19	20	21	22	
Web weight, polyamide fiber only, (gsm)	145	146	147	143	145
Pre-bond coating add-on weight, (gsm)	74	75	79	76	77
Web weight after pre-bond, (gsm)	219	221	226	219	222
Web thickness after pre-bond, cm	0.88	0.89	0.92	0.87	0.90
Density, g/cm3	0.025	0.025	0.025	0.025	0.025
Amount of Oxazoline (PHR)	5	7	3	10	none
Abrasive grain 3, wt. %	60.0	59.7	57.3	60.4	62.6
Phenol resin, wt. %	32.1	31.9	30.6	32.2	33.4
Oxazoline polymer WS-700, wt. %	2.7	4.4	6.0	0.9	None
Water	5.2	4.0	6.1	6.5	4.0
Total (wt%)	100.0	100.0	100.0	100.0	100.0

EXAMPLES 23-27 AND COMPARATIVE EXAMPLE G

Nonwoven abrasive discs were prepared according to the following procedure using amounts reported in TABLE 7, below. A lofty open nonwoven fiber mat (polyamide fibers, 17 dtex, basis weight = 1.4-1.6 g/100 cm^2) was spray-coated with prebond precursor composition (phenolic resin along with a coloring agent) and then the coated nonwoven fiber mat was cured in an oven at 90°C for 30 minutes. The prebond treated nonwoven fiber mats were spray-coated with abrasive slurry using the composition listed in TABLE 7 at an add-on weight 4.2-4.4 g/100 cm^2. The coated nonwoven fiber mat was cured in an oven at 150°C for 5 minutes.

TABLE 7

	EXAMPLE					COMPARATIVE EXAMPLE G
	23	24	25	26	27	
Web weight, polyamide fiber only, (gsm)	144	144	142	145	146	143
Pre-bond coating add-on weight, (gsm)	74	77	72	74	78	73
Web weight after pre-bond, (gsm)	218	221	214	219	224	216
Web thickness after pre-bond, cm	0.87	0.88	0.86	0.88	0.90	0.86
Density, g/cm3	0.025	0.025	0.025	0.025	0.025	0.025
Amount of Oxazoline (PHR)	3	1	5	7	10	none
Abrasive grain Aluminum oxide	50.4	51.2	49.7	48.9	47.9	51.6
Urethane acrylic resin	47.3	48.0	46.6	45.9	44.9	48.4
Oxazoline polymer	2.3	0.8	3.7	5.2	7.2	None
Total (wt%)	100.0	100.0	100.0	100.0	100.0	100.0

SCHIEFER ABRASION TEST

The resultant nonwoven abrasive mat was cut into a size of 10 cm, thickness: 0.87-1.06 cm, and the Schiefer Abrasion test was performed with a polymethyl methacrylate plate (10.16 cm diameter, 0.3 cm thickness). Nonwoven abrasive article test specimens were prepared as 10-cm diameter discs that are stacked and then secured to a foam back-up pad by means of a hook-and-loop fastener. The back-up pad/fastener assembly had a Shore Durometer OO hardness of 85. The abrasive disc and back-up pad assembly was installed on a Schiefer Uniform Abrasion Tester (available from Frazier Precision Instrument Company, Inc. Hagerstown, Maryland), and the abrasive disc was used to abrade a disc (10.16 cm diameter, 0.3 cm thickness) of polymethyl methacrylate (PMMA) from Mitsubishi Chemical Corporation, Tokyo, Japan. The load was 10 lb

(4.5 kg). The test duration was 6000 cycles of the abrasive disc. The amount of PMMA polymer removed was measured at the end of test.

TABLES 8-13, below, report the Schiefer Abrasion Test results.

