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(54) **NONWOVEN ABRASIVE ARTICLE CONTAINING ELASTOMER BOUND AGGLOMERATES OF SHAPED ABRASIVE GRAIN**

VLIES-SCHLEIFARTIKEL MIT ELASTOMERGEBUNDENEN AGGLOMERATEN AUS GEFORMTEN SCHLEIFKÖRNERN

ARTICLE ABRASIF NON TISSÉ CONTENANT DES AGGLOMÉRATS LIÉS À UN ÉLASTOMÈRE DE GRAIN ABRASIF FAÇONNÉ

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**Description****BACKGROUND**

5 [0001] Nonwoven abrasive articles generally have a nonwoven web (e.g., a lofty open fibrous web), abrasive particles, and a binder material (commonly termed a "binder") that bonds the fibers within the nonwoven web to each other and secures the abrasive particles to the nonwoven web. Examples of nonwoven abrasive articles include nonwoven abrasive hand pads such as those marketed by 3M Company of Saint Paul, Minnesota under the trade designation "SCOTCH-BRITE".

10 [0002] Other examples of nonwoven abrasive articles include convolute abrasive wheels and unitized abrasive wheels. Nonwoven abrasive wheels typically have abrasive particles distributed through the layers of nonwoven web bonded together with a binder that bonds layers of nonwoven webs together, and likewise bonds the abrasive particles to the nonwoven web. Unitized abrasive wheels have individual discs of nonwoven web arranged in a parallel fashion to form a cylinder having a hollow axial core. Alternatively, convolute abrasive wheels have a nonwoven web that is spirally wound about and affixed to a core member.

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**SUMMARY**

20 [0003] The cut and resulting finish of nonwoven abrasive articles while using them on a work piece are important performance attributes. For some applications, reducing the resulting surface roughness (finish) on the work piece while maintaining or even increasing the cut of the nonwoven abrasive article in use is very desirable. It was surprisingly found that nonwoven abrasive articles according to the present invention exhibit significant improvements in the surface finish, as evaluated according to the test methods disclosed, when compared to alternative nonwoven abrasive articles as shown in the Examples.

25 [0004] In particular, using a flexible binder such as a polyurethane binder when making agglomerates of formed ceramic abrasive particles, it was found that the resulting surface finish of the work piece was significantly improved. This finding was quite surprising since it was previously thought that the binder to make the agglomerates was not a significant contributor to the resulting finish of the nonwoven abrasive article. Previously, the resulting surface finish was attributed to the type of binder class (urethane versus phenolic) holding the nonwoven layers together in the abrasive wheel when using identical abrasive particle sizes and amounts in each wheel. Additionally, it was surprisingly found that the flexible bound agglomerates of formed abrasive particles produced a finer finish than nonwoven abrasive articles made using the identical formed abrasive particles that were not agglomerated. Previously, it was thought that agglomerating the formed abrasive particles would only increase the life of the abrasive article, and the resulting finish would be identical to non-agglomerated abrasive particles having the identical size.

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35 [0005] Hence, in one aspect, the invention resides in a nonwoven abrasive article comprising a nonwoven web; agglomerates comprising formed ceramic abrasive particles bound together by a first flexible binder; and a second binder binding the agglomerates to the nonwoven fiber web.

**BRIEF DESCRIPTION OF THE DRAWINGS**

40 [0006] Repeated use of reference characters in the specification and drawings is intended to represent the same or analogous features or elements of the disclosure.

45 FIG. 1 is a perspective view of an exemplary nonwoven abrasive article according to the present invention; FIG. 2 is a perspective schematic view of an exemplary convolute abrasive wheel according to one aspect of the present invention; and

FIG. 3 is a perspective schematic view of an exemplary unitized abrasive wheel according to another aspect of the present invention.

50 FIG. 4 is a photomicrograph of one embodiment of an abrasive agglomerate made from formed abrasive particles. FIG. 5 is a photomicrograph of another embodiment of an abrasive agglomerate made from formed abrasive particles. FIG. 6 is a photomicrograph of another embodiment of an abrasive agglomerate made from formed abrasive particles.

**DEFINITIONS**

55 [0007] As used herein, variations of the words "comprise", "have", and "include" are legally equivalent and open-ended. Therefore, additional non-recited elements, functions, steps or limitations may be present in addition to the recited elements, functions, steps, or limitations.

[0008] As used herein, the term "cure" means hardening a material, either by drying (i.e., evaporation of solvent),

polymerizing (e.g., providing a sufficient degree of chain extension of the curable polyurethane prepolymer), or cooling a molten material.

**[0009]** As used herein, the term "flexible binder" means that the cured binder material has a modulus of elasticity such that the cured binder material is able to bend a significant amount without breaking unlike a phenolic binder which would break. The modulus of elasticity is less than 28,000 psi (193,053 kPa). In various embodiments of the invention, the modulus of elasticity can be less than 25,000 psi (172,369 kPa) or less than 23,000 psi (158,579 kPa) as tested by ASTM D882. Examples of suitable flexible binders include those of polyurethane, polyurea, polyisoprene, polybutadiene, polychloroprene, butyl rubber, styrene-butadiene copolymer, and nitrile rubber.

**[0010]** As used herein "formed ceramic abrasive particle" means an abrasive particle having at least a partially replicated shape. Non-limiting processes to make formed abrasive particles include shaping the precursor ceramic abrasive particle in a mold having a predetermined shape to make shaped ceramic abrasive particles, extruding the precursor ceramic abrasive particle through an orifice having a predetermined shape, printing the precursor ceramic abrasive particle through an opening in a printing screen having a predetermined shape, or embossing the precursor ceramic abrasive particle into a predetermined shape or pattern. Non-limiting examples of formed ceramic abrasive particles include shaped ceramic abrasive particles, such as triangular plates as disclosed in U.S. RE 35,570; 5,201,916, and 5,984,998; in U.S. patent publications 2009/0169816; 2009/0165394; 2010/0151195; 2010/0151201; 2010/0146867; 2010/0151196 and 2010/0319269 or elongated ceramic rods/filaments often having a circular cross section produced by Saint-Gobain Abrasives an example of which is disclosed in U.S. patent number 5,372,620.

**[0011]** As used herein, the term "mineral" means abrasive particles or a mixture of abrasive particles and filler.

## DETAILED DESCRIPTION

**[0012]** Various exemplary abrasive articles according to the present invention, including lofty open nonwoven abrasive articles (e.g., webs and sheets), unitized abrasive wheels, and convolute abrasive wheels, may be manufactured through processes that include steps such as, for example, coating a curable composition, typically in slurry form, on a nonwoven web. The curable composition comprises: a curable polyurethane prepolymer; an effective amount of an amine curative; at least one of a cationic surfactant, anionic surfactant, fluorinated nonionic surfactant, or silicone-based nonionic surfactant; and a dipodal aminosilane. In the formation of convolute or unitized abrasive wheels, the nonwoven web is typically compressed (i.e., densified) relative to nonwoven webs used in lofty open nonwoven fiber articles.

### Nonwoven Webs

**[0013]** Nonwoven webs suitable for use in the aforementioned abrasive articles are well known in the abrasives art. Typically, the nonwoven web comprises an entangled web of fibers. The fibers may comprise continuous fiber, staple fiber, or a combination thereof. For example, the nonwoven 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. If a spunbond nonwoven is used, the filaments may be of substantially larger diameter, for example, up to 2 mm or more in diameter.

**[0014]** The nonwoven web may be manufactured, for example, by conventional air laid, carded, stitch bonded, spun bonded, wet laid, and/or melt blown procedures. Air laid nonwoven webs may be prepared using equipment such as, for example, that available under the trade designation "RANDO WEBBER" commercially available from Rando Machine Company of Macedon, New York.

**[0015]** Nonwoven webs are typically selected to be suitably compatible with adhering binders and abrasive particles while also being processable in combination 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 composition. The fibers may be chosen to affect properties of the abrasive article such as, for example, flexibility, elasticity, durability or longevity, abrasiveness, and finishing properties. Examples of 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), nylon (e.g., hexamethylene adipamide, polycaprolactam), 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, wool, 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.

**[0016]** Prior to impregnation with the curable 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 200 gsm; and/or less than about 400 gsm, less than about 350 gsm, or less than about 300 gsm, as measured prior to any coating (e.g., with the curable composition or optional pre-bond resin), although greater and lesser basis weights may also be used. In addition, prior to impregnation with the curable composition, the fiber web typically has a thickness of at least about 5 mm, at least about 6 mm, or at least about 10 mm; and/or less than about 200 mm, less than about 75 mm, or less than about 30 mm, although greater and lesser thicknesses may also be useful.

**[0017]** Further details concerning nonwoven abrasive articles, abrasive wheels and methods for their manufacture may be found, for example, in U.S. Pat. Nos. 2,958,593 (Hoover et al.); 5,591,239 (Larson et al.); 6,017,831 (Beardsley et al.); and U.S. Pat. Appln. Publ. 2006/0041065 A1 (Barber, Jr.).

