(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 571 011 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.04.2025 Bulletin 2025/17

(21) Application number: **18702806.3**

(22) Date of filing: **16.01.2018**

(51) International Patent Classification (IPC):
B24D 11/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B24D 11/005; B24D 11/001

(86) International application number:
PCT/IB2018/050263

(87) International publication number:
WO 2018/134732 (26.07.2018 Gazette 2018/30)

(54) **MAGNETICALLY ASSISTED TRANSFER OF MAGNETIZABLE ABRASIVE PARTICLES AND METHODS, APPARATUSES AND SYSTEMS RELATED THERETO**

MAGNETISCH UNTERSTÜTZTE ÜBERTRAGUNG VON MAGNETISIERBAREN SCHLEIFPARTIKEL UND VERFAHREN, VORRICHTUNGEN UND SYSTEME IM ZUSAMMENHANG DAMIT

TRANSFERT ASSISTÉ MAGNÉTIQUEMENT DE PARTICULES ABRASIVES MAGNÉTISABLES ET PROCÉDÉS, APPAREILS ET SYSTÈMES ASSOCIÉS

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **19.01.2017 US 201762448141 P**

(43) Date of publication of application:
27.11.2019 Bulletin 2019/48

(73) Proprietor: **3M Innovative Properties Company**
St. Paul, MN 55133-3427 (US)

(72) Inventors:
- **NIENABER, Aaron K.**
  Saint Paul, Minnesota 55133-3427 (US)
- **ECKEL, Joseph B.**
  Saint Paul, Minnesota 55133-3427 (US)
- **JESME, Ronald D.**
  Saint Paul, Minnesota 55133-3427 (US)
- **JAVID, Samad**
  Saint Paul, Minnesota 55133-3427 (US)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstraße 3
81675 München (DE)

(56) References cited:

WO-A1-2016/196795	**WO-A1-2016/205267**
US-A- 2 027 087	**US-A1- 2014 290 147**

Description

TECHNICAL FIELD

[0001] This document pertains generally to abrasive particles, abrasive articles, and related apparatuses, systems and methods.

BACKGROUND

[0002] Various types of abrasive articles are known in the art. For example, coated abrasive articles generally have abrasive particles adhered to a backing by a resinous binder material. Examples include sandpaper and structured abrasives having precisely shaped abrasive composites adhered to a backing. The abrasive composites generally include abrasive particles and a resinous binder.

[0003] Coated abrasive articles are conventionally coated by either drop coating or electrostatic coating of the abrasive particles onto a resin-coated backing. Of the two methods, electrostatic coating has been often preferred, as it provides some degree of orientation control for grains having an aspect ratio other than one.

[0004] In general, positioning and orientation of the abrasive particles and their cutting points is important in determining abrasive performance and orientation. PCT International Publ. No. WO 2012/112305 A2 (Keipert) discloses coated abrasive articles manufactured through use of precision screens having precisely spaced and aligned non-circular apertures to hold individual abrasive particles in fixed positions that can be used to rotationally align a surface feature of the abrasive particles in a specific z-direction rotational orientation. In that method, a screen or perforated plate is laminated to an adhesive film and loaded with abrasive particles. The orientation of the abrasive particles could be controlled by the screen geometry and the restricted ability of the abrasive particles to contact and adhere to the adhesive through the screen openings. Removal of the adhesive layer from the filled screen transferred the oriented abrasive particles in an inverted fashion to an abrasive backing. The method relies on the presence of adhesive which can be cumbersome, prone to detackifying (e.g., due to dust deposits) over time, and which can transfer to the resultant coated abrasive article creating the possibility of adhesive transfer to, and contamination of, a workpiece.

[0005] From US 2014/290147 A1 there is known a method of making an abrasive article, the method comprising: providing dispensable magnetizable abrasive particles and a distribution tool, wherein the distribution tool is configured to receive the magnetizable abrasive particles therein, and wherein the distribution tool configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles; positioning a backing adjacent to the distribution tool and spaced therefrom by a gap, applying a magnetic field to at least the backing and a portion of the gap between the backing and the distribution tool to exert a magnetic force on the magnetizable abrasive particles to influence transfer of the magnetizable abrasive particles from the distribution tool to the backing; transferring the magnetizable abrasive particles from the distribution tool to a first major surface of the backing, wherein the magnetic field is applied during the transfer of the magnetizable abrasive particles. From US 2014/290147 A1 there is also known an abrasive particle positioning system comprising: a distribution tool configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles, the distribution tool comprising: a carrier member (203) having an dispensing surface and a back surface opposite the dispensing surface, a backing disposed adjacent to the distribution tool and spaced therefrom by a gap; the backing having a first major surface facing the distribution tool and a second major surface opposing the first major surface; and a magnet, the magnet applying a magnetic field to exert a magnetic force on the magnetizable abrasive particles to influence a transfer of the magnetizable abrasive particles from the distribution tool to the backing to aid in achieving at least one of a predetermined orientation and alignment of the magnetizable abrasive particles on a first major surface of the backing.

OVERVIEW

[0006] The invention is directed to a method as defined by claim 1 and to a system as defined by claim 10.

[0007] Other embodiments are defined by the dependent claims.

[0008] Alignment and orientation of abrasive particles in an abrasive article can be important for article cutting performance and durability. If the abrasive particles are inverted (so as to be base up) or are out of alignment with respect to a cutting direction, a premature breakdown of the abrasive article can occur. Conventional methods such as drop coating and electrostatic deposition provide a random distribution of spacing and particle clustering often results where two or more shaped abrasive particles end up touching each other near the tips or upper surfaces of the shaped abrasive particles. Clustering can also create poor cutting performance due to local enlargement of bearing areas in those regions and inability of the shaped abrasive particles in the cluster to fracture and breakdown properly during use because of mutual mechanical reinforcement. Clustering can create undesirable heat buildup compared to coated abrasive articles having more uniformly spaced shaped abrasive particles.

[0009] In view of the foregoing, the present inventors have recognized, among other things, that a variety of abrasive articles can benefit from more precise positioning and orientation of abrasive particles. As such, the present inventors have developed processes, systems and apparatuses that use magnetic fields to control magnetizable abrasive particles. More particularly, the present inventors have discovered that by transferring the abrasive particles from the distribution tool under the influence of an applied magnetic field, the gap between the distribution tool and a backing can be significantly increased (e.g., up to about 4 times), while still achieving a same or substantially similar orientation as achieved using a narrower gap and no applied magnetic field. Such larger gap can avoid fouling of the distribution tool and/or damage to the abrasive article.

[0010] The processes, systems and apparatuses can position and/or orient the magnetizable abrasive particles as desired. In some embodiments, a non-random predetermined pattern for the magnetizable abrasive particles within the abrasive article can be achieved as a result of the distribution tool and the magnetic field. The magnetic field can be applied to the magnetizable abrasive particles during transfer from the distribution tool to the backing to improve not just the drop height but the propensity of the magnetizable abrasive particles to be oriented and/or aligned as desired once received on the backing.

[0011] According to one exemplary embodiment, a method of making a coated abrasive article is disclosed. The method can comprise: providing dispensable magnetizable abrasive particles and a distribution tool, wherein the distribution tool is configured to receive the magnetizable abrasive particles therein, and wherein the distribution tool is configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles, positioning a backing adjacent to the distribution tool and spaced therefrom by a gap; applying a magnetic field to at least the backing and a portion of the gap between the backing and the distribution tool, and transferring the magnetizable abrasive particles from the distribution tool to a first major surface of the backing, wherein the magnetic field is applied during the transfer of the magnetizable abrasive particles.

[0012] According to another exemplary embodiment, an abrasive particle positioning system is disclosed. The system can comprise: a distribution tool configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles, the distribution tool can comprise: a carrier member having a dispensing surface and a back surface opposite the dispensing surface, wherein the carrier member has cavities formed therein, wherein the cavities extend into the carrier member from the dispensing surface toward the back surface, magnetizable abrasive particles removably disposed within at least some of the cavities, a backing disposed adjacent to the distribution tool and spaced therefrom by a gap, the backing having a first major surface facing the distribution tool and a second major surface opposing the first major surface, and a magnet disposed below the second major surface of the backing, the magnet applying a magnetic field during a transfer of the magnetizable abrasive particles from the distribution tool to the backing to aid in achieving at least one of a predetermined orientation and alignment of the magnetizable abrasive particles on a first major surface of the backing.

[0013] According to yet another exemplary embodiment, abrasive particle positioning system is disclosed. The system can comprise: a distribution tool configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles, the distribution tool can comprise: a member includes a plurality of walls defining slots configured to allow for the passage of one or more of the magnetizable abrasive particles therethrough, each one of the slots being open at a first end to a dispensing surface of the distribution tool and open at a second end to feed surface of the distribution tool, a backing disposed adjacent to the distribution tool and spaced therefrom by a gap, the backing having a first major surface facing the dispensing surface and a second major surface opposing the first major surface, and a magnet disposed below the second major surface of the backing, the magnet applying a magnetic field during a transfer of the magnetizable abrasive particles from the distribution tool to the backing to aid in achieving at least one of a predetermined orientation and alignment of the magnetizable abrasive particles on a first major surface of the backing.

[0014] According to another exemplary embodiment, a method of making a coated abrasive article is disclosed. The method can comprise: providing dispensable magnetizable abrasive particles and a distribution tool, wherein the distribution tool is configured to receive the magnetizable abrasive particles therein, and wherein the distribution tool is configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles, positioning a backing adjacent to the distribution tool and spaced therefrom by a gap, applying a magnetic field to at least the backing and a portion of the gap between the backing and the distribution tool, and transferring the magnetizable abrasive particles from the distribution tool to a first major surface of the backing, wherein the magnetic field is applied during the transfer of the magnetizable abrasive particles.

[0015] As used herein:

The term "a", "an", and "the" are used interchangeably with "at least one" to mean one or more of the elements being described.

[0016] The term "and/or" means either or both. For example "A and/or B" means only A, only B, or both A and B.

[0017] The terms "including," "comprising," or "having," and variations thereof, are meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0018] Unless specified or limited otherwise, the term "coupled" is used broadly and encompass both direct and indirect couplings.