TABLE 8

		EXAMPLE					COMPARATIVE EXAMPLE A
		1	2	3	4	5	
Amount of Oxazoline, PHR		1	3	5	7	10	none
Accumulated Cut of acrylic disc, g	2000 cycles	1.9351	2.2943	2.1245	2.1834	2.0756	2.0515
	4000 cycles	2.3892	2.2858	2.1237	2.1551	2.0554	2.0691
	6000 cycles	2.2897	2.2313	2.1073	2.1385	2.0071	2.0031
Accumulated total Cut of acrylic disc, g		6.614	6.8114	6.3555	6.477	6.1381	6.1237
Accumulated Wear of nonwoven abrasive, g		55.2	43.9	50.3	55.5	80.8	73.4
Roughness Ra (µm)		0.447	0.451	0.442	0.440	0.442	0.447

TABLE 9

		EXAMPLE					COMPARATIVE EXAMPLE B
		6	7	8	9	10	
Amount of Oxazoline (PHR)		3	5	7	10	1	none
Accumulated Cut of acrylic disc (g)	2000 cycles	2.6597	2.6600	2.3917	2.6397	2.6696	2.8772
	4000 cycles	2.3587	2.3668	2.2651	2.3146	2.3055	2.4612
	6000 cycles	2.1544	2.1688	2.1045	2.1052	2.1063	2.2195
Accumulated total Cut of acrylic disc (g)		7.1728	7.1956	6.7613	7.0595	7.0814	7.5579
Accumulated Wear of nonwoven abrasive (milligram, mg)		15.2	13.3	11.8	12.3	25.3	23.6
Roughness: Ra (µm)		0.550	0.548	0.551	0.554	0.554	0.549

TABLE 10

		EXAMPLE			COMPARATIVE EXAMPLE	
		11	12	13	C	D
Amount of Oxazoline (PHR)		3	5	7	none	none
Accumulated Cut of acrylic disc (g)	2000 cycles	2.7055	2.7565	2.6148	2.5809	2.2412
	4000 cycles	2.4220	2.3122	2.3872	2.3650	2.0493
	6000 cycles	2.2269	2.1318	2.1790	2.2278	1.9040
Accumulated total Cut of acrylic disc (g)		7.3544	7.2005	7.1810	7.1737	6.1945
Accumulated Wear of nonwoven abrasive (mg)		9.0	7.5	9.2	12.8	25.0
Roughness: Ra (μm)		0.587	0.586	0.587	0.584	0.582

TABLE 11

		EXAMPLE					COMPARATIVE EXAMPLE E
		14	15	16	17	18	
Amount of Oxazoline (PHR)		5	7	10	1	3	none
Accumulated Cut of acrylic disc (g)	2000 cycles	1.7251	1.6051	1.1334	1.6061	1.6623	1.6007
	4000 cycles	0.9890	1.0098	1.4216	0.9909	1.0763	0.9617
	6000 cycles	0.6586	0.6860	0.9393	0.6409	0.6962	0.6153
Accumulated total Cut of acrylic disc (g)		3.3727	3.3009	3.4943	3.2379	3.4348	3.1777
Accumulated Wear of nonwoven abrasive (mg)		49.8	44.2	48.1	101.2	87.2	107.3
Roughness: Ra (μm)		0.549	0.552	0.555	0.549	0.550	0.551

TABLE 12

		EXAMPLE				COMPARATIVE EXAMPLE F
		19	20	21	22	
Amount of Oxazoline (PHR)		5	7	3	10	none
Accumulated Cut of acrylic disc (g)	2000 cycles	0.9685	0.8715	0.8617	0.7036	1.3776
	4000 cycles	1.4562	1.4156	1.4488	1.7265	1.2008
	6000 cycles	1.6426	1.6084	1.6932	1.8255	1.3763
Accumulated total Cut of acrylic disc (g)		4.0673	3.8955	4.0037	4.2556	3.9547
Accumulated Wear of nonwoven abrasive (mg)		8.0	7.5	11.2	10.1	11.0
Roughness: Ra (μm)		3.389	3.385	3.387	3.388	3.3959

TABLE 13

		EXAMPLE					COMPARA-TIVE EXAMPLE G
		23	24	25	26	27	
Amount of Oxazoline (PHR)		3	1	5	7	10	none
Accumulated Cut of acrylic disc (g)	2000 cycles	1.2213	1.1279	1.3054	1.3081	1.2820	1.0054
	4000 cycles	0.9696	0.8564	0.8451	0.9664	0.9355	0.9418
	6000 cycles	0.8183	0.8196	0.6580	0.7816	0.7588	0.8778
Accumulated total Cut of acrylic disc (g)		3.0092	2.8039	2.8085	3.0561	2.9763	2.8250
Accumulated Wear of nonwoven abrasive (mg)		25.1	32.3	51.9	72.5	81.4	35.7
Roughness: Ra (μm)		0.215	0.215	0.218	0.219	0.218	0.2146

All cited references, patents, and patent applications in this application are incorporated by reference in a consistent manner. In the event of inconsistencies or contradictions between portions of the incorporated references and this application, the information in this application shall control.