**[0018]** Frequently, it is useful to apply a prebond resin to the nonwoven web prior to coating with the curable composition. The prebond resin serves, for example, to help maintain the nonwoven web integrity during handling, and may also facilitate bonding of a urethane binder to the nonwoven 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 prebond resin used in this manner is typically adjusted toward the minimum amount consistent with bonding the fibers together at their points of crossing contact. If the nonwoven web includes thermally bondable fibers, thermal bonding of the nonwoven web may also be helpful to maintain web integrity during processing.

#### Abrasive Particles

**[0019]** Useful abrasive particles for incorporating into the agglomerates of the invention are formed ceramic abrasive particles and, in particular, shaped ceramic abrasive particles. Shaped ceramic abrasive particles were prepared according to the disclosures of copending U.S. Patent Publication 2010/0151196. The shaped ceramic abrasive particles were prepared by shaping alumina sol gel from, for example, equilateral triangle-shaped polypropylene mold cavities of side length 0.054 inch (1.37 mm) and a mold depth of 0.012 inch (0.3 mm). After drying and firing, such resulting shaped ceramic abrasive particles comprised triangular plates that were about 570 micrometers (longest dimension) and would pass through a 30-mesh sieve.

**[0020]** In addition to shaped ceramic abrasive particles, inventive articles may also contain conventional (e.g., crushed) abrasive particles. Examples of useful conventional abrasive particles for blending with the shaped ceramic abrasive particles include any abrasive particles known in the abrasive art. Exemplary useful abrasive particles include fused aluminum oxide based materials such as aluminum oxide, ceramic aluminum oxide (which may include one or more metal oxide modifiers and/or seeding or nucleating agents), and heat-treated aluminum oxide, silicon carbide, co-fused alumina-zirconia, diamond, ceria, titanium diboride, cubic boron nitride, boron carbide, garnet, flint, emery, sol-gel derived abrasive particles, and mixtures thereof. The abrasive particles may be in the form of, for example, individual particles, agglomerates, composite particles, and mixtures thereof.

**[0021]** The conventional 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, less than about 1300 micrometers, or less than about 1000 micrometers, although larger and smaller abrasive particles may also be used. For example, the conventional 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 (i.e., 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, JIS150, JIS180, JIS220, JIS240, JIS280, JIS320, JIS360, JIS400, JIS400, JIS600, JIS800, JIS1000, JIS1500, JIS2500, JIS4000, JIS6000, JIS8000, and JIS10000.

#### Abrasive Particle Agglomerates

**[0022]** The inventive agglomerates comprise a first flexible binder. Examples of suitable flexible binders include those of polyurethane, polyurea, polyisoprene, polybutadiene, polychloroprene, butyl rubber, styrene-butadiene copolymer, and nitrile rubber.

**[0023]** A typical flexible binder for preparation of agglomerates comprising formed ceramic abrasive particles is a polyurethane binder. 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, etc.) 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.

**[0024]** Useful polyisocyanates include, for example, aliphatic polyisocyanates (e.g., hexamethylene diisocyanate or trimethylhexamethylene diisocyanate); alicyclic polyisocyanates (e.g., hydrogenated xylylene diisocyanate or isophorone diisocyanate); aromatic polyisocyanates (e.g., tolylene diisocyanate or 4,4'-diphenylmethane diisocyanate); adducts of any of the foregoing polyisocyanates with a polyhydric alcohol (e.g., a diol, low molecular weight hydroxyl group-containing polyester resin, water, etc.); adducts of the foregoing polyisocyanates (e.g., isocyanurates, biurets); and mixtures thereof.

**[0025]** Useful commercially available polyisocyanates include, for example, those available under the trade designation "ADIPRENE" from Chemtura Corporation, Middlebury, Connecticut (e.g., "ADIPRENE L 0311", "ADIPRENE L 100", "ADIPRENE L 167", "ADIPRENE L 213", "ADIPRENE L 315", "ADIPRENE L 680", "ADIPRENE LF 1800A", "ADIPRENE LF 600D", "ADIPRENE LFP 1950A", "ADIPRENE LFP 2950A", "ADIPRENE LFP 590D", "ADIPRENE LW 520", and "ADIPRENE PP 1095"); polyisocyanates available under the trade designation "MONDUR" from Bayer Corporation, Pittsburgh, Pennsylvania (e.g., "MONDUR 1437", "MONDUR MP-095", or "MONDUR 448"); and polyisocyanates available under the trade designations "AIRTHANE" and "VERSATHANE" from Air Products and Chemicals, Allentown, Pennsylvania (e.g., "AIRTHANE APC-504", "AIRTHANE PST-95A", "AIRTHANE PST-85A", "AIRTHANE PET-91A", "AIRTHANE PET-75D", "VERSATHANE STE-95A", "VERSATHANE STE-P95", "VERSATHANE STS-55", "VERSATHANE SME-90A", and "VERSATHANE MS-90A").

**[0026]** To lengthen pot-life, polyisocyanates such as, for example, those mentioned above may be blocked with a blocking agent according to various techniques known in the art. Exemplary blocking agents include ketoximes (e.g., 2-butanone oxime); lactams (e.g., epsilon-caprolactam); malonic esters (e.g., dimethyl malonate and diethyl malonate); pyrazoles (e.g., 3,5-dimethylpyrazole); alcohols including tertiary alcohols (e.g., t-butanol or 2,2-dimethylpentanol), phenols (e.g., alkylated phenols), and mixtures of alcohols as described.

**[0027]** Exemplary useful commercially-available blocked polyisocyanates include those marketed by Chemtura Corporation under the trade designations "ADIPRENE BL 11", "ADIPRENE BL 16", "ADIPRENE BL 31", and blocked polyisocyanates marketed by Baxenden Chemicals, Ltd., Accrington, England under the trade designation "TRIXENE" (e.g., "TRIXENE BL 7641", "TRIXENE BL 7642", "TRIXENE BL 7772", and "TRIXENE BL 7774").

**[0028]** Typically, the amount of urethane prepolymer present in the curable composition is in an amount of from 10 to 40 percent by weight, more typically in an amount of from 15 to 30 percent by weight, and even more typically in an amount of from 20 to 25 percent by weight based on the total weight of the curable composition, although amounts outside of these ranges may also be used.

**[0029]** Suitable amine curatives include aromatic, alkyl-aromatic, or alkyl polyfunctional amines, preferably primary amines. Examples of useful amine curatives include 4,4'-methyleneedianiline; polymeric methylene dianilines having a functionality of 2.1 to 4.0 which include those known under the trade designations "CURITHANE 103", commercially available from the Dow Chemical Company, and "MDA-85" from Bayer Corporation, Pittsburgh, Pennsylvania; 1,5-diamine-2-methylpentane; tris(2-aminoethyl) amine; 3-aminomethyl-3,5,5-trimethylcyclohexylamine (i.e., isophoronediamine), trimethylene glycol di-p-aminobenzoate, bis(o-aminophenylthio)ethane, 4,4'-methylenebis(dimethyl antranilate), bis(4-amino-3-ethylphenyl)methane (e.g., as marketed under the trade designation "KAYAHARD AA" by Nippon Kayaku Company, Ltd., Tokyo, Japan), and bis(4-amino-3,5-diethylphenyl)methane (e.g., as marketed under the trade designation "LONZACURE M-DEA" by Lonza, Ltd., Basel, Switzerland), and mixtures thereof. If desired, polyol(s) may be added to the curable composition, for example, to modify (e.g., to retard) cure rates as required by the intended use.

**[0030]** The amine curative should be present in an amount effective (i.e., an effective amount) to cure the blocked polyisocyanate to the degree required by the intended application; for example, the amine curative may be present in a stoichiometric ratio of curative to isocyanate (or blocked isocyanate) in a range of from 0.8 to 1.35; for example, in a range of from 0.85 to 1.20, or in a range of from 0.90 to 0.95, although stoichiometric ratios outside these ranges may also be used.

**[0031]** Typically, the curable composition will include at least one organic solvent (e.g., isopropyl alcohol or methyl ethyl ketone) to facilitate coating of the curable composition on the nonwoven fiber web, although this is not a requirement. Optionally, the curable composition may be mixed with and/or include one or more additives. Exemplary additives include fillers, plasticizers, surfactants, lubricants, colorants (e.g., pigments), bactericides, fungicides, grinding aids, and antistatic agents. Typically, the curable composition (including any 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.