[0019] The phrase "major surface" hereof, is used to describe an article having a thickness that is small relative to its length and width. The length and width of such articles can define the "major surface" of the article, but this major surface, as well as the article, need not be flat or planar. For example, the above phrases can be used to describe an article having a first ratio (R_1) of thickness (e.g., in a Z direction that is orthogonal to a major surface of the article at any point along the major surface) to a first surface dimension of the major surface (e.g., width or length), and a second ratio (R_2) of thickness to a second surface dimension of the major surface, where the first ratio (R_1) and the second ratio (R_2) are both less than 0.1. In some embodiments, the first ratio (R_1) and the second ratio (R_2) can be less than 0.01; in some embodiments, less than 0.001; and in some embodiments, less than 0.0001. Note that the two surface dimensions need not be the same, and the first ratio (R_1) and the second ratio (R_2) need not be the same, in order for both the first ratio (R_1) and the second ratio (R_2) to fall within the desired range. In addition, none of the first surface dimension, the second surface dimension, the thickness, the first ratio (R_1), and the second ratio (R_2) need to be constant in order for both the first ratio (R_1) and the second ratio (R_2) to fall within the desired range.

[0020] The term "ceramic" refers to any of various hard, brittle, heat- and corrosion-resistant materials made of at least one metallic element (which can include silicon) combined with oxygen, carbon, nitrogen, or sulfur.

[0021] The term "conductive" means electrically conductive (e.g., at the level of a conductor), unless otherwise specified.

[0022] The term "ferrimagnetic" refers to materials that exhibit ferrimagnetism. Ferrimagnetism is a type of permanent magnetism that occurs in solids in which the magnetic fields associated with individual atoms spontaneously align themselves, some parallel, or in the same direction (as in ferromagnetism), and others generally antiparallel, or paired off in opposite directions (as in antiferromagnetism). The magnetic behavior of single crystals of ferrimagnetic materials can be attributed to the parallel alignment; the diluting effect of those atoms in the antiparallel arrangement keeps the magnetic strength of these materials generally less than that of purely ferromagnetic solids such as metallic iron. Ferrimagnetism occurs chiefly in magnetic oxides known as ferrites. The spontaneous alignment that produces ferrimagnetism is entirely disrupted above a temperature called the Curie point, characteristic of each ferrimagnetic material. When the temperature of the material is brought below the Curie point, ferrimagnetism revives.

[0023] The term "ferromagnetic" refers to materials that exhibit ferromagnetism. Ferromagnetism is a physical phenomenon in which certain electrically uncharged materials strongly attract others. In contrast to other substances, ferromagnetic materials are magnetized easily, and in strong magnetic fields the magnetization approaches a definite limit called saturation. When a field is applied and then removed, the magnetization does not return to its original value. This phenomenon is referred to as hysteresis. When heated to a certain temperature called the Curie point, which is generally different for each substance, ferromagnetic materials lose their characteristic properties and cease to be magnetic; however, they become ferromagnetic again on cooling.

[0024] The terms "magnetic" and "magnetized" mean being ferromagnetic or ferrimagnetic at 20°C, unless otherwise specified.

[0025] The term "magnetizable" means that the item being referred to is magnetic or can be made magnetic using an applied magnetic field, and has a magnetic moment of at least 0.001 electromagnetic units (emu), in some cases at least 0.005 emu, and yet other cases 0.01 emu, up to an including 0.1 emu, although this is not a requirement.

[0026] The term "magnetic field" refers to magnetic fields that are not generated by any astronomical body or bodies (e.g., Earth or the sun). **In** general, magnetic fields used in practice of the present disclosure have a field strength in the region of the magnetizable abrasive particles being oriented of at least about 10 gauss (1 mT), in some cases at least about 100 gauss (10 mT), and in yet other cases at least about 1000 gauss (0.1 T) .

[0027] The term "magnetizable" means capable of being magnetized or already in a magnetized state.

[0028] The term "shaped ceramic body" refers to a ceramic body that has been intentionally shaped (e.g., extruded, die cut, molded, screen-printed) at some point during its preparation such that the resulting ceramic body is non-randomly shaped. The term "shaped ceramic body" as used herein excludes ceramic bodies obtained by a mechanical crushing or milling operation.

[0029] The terms "precisely-shaped ceramic body" refers to a ceramic body wherein at least a portion of the ceramic body has a predetermined shape that is replicated from a mold cavity used to form a precursor precisely-shaped ceramic body that is sintered to form the precisely-shaped ceramic body. A precisely-shaped ceramic body will generally have a predetermined geometric shape that substantially replicates the mold cavity that was used to form the shaped abrasive particle.

[0030] The term "length" refers to the longest dimension of an object.

[0031] The term "width" refers to the longest dimension of an object that is perpendicular to its length.

[0032] The term "thickness" refers to the longest dimension of an object that is perpendicular to both of its length and width.

[0033] The term "aspect ratio" refers to the ratio length/thickness of an object.

[0034] The term "orientation" "oriented" or "orient" as it refers to the magnetizable abrasive particles provided by distribution tools and/or the magnetic fields of the present disclosure can refer to a non-random disposition of at least a majority of the particles relative to the distribution tool(s) and/or the backing. For example, a majority of the magnetizable abrasive particles have a major planar surface disposed at an angle of at least 70 degrees relative to the first major surface of the backing upon transfer to the backing. Thus, a majority of the magnetizable abrasive particles do not have a major surface that rests flat upon the backing after transfer but have at least one minor surface that rests upon the backing. These terms also can refer to major axes and dimensions of the magnetizable abrasive particles themselves. For example, the particle maximum length, height and thickness are a function of a shape of the magnetizable abrasive particle, and the shape may or may not be uniform. The present disclosure is in no way limited to any particular abrasive particle shape, dimensions, type, etc., and many exemplary magnetizable abrasive particles useful with the present disclosure are described in greater detail below. However, with some shapes, the "height", "width" and "thickness" give rise to major faces and minor side faces. Regardless of an exact shape, any magnetizable abrasive particle can have a centroid at which particle Cartesian axes can be defined. With these conventions, the particle z-axis is parallel with the maximum height, the particle y-axis is parallel with the maximum length, and the particle x-axis is parallel with the maximum thickness of the particle. As a point of reference, the particle axes can identified for each magnetizable abrasive particle as a standalone object independent of the backing construction; once applied to the backing, a "z-axis rotation orientation" of the magnetizable abrasive particle is defined by the particle’s angular rotation about a z-axis passing through the particle and through the backing to which the particle is attached at a 90 degree angle to the backing. The orientation effected by the distribution tools of the present disclosure entail dictating or limiting a spatial arrangement of the abrasive particle to a range of rotational orientations about the particle in one or more of the z-axis, the y-axis and/or the x-axis to a range of rotational orientations about the particle axes. For example, the embodiments of FIGS. 5-6A slots that are configured to limit a rotational orientation of the magnetizable abrasive particle about two axes but can be free to assume any rotational orientation about a third axis.

[0035] The term "alignment" "aligned" or "align" as it refers to the magnetizable abrasive particles provided by distribution tools and/or the magnetic fields of the present disclosure can refer to a non-random positioning of at least a majority of the magnetizable abrasive particles such that at least the majority of the magnetizable abrasive particles have a minor surface/cutting edge(s) that is positioned in a direction of cutting when the abrasive article is used.

[0036] The term "pattern" "patterned" or "patterning" as it refers to the magnetizable abrasive particles refers to a controlled spacing of either individual or groupings of the magnetizable abrasive particles. Thus, the term does not necessarily imply a particular alignment or orientation. In some instances, the pattern can have a repeated controlled spacing of either individual or groupings of the magnetizable abrasive particles. It refers to the magnetizable abrasive particles provided by distribution tools and/or the magnetic fields of the present disclosure can refer to a non-random spacing between at least a majority of the particles relative to one another whether in the distribution tool and/or disposed upon the backing.

[0037] The term "substantially" means within 35 percent (within 30 percent, in yet other cases within 25 percent, in yet other cases within 20 percent, in yet other cases within 10 percent, and in yet other cases within 5 percent) of the attribute being referred to.

[0038] Features and advantages of the present disclosure will be further understood upon consideration of the detailed description as well as the appended claims.

[0039] This overview is intended to provide an overview of subject matter of the present patent application. It is not intended to provide an exclusive or exhaustive explanation of the invention. The detailed description is included to provide further information about the present patent application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040]

FIG. 1 is a schematic perspective view of an exemplary magnetizable abrasive particle 100 according to one embodiment of the present disclosure.

FIG. 1A is an enlarged view of region 1A in FIG. 1.

FIG. 2 is schematic view of an apparatus for making a coated abrasive article that can include the magnetizable abrasive particle of FIG. 1 according to an example of the present disclosure.

FIG. 2A is an enlarged view of a portion of the apparatus of FIG. 2 including a distribution tool according to an example of the present disclosure.

FIG. 3 is a schematic view of another embodiment of a distribution tool with magnetizable abrasive particles retained therein and spaced from a backing and a magnet according to an example of the present disclosure.

FIG. 4 is a schematic perspective view of a portion of an exterior surface of a distribution tool according to another embodiment, the distribution tool receiving magnetizable abrasive particles therein according to an example of the present disclosure.

FIG. 5 is a schematic view of a distribution tool according to another embodiment, the distribution tool receiving magnetizable abrasive particles and passing the particles through slots formed by the distribution tool according to an example of the present disclosure.

FIGS. 6 and 6A show schematic perspective views of a distribution tool according to another embodiment, the distribution tool receiving magnetizable abrasive particles and passing the particles through slots formed by the distribution tool according to an example of the present disclosure.

FIG. 7 is a digital image of the exterior surface of the distribution tool receiving magnetizable abrasive particles therein in accordance with Example 1.

FIG. 8 is a digital image of a coated abrasive article with magnetizable abrasive particles oriented and positioned in accordance with Example 1.

FIG. 9 is a digital image of a coated abrasive article with magnetizable abrasive particles after having undergoing a process in accordance with Comparative Example A.

FIG. 10 is a digital image of a coated abrasive article with magnetizable abrasive particles oriented and positioned in accordance with Example 2.

FIG. 11 is a digital image of a coated abrasive article with magnetizable abrasive particles after having undergoing a process in accordance with Comparative Example B.