The preceding description, given in order to enable one of ordinary skill in the art to practice the claimed disclosure, is not to be construed as limiting the scope of the disclosure, which is defined by the claims and all equivalents thereto.

What is claimed is:

1. A nonwoven abrasive article comprising:

a lofty open nonwoven fiber web;

a prebond composition disposed on at least a portion of the lofty open nonwoven fiber web, an abrasive layer disposed on and secured to at least a portion of the prebond composition, wherein the abrasive layer comprises a binder composition retaining abrasive particles,

wherein at least one of the prebond composition and the binder composition comprises a reaction product of a polymer having a plurality of oxazolinyl groups.

2. The nonwoven abrasive article of claim 1, wherein the polymer having a plurality of oxazolinyl groups comprises an acrylic polymer.

3. The nonwoven abrasive article of claim 1 or claim 2, wherein the polymer having a plurality of oxazolinyl groups comprises a methacrylic polymer.

4. The nonwoven abrasive article of any one of claims 1-3, wherein the polymer having a plurality of oxazolinyl groups is at least 1 part per hundred parts of resin (PHR).

5. The nonwoven abrasive article of any one of claims 1-4, wherein the polymer having a plurality of oxazolinyl groups is at least 3 parts per hundred parts of resin (PHR).

6. The nonwoven abrasive article of any one of claims 1-5, wherein the prebond composition comprises a reaction product of a polyurethane having a plurality of carboxyl groups, wherein, on a solids basis, the (meth)acrylic polymer and the polyurethane are present in a weight ratio of from 1:99 to 8:92.

7. The nonwoven abrasive article of claim 6, wherein, on a solids basis, the (meth)acrylic polymer having a plurality of oxazolinyl groups and the polyurethane having a plurality of carboxyl groups are present in a weight ratio of from 1:99 to 7:93.

8. The nonwoven abrasive article of any one of claims 1-7, wherein the binder composition comprises phenolic.

9. The nonwoven abrasive article of any one of claims 1-8, wherein the nonwoven abrasive article comprises a nonwoven abrasive disc.

10. The nonwoven abrasive article of any one of claims 1-9, wherein the lofty open nonwoven fiber web comprises polyamide.

11. A method of making a nonwoven abrasive article, the method comprising:

disposing a curable prebond precursor composition on at least a portion of a lofty open nonwoven fiber web,

at least partially curing the curable prebond precursor composition to provide a prebond composition;

disposing an abrasive layer precursor composition onto at least a portion of the prebond composition, wherein the abrasive layer precursor composition comprises phenolic resin and abrasive particles;

wherein at least one of the curable prebond precursor composition and the abrasive layer precursor composition comprises a polymer having a plurality of oxazolinyl groups; and

at least partially curing the abrasive layer precursor composition.

12. A method of making a nonwoven abrasive article, the method comprising:

disposing a curable prebond precursor composition on at least a portion of a lofty open nonwoven fiber web,

at least partially curing the curable prebond precursor composition to provide a prebond composition;

disposing a curable make layer precursor composition onto at least a portion of the prebond composition, wherein the curable make layer precursor composition comprises phenolic resin;

wherein at least one of the curable prebond precursor composition and the curable make layer precursor composition comprises a polymer having a plurality of oxazolinyl groups;

at least partially embedding abrasive particles into the curable make layer precursor composition; and

at least partially curing the curable make layer precursor composition to provide an at least partially cured make layer composition.

13. The method of claim 11 or 12, wherein the polymer having a plurality of oxazolinyl groups comprises an acrylic polymer.

14. The method of any one of claims 11-13, wherein the polymer having a plurality of oxazolinyl groups is at least 1 part per hundred parts of resin (PHR).

15. The method of any one of claims 11-14, wherein the curable prebond precursor composition comprises a polyurethane having a plurality of carboxyl groups, wherein, on a solids basis, the

polymer having a plurality of oxazolinyl groups and the polyurethane are present in a weight ratio of from 1:99 to 8:92.