**[0032]** Filler materials other than conventional abrasive particles may be blended with shaped ceramic abrasive particles in the inventive agglomerates. Examples of useful fillers for this invention include metal carbonates (such as calcium carbonate, calcium magnesium carbonate, sodium carbonate, magnesium carbonate), silica (such as quartz, glass beads, glass bubbles and glass fibers), silicates (such as talc, clays, montmorillonite, feldspar, mica, calcium silicate,

calcium metasilicate, sodium aluminosilicate, sodium silicate), metal sulfates (such as calcium sulfate, barium sulfate, sodium sulfate, aluminum sodium sulfate, aluminum sulfate), gypsum, vermiculite, sugar, wood flour, aluminum trihydrate, carbon black, metal oxides (such as calcium oxide, aluminum oxide, tin oxide, titanium dioxide), metal sulfites (such as calcium sulfite), thermoplastic particles (such as polycarbonate, polyetherimide, polyester, polyethylene, poly(vinylchloride), polysulfone, polystyrene, acrylonitrile-butadiene-styrene block copolymer, polypropylene, acetal polymers, polyurethanes, nylon particles) and thermosetting particles (such as phenolic bubbles, phenolic beads, polyurethane foam particles and the like). The filler may also be a salt such as a halide salt. Examples of halide salts include sodium chloride, potassium cryolite, sodium cryolite, ammonium cryolite, potassium tetrafluoroborate, sodium tetrafluoroborate, silicon fluorides, potassium chloride, magnesium chloride. Examples of metal fillers include, tin, lead, bismuth, cobalt, antimony, cadmium, iron and titanium. Other miscellaneous fillers include sulfur, organic sulfur compounds, graphite, lithium stearate and metallic sulfides.

**[0033]** For best results, the size of the agglomerates have a maximum diameter (if generally spherical) or a maximum side edge length (if generally cylindrical, ovoid, or other geometric shape) ranging from 0.8 mm to 5 mm, or 1.4 mm to 4 mm, or 1.8 to 3 mm and may be spherical, ovoid, cylindrical, pyramidal, conical or any multi-sided Platonic solid (tetrahedron, octahedron, etc.). For best results, the ratio of the formed abrasive particle size (measuring the edge length of the formed abrasive particles) divided by the agglomerate size (measuring the maximum diameter or maximum side edge length of the agglomerate) is 0.0033 to 0.5 (approximately 300 to 2 formed abrasive particles across the agglomerate), or 0.01 to 0.33 (approximately 100 to 3 formed abrasive particles across the agglomerate), or 0.05 to 0.25 (approximately 20 to 4 formed abrasive particles across the agglomerate). For best results if filler particles (conventional crushed abrasive particles or diluents) are used they have an average particle size less than that of the formed ceramic abrasive particles, or the ratio of the filler particle size (maximum diameter) divided by the formed abrasive particles size (measuring the maximum diameter or maximum side edge length of the agglomerate) is 0.001 to 1.0, or 0.003 to 0.5, or 0.01 to 0.1. Typical inventive agglomerates can comprise no more than 30 weight percent (wt. %) first flexible binder, no more than 20 wt. % first flexible binder, no more than 15 wt. % first flexible binder, or even no more than 10 wt. % first flexible binder. Typical inventive agglomerates comprise at least 50 wt. % formed ceramic abrasive particles. For best results, the formed ceramic abrasive particle content is 50 wt. % to 98 wt. %, 75 wt. % to 96 wt. %, or 80 wt. % to 94 wt. %; the resin content is 2 wt. % to 20 wt. %, 4 wt. % to 10 wt. %, or 5 wt. % to 8 wt. %; and the filler particle content is 0 wt. % to 40 wt. %, 10 wt. % to 35 wt. %, or 15 wt. % to 30 wt. %. It is understood the above ranges for the various properties can be combined or selected in any manner to specify the agglomerate's attributes.

### Nonwoven Abrasive Web

**[0034]** The nonwoven abrasive web is prepared by adhering the agglomerates of the invention to a nonwoven web with a curable second binder. Typically, the coating weight for the abrasive agglomerates (independent of other ingredients in the curable composition) may depend, for example, on the particular second binder used, the process for applying the abrasive agglomerates, and the size of the abrasive agglomerates. For example, the coating weight of the abrasive agglomerates on the nonwoven web (before any compression) 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 be also be used.

**[0035]** Second binders useful for adhering the agglomerates to the nonwoven fiber web are known in the art and are selected according to the final product requirements. Typical binders include those comprising polyurethane, phenolic, acrylate, and blends of phenolic and acrylate. Useful polyurethane binder materials and their precursors for adhering agglomerates to nonwoven web have been described herein above.

**[0036]** Phenolic materials are useful binder precursors because of their thermal properties, availability, cost, and ease of handling. Resole phenolics have a molar ratio of formaldehyde to phenol of greater than or equal to one, typically between 1.5:1.0 to 3.0:1.0. Novolac phenolics have a molar ratio of formaldehyde to phenol of less than 1.0:1.0. Examples of commercially available phenolics include those known by the trade names DUREZ and VARCUM from Occidental Chemicals Corp.; RESINOX from Monsanto; AROFENE from Ashland Chemical Co. and AROTAP from Ashland Chemical Co.

**[0037]** Emulsions of crosslinked acrylic resin particles may also find utility in the present invention.

**[0038]** Some binder precursors include a phenolic mixed with a latex. Examples of such latexes include materials containing acrylonitrile butadiene, acrylics, butadiene, butadiene-styrene, and combinations thereof. These latexes are commercially available from a variety of different sources and include those available under the trade designations RHOPLEX and ACRYLSOL commercially available from Rohm and Haas Company, FLEXCRYL and VALTAC commercially available from Air Products & Chemicals Inc., SYNTHEMUL, TYCRYL, and TYLAC commercially available from Reichold Chemical Co., HYCAR and GOODRITE commercially available from B. F. Goodrich, CHEMIGUM commercially available from Goodyear Tire and Rubber Co., NEOCRYL commercially available from ICI, BUTAFON commercially available from BASF, and RES commercially available from Union Carbide.

Nonwoven Abrasive Articles

**[0039]** Nonwoven abrasive articles of the invention may take any of a variety of conventional forms. FIG. 1 shows a nonwoven abrasive article 100 comprising a nonwoven web; agglomerates comprising formed ceramic abrasive particles bound together by a first flexible binder; and a second binder binding the agglomerates to the nonwoven fiber web. FIGS. 4-6 show abrasive agglomerates comprising shaped ceramic abrasive particles and a first flexible binder. The shaped ceramic abrasive particles comprises triangular plates as seen.

**[0040]** Preferred nonwoven abrasive articles are in the form of wheels. Nonwoven abrasive wheels are typically in the form of a disc or right cylinder having dimensions that may be very small, e.g., a cylinder height on the order of a few millimeters or very large, e.g., a meter or more, and a diameter which may be very small, e.g., on the order of a few centimeters, or very large, e.g., tens of centimeters. Wheels typically have a central opening for support by an appropriate arbor or other mechanical holding means to enable the wheels to be rotated in use. Wheel dimensions, configurations, means of support, and means of rotation are all well known in the art.

**[0041]** Convolute abrasive wheels may be provided, for example, by winding the nonwoven web that has been impregnated with the curable composition under tension around a core member (e.g., a tubular or rod-shaped core member) such that the impregnated nonwoven layers become compressed, and then curing the curable composition to provide, in one embodiment, a polyurethane binder binding the abrasive agglomerates to the layered nonwoven web and binding layers of the layered nonwoven web to each other. An exemplary convolute abrasive wheel 200 is shown in FIG. 2, wherein layered nonwoven fiber web 210, coated with binder binding the abrasive agglomerates to the layered nonwoven fiber web and binding layers of the layered nonwoven fiber web to each other is spirally disposed around and affixed to core member 230. If desired, convolute abrasive wheels may be dressed prior to use to remove surface irregularities, for example, using methods known in the abrasive arts.

**[0042]** An exemplary unitized abrasive wheel is shown in FIG. 3, and can be provided, for example, by layering the impregnated above-provided nonwoven web 310 (e.g., as a layered continuous web or as a stack of sheets) compressing the nonwoven layers, curing the curable composition (e.g., using heat), and die cutting the resultant abrasive article to provide a unitized abrasive wheel having a hollow axial core 320. In compressing the layers of impregnated nonwoven web, the layers are typically compressed to form a bun having a density that is from 1 to 20 times that of the density of the layers in their non-compressed state. The bun is then typically subjected to heat molding (e.g., for from 2 to 20 hours) at elevated temperature (e.g., at 135 °C), typically depending on the urethane prepolymer and bun size.

**EXAMPLES**

**[0043]** Objects and advantages of this disclosure are further illustrated by the following non-limiting examples. 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. Unless otherwise noted, all parts, percentages, ratios, etc. in the Examples and the rest of the specification are by weight.