DETAILED DESCRIPTION

[0041] Magnetizable abrasive particles are described herein by way of example and can have various configurations. For example, the magnetizable abrasive particles can be constructed of various materials including but not limited to ceramics, metal alloys, composites or the like. Similarly, the magnetizable abrasive particles can be substantially entirely constructed of magnetizable material, can have magnetizable portions disposed therein (e.g., ferrous traces), or can have magnetizable portions disposed as layers on one or more surfaces thereof (e.g., one or more surfaces can be coated with a magnetizable material) according to some examples. The magnetizable abrasive particles can be shaped according to some examples. According to other examples the magnetizable abrasive particles can comprise crush grains, agglomerates, or the like. Magnetizable abrasive particles can be used in loose form (e.g., free-flowing or in a slurry) or they can be incorporated into various abrasive articles (e.g., coated abrasive articles, bonded abrasive articles, nonwoven abrasive articles, and/or abrasive brushes).

[0042] Referring now to FIGS. 1 and 1A, an exemplary magnetizable abrasive particle 100 is disclosed. The magnetizable abrasive particle 100 can have a shaped ceramic body 110 and magnetizable layer 120. The magnetizable layer 120 can be comprised of magnetizable particles 125 retained in a binder matrix 130 (also referred to simply as "binder") as further shown in FIG. 1A. The ceramic body 110 can have two opposed major surfaces 160, 162 connected to each other by three side surfaces 140a, 140b, 140c. The magnetizable layer 120 is disposed on side surface 140a of ceramic body 110.

[0043] The magnetizable layer 120 can optionally extend somewhat onto other surfaces of the shaped ceramic body 110. In some embodiments, the magnetizable layer 120 can extend to cover a majority of any surface of the shaped ceramic body 110 as desired. As shown, magnetizable layer 120 can be coextensive with side surface 140a. Magnetizable abrasive particles of the type shown can be aligned with the magnetizable layer-coated surface parallel to magnetic field lines of force as will be discussed subsequently.

[0044] In general, since orientation of the magnetic field lines tends to be different at the center and edge of a magnet it is also possible to create various desired orientations of the magnetizable abrasive particles during their inclusion into an abrasive article.

[0045] The magnetizable layer can be a unitary magnetizable material, or it can comprise magnetizable particles in a binder matrix. Suitable binders can be vitreous or organic, for example, as described for the binder matrix 130 hereinbelow. The binder matrix can be, for example selected from those vitreous and organic binders. The ceramic body can comprise any ceramic material (a ceramic abrasive material), for example, selected from among the ceramic (i.e., not including diamond) abrasive materials listed hereinbelow. The magnetizable layer can be disposed on the ceramic body by any suitable method such as, for example, dip coating, spraying, painting, physical vapor deposition, and powder coating. Individual magnetizable abrasive particles can have magnetizable layers with different degrees of coverage and/or locations of coverage. The magnetizable layer can be essentially free of (i.e., containing less than 5 weight percent of, in yet other cases containing less than 1 weight percent of) ceramic abrasive materials used in the ceramic body.

[0046] The magnetizable layer can consist essentially of magnetizable materials (e.g., >99 to 100 percent by weight of vapor coated metals and alloys thereof), or it can contain magnetic particles retained in a binder matrix. The binder matrix of the magnetizable layer, if present, can be inorganic (e.g., vitreous) or organic resin-based, and is typically formed from a respective binder precursor.

[0047] Magnetizable abrasive particles according to the present disclosure can be prepared, for example, by applying a magnetizable layer or precursor thereof to the ceramic body. Magnetizable layers can be provided by physical vapor deposition as discussed hereinbelow. Magnetizable layer precursors can be provided as a dispersion or slurry in a liquid vehicle. The dispersion or slurry vehicle and can be made by simple mixing of its components (e.g., magnetizable particles, optional binder precursor, and liquid vehicle), for example. Exemplary liquid vehicles include water, alcohols (e.g., methanol, ethanol, propanol, butanol, ethylene glycol monomethyl ether), ethers (e.g., glyme, diglyme), and combinations thereof. The dispersion or slurry can contain additional components such as, for example, dispersant, surfactant, mold release agent, colorant, defoamer, and rheology modifier. Typically, after coating onto the ceramic bodies the magnetizable layer precursor is dried to remove most or all of the liquid vehicle, although this is not a requirement. If a curable binder precursor is used, then a curing step (e.g., heating and/or exposure to actinic radiation) generally follows to provide the magnetizable layer.

[0048] Vitreous binder can be produced from a precursor composition comprising a mixture or combination of one or more raw materials that when heated to a high temperature melt and/or fuse to form a vitreous binder matrix. Further disclosure of appropriate vitreous binders that can be used with the abrasive article can be found in United States Provisional Pat. Appl. Ser. Nos. 62/412,402, 62/412,405, 62/412,411, 62/412,416, 62/412,427, 62/412,440, 62/412,459, and 62/412,470.

[0049] In some embodiments, the magnetizable layer can be deposited using a vapor deposition technique such as, for example, physical vapor deposition (PVD) including magnetron sputtering. PVD metallization of various metals, metal oxides and metallic alloys is disclosed in, for example, U. S. Pat. Nos. 4,612,242 (Vesley) and 7,727,931 (Brey et al.). Magnetizable layers can typically be prepared in this general manner, but care should be generally taken to prevent the vapor coating from covering the entire surface of the shaped ceramic body. The can be accomplished by masking a portion of the ceramic body to prevent vapor deposition.

[0050] Examples of metallic materials that can be vapor coated include stainless steels, nickel, cobalt. Exemplary useful magnetizable particles/materials can comprise: iron; cobalt; nickel; various alloys of nickel and iron marketed as Permalloy in various grades; various alloys of iron, nickel and cobalt marketed as Fernico, Kovar, FerNiCo I, or FerNiCo II; various alloys of iron, aluminum, nickel, cobalt, and sometimes also copper and/or titanium marketed as Alnico in various grades; alloys of iron, silicon, and aluminum (typically about 85:9:6 by weight) marketed as Sendust alloy; Heusler alloys (e.g., Cu_2MnSn); manganese bismuthide (also known as Bismanol); rare earth magnetizable materials such as gadolinium, dysprosium, holmium, europium oxide, and alloys of samarium and cobalt (e.g., $SmCo_5$); MnSb; ferrites such as ferrite, magnetite; zinc ferrite; nickel ferrite; cobalt ferrite, magnesium ferrite, barium ferrite, and strontium ferrite; and combinations of the foregoing. In some embodiments, the magnetizable material comprises at least one metal selected from iron, nickel, and cobalt, an alloy of two or more such metals, or an alloy of at one such metal with at least one element selected from phosphorus and manganese. In some embodiments, the magnetizable material is an alloy containing 8 to 12 weight percent (wt. %) aluminum, 15 to 26 wt. % nickel, 5 to 24 wt. % cobalt, up to 6 wt. % copper, up to 1 wt. % titanium, wherein the balance of material to add up to 100 wt. % is iron. Alloys of this type are available under the trade designation "ALNICO".

[0051] Useful abrasive materials that can be used as ceramic bodies include, for example, 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 of St. Paul, Minnesota, black silicon carbide, green silicon carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, cubic boron nitride, garnet, fused alumina zirconia, sol-gel derived ceramics (e.g., alumina ceramics doped with chromia, ceria, zirconia, titania, silica, and/or tin oxide), silica (e.g., quartz, glass beads, glass bubbles and glass fibers), feldspar, or flint. Examples of sol-gel derived crushed ceramic particles 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.).

[0052] As discussed previously, the body of the abrasive particle can be shaped (e.g., precisely-shaped) or random (e.g., crushed). Shaped abrasive particles and precisely-shaped ceramic bodies can be prepared by a molding process using sol-gel technology as described in U. S. Pat. Nos. 5,201,916 (Berg); 5,366,523 (Rowenhorst (Re 35,570)); and 5,984,988 (Berg). U. S. Pat. No. 8,034,137 (Erickson et al.) describes alumina particles that have been formed in a specific shape, then crushed to form shards that retain a portion of their original shape features. In some embodiments, the ceramic bodies are precisely-shaped (i.e., the ceramic bodies have shapes that are at least partially determined by the shapes of cavities in a production tool used to make them).

[0053] Exemplary shapes of ceramic bodies include crushed, pyramids (e.g., 3-, 4-, 5-, or 6-sided pyramids), truncated pyramids (e.g., 3-, 4-, 5-, or 6-sided truncated pyramids), cones, truncated cones, rods (e.g., cylindrical, vermiform), and prisms (e.g., 3-, 4-, 5-, or 6-sided prisms).

[0054] Exemplary magnetizable materials that can be suitable for use in magnetizable particles can comprise: iron; cobalt; nickel; various alloys of nickel and iron marketed as Permalloy in various grades; various alloys of iron, nickel and cobalt marketed as Fernico, Kovar, FerNiCo I, or FerNiCo II; various alloys of iron, aluminum, nickel, cobalt, and sometimes also copper and/or titanium marketed as Alnico in various grades; alloys of iron, silicon, and aluminum (typically about 85:9:6 by weight) marketed as Sendust alloy; Heusler alloys (e.g., Cu_2MnSn); manganese bismuthide (also known as Bismanol); rare earth magnetizable materials such as gadolinium, dysprosium, holmium, europium oxide, alloys of neodymium, iron and boron (e.g., $Nd_2Fe_{14}B$), and alloys of samarium and cobalt (e.g., $SmCo_3$); MnSb;

$MnOFe_2O_3$; $Y_3Fe_3O_{12}$; CrO_2; MnAs; ferrites such as ferrite, magnetite; zinc ferrite; nickel ferrite; cobalt ferrite, magnesium ferrite, barium ferrite, and strontium ferrite; yttrium iron garnet; and combinations of the foregoing. In some embodiments, the magnetizable material comprises at least one metal selected from iron, nickel, and cobalt, an alloy of two or more such metals, or an alloy of at one such metal with at least one element selected from phosphorus and manganese. In some embodiments, the magnetizable material is an alloy (e.g., Alnico alloy) containing 8 to 12 weight percent (wt. %) aluminum, 15 to 26 wt. % nickel, 5 to 24 wt. % cobalt, up to 6 wt. % copper, up to 1 wt. % titanium, wherein the balance of material to add up to 100 wt. % is iron.