16. The method of claim 15, wherein, on a solids basis, the polymer having a plurality of oxazolinyl groups and the polyurethane are present in a weight ratio of from 1:99 to 7:93.

17. The method of any one of claims 11-16, further comprising:

disposing a curable size layer precursor composition on the at least partially cured make layer composition; and

at least partially curing the curable size layer precursor composition.

18. The method of any one of claims 11-17, wherein the nonwoven abrasive article comprises a nonwoven abrasive disc.

19. The method of any one of claims 11-18, wherein the lofty open nonwoven fiber web comprises polyamide.

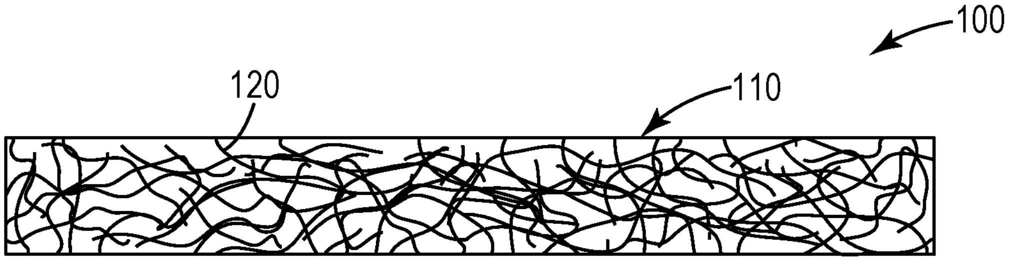

FIG. 1

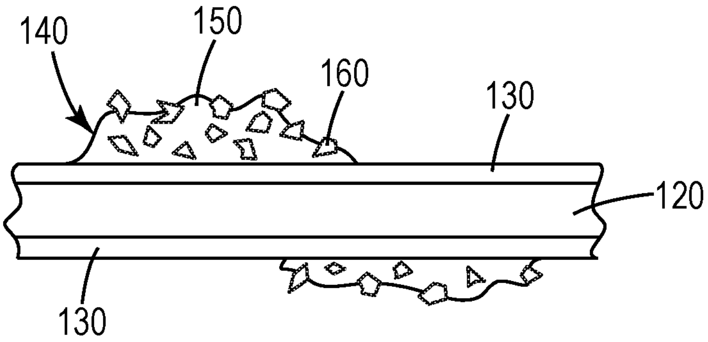

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/051534

A. CLASSIFICATION OF SUBJECT MATTER

INV. B24D3/34

ADD.

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)

B24D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/078138 A1 (MARTINEZ JAIME A [US] ET AL) 18 March 2021 (2021-03-18) paragraphs [0004], [0005], [0012], [0013], [0018], [0030], [0031] -----	1-19
X	US 2010/092746 A1 (COANT JEAN-MARIE [FR] ET AL) 15 April 2010 (2010-04-15) paragraphs [0005], [0006], [0030], [0033], [0034]; figures 1,2 -----	1-19
X	US 2006/178090 A1 (HIBBARD LOU D [US]) 10 August 2006 (2006-08-10) paragraphs [0025] - [0029]; figures 1-2 -----	1,11,12

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

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search 24 April 2023	Date of mailing of the international search report 03/05/2023
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Bonetti, Serena

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2023/051534

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2021078138 A1	18-03-2021	CN 110869167 A	06-03-2020
		EP 3651934 A1	20-05-2020
		US 2021078138 A1	18-03-2021
		WO 2019014050 A1	17-01-2019
US 2010092746 A1	15-04-2010	US 2010092746 A1	15-04-2010
		WO 2010045053 A2	22-04-2010
US 2006178090 A1	10-08-2006	BR PI0606799 A2	09-02-2010
		CA 2595993 A1	10-08-2006
		CN 101115429 A	30-01-2008
		EP 1843691 A2	17-10-2007
		JP 4805951 B2	02-11-2011
		JP 2008529589 A	07-08-2008
		JP 2011189189 A	29-09-2011
		KR 20070099665 A	09-10-2007
		TW 200633670 A	01-10-2006
		US 2006178090 A1	10-08-2006
		US 2007204518 A1	06-09-2007
		WO 2006083570 A2	10-08-2006