**[0044]** The following abbreviations are used throughout the Examples.

BL16	urethane prepolymer available under the trade designation "ADIPRENE BL16" from Chemtura Corporation, Middlebury, Connecticut
K-450	4,4'-methylenebis(2-ethylalanine) available from Atul Limited, Mumbai, India under the trade name "LAPOX K-450"
K-450S	42 weight percent solution of 4,4'-methylenebis(2-ethylalanine) in PMA
PMA	propylene glycol methyl ether acetate available under the trade designation "DOWANOL PMA" from the DOW Chemical Company, Midland, Michigan
MP-22VF	Micronized synthetic wax available from Micro Powders, Inc., Tarrytown, New York
Phenoxy	25 weight percent solution of phenoxy resin in PMA available under the trade designation "INCHEMREZ PKHS 25M Solution of Phenoxy Resin" from InChem, Naperville, Illinois
Kaolin	Anhydrous aluminum silicate available under the trade designation "KAMIN 70C" from Kamin Corporation, Macon, Georgia
D-1122	bis(triethoxysilylpropyl)amine available under the trade designation "DYNASYLAN 1122" from Evonik Degussa, Kirkwood, Missouri
Phenolic	A waterborne (70% solids in water) resole phenolic resin available under the trade designation "BB077" from Neste Resins Canada, a Division of Neste Canada Inc., Mississauga, Ontario

(continued)

5	SR511	2-hydroxymethylene urea (75% solids in water) available from Sartomer Company, Inc., Exton Pennsylvania
Acrylate 1	Acrylate resin available under the trade name "CN132" from Sartomer Company, Inc.	
Acrylate2	Polyester acrylate resin available under the trade name "CN292" from Sartomer Company, Inc.	
Acrylate3	Polyether acrylate resin available under the trade name "CN501" from Sartomer Company, Inc.	
10	Acrylate4	Polyester acrylate resin available under the trade name "CN2302" from Sartomer Company, Inc.
Acrylate5	Polyester acrylate resin available under the trade name "CN2303" from Sartomer Company, Inc.	
15	Acrylate6	Polyester acrylate resin available under the trade name "CN2304" from Sartomer Company, Inc.
Acrylate7	Blend of urethane and acrylate resins available under the trade name "CN2921" from Sartomer Company, Inc.	
Initiator	1,1'-Azobis(cyclohexanecarbonitrile) free radical initiator available from Aldrich Chemical Company, Inc., Milwaukee, Wisconsin	
20	Initiator S	Two weight percent solution of 1,1'-Azobis(cyclohexanecarbonitrile) in methanol
Methanol	99.8+% ultrapure, Spectrophotometric Grade, methanol available from Alfa Aesar, Ward Hill, Massachusetts	
25	SAP1	Shaped ceramic abrasive particles of about 570 micrometers (longest dimension) and passing through a 30-mesh sieve, prepared according to the teachings of U.S. Patent Application serial number 12/337,075.
SAP2	Shaped ceramic abrasive particles of about 550 micrometers (longest dimension) and passing through a 35-mesh sieve, prepared according to the teachings of U.S. Patent Application serial number 12/337,075.	
30	36 grit Cubitron 321	Crushed ceramic abrasive grain available from 3M Company, St. Paul, Minnesota
36 grit AlOx	P36 graded aluminum oxide available under the trade name "Alodur BFRPL" from Treibacher Chemische Werke AG, Villach, Austria	
35	120 grit Cubitron 321	Crushed ceramic abrasive grain available from 3M Company, St. Paul, Minnesota
120 grit AlOx	P120 graded aluminum oxide available under the trade name "Alodur BFRPL" from Treibacher Chemische Werke AG, Villach, Austria	

40 Preparation of Agglomerate Binders

[0045] Agglomerated binder solutions for the Examples were prepared by mixing components as described below.

[0046] Binder AR1 was 72.3% BL16, 26.8% K-450S, and 0.9% D-1122.

[0047] Binder AR2 was 63.9% Phenolic, 27.7% tap water, 7.8% SR511, and 0.6% D-1122.

[0048] Binder AR3 was 87% of a free radical-cured resin selected from Acrylic1 through Acrylic7, inclusive, and 13% Initiator S.

[0049] Binder AR4 was 61.4% BL16, 22.7% K4-450S, 15.3% PMA, and 0.6% D-1122.

50 Preparation of Agglomerates

[0050] Agglomerate precursor compositions included mineral (abrasive particles with optional fillers) and binder mixed by hand with a spatula. Agglomerates prepared with AR1, AR2, and AR4 were 94 wt. % mineral based on solids content. Agglomerates prepared with AR3 were 90 wt. % mineral based on solids content.

## 55 Method 1

[0051] A stainless steel putty knife was used to force an agglomerate precursor composition into the cavities of 15 cm

by 86 cm sheets of microreplicated polypropylene tooling. The tooling had total thickness of 2.2 mm, a plurality of precisely-shaped, microreplicated cavities 4.0 mm square and 1.6 mm deep separated by walls 1.5 mm thick. The tooling was prepared from a corresponding master roll generally according to the procedure of U.S. Pat. No. 6,076,248 to Hoopman et al.

[0052] Filled sheets of polypropylene tooling were heated in a forced air oven to cure the agglomerates. Urethane agglomerates were cured for 20 minutes at 260 °F (127 °C). Phenolic agglomerates were cured at 200 °F (91 °C) for 90 minutes followed by 16 hours at 215 °F (102 °C). Agglomerates containing free radical cured resins were cured for 30 minutes at 280°F (138 °C). The cured agglomerates were removed from the tooling by ultrasonic energy. More particularly, the backside of the tooling was pulled, under tension, across the forward edge of an ultrasonic horn tapered to a single edge. The horn was oscillated at a frequency of 19,100 HZ at amplitude of about 130 micrometers. The horn was composed of 6-4 titanium and was driven with a 900 watt 184 V Branson power source coupled with a 2:1 Booster 802 piezoelectric converter. Examples of the resulting abrasive agglomerates are shown in FIG. 4.

#### Method 2

[0053] 3000 grams of abrasive particles was thoroughly mixed with 250 grams of AR1 producing a friable, tacky agglomerate precursor composition. The agglomerate precursor composition was processed into abrasive agglomerate particles with the aid of a size reduction machine obtained under the trade designation "QUADRO COMIL" ("Model #197", Quadro Engineering Incorporated, Waterloo, Ontario, Canada). Details of the operation of the size reduction machine can be found in WO 02/32832 A1 to Culler et.al. The premix was forced through the 75 mil (1.9 mm) circular openings of a conical screen using an impeller driven at a range of 50 rpm to 3500 rpm. Upon attaining a critical length, the filamentary shaped agglomerate precursor particle separates and falls by gravity to an aluminum collection pan. A mono- or bi-layer of precursor particles were collected in a pan, which was then placed in an oven set to 320 °F (160 °C) for 15 minutes in order to cure the binder resin. After cooling to room temperature, the abrasive agglomerate particles were size-reduced by running them once through the size reduction machine ("QUADRO COMIL") set up with a conical screen pierced by 95 mil (2.4 mm) round holes. The size-reduced particles were sieved on a 14-mesh (1400 micron) screen. Those particles retained on the screen were used to produce unitized abrasive wheels. An example of the abrasive agglomerate is shown in FIG. 5.

#### Method 3

[0054] Agglomerates of abrasive grain, or abrasive grain and fillers, were produced by applying drops of AR4 to beds of mineral one to two centimeters in thickness. Drops were produced by feeding the solution through a blunt-tipped 22-gauge hypodermic needle supported in a vertical position approximately seven centimeters above the mineral bed. The resin droplets wicked into the mineral beds within 10 seconds of application, wetting a volume of material dependent upon the surface area of the mineral or mineral/filler blends. The agglomerates were cured at 302°F (150 °C) for 30 minutes and then sieved from the non-agglomerated mineral, which was recycled back into the agglomerate forming process. Alternatively, AR2 was dripped onto the mineral or mineral/filler bed in a similar manner and cured at 200 °F (91 °C) for 90 minutes followed by 16 hours at 215 °F (102 °C). Individual agglomerates weighed between 0.033 and 0.076 grams and contained from twelve to four percent resin by weight. An example of the resulting abrasive agglomerate is show in FIG. 6.

#### Unitized Abrasive Wheel Preparation

[0055] A nonwoven web was formed on an air laid fiber web forming machine, available under the trade designation "RANDO-WEBBER" from the Rando Machine Corporation of Macedon, New York. The fiber web was formed from 70 denier nylon crimp set fiber with a staple length of one and one-half inches (available from E. I. du Pont de Nemours & Company, Wilmington, Delaware). The weight of the web was approximately 105 grams per square meter (gsm), and the thickness was approximately 0.4 inches (10 mm). The web was conveyed to a horizontal, two-roll coater, where a pre-bond resin was applied at a wet add-on weight of 89 gsm. The pre-bond resin had the following composition (all percentages relative to component weight): 54.1% BL16, 19.9% K450S, 26% PMA. The pre-bond resin was cured to a non-tacky condition by passing the coated web through a convection oven at 330 °F (166 °C) for 4.5 minutes, yielding a pre-bonded, nonwoven web of approximately 6 mm thickness and having a basis weight of 168 gsm.