[0055] The magnetizable abrasive particles can have any size, but can be much smaller than the ceramic bodies as judged by average particle diameter, in yet other cases 4 to 2000 times smaller, in yet other cases 100 to 2000 times smaller, and in yet other cases 500 to 2000 times smaller, although other sizes can also be used. In this embodiment, the magnetizable particles can have a Mohs hardness of 6 or less (e.g., 5 or less, or 4 or less), although this is not a requirement.

[0056] FIG. 2 shows an apparatus 200 for making coated abrasive articles according to one embodiment of the present disclosure. The apparatus 200 includes magnetizable abrasive particles 202 such as those previously illustrated and described. These magnetizable abrasive particles 202 can be removeably disposed within cavities of a distribution tool 204 as will be discussed subsequently. The apparatus 200 can have a first web path 206 guiding the distribution tool 204 through a coated abrasive article maker such that it wraps a portion of an outer circumference of an abrasive particle transfer roller 222. The apparatus 200 can also include, for example, an unwind 210, a make coat delivery system 212, and a make coat applicator 214. These components unwind a backing 216, deliver a make coat resin 218 via a make coat delivery system 212 to the make coat applicator 214 and apply the make coat resin to a first major surface 220 of the backing. Thereafter, the resin coated backing 216 is positioned by an idler roller for application of the abrasive particles 202 to the first major surface 220 coated with the make coat resin 218. A second web path 226 for the resin coated backing 216 guides the resin coated backing through the coated abrasive article maker apparatus such that it is disposed adjacent a portion of the outer circumference of the abrasive particle transfer roller 222 with the resin layer positioned facing the dispensing surface of the distribution tool 204, which can be positioned between the resin coated backing 216 and the outer circumference of the abrasive particle transfer roller 222. Suitable unwinds, make coat delivery systems, make coat resins, coaters and backings are known to those of skill in the art. The make coat delivery system 212 can be a simple pan or reservoir containing the make coat resin or a pumping system with a storage tank and delivery plumbing to translate the make coat resin to the needed location. The backing 216 can be a cloth, paper, film, nonwoven, scrim, or other web substrate. The make coat applicator can be, for example, a coater, a roller coater, a spray system, or a rod coater. Alternatively, a pre-coated coated backing can be positioned by the idler roller 224 for application of the abrasive particles to the first major surface.

[0057] As shown in the enlargement of FIG. 2A, the distribution tool 204 can include a plurality of cavities 230 having a complimentary shape to the intended magnetizable abrasive particle 202 to be contained therein.

[0058] As shown in FIG. 2, an abrasive particle feeder 232 can supply at least some abrasive particles to the distribution tool 204. The abrasive particle feeder 232 can supply an excess of magnetizable abrasive particles 202 such that there are more abrasive particles present per unit length of the distribution tool 204 in the machine direction than cavities 230 (FIG. 2A) present. Supplying an excess of abrasive particles helps to ensure a majority to all of the cavities 230 within the distribution tool 204 are eventually filled with the magnetizable abrasive particles 202. The abrasive particle feeder 232 can be the same width as the distribution tool 204 and supplies the magnetizable abrasive particles 202 across the entire width of the distribution tool 204. The abrasive particle feeder 232 can be, for example, a vibratory feeder, a hopper, a chute, a silo, a drop coater, or a screw feeder.

[0059] Optionally, a filling assist member 234 can be provided after the abrasive particle feeder 232 to move the magnetizable abrasive particles 202 around on the surface of the distribution tool 204 and to help orientate or slide the abrasive particles into the cavities 230 (FIG. 2A). The filling assist member 234 can be, for example, a doctor blade, a felt wiper, a brush having a plurality of bristles, a vibration system, a blower or air knife, a vacuum box 236, one or more magnets or combinations thereof. The filling assist member 234 moves, translates, sucks, or agitates the magnetizable abrasive particles on the dispensing surface 238 (outside or outer facing surface of the distribution tool 204 in Fig. 2A) to place more magnetizable abrasive particles into the cavities.

[0060] The vacuum box 236, if in conjunction with the distribution tool 204 can communicate with cavities 230 as will be further illustrated and described in reference to FIG. 3. This can be accomplished by passages extending through the distribution tool 204.

[0061] Further details regarding various additional elements and sub-assemblies that can be used with the apparatus 200 and the distribution tool 204 described herein can be found in PCT International Publ. Nos. WO2015/100020, WO2015/100220 and WO201510001 8.

[0062] FIG. 2A shows the distribution tool 204 having a carrier member 203 designed to carry the magnetizable abrasive particles 202. The distribution tool 204 with the magnetizable abrasive particles 202 can pass closely adjacent the backing 216 but are spaced therefrom by at least a gap G. The gap G comprises a minimum spacing between the dispensing surface 238 of the distribution tool 204 and the backing 216. According to some embodiments, the gap G can be at least as large as a maximum dimension of the magnetizable abrasive particles 202. According to further embodiments, the gap G can be at least twice a maximum dimension of the magnetizable abrasive particles 202. According to yet further embodiments, the gap G can be at least three times as large a maximum dimension of the magnetizable abrasive particles 202. According to one embodiment, the gap G can be between 0.254 mm and 25.4 mm (between 0.010 inches and 1.0 inches) in extent as measured from a closest most point of the distribution tool 204 to the first major surface 220 of the backing 216.

[0063] The apparatus 200 as shown in FIG. 2A includes a magnet (a permanent or electromagnet) 250 disposed adjacent to the carrier member 203 and the backing 216. More particularly, the magnet 250 can be positioned below the backing 216 such that the backing 216 and a gap G space the magnet 250 from the dispensing surface 238 of the carrier member 203. Thus, the magnet 250 is spaced from the magnetizable abrasive particles 202 by a distance comprising at least the gap G and the backing 216. In some cases, the magnet 250 (such as illustrated in FIG. 2A) can interface with a second major surface 256 of the backing 216. The second major surface 256 can be opposed by the first major surface 220 that receives the magnetizable abrasive particles 202 upon transfer. The magnet 250 can be disposed to be relatively nearer the second major surface 256 than the first major surface 220 according to some embodiments. In further embodiments, the magnet 250 can be disposed relatively nearer to the first major surface 220 of the backing 216 than the distribution tool 204. The magnet 250 exerts a first magnetic force (illustrated as F1) on the magnetizable abrasive particles 202 during at least a portion of the magnetizable abrasive particles 202 travel around the roller 222 when at least some of the magnetizable abrasive particles 202 become partially or totally inverted relative to the force of gravity and/or the backing 216.

[0064] For the purposes of this disclosure, the first magnetic force F1 can optionally be used to facilitate or influence a transfer of the magnetizable abrasive particles from the cavities 230 of the distribution tool 204 to the backing 216. The first magnetic force F1 can be substantially uniform over the magnetizable abrasive particles 202 in the distribution tool 204, or it can be uneven, or even effectively separated into discrete sections. The orientation of the first magnetic force F1 is configured to influence the transfer of the magnetizable abrasive particles 202 from the distribution tool 204 to the backing 216 to achieve at least one of the predetermined orientation and alignment of the magnetizable abrasive particles 202 on the first major surface 220 of the backing 216.

[0065] In the embodiment of FIG. 2A, the magnetic force F1 acts on the magnetizable abrasive particles 202 in substantially a same direction as a gravitational field and together the magnetic field and the gravitational field urge the magnetizable abrasive particles from the cavities 230 of the distribution tool 204 and influence a passage of the magnetizable abrasive particles 204 through the gap G to the first major surface 220 of the backing 216. Thus, in the embodiment of FIG. 2A, the lines of force of the magnetic force F1 are substantially perpendicular to the backing 216 in a region comprising the gap G between the backing 216 and the distribution tool 204.

[0066] Examples of magnetic field configurations and apparatuses for generating them are described in U.S. Patent Application. Publication. Nos. 2008/0289262 A1 (Gao) and U. S. Pat. Nos. 2,370,636 (Carlton), 2,857,879 (Johnson), 3,625,666 (James), 4,008,055 (Phaal), 5,181,939 (Neff), and British Pat. No. (G. B.) 1 477 767 (Edenville Engineering Works Limited).

[0067] In some embodiments, a second element 252 (e.g, a permanent magnet, an electromagnet, a vacuum) acting with a force (indicated as F2) can be used to retain the magnetizable abrasive particles 202 within the cavities 230 for at least a portion of the travel around the roller 222 when at least some of the magnetizable abrasive particles 202 become inverted become partially or totally inverted relative to the force of gravity and/or the backing 216. In such inverted position, the earth's gravitational field would to attempt to remove the magnetizable abrasive particles 202 from the cavities 230. According to some embodiments, if a magnet is used as second element 252 to apply a second magnet field, rather than having a second magnet, the first magnet 250 can have a second portion with a second polarity designed to retain the magnetizable abrasive particles 202 within the cavities 230. According to other embodiments, if a vacuum is used as second element 252 to apply the force F2, the vacuum would be used to retain at least some of the magnetizable abrasive particles 202 within the cavities 230.

[0068] According to some embodiments, the force F2 that retains the magnetizable abrasive particles 202 in the cavities 230 can be selectively removed or changed prior to or simultaneous with transfer of the magnetizable abrasive particles 202 from the plurality of cavities 230. Removal of the force F2 can occur by removing power to the second element 252 (e.g., if the second element 252 comprises an electromagnet) or by positioning or configuring the second element 252 such that the strength of the force F2 is substantially reduced toward zero prior to reaching the region where force F1 has an influence. In other embodiments, the second force F2 can be changed in orientation (e.g., reversed in polarity, reduced in strength to a point where the gravitational force G exceeds the force F2 applied on the magnetizable abrasive particles 202) rather than being removed.

[0069] The backing 216 can have a make layer precursor (i.e., the binder precursor for the make layer) coated therein. As desired the magnetizable abrasive particle 202 can maintain a vertical or somewhat inclined orientation relative to the horizontal backing 216. For example, a majority of the magnetizable abrasive particles 202 can have a major planar surface (previously discussed and illustrated with regard to FIG. 1) disposed at an angle of at least 70 degrees relative to the first major surface 220 of the backing 216 upon transfer to the backing 216. After at least partially curing the make layer precursor, the magnetizable abrasive particles 202 are fixed in their placement and orientation. In some embodiments, a size layer precursor can be disposed on at least a portion of the at least partially cured make layer precursor. The size layer precursor can be at least partially cured. An analogous process can be used for manufacture of slurry coated abrasive articles, except that the magnetic field acts on the magnetizable particles within the slurry. The above processes can also be carried out on nonwoven backings to make nonwoven abrasive articles.