[0056] Unitized abrasive wheels were prepared from the pre-bonded nonwoven web as follows. A 9-inch (23-cm) square section was cut from the prebonded nonwoven web and saturated with one of two wheel adhesives. Wheel adhesive one (WA1) was 44% BL16, 16.4% K-450S, 15.8% PMA, 7% MP-22VF, 6% phenoxy, 9.9% kaolin, and 0.4% D-1122. Wheel adhesive two (WA2) was 60.8% Phenolic, 31.2% water, 7.4% SR511, and 0.6% D-1122. The saturated prebonded web was then passed through the nip of a roll coater having 4-inch (10-cm) diameter rubber rolls of 85-Shore

A durometer hardness to remove excess resin until the desired resin add-on weight of  $0.49 \pm 0.035$  oz (14  $\pm$  1 g) for WA1 or  $0.60 \pm 0.035$  oz (17  $\pm$  1 g) for WA2 was obtained. Typically, multiple passes through the nip at 11 fpm (3.35 ppm) under pressures of 10-21 psi (69-145 kPa) were required to reach the target weight. For each wheel, seven sections of pre-bonded web were coated in the above manner. The coated sections of prebonded web were placed in a forced air oven set at 260 °F (127 °C) for one minute to remove a majority of the solvent. In order to form a single, unitized slab of nonwoven, abrasive material, six sections of prebond were each covered with 42 grams of randomly, uniformly distributed mineral or mineral agglomerates. The six coated sections were then stacked and covered with a seventh section of prebond. A release liner was then applied to the top and bottom of the stack before it was placed in a hydraulic, heated platen press. A pressure of 5,000 psi (34.5 MPa) was applied to the platens. Consistent thickness of the unitized slab was maintained by placing 0.25 inch (0.635 cm) thick metal spacers in each corner of the platen. Stacks containing WA1 (urethane) were left in the press, set at 260 °F (127 °C), for 30 minutes. Stacks containing WA2 (phenolic) were left in the press, set at 200 °F (93 °C), for five hours. When the press was opened, the sections of web had fused together into a single, unitized slab. The slab was then placed in a forced air oven set at 260 °F (127 °C) for two hours (WA1), or at 215 °F (102 °C) for 16 hours (WA2). After removal from the oven, the slab was cooled to room temperature, and an 8.0-inch (20-cm) diameter unitized abrasive wheel with a 1.25-inch (3.2-cm) center hole was die cut from it using a SAMCO SB-25 swing beam press manufactured by Deutsche Vereinigte Schuhmaschinen GmbH & Co., Frankfurt, Germany.

#### Unitized Abrasive Wheel Performance Test

**[0057]** A pre-weighed, 0.25 inch (6.4 mm)-thick unitized abrasive wheel to be tested was mounted in a vertical orientation on the arbor of a mechanically driven, variable speed lathe adjusted to generate a surface speed at the wheel's edge of approximately 3500 feet (1065 meters) per minute. The edge of a 0.0625 inch (1.59 mm)-thick, two-inch by eleven-inch (5.08-cm by 27.9-cm) cold rolled carbon steel or T304 stainless steel panel held horizontally at the height of the arbor was plunged into the rotating edge of the wheel with approximately 5 pounds (22.2 Newtons) of force for 20 seconds. The amount of material removed from the panel during the test sequence was designated as the "cut" and was defined as the difference between the weight of the panel before and after the test sequence. The amount of material removed from the wheel during the test sequence was designated as the "wear" and was defined as the difference between the weight of the wheel before and after the test sequence.

#### Unitized Abrasive Wheel Finish Test

**[0058]** Finish samples were produced by placing the 6.4 mm-thick wheels on a back stand and adjusting the speed to produce a surface speed of approximately 3500 feet (1065 meters) per minute. The faces of 0.0625 inch (1.59 mm)-thick, two-inch by eleven-inch (5.08-cm by 27.94-cm) cold rolled carbon steel or T304 stainless steel panels were abraded while applying roughly five pounds (22.2 Newtons) of pressure. A 4-inch (10.2-cm) length of panel was finished by passing the panel over the wheel eight times, stepping roughly 0.25 inch (6.4 mm) between passes and moving the panel approximately 2 inches (5.04 cm) per second. Finish was measured using a Perthometer PRK profilometer (Feinprüf GmbH; Gottingen, Germany). Ten measurements were taken on each surface. The high and low values were discarded and the remaining eight data points averaged.

#### Measurement of Resin Modulus

**[0059]** Films for modulus measurements were prepared by placing 16 grams of AR1 on a circular stainless steel form with a diameter of 5.5 inches (14 cm) and a side wall 0.12 inch (3 mm) high. Samples were placed in a forced air oven set at 180 °F (82 °C) for one hour to drive off the majority of solvent. The oven was then set at 260 °F (127 °C) for two hours to complete curing. The resulting films, approximately 0.027 in (0.69 mm) thick, were removed from the steel form. Specimens measuring 1 in x 4 in (2.54 cm x 10.2 cm) were cut from the films and measured according to ASTM D882-10 "Standard Test Method for Tensile Properties of Thin Plastic Sheeting" using a MTS Model QTest Elite 100 tensile tester equipped with Advantage™ 2000N capacity pneumatic sample grips, available from MTS Systems Corporation, Eden Prairie, Minnesota.

#### EXAMPLES 1 - 3 AND COMPARATIVE EXAMPLES A - L

**[0060]** Urethane-bound unitized abrasive wheels were prepared according to the procedures set forth above in the sections on Preparation of Agglomerates and Unitized Abrasive Wheel Preparation, using the components reported in Table 1. The unitized abrasive wheels were tested according to the Unitized Abrasive Wheel Performance Test and Unitized Abrasive Wheel Finish Testing. Results are reported in Table 2. For Comparative Examples G through L, the

cut and wear data were not collected because the smaller abrasive particle size resulted in very low cut. Comparative Examples G through L are presented to show the comparative finishes obtained.

[0061] The results show that in conformable (urethane bound) nonwoven abrasive wheels, shaped ceramic abrasive grain, when agglomerated with a flexible binder (urethane), produces a finer finish relative to non-agglomerated identical shaped ceramic abrasive grain in the same construction. Furthermore, standard crushed grain of a similar particle size, whether ceramic or aluminum oxide, produces a coarser finish when agglomerated with the same urethane binder. All abrasive particles tested produced a coarser finish, relative to their non-agglomerated controls, when agglomerated with a rigid binder (phenolic). Lastly, in addition to the finer finish, the shaped ceramic abrasive particles made into agglomerates still provided the performance improvement (cut and wear) expected from agglomerated abrasive particles.

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TABLE 1

	Mineral	Agglomerated	Agglomeration Method	Agglomerate Binder	Wheel Binder
Example 1	SAP1	No	--	--	1 (U)
Example 2	SAP1	Yes	1	1 (U)	1 (U)
Example 3	SAP1	Yes	1	2 (P)	1 (U)
Comparative Example A	36 grit Cubitron 321	No	--	--	1 (U)
Comparative Example B	36 grit Cubitron 321	Yes	1	1 (U)	1 (U)
Comparative Example C	36 grit Cubitron 321	Yes	1	2 (P)	1 (U)
Comparative Example D	36 grit AlOx	No	--	--	1 (U)
Comparative Example E	36 grit AlOx	Yes	1	1 (U)	1 (U)
Comparative Example F	36 grit AlOx	Yes	1	2 (P)	1 (U)
Comparative Example G	120 grit Cubitron 321	No	-	-	1 (U)
Comparative Example H	120 grit Cubitron 321	Yes	1	1 (U)	1 (U)
Comparative Example I	120 grit Cubitron 321	Yes	1	2 (P)	1 (U)
Comparative Example J	120 grit AlOx	No	--	--	1 (U)
	Mineral	Agglomerated	Agglomeration Method	Agglomerate Binder	Wheel Binder
Comparative Example K	120 grit AlOx	Yes	1	1 (U)	1 (U)
Comparative Example L	120 grit AlOx	Yes	1	2 (P)	1 (U)

50

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TABLE 2

	Cut (g)	Wear (g)	Cut/Wear	Carbon Steel Finish (microinches)		Stainless Steel Finish (microinches)		
				Ra	St. Dev.	Ra	St. Dev.	
5	Example 1	0.66	6.65	0.099	55.2	6.9	38.8	1.6
10	Example 2	0.99	4.89	0.202	44.2	3.5	30.1	4.4
15	Example 3	1.09	7.15	0.152	78.3	11	64.8	8.2
20	Comparative Example A	0.8	7.52	0.106	96.4	11.2	55.8	2.8
25	Comparative Example B	1.01	5.3	0.191	108.9	5.9	62.8	5.3
30	Comparative Example C	0.92	8.69	0.106	113	7.9	68.8	4.9
35	Comparative Example D	0.84	7.24	0.116	88.4	7.8	43.3	2.5
40	Comparative Example E	1.02	6.31	0.162	97.4	5.8	45.9	1.5
	Comparative Example F	0.83	11.5	0.072	111	12.2	47.9	3.8
	Comparative Example G	n.d. <sup>1</sup>	n.d.	n.d.	20	1.1	15.5	2
	Comparative Example H	n.d.	n.d.	n.d.	23.5	2.3	17	2.7
	Comparative Example I	n.d.	n.d.	n.d.	31.3	2.7	20.4	2.7
	Comparative Example J	n.d.	n.d.	n.d.	22.3	3.2	14.9	1.6
	Comparative Example K	n.d.	n.d.	n.d.	23.8	3.2	16.4	1.7
	Comparative Example L	n.d.	n.d.	n.d.	29.6	6.1	19	2.4
	1 n.d.= not determined							

EXAMPLES 4 - 6 AND COMPARATIVE EXAMPLES M - R

45 [0062] Phenolic-bound unitized abrasive wheels were prepared according to the procedures set forth above in the sections Preparation of Agglomerates and Unitized Abrasive Wheel Preparation, using the ingredients reported in Table 3. The unitized abrasive wheels were tested according to the Unitized Abrasive Wheel Performance Test and Unitized Abrasive Wheel Finish Testing. Results are reported in Table 4.

50 [0063] The results show that the trends in the finish data (for non-agglomerated / urethane-agglomerated / phenolic-agglomerated) also hold for non-conformable wheels bound with phenolic second binder. The urethane agglomerates provide finer finishes than control, and phenolic agglomerates provide coarser finishes.

TABLE 3

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
55 Example 4	SAP1	---	---	2 (P)
Example 5	SAP1	1	1 (U)	2 (P)

(continued)

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
5	Example 6	SAP1	1	2 (P)
Comparative Example M	36 grit Cubitron 321	---	---	2 (P)
Comparative Example N	36 grit Cubitron 321	1	1 (U)	2 (P)
Comparative Example O	36 grit Cubitron 321	1	2 (P)	2 (P)
10	Comparative Example P	120 grit Cubitron 321	---	---
Comparative Example Q	120 grit Cubitron 321	1	1 (U)	2 (P)
Comparative Example R	120 grit Cubitron 321	1	2 (P)	2 (P)

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TABLE 4

	Cut	Wear	Cut/Wear	Carbon Steel Finish (microinches)		Stainless Steel Finish (microinches)	
				Ra	St. Dev.	Ra	St. Dev.
20	Example 4	1.84	17.9	0.103	104.7	18.9	81.6
25	Example 5	1.98	20.62	0.096	98.3	8.5	69.1
30	Example 6	1.58	21.72	0.073	171.5	26.2	110
35	Comparative Example M				168.2	18.5	101.8
40	Comparative Example N				116.5	5.8	81.3
Comparative Example O					205.2	7	116.5
Comparative Example P					61.4	3.5	56.5
Comparative Example Q					51.5	3	37.1
Comparative Example R					79.9	3.5	43.2

EXAMPLES 7a, 7b, and 7c AND COMPARATIVE EXAMPLES S - Y

[0064] The modulus of AR1 was measured according to the procedure in the section on Measurement of Resin Modulus above. Urethane bound unitized wheels containing agglomerates bound by a variety of free radical cured resins were produced according to the procedures set forth above in the sections Preparation of Agglomerates and Unitized Abrasive Wheel Preparation, using the ingredients reported in Table 5. The unitized abrasive wheels were tested according to the Unitized Abrasive Wheel Finish Testing. Results are reported in Table 6.

[0065] The results show the data demonstrates that for the purposes of defining an agglomerate binder resin as 'flexible' or 'rigid' the transition occurs when the modulus value decreases to less than 30,000 psi as measured by ASTM D882.

TABLE 5

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
55	Example 7a	SAP1	1	1 (U)
	Example 7b	SAP1	1	3 - Acrylate7

(continued)

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
5	Example 7c	SAP1	1	3 - Acrylate3 1 (U)
	Comparative Example U	SAP1	1	3 - Acrylate 1 1 (U)
	Comparative Example V	SAP1	1	3 - Acrylate5 1 (U)
	Comparative Example W	SAP1	1	3 - Acrylate4 1 (U)
	Comparative Example X	SAP1	1	3 - Acrylate2 1 (U)
	Comparative Example Y	SAP1	1	3 - Acrylate6 1 (U)

15 TABLE 6

	Modulus	Carbon Steel Finish (microinches)		Stainless Steel Finish (microinches)	
		Ra	St. Dev.	Ra	St. Dev.
20	Example 7a	6500	44.2	3.5	30.1
	Example 7b	18,200 <sup>1</sup>	41	2.1	33.1
25	Example 7c	21,651 <sup>1</sup>	40.1	2	33.5
	Comparative Example U	30,000 <sup>1</sup>	57.1	3.4	44.5
	Comparative Example V	37,500 <sup>1</sup>	57.9	2.8	44.6
30	Comparative Example W	55,000 <sup>1</sup>	61.0	4.3	44.0
	Comparative Example X	57,000 <sup>1</sup>	62.9	5.5	43.6
	Comparative Example Y	204,000 <sup>1</sup>	65.1	4.7	44.5

<sup>1</sup> Value provided by resin supplier; determined using ASTM D882.

## 35 EXAMPLES 8 &amp; 9 AND EXAMPLES Z &amp; AA

35 [0066] Examples 8 and 9 and examples Z and AA were prepared to demonstrate the effect of filler on the finish produced by agglomerates of precisely shaped grain. Urethane bound unitized abrasive wheels were prepared according to the procedures set forth above in the sections Preparation of Agglomerates and Unitized Abrasive Wheel Preparation, using the ingredients reported in Table 7. The unitized abrasive wheels were tested according to the Unitized Abrasive Wheel Performance Test and Unitized Abrasive Wheel Finish Testing. Results are reported in Table 8.

40 [0067] The results show the addition of fillers (particles other than formed ceramic abrasive particles) in the flexible binder agglomerates of formed ceramic abrasive particles results in a finer finish.

45 TABLE 7

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
	Example 8	SAP2	2	1 (U)
	Example 9	SAP1	2	1 (U)
50	Example Z	70% SAP2; 30% 120 Grit Alox	2	1 (U)
	Example AA	70% SAP1; 30% 120 Grit Alox	2	1 (U)

TABLE 8

			Carbon Steel Finish (microinches)		Stainless Steel Finish (microinches)		
			Cut (g)	Wear (g)	Cut/Wear	Ra	St. Dev.
5	Example 8	1.39	8.52	0.16	55.3	3.2	42.9
10	Example 9	1.49	7.30	0.20	75	4.5	56.5
15	Example Z	1.12	7.87	0.14	48.8	2	38.8
20	Example AA	1.21	6.04	0.20	57	2.9	49
25							2.9

EXAMPLES 10 & 11

**[0068]** Examples 10 and 11 were prepared to demonstrate that the unexpected improved finish result is independent of the method of agglomerate production. Urethane bound unitized abrasive wheels were prepared according to the procedures set forth above in the sections Preparation of Agglomerates and Unitized Abrasive Wheel Preparation, using the variables reported in Table 9. The unitized abrasive wheels were tested according to the Unitized Abrasive Wheel Performance Test and Unitized Abrasive Wheel Finish Testing. Results are reported in Table 10.

**[0069]** The results show that the surprising finish improvement provided by agglomerating shaped ceramic abrasive particles with flexible resins is independent of the agglomerate's shape. Examples 1-7 and comparatives A-Y were molded squares. Examples 10 & 11 were random shapes.

TABLE 9

	Mineral	Agglomeration Method	Agglomerate Binder	Wheel Binder
30	Example 10	SAP1	3	4 (U)
35	Example 11	SAP1	3	2 (P)

TABLE 10

	Cut (g)	Wear (g)	Cut/Wear	Carbon Steel Finish (microinches)		Stainless Steel Finish (microinches)	
				Ra	St. Dev.	Ra	St. Dev.
35	Example 10	1.2	5.69	0.21	48	2.4	43.5
40	Example 11	1.27	12.46	0.10	82.4	3.9	71.9
45							2.3
50							7.4

**[0070]** Other modifications and variations to the present disclosure may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present disclosure, which is more particularly set forth in the appended claims. It is understood that aspects of the various embodiments may be interchanged in whole or part or combined with other aspects of the various embodiments. All cited references, patents, or patent applications in the above application for letters patent are herein incorporated by reference in their entirety in a consistent manner. In the event of inconsistencies or contradictions between portions of the incorporated references and this application, the information in the preceding description 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.

## Claims

55 1. A nonwoven abrasive article comprising:

5 a nonwoven web;  
 agglomerates comprising formed ceramic abrasive particles bound together by a first flexible binder, wherein  
 a modulus of elasticity of the first flexible binder is less than 193,053 kPa (28,000 psi) as tested by ASTM D882,  
 and  
 the formed ceramic abrasive particles are particles having at least a partially replicated shape; and  
 a second binder binding the agglomerates to the nonwoven fiber web.

10 2. The nonwoven abrasive article of claim 1 wherein the formed ceramic particles comprise shaped ceramic abrasive  
 particles comprising triangular plates.

15 3. The nonwoven abrasive article of claims 1 or 2 wherein the first flexible binder comprises a polyurethane and the  
 second binder comprises a polyurethane.

20 4. The nonwoven abrasive article of claims 1 or 2 wherein the first flexible binder comprises a polyurethane and the  
 second binder comprises a phenolic.

25 5. The nonwoven abrasive article of claims 1 or 2 wherein a modulus of elasticity of the first flexible binder is less than  
 158,579 kPa (23,000 psi) as tested by ASTM D882.