[0070] FIG. 3 shows another embodiment comprising an abrasive article positioning system 300. The system 300 can include aspects of the apparatus 200 previously described and can include magnetizable abrasive particles 302, a distribution tool 304, a backing 316 and a magnet 350.

[0071] FIG. 3 shows the distribution tool 304 in a cross-web direction in a completely noninverted position relative to the backing 316 and gravitational force F3. The magnetizable abrasive particles 302 are illustrated just prior to transfer to the backing 316.

[0072] In the embodiment of FIG. 3, the distribution tool 304 can comprise a carrier member 328 having shaped cavities 330 that open to a dispensing surface 332 of the carrier member 328. The cavities 330 can be shaped to match a shape of the magnetizable abrasive particles 302. According to some examples, the carrier member 328 comprises a polymer and is flexible.

[0073] In FIG. 3, the gravitational force F3 aids in retaining the magnetizable abrasive particles 302 within the cavities 330 of the distribution tool 304. As shown in the embodiment of FIG. 3, a magnetic force F4 generated by the magnet 350 acts on the magnetizable abrasive particles 302 in a substantially opposing direction as the gravitational force F3. The magnetic force F4 acts to overcome the gravitational force F3 to urge the magnetizable abrasive particles 302 from the distribution tool 304 and influence a passage of the magnetizable abrasive particles 302 through the gap G to the first major surface 354 of the backing 316.

[0074] It should be understood that in other embodiments, the orientation of components shown in FIG. 3 can be reversed such that the magnetic force generated by the magnet acts on the magnetizable abrasive particles in a substantially a same direction as the gravitational force F3.

[0075] The magnet 350 (a permanent or electromagnet) can be part of the distribution tool 304 and system 300 but may be spaced from the carrier member 328, the cavities 330 and the dispensing surface 332 as illustrated in FIG. 3. The magnet 350 can apply a magnetic force (indicated by F4) to remove the magnetizable abrasive particles 302 from the cavities 330 as previously described.

[0076] FIG. 4 shows a portion of a distribution tool 404 in both cross-web and down-web directions with exemplary magnetizable abrasive particles 402 disposed adjacent thereto. A magnet (not shown) (permanent or electromagnet) can be disposed adjacent to the distribution tool 404 to apply a magnetic field to the magnetizable abrasive particles 402.

[0077] According to the embodiment of FIG. 4, the distribution tool 404 comprises carrier member 428 having a dispensing surface 432 and a back surface 434. The carrier member 428 can define cavities 430 that are open to the dispensing surface 432. More particularly, the cavities 430 extend into carrier member 428 from cavity openings 436 at the dispensing surface 432. Optionally, a compressible resilient layer 438 is secured to back surface 434. The cavities 430 can be disposed in an array 340 or pattern.

[0078] Typically, the cavity openings 436 of the carrier member 428 can be rectangular; however, this is not a requirement. The length, width, and depth of the cavities 420 in the carrier member 428 will generally be determined at least in part by the shape and size of the magnetizable abrasive particles 402 with which they are to be used. For example, if the magnetizable abrasive particles 402 are shaped as equilateral trigonal platelets, then the lengths of individual cavities should be from 1.1 - 1.2 times the maximum length of a side of the magnetizable abrasive particles 402, the widths of individual cavities 430 are from 1.1 - 2.5 times the thickness of the magnetizable abrasive particles 402, and the respective depths of the cavities 430 are 1.0 to 1.2 times the width of the magnetizable abrasive particles 402 if the magnetizable abrasive particles 402 are to be contained within the cavities 430 .

[0079] Alternatively, for example, if the magnetizable abrasive particles 402 are shaped as equilateral trigonal plates, then the lengths of individual cavities 430 could be less than that of an edge of the magnetizable abrasive particles 402, and/or the respective depths of the cavities 430 could be less than that of the width of the magnetizable abrasive particles 402 if the magnetizable abrasive particles 402 are to protrude from the cavities 430. Similarly, the width of the cavities 430 could be selected such that a single magnetizable abrasive particle 402 fits within each one of the cavities 430.

[0080] Suitable carrier members 428 may be rigid or flexible, but are sufficiently flexible to permit use of normal web handling devices such as rollers. According to some embodiments, the carrier member 428 comprises metal and/or organic polymer. Such organic polymers are moldable, have low cost, and are reasonably durable when used in the abrasive particle deposition process of the present disclosure.

[0081] The distribution tool 404 can be in the form of, for example, an endless belt (e.g., endless belt as shown in FIG. 2), a sheet, a continuous sheet or web, a coating roll, a sleeve mounted on a coating roller, or die. If the distribution tool 404 is in the form of a belt, sheet, web, or sleeve, it will have a contacting surface and a non-contacting surface. It should be understood with any of the disclosed embodiments that one of the backing and the distribution tool can be moved relative to the other of the backing and distribution tool. For example, the distribution tool 404 can utilize a belt and the backing can move relative to the belt (i.e. at a higher or lower rate of speed). According to other embodiments, the distribution tool may be stator and the backing can move relative to the distribution tool. In yet further embodiments, the distribution tool can move while the backing can remain stator. The apparatuses and systems described can be part of a method of making an abrasive article, in particular, the method can be that of a continuous process or a batch process.

[0082] The topography of the abrasive article formed by the method will have the inverse of the pattern of the contacting surface of the production tool. The pattern of the contacting surface of the production tool will generally be characterized by a plurality of cavities or recesses. The opening of these cavities can have any shape, regular or irregular, such as, for example, a rectangle, semicircle, circle, triangle, square, hexagon, or octagon. The walls of the cavities can be vertical or tapered. The pattern formed by the cavities can be arranged according to a specified plan or can be random.

[0083] FIG. 5 shows an apparatus 500 that includes a distribution tool 504 according to another embodiment. The magnetizable abrasive particles 502 (a size of which is exaggerated in FIG. 5 for ease of understanding) are applied to a first major surface 554 of a backing 516 by the distribution tool 504 that otherwise distributes the abrasive particles 502 from a source as described below. After application of the magnetizable abrasive particles 502, the backing 516 exits the distribution tool 504. The magnetizable abrasive particles 502 can optionally be subjected to further processing (e.g., application of a size coat, application of additional abrasive particles by conventional means (e.g., e-coat), application of a grinding aid, application of a supersize coat, curing, cutting, etc.) to produce a final abrasive article, such as a coated abrasive article as has previously been discussed herein.

[0084] The distribution tool 504 is configured to impart at least one of a predetermined orientation and alignment of at least a majority of the magnetizable abrasive particles 502 as applied to and subsequently bonded to the first major face 554 of the backing 516. With this in mind, the distribution tool 504 is shown in simplified form in FIG. 5. **In** general terms, the distribution tool 504 can have any a shape, not just the rectangular shape illustrated. The distribution tool 504 has a plurality of walls 506 that are generally transversely oriented relative to the first major surface 554 of the backing 516. The plurality of walls 506 define a plurality of slots 508 therebetween. The slots 508 are each open to a dispensing surface 510 of the distribution tool 504 interfacing with the backing 516 but spaced therefrom by a gap G.

[0085] The distribution tool 504 can have or define a feed surface 512 such as a central bore in some embodiments. The feed surface 512 can comprise a plurality of interior surfaces that can be configured to receive the magnetizable abrasive particles 502 as a feed. Each of the slots 508 are also open to the central portion. The distribution tool 504 is configured to distribute the magnetizable abrasive particles from the feed surface 512 to the dispensing surface 510 thereof in a manner that imparts at least one of an orientation, spacing and alignment of the magnetizable abrasive particles 502. For example, the slots 508 extend in a cross-web as well as a down-web direction and each have a substantially similar width W_S (e.g., the width W_S of the slots 508 can vary from one another by no more than 10%) that is selected in accordance with expected nominal dimensions of the magnetizable abrasive particles 502 so as to bias the magnetizable abrasive particles 502 to at least one of the predetermined orientation and alignment at the dispensing surface 510.

[0086] In the embodiment of FIG. 5, the walls 506 are elongated, substantially planar (e.g., within 10% of a truly planar construction) bodies formed of a relatively rigid material (e.g., metal, plastic, ceramic, etc.). The walls 506 can be maintained relative to one another in various fashions. The length Ls of each of the slots 508 is selected in accordance with expected nominal dimensions of the magnetizable abrasive particles 502 with which the distribution tool 504 will be used, including the slot length Ls being sufficient to simultaneously receive a multiplicity of the magnetizable abrasive particles 502 as illustrated. A depth of each slot 508 as defined by a depth of each wall 506 as well as the other dimensions that define the width W_S and the length Ls is selected in accordance with expected nominal dimensions of the magnetizable abrasive particles 502. In some embodiments, the dimensions of each slot 508 may not be substantially identical as illustrated but can be varied as desired.

[0087] Similar to the embodiments previously described, the apparatus 500 as shown in FIG. 5 includes a magnet (a permanent or electromagnet) 550 disposed adjacent to the distribution tool 504 and the backing 516. More particularly, the magnet 550 can be positioned below the backing 516 such that the backing 516 and the gap G space the magnet 550 from the dispensing surface 510. Thus, the magnet 550 is spaced from the magnetizable abrasive particles 502 by a distance comprising at least the gap G and the backing 516. In some cases, the magnet 550 can interface with a second major surface 556 of the backing 516. The second major surface 556 can be opposed by the first major surface 554 that receives the magnetizable abrasive particles 502 upon transfer. The magnet 550 can be disposed to be relatively nearer the second major surface 556 than the first major surface 554 according to some embodiments. In further embodiments, the magnet 550 can be disposed relatively nearer to the first major surface 554 of the backing 516 than the distribution tool 504. The magnet 550 exerts a first magnetic force (illustrated as F1) on the magnetizable abrasive particles 502 during at least a portion of the fall of the magnetizable abrasive particles 502 through at least a portion the gap G to the first major surface 554. According to some embodiments, the first magnetic force F1 is also exerted on the magnetizable abrasive particles 502 as the magnetizable abrasive particles 502 fall through at least a portion of the length L_S the slots 508.

[0088] For the purposes of this disclosure, the first magnetic force F1 can optionally be used to facilitate or influence a transfer of the magnetizable abrasive particles 502 from the slots 508 of the distribution tool 504 to the backing 516. The first magnetic force F1 can be substantially uniform over the magnetizable abrasive particles 502 in the distribution tool 504, or it can be uneven, or even effectively separated into discrete sections. The orientation of the first magnetic force F1 is configured to influence the transfer of the magnetizable abrasive particles 502 from the distribution tool 504 to the backing 516 to achieve at least one of the predetermined orientation and alignment of the magnetizable abrasive particles 502 on the first major surface 554 of the backing 516.

[0089] In the embodiment of FIG. 5,the slots 508 generally align with earth's gravitational field the magnetic force F1 acts on the magnetizable abrasive particles 502 in substantially a same direction as the gravitational field and together the magnetic field and the gravitational field urge the magnetizable abrasive particles from the slots 508 of the distribution tool 504 and influence a passage of the magnetizable abrasive particles 504 through the gap G to the first major surface 554 of the backing 516. Thus, in the embodiment of FIG. 5, the lines of force of the magnetic force F1 are substantially perpendicular to the backing 516 in a region comprising the gap G between the backing 516 and the distribution tool 504.

[0090] However, according to other embodiments, while the slots 508 generally align with the gravitational field and the magnetic field can act on the magnetizable abrasive particles in an opposing direction to the gravitational field. The magnetic field can overcome the gravitational field to urge the magnetizable abrasive particles from the distribution tool through the slots and can influence a passage of the magnetizable abrasive particles through the gap to the first major surface of the backing.

[0091] Similar to the previously described embodiments, the distribution tool 504 can be disclosed closely adjacent the backing 516 but can be spaced therefrom by at least the gap G. The gap G can comprise a minimum spacing between the dispensing surface 510 (an exterior surface) of the distribution tool 504 and the backing 516. According to some embodiments, the gap G can be at least as large as a maximum dimension of the magnetizable abrasive particles 502. According to further embodiments, the gap G can be at least twice a maximum dimension of the magnetizable abrasive particles 502. According to yet further embodiments, the gap G can be at least three times as large a maximum dimension of the magnetizable abrasive particles 502. According to one embodiment, the gap G can be between 0.254 mm and 25.4 mm (0.010 inches and 1.0 inches) in extent as measured from a closest most point of the distribution tool 504 to the first major surface 554 of the backing 516.

[0092] FIGS. 6 and 6A show another example of an apparatus 600 that is constructed and operates in a manner similar to the apparatus 500 of FIG. 5. The apparatus 600 includes a distribution tool 604 that has circumferentially extending slots 608 therein defined by spaced walls 606 (FIG. 6A). The distribution tool 604 can be spaced from a backing 616 by a gap G (FIG. 6) as previously described.

[0093] The distribution tool 604 has a generally cylindrical shape, for example akin to a hollow right cylinder. The slots 608 are each open to an exterior of the distribution tool 604 as well as to an interior comprising a central bore 610. The distribution tool 604 is configured such that magnetizable abrasive particles 602 will become loaded into certain ones of the slots 608. The number of slots 608 provided with the distribution tool 604 can selected as a function of the desired slot width and a dimension (e.g., cross-web width) of the backing 616 as previously described. In yet other embodiments, the apparatus of any of the embodiments described herein can include two or more of the distribution tools assembled in series or parallel relative to the backing.

[0094] During use, a supply of the abrasive particles 602 is loaded to the distribution tool 604 via a source 614 (FIG. 6). For example, the source 614 can be akin to a mineral dropper having an outlet that extends into the central bore 610. The supply of the magnetizable abrasive particles 602 flows through the outlet and into the central bore 610. Once within the central bore 610, individual ones of the magnetizable abrasive particles 602 will enter a respective one of the slots 608 upon achieving at least one of a predetermined orientation and alignment dictated by dimensions of the slots 608. For example, FIG. 6A is a simplified representation of a portion of the distribution tool 604 with a portion of the distribution tool 604 removed such that the magnetizable abrasive particles 602 in the slots 608 are visible. The magnetizable abrasive particles 602 are spatially oriented so as to enter the slots 608 in one orientation (i.e. with a non-major surface interfacing with the slots 608). Such orientation with a major surface interfacing with the slots 608 and interior of the walls 606 prevents entry of the magnetizable abrasive particles 602 into the slots 608.

[0095] By way of example, loading of the supply can include pouring or funneling (e.g., via vibratory feeder, belt driven drop coater, etc.) a large number of the magnetizable abrasive particles 602 on to (or into) the distribution tool 604 under the force of gravity, with individual ones of the so-loaded magnetizable abrasive particles 602 randomly assuming any spatial orientation. With reference between FIGS. 6 and 6A, as the individual abrasive particles 602 repeatedly contact one or more of the interior of the walls 606 (FIG. 6A), baffles or other features, they re-orient and assume a new spatial orientation, eventually becoming generally aligned with and assuming a spatial orientation appropriate for entering one of the slots 608. In this regard, as the supply of the magnetizable abrasive particles 602 flows into the distribution tool 504, the distribution tool 604 can be rotated as shown in FIG. 6 by arrow A. This rotation can cause the magnetizable abrasive particles 602 to mix and/or vibrate around on surfaces of the distribution tool 604 until they obtain a suitable orientation and fall through the slots 608. Regardless, a large number of the magnetizable abrasive particles 602 can be disposed within individual one of the slots 608 at any one point in time.

[0096] As previously described, a magnet 650 (a permanent or electromagnet) can be disposed adjacent to the distribution tool 604 and the backing 616 as illustrated in FIG. 6A. More particularly, the magnet 650 can be positioned below the backing 616 such that the backing 616 and the gap G (FIG. 6) space the magnet 650 from the exterior of the distribution tool 604. Thus, the magnet 650 is spaced from the magnetizable abrasive particles 602 by a distance comprising at least the gap G and the backing 616. **In** some cases, the magnet 650 can interface with a second major surface 656 (FIG. 6A) of the backing 616. The second major surface 656 can be opposed by the first major surface 654 that receives the magnetizable abrasive particles 602 upon transfer. The magnet 650 can be disposed to be relatively nearer the second major surface 656 than the first major surface 654 according to some embodiments. In further embodiments, the magnet 650 can be disposed relatively nearer to the first major surface 654 of the backing 616 than the distribution tool 604. The magnet 650 exerts a first magnetic force (illustrated as F1) on the magnetizable abrasive particles 602 during at least a portion of the fall of the magnetizable abrasive particles 602 through at least a portion the gap G to the first major surface 654. According to some embodiments, the first magnetic force F1 is also exerted on the magnetizable abrasive particles 602 as the magnetizable abrasive particles 602 fall through at least a portion of the length of the slots 608.

[0097] Further distribution tools that can be used with the magnetizable abrasive particles disclosed herein can be found in WO 2017/007714, WO2017/007703, WO2016/ 201 5267.

[0098] Abrasive articles according to the present disclosure are useful for abrading a workpiece. Methods of abrading range from snagging (i.e., high pressure high stock removal) to polishing (e.g., polishing medical implants with coated abrasive belts), wherein the latter is typically done with finer grades of abrasive particles. One such method includes the step of frictionally contacting an abrasive article with a surface of the workpiece, and moving at least one of the abrasive article or the workpiece relative to the other to abrade at least a portion of the surface.

[0099] Examples of workpiece materials include metal, metal alloys, exotic metal alloys, ceramics, glass, wood, wood-like materials, composites, painted surfaces, plastics, reinforced plastics, stone, and/or combinations thereof. The workpiece may be flat or have a shape or contour associated with it. Exemplary workpieces include metal components, plastic components, particleboard, camshafts, crankshafts, furniture, and turbine blades. The applied force during abrading typically ranges from about 1 kilogram to about 100 kilograms.

[0100] Abrasive articles according to the present disclosure may be used by hand and/or used in combination with a machine. At least one of the abrasive article and the workpiece is moved relative to the other when abrading. Abrading may be conducted under wet or dry conditions. Exemplary liquids for wet abrading include water, water containing conventional rust inhibiting compounds, lubricant, oil, soap, and cutting fluid. The liquid may also contain defoamers, degreasers, for example.

[0101] The following embodiments are intended to be illustrative of the present disclosure and not limiting.

TABLE 1

ABBREVIATION	DESCRIPTION
PR	Resole phenolic resin, a 1.5:1 to 2.1:1 (phenol:formaldehyde) condensate catalyzed by 2.5% potassium hydroxide, obtained as GP 8339 R-23155B from Georgia Pacific Chemicals, Atlanta, Georgia.
PME	Propylene glycol methyl ether, obtained as "DOWANOL PM" from DOW Chemical Company, Midland, Michigan.
SAP	Shaped abrasive particles were prepared according to the disclosure of U. S. Pat. No. 8,142,531 (Adefris et al). The shaped abrasive particles were prepared by molding alumina sol gel in equilateral triangle-shaped polypropylene mold cavities. After drying and firing, the resulting shaped abrasive particles were about 1.4 mm (side length) × 0.35 mm (thickness), with a draft angle approximately 98 degrees.
TOOL	A tooling having vertically-oriented triangular cavities generally described in patent publication WO2015/100220 and configured as shown in Figures 3A-3C in WO2015/100220, wherein length = 1.875 mm, width = 0.785 mm, depth = 1.62 mm, bottom width = 0.328 mm) arranged in a rectangular array (length-wise pitch = 1.978 mm, width-wise pitch = 0.886 mm) with all long dimensions in the same direction.

Preparation of Magnetizable Abrasive Particles

[0102] SAP was coated with 304 stainless steel using physical vapor deposition with magnetron sputtering. 304 Stainless steel sputter target, described by Barbee et al. in Thin Solid Films, 1979, vol. 63, pp. 143-150, deposited as the magnetic ferritic body centered cubic form. The apparatus used for the preparation of 304 stainless steel film coated abrasive particles (i.e., magnetizable abrasive particles) was disclosed in U. S. Pat. No. 8,698,394 (McCutcheon et al.). The physical vapor deposition was carried out for 4 hours at 1.0 kilowatt at an argon sputtering gas pressure of 10 millitorr (1.33 pascal) onto 51.94 grams of SAP. The density of the coated SAP was 4.0422 grams per cubic centimeter. The weight percentage of metal coating in the coated SAP was approximately 2% and the coating thickness is 1.5 micrometers.