30 6. The nonwoven abrasive article of claims 1 or 2 wherein the agglomerates comprise filler particles having an average  
 particles size less than that of the formed ceramic abrasive particles and the filler particles comprise from 5% to  
 40% by weight of the total particles in the agglomerates.

35 7. The nonwoven abrasive article of claims 1 or 2 where the agglomerates have a size comprising a maximum diameter,  
 if generally spherical, or a maximum side edge length if non-spherical from 1.8 to 3 mm.

8. The nonwoven abrasive article of claims 1 or 2 wherein a ratio of the formed ceramic abrasive particle size divided  
 by the agglomerate size is 0.0033 to 0.5.

30 9. The nonwoven abrasive article of claims 1 or 2 wherein the agglomerates comprise filler particles and wherein the  
 formed ceramic abrasive particle content is from 75 wt. % to 96 wt. %, the first flexible binder content is from 4 wt.  
 % to 10 wt. %, and the filler particle content is from 10 wt. % to 35 wt. %.

35 10. The nonwoven abrasive article of claims 1 or 2 comprising either a convolute abrasive wheel or a unitized abrasive  
 wheel.

### Patentansprüche

40 1. Schleifstück aus Vliesstoff, das Folgendes aufweist:  
 eine Vliesstoffbahn;  
 Agglomerate, die ausgebildete Keramik-Schleifteilchen aufweisen, die über ein erstes flexibles Bindemittel  
 zusammengebunden sind, wobei  
 der Elastizitätsanteil des ersten flexiblen Bindemittels weniger als 193.053 kPa (28.000 psi) beträgt, wie nach  
 Richtlinie ASTM D882 getestet, und  
 die ausgebildeten Keramik-Schleifteilchen sind Teilchen, die eine zumindest teilweise replizierte Form haben;  
 sowie ein  
 zweites Bindemittel, das die Agglomerate an die Vliesstofffaser-Bahn binden.

50 2. Schleifstück aus Vliesstoff nach Anspruch 1, bei dem die ausgebildeten Keramikteilchen geformte Keramik-Schleif-  
 teilchen aufweise, die dreieckige Platten umfassen.

55 3. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem das erste flexible Bindemittel ein Polyurethan und das  
 zweite Bindemittel ein Polyurethan aufweist.

4. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem das erste flexible Bindemittel ein Polyurethan und das  
 zweite Bindemittel ein Phenol aufweist.

5. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem der Elastizitätsanteil des ersten flexiblen Bindemittels weniger als 158.579 kPa (23.000 psi) beträgt, wie nach Richtlinie ASTM D882 getestet.
6. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem die Agglomerate Füller-Teilchen aufweisen, die über eine durchschnittliche Teilchengröße verfügen, die unter der der ausgebildeten Keramik-Schleifteilchen liegt, und Füller-Teilchen von 5 Gew.% bis 40 Gew.% der gesamten Teilchen in den Agglomeraten aufweisen.
- 10 7. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem die Agglomerate über eine Größe verfügen, die einen maximalen Durchmesser aufweist, wenn sie allgemein sphärisch sind, oder die eine maximale Seitenkantenlänge von 1,8 bis 3 mm aufweisen, wenn sie nicht sphärisch sind.
- 15 8. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem das Verhältnis der Größe des ausgebildeten Keramik-Schleifteilchens geteilt durch die Agglomerat-Größe 0,0033 bis 0,5 beträgt.
- 10 9. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, bei dem die Agglomerate Füller-Teilchen aufweisen und bei dem der Gehalt des ausgebildeten Keramik-Schleifteilchens von 75 Gew.% bis 96 Gew.%, der Gehalt des ersten flexiblen Bindemittels von 4 Gew.% bis 10 Gew.% und der Gehalt des Füller-Teilchens von 10 Gew.% bis 35 Gew.% beträgt.
- 20 10. Schleifstück aus Vliesstoff nach Anspruch 1 oder 2, das entweder eine gewickelte Schleifscheibe oder eine Kom-paktschleifscheibe aufweist.

**Revendications**

- 25 1. Article abrasif non tissé comprenant :
  - une bande non tissée ;
  - des agglomérats comprenant des particules abrasives de céramique façonnées liées entre elles par un premier liant souple, dans lequel
  - 30 un module d'élasticité du premier liant souple est inférieure à 193 053 kPa (28 000 psi) selon un essai conforme à l'ASTM D882, et
  - les particules abrasives de céramique façonnées sont des particules présentant au moins une forme partiellement répliquée ; et
  - 35 un deuxième élément de liaison liant les agglomérats à la bande de fibres non tissées.
2. Article abrasif non tissé selon la revendication 1, dans lequel les particules de céramique façonnées comprennent des particules abrasives de céramique mises en forme comprenant des plaques triangulaires.
- 40 3. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel le premier liant souple comprend un polyuréthane et le deuxième liant comprend un polyuréthane.
4. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel le premier liant souple comprend un polyuréthane et le deuxième liant comprend un phénolique.
- 45 5. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel un module d'élasticité du premier liant souple est inférieur à 158 579 kPa (23 000 psi) selon un essai conforme à l'ASTM D882.
6. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel les agglomérats comprennent des particules de charge présentant une taille de particule moyenne inférieure à celle des particules abrasives de céramique façonnées et les particules de charge comprennent de 5 % à 40 % en poids des particules totales dans les agglomérats.
- 50 7. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel les agglomérats ont une taille comprenant un diamètre maximal s'ils sont globalement sphériques ou une longueur de bord latéral maximale de 1,8 à 3 mm s'ils ne sont pas sphériques .
8. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel un rapport de la taille de particule abrasive de

céramique façonnée divisé par la taille de l'agglomérat est 0,0033 à 0,5.

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- 9. Article abrasif non tissé selon les revendications 1 ou 2, dans lequel les agglomérats comprennent des particules de charge et dans lequel la teneur en particules abrasives de céramique façonnées est comprise entre 75 % en poids et 96 % en poids, la teneur en premier liant souple est comprise entre 4 % en poids et 10 % en poids et la teneur en particules de charge est comprise entre 10 % en poids et 35 % en poids.
- 10. Article abrasif non tissé selon les revendications 1 ou 2 comprenant une roue abrasive enroulée ou une roue abrasive unitaire.