EXAMPLE 1

[0103] A section of cloth backing obtained as ERATEX QUALITY N859 P39 YB1700 from Gustav Ernstmeier GmbH & Co. KG, Herford, Germany, was coated with 209.2 g/m^2 of a phenolic make resin consisting of 49.2 parts of PR, 40.6 parts of calcium metasilicate (obtained as WOLLASTOCOAT from NYCO Company, Willsboro, NY), and 10.2 parts of water. A brush was used to apply the resin.

[0104] A section of TOOL1 was filled with the coated SAP particles by placing 50 grams of coated SAP on top of TOOL1 and then shaking and tapping the tooling to allow the particles to fill the cavities as shown in Figure 7. Excess particles were removed with a gentle stream of air directed across the surface. A section of cloth backing obtained as ERATEX QUALITY N859 P39 YB1700 from Gustav Ernstmeier GmbH & Co. KG, Herford, Germany, was coated with 62.8 g/m^2 of PR using a brush to apply. The coated backing was adhered with double sided tapes onto top of North side of a 4 inches (10.16 cm) × 2 inches (5.08 cm) × 1 inch (2.54 cm) Neodymium magnet (Grade N42), which was magnetized through the 1-inch thickness. Two 75 mil (1.905 mm) shims were placed on top of the backing with a gap of about 0.5 inch (1.27 cm) between them. The filled tooling was set on top of the shims with the vacuum source still engaged and with the cavity openings facing the gap. The setup has been generally shown and described previously in regards to the embodiments of FIGS. 2-4. Then the vacuum source was turned off, the particles came out of the tooling in between the two shims, falling through the gap, and adhered onto the coated backing.

[0105] The resulting coated abrasive article had 97% of abrasive particles retaining the intended orientation and most retained an alignment in the cutting direction. A representative image of the coated abrasive article is shown in FIG. 8.

COMPARATIVE EXAMPLE A

[0106] The procedure generally described in EXAMPLE 1 was repeated, with the exception that the procedure was carried out without ever being subjected to the magnetic field (i.e. no magnet was used). The resulting coated abrasive article had only 60% of particles remaining upright and oriented in the cutting direction. A representative image of the coated abrasive article is shown in FIG. 9.

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.

EXAMPLE 2

[0107] SAP2 was coated with 304 stainless steel using physical vapor deposition with magnetron sputtering. 304 Stainless steel sputter target, described by Barbee et al. in Thin Solid Films, 1979, vol. 63, pp. 143-150, deposited as the magnetic ferritic body centered cubic form. The apparatus used for the preparation of 304 stainless steel film coated abrasive particles (i.e., magnetizable abrasive particles) was disclosed in U. S. Pat. No. 8,698,394 (McCutcheon et al.). The physical vapor deposition was carried out for 4 hours at 1.0 kilowatt at an argon sputtering gas pressure of 10 millitorr (1.33 pascal) onto 51.94 grams of SAP. The density of the coated SAP was 4.0422 grams per cubic centimeter. The weight percentage of metal coating in the coated SAP was approximately 2% and the coating thickness is 1.5 micrometers.

[0108] A tooling containing multiple plastic shims, generally described in U. S. patent application filing number 62/182077 (attorney docket No. 76715US002), was generated by 3D printing. The tooling had dimensions of 1.5 inches (3.81 cm) × 1 inch (2.54 cm) × 0.5 inch (1.27 cm). Each shim was 0.020-inch (0.51-mm) thick, 1-inch (2.54-cm) high, and the gap between each shim was 0.051 inch (1.3 mm). Design images of the shims and the tooling has been described previously in regards to the slot examples of FIGS. 5-6A.

[0109] A cloth backing obtained as ERATEX QUALITY N859 P39 YB1700 from Gustav Ernstmeier GmbH & Co. KG, Herford, Germany, was coated with 62.8 g/m^2 of PR using a brush to apply. The coated backing was placed on top of a 6 inches (15.24 cm) × 3 inches (7.62 cm) surface of a 6 inches (15.24 cm) × 3 inches (7.62 cm) × 0.5 inch (1.27 cm) Neodymium magnet (Grade N42), which was magnetized through the 0.5-inch thickness. The tooling was spaced at 0.350 inch (8.9 mm) above the coated backing. The backing was moved along the length of the backing at a 1 foot (30.48 cm) per minute while particles were dropped on the top surface of the tooling. The particles oriented themselves to fall through the gaps in the tooling and then dropped onto the coated backing. A representative photo of the resulting coated abrasive article is shown in Figure 10. A majority of the abrasive particles oriented upwards on the coated backing.

COMPARATIVE EXAMPLE B

[0110] The procedure generally described in EXAMPLE 2 was repeated, with the exception that no magnet was used (i.e. the procedure was carried out without ever being subjected to the magnetic field).

[0111] A representative photo of the resulting coated abrasive article is shown in Figure 11. A majority of the abrasive particles laid flat on the coated backing.

Claims

1. A method of making a coated abrasive article, the method comprising:

   providing dispensable magnetizable abrasive particles (202) and a distribution tool (204), wherein the distribution tool (204) is configured to receive the magnetizable abrasive particles (202) therein, and wherein the distribution tool (204) comprises a plurality of cavities configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles (202);
   dispensing the magnetizable abrasive particles into the cavities of the distribution tool and applying a force F2 to retain the magnetizable abrasive particles within the cavities;
   inverting the distribution tool such that the force F2 retains at least some of the magnetizable abrasive particles against the force of gravity;
   positioning (i) a backing (216) adjacent to the distribution tool (204) and spaced therefrom by a gap (G), wherein the gap (G) is at least as large as a maximum dimension of the magnetizeable abrasive particles (202); and (ii) a magnet (250) below the backing;
   using the magnet (250), applying a magnetic field to at least the backing (216) and a portion of the gap (G) between the backing (216) and the distribution tool (204) to exert a first magnetic force F1 on the magnetizable abrasive particles to influence transfer of the magnetizable abrasive particles from the cavities (230) of the distribution tool (204) to the backing (216); and
   removing or changing the force F2 prior to or simultaneous with transfer of the magnetizable abrasive particles (202) from the plurality of cavities (230);
   transferring the magnetizable abrasive particles (202) from the distribution tool (204) to a first major surface (220) of the backing (216), wherein the magnetic field is applied during the transfer of the magnetizable abrasive particles (202).

2. The method of claim 1, wherein the distribution tool (204) is configured to provide a predetermined pattern to the magnetizable abrasive particles (202).

3. The method of any one of claims 1-2, wherein one of the backing (216) and distribution tool (204) is moved relative to the other of the backing (216) and distribution tool (204), and the method is part of a continuous process.

4. The method of any one of claims 1-3, wherein the distribution tool (204) has an exterior dispensing surface (238) with cavities (230) therein, and wherein each of the cavities (230) is shaped to receive at least part of one of the magnetizable abrasive particles (202) therein.

5. The method of claim 4, wherein the force F2 is applied by a vacuum.

6. The method of any one of claims 1-5, further comprising:

   at least partially curing a make layer precursor disposed on the backing (216);
   disposing a size layer precursor on at least a portion of the at least partially cured make layer precursor; and
   at least partially curing the size layer precursor.

7. The method of any one of claims 1-6, wherein the magnetic field acts on the magnetizable abrasive particles (202) in substantially a same direction as a gravitational field and together the magnetic field and the gravitational field urge the magnetizable abrasive particles (202) from the distribution tool (204) and influence a passage of the magnetizable abrasive particles (202) through the gap (G) to the first major surface (220) of the backing (216).

8. The method of any one of claims 1-7, wherein the gap (G) is between 0.254 mm and 25.4 mm (between 0.010 inches and 1.0 inches)

in extent as measured from a closest most point of the distribution tool (204) to the first major surface (220) of the backing (216).

9. The method of any one of claims 1-8, wherein a majority of the magnetizable abrasive particles (202) have a major planar surface disposed at an angle of at least 70 degrees relative to the first major surface (220) of the backing (216) upon transfer to the backing (216).

10. An abrasive particle positioning system comprising:

a distribution tool (204) configured to impart at least one of a predetermined orientation and alignment of the magnetizable abrasive particles (202), the distribution tool (204) comprising:
a carrier member (203) having an inverted dispensing surface (238) and a back surface opposite the dispensing surface, wherein the carrier member (203) has cavities (230) formed therein, wherein the cavities (230) extend into the carrier member (203) from the dispensing surface (238) toward the back surface;
magnetizable abrasive particles (202) removably disposed within at least some of the cavities (230) and retained within the cavities against the force of gravity by a force F2, wherein the force F2 is configured to be removed or changed prior to or simultaneous with transfer of the magnetizable abrasive particles 202 from the plurality of cavities (230);
a backing (216) disposed adjacent to the distribution tool (204) and spaced therefrom by a gap (G), wherein the gap (G) is at least as large as a maximum dimension of the magnetizeable abrasive particles (202), the backing (216) having a first major surface (220) facing the distribution tool (204) and a second major surface (256) opposing the first major surface (220); and
a magnet (250) disposed below the backing (216) and facing the second major surface (256) of the backing (216), the magnet (250) applying a magnetic field to exert a first magnetic force F1 on the magnetizable abrasive particles to influence a transfer of the magnetizable abrasive particles (202) from the distribution tool (204) to the backing (216) to aid in achieving at least one of a predetermined orientation and alignment of the magnetizable abrasive particles (202) on a first major surface (220) of the backing (216).

11. The abrasive particle positioning system of claim 10, wherein the carrier member (203) comprises a polymer and is flexible.

12. The abrasive particle positioning system of any one of claims 10-11, wherein the distribution tool (204) comprises an endless belt.