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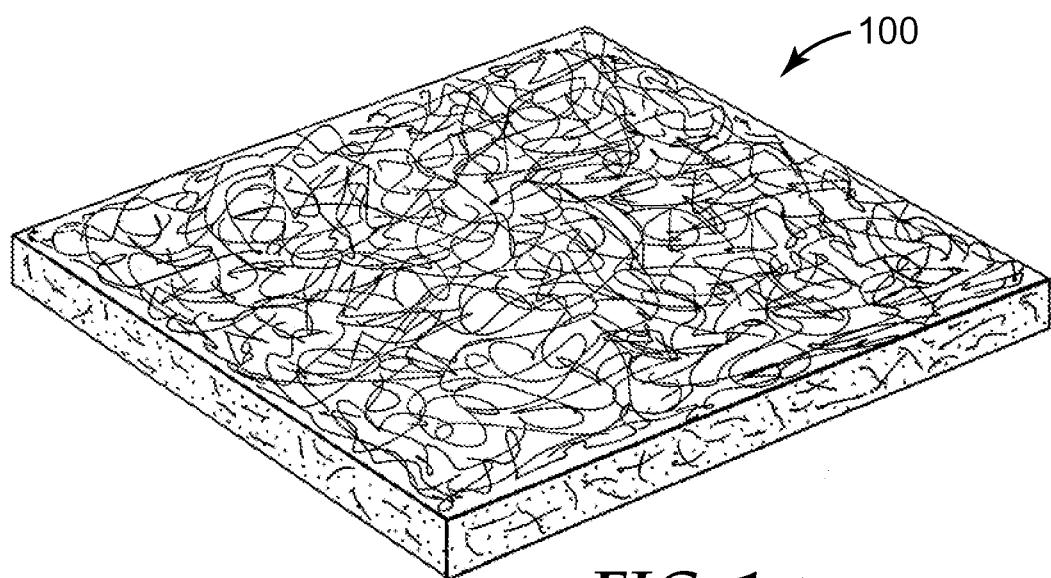
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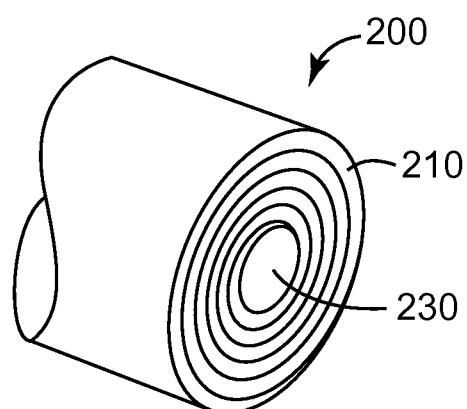
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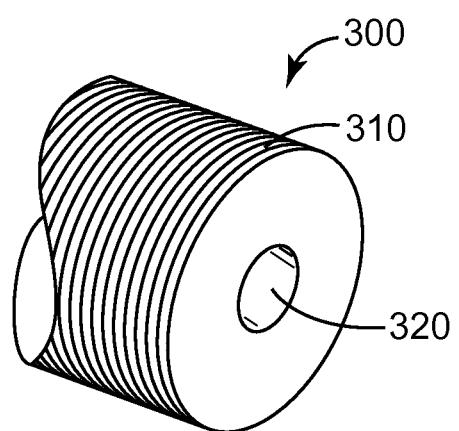
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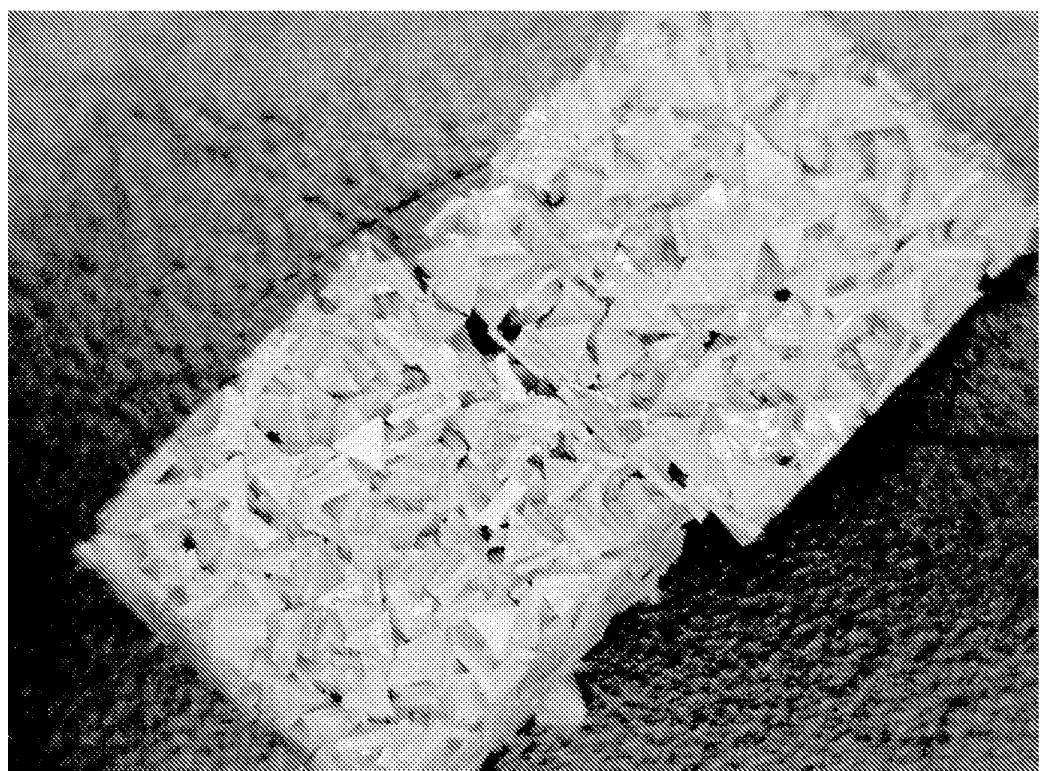
**FIG. 1**



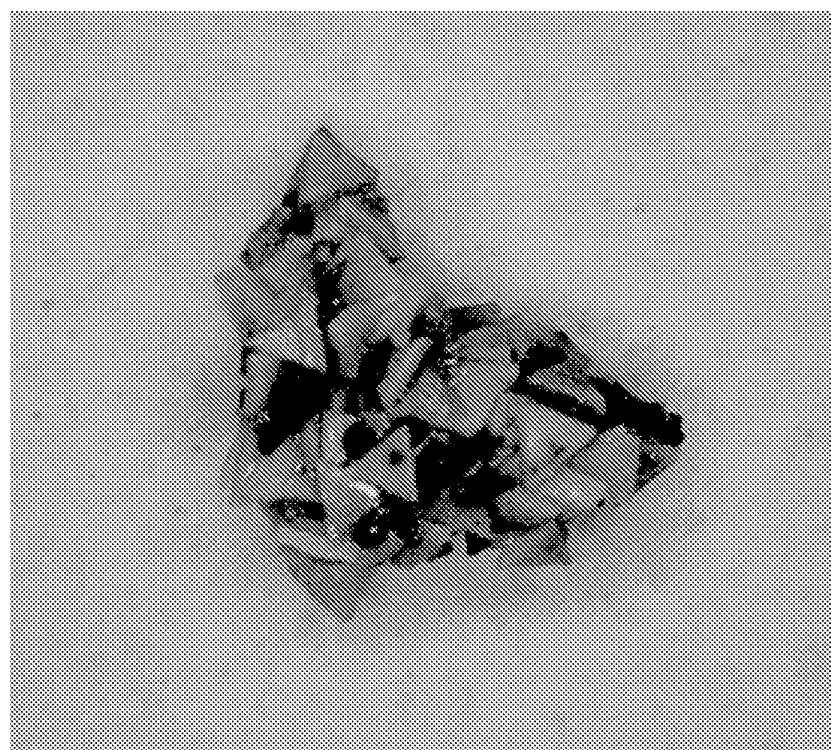
**FIG. 2**



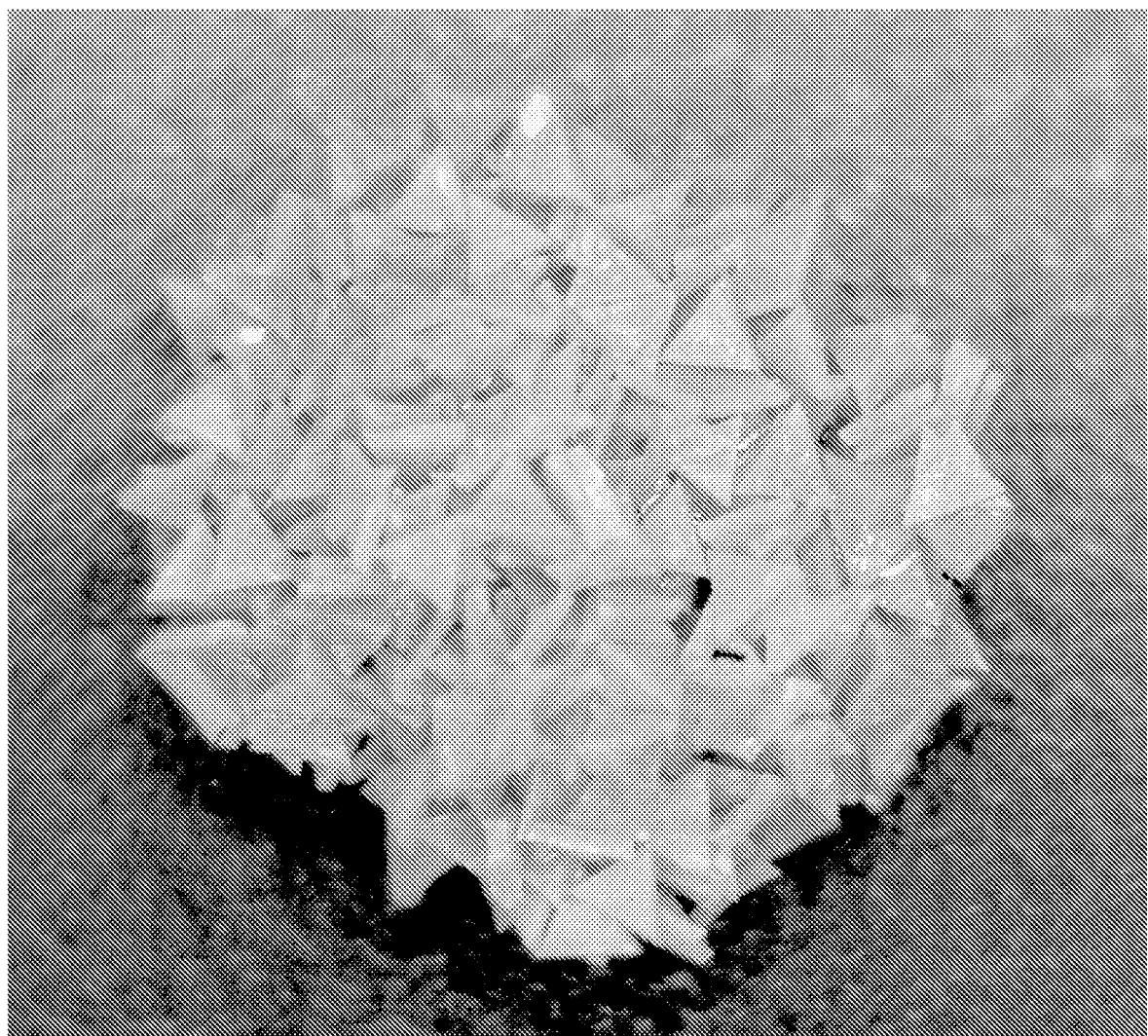
**FIG. 3**



*FIG. 4*



*FIG. 5*



*FIG. 6*

**REFERENCES CITED IN THE DESCRIPTION**

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