Patentansprüche

1. Ein Verfahren zum Herstellen eines beschichteten Schleifgegenstands, das Verfahren aufweisend:

Bereitstellen von abgebbaren magnetisierbaren Schleifteilchen (202) und eines Verteilungswerkzeugs (204), wobei das Verteilungswerkzeug (204) konfiguriert ist, um die magnetisierbaren Schleifteilchen (202) darin aufzunehmen, und wobei das Verteilungswerkzeug (204) eine Mehrzahl von Hohlräumen aufweist, die konfiguriert sind, um den magnetisierbaren Schleifteilchen (202) mindestens eines von einer vorab festgelegten Orientierung und Ausrichtung zu geben;
Abgeben der magnetisierbaren Schleifteilchen in die Hohlräume des Verteilungswerkzeugs und Anlegen einer Kraft F2, um die magnetisierbaren Schleifteilchen innerhalb der Hohlräume zurückzuhalten;
Invertieren des Verteilungswerkzeugs derart, dass die Kraft F2 mindestens einige der magnetisierbaren Schleifteilchen entgegen der Schwerkraft zurückhält;
Positionieren (i) einer Unterlage (216) neben dem Verteilungswerkzeug (204) und davon beabstandet durch einen Spalt (G), wobei der Spalt (G) mindestens so groß wie eine maximale Abmessung der magnetisierbaren Schleifteilchen (202) ist; und (ii) eines Magneten (250) unterhalb der Unterlage;
unter Verwendung des Magneten (250), Anlegen eines Magnetfelds an mindestens die Unterlage (216) und einen Abschnitt des Spalts (G) zwischen der Unterlage (216) und dem Verteilungswerkzeug (204), um eine erste magnetische Kraft F1 auf die magnetisierbaren Schleifteilchen auszuüben, um eine Übertragung der magnetisierbaren Schleifteilchen aus den Hohlräumen (230) des Verteilungswerkzeugs (204) auf die Unterlage (216) zu beeinflussen; und
Entfernen oder Ändern der Kraft F2 vor oder gleichzeitig mit der Übertragung der magnetisierbaren Schleifteilchen (202) aus der Mehrzahl von Hohlräumen (230);

Übertragen der magnetisierbaren Schleifteilchen (202) aus dem Verteilungswerkzeug (204) auf eine erste Hauptoberfläche (220) der Unterlage (216), wobei während der Übertragung der magnetisierbaren Schleifteilchen (202) das Magnetfeld angelegt wird.

2. Das Verfahren nach Anspruch 1, wobei das Verteilungswerkzeug (204) konfiguriert ist, den magnetisierbaren Schleifteilchen (202) ein vorab festgelegtes Muster zu geben.

3. Das Verfahren nach einem der Ansprüche 1 bis 2, wobei eines der Unterlage (216) und des Verteilungswerkzeugs (204) relativ zu dem anderen der Unterlage (216) und des Verteilungswerkzeugs (204) bewegt wird und das Verfahren Teil eines kontinuierlichen Prozesses ist.

4. Das Verfahren nach einem der Ansprüche 1 bis 3, wobei das Verteilungswerkzeug (204) eine äußere Abgabeoberfläche (238) mit Hohlräumen (230) darin aufweist und wobei jeder der Hohlräume (230) geformt ist, um mindestens einen Teil eines der magnetisierbaren Schleifteilchen (202) darin aufzunehmen.

5. Verfahren nach Anspruch 4, wobei die Kraft F2 durch ein Vakuum angelegt wird.

6. Das Verfahren nach einem der Ansprüche 1 bis 5, ferner aufweisend:

mindestens teilweises Aushärten eines Grundschichtvorläufers, der auf der Unterlage (216) angeordnet ist;
Anordnen eines Deckschichtvorläufers auf mindestens einem Abschnitt des mindestens teilweise ausgehärteten Grundschichtvorläufers; und
mindestens teilweises Aushärten des Deckschichtvorläufers.

7. Das Verfahren nach einem der Ansprüche 1 bis 6, wobei das Magnetfeld auf die magnetisierbaren Schleifteilchen (202) im Wesentlichen in einer gleichen Richtung wie ein Schwerefeld einwirkt und das Magnetfeld und das Schwerefeld gemeinsam die magnetisierbaren Schleifteilchen (202) aus dem Verteilungswerkzeug (204) drängen und einen Durchgang der magnetisierbaren Schleifteilchen (202) durch den Spalt (G) zu der ersten Hauptoberfläche (220) der Unterlage (216) beeinflussen.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei der Spalt (G) zwischen 0,254 mm und 25,4 mm (zwischen 0,010 Zoll und 1,0 Zoll) in Ausdehnung beträgt, gemessen von einem nächstgelegenen Punkt des Verteilungswerkzeugs (204) zu der ersten Hauptoberfläche (220) der Unterlage (216).

9. Das Verfahren nach einem der Ansprüche 1 bis 8, wobei ein Großteil der magnetisierbaren Schleifteilchen (202) eine planare Hauptoberfläche aufweist, die bei der Übertragung auf die Unterlage (216) in einem Winkel von mindestens 70 Grad relativ zu der ersten Hauptoberfläche (220) der Unterlage (216) angeordnet ist.

10. Ein Schleifteilchenpositionierungssystem, aufweisend:
ein Verteilungswerkzeug (204), das konfiguriert ist, um den magnetisierbaren Schleifteilchen (202) mindestens eines von einer vorab festgelegten Orientierung und Ausrichtung zu geben, das Verteilungswerkzeug (204) aufweisend:

ein Trägerelement (203), das eine invertierte Abgabeoberfläche (238) und eine hintere Oberfläche gegenüberliegend der Abgabeoberfläche aufweist, wobei das Trägerelement (203) Hohlräume (230) aufweist, die darin ausgebildet sind, wobei sich die Hohlräume (230) von der Abgabeoberfläche (238) in Richtung der Rückseite in das Trägerelement (203) hinein erstrecken;
magnetisierbare Schleifteilchen (202), die innerhalb mindestens einiger der Hohlräume (230) entfernbar angeordnet sind und durch eine Kraft F2 gegen die Schwerkraft innerhalb der Hohlräume zurückgehalten werden, wobei die Kraft F2 konfiguriert ist, um vor oder gleichzeitig mit der Übertragung der magnetisierbaren Schleifteilchen 202 aus der Mehrzahl von Hohlräumen (230) entfernt oder geändert zu werden;
eine Unterlage (216), die neben dem Verteilungswerkzeug (204) angeordnet und durch einen Spalt (G) davon beabstandet ist, wobei der Spalt (G) mindestens so groß wie eine maximale Abmessung der magnetisierbaren Schleifteilchen (202) ist, die Unterlage (216) eine erste Hauptoberfläche (220), die dem Verteilungswerkzeug (204) zugewandt ist, und eine zweite Hauptoberfläche (256) gegenüberliegend der ersten Hauptoberfläche (220) aufweist; und
einen Magneten (250), der unterhalb der Unterlage (216) angeordnet ist und der zweiten Hauptoberfläche (256) der Unterlage (216) zugewandt ist, wobei der Magnet (250) ein Magnetfeld anlegt, um eine erste magnetische Kraft F1 auf die magnetisierbaren Schleifteilchen auszuüben, um eine Übertragung der magnetisierbaren

Schleifteilchen (202) aus dem Verteilungswerkzeug (204) auf die Unterlage (216) zu beeinflussen, um ein Erreichen von mindestens einem von einer vorab festgelegten Orientierung und Ausrichtung der magnetisierbaren Schleifteilchen (202) auf einer ersten Hauptoberfläche (220) der Unterlage (216) zu unterstützen.

11. Das Schleifteilchenpositionierungssystem nach Anspruch 10, wobei das Trägerelement (203) ein Polymer aufweist und flexibel ist.

12. Das Schleifteilchenpositionierungssystem nach einem der Ansprüche 10 bis 11, wobei das Verteilungswerkzeug (204) ein endloses Band aufweist.

Revendications

1. Procédé de fabrication d'un article abrasif revêtu, le procédé comprenant :

la fourniture de particules abrasives magnétisables (202) distribuables et d'un outil de distribution (204), dans lequel l'outil de distribution (204) est conçu pour recevoir les particules abrasives magnétisables (202) dans celui-ci, et dans lequel l'outil de distribution (204) comprend une pluralité de cavités conçues pour conférer au moins l'un parmi une orientation et un alignement prédéterminés des particules abrasives magnétisables (202) ;
la distribution des particules abrasives magnétisables dans les cavités de l'outil de distribution et l'application d'une force F2 afin de retenir les particules abrasives magnétisables à l'intérieur des cavités ;
l'inversion de l'outil de distribution de sorte que la force F2 retient au moins certains des particules abrasives magnétisables contre la force de gravité ;
le positionnement (i) d'un support (216) adjacent à l'outil de distribution (204) et espacé de celui-ci par un espace (G), dans lequel l'espace (G) est au moins aussi grand qu'une dimension maximale des particules abrasives magnétisables (202) ; et (ii) d'un aimant (250) au-dessous du support ;
à l'aide de l'aimant (250), l'application d'un champ magnétique au moins au support (216) et à une partie de l'espace (G) entre le support (216) et l'outil de distribution (204) afin d'exercer une première force magnétique F1 sur les particules abrasives magnétisables de manière à influencer le transfert des particules abrasives magnétisables à partir des cavités (230) de l'outil de distribution (204) au support (216) ; et
la suppression ou la modification de la force F2 avant ou simultanément avec le transfert des particules abrasives magnétisables (202) à partir de la pluralité de cavités (230) ;
le transfert des particules abrasives magnétisables (202) à partir de l'outil de distribution (204) à une première surface principale (220) du support (216), dans lequel le champ magnétique est appliqué pendant le transfert des particules abrasives magnétisables (202).

2. Procédé selon la revendication 1, dans lequel l'outil de distribution (204) est conçu pour fournir un motif prédéterminé aux particules abrasives magnétisables (202).

3. Procédé selon l'une quelconque des revendications 1 à 2, dans lequel l'un parmi le support (216) et l'outil de distribution (204) se déplace par rapport à l'autre parmi le support (216) et l'outil de distribution (204), et le procédé fait partie d'un processus continu.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel l'outil de distribution (204) a une surface de distribution (238) externe avec des cavités (230) dans celle-ci, et dans lequel chacune des cavités (230) est formée de sorte à recevoir au moins une partie de l'une des particules abrasives magnétisables (202) dans celle-ci.

5. Procédé selon la revendication 4, dans lequel la force F2 est appliquée par un vide.

6. Procédé selon l'une quelconque des revendications 1 à 5, comprenant en outre :

le durcissement au moins partiel d'un précurseur de couche de fabrication disposé sur le support (216) ;
la disposition d'un précurseur de couche d'encollage sur au moins une partie du précurseur de couche de fabrication au moins partiellement durci ; et
le durcissement au moins partiel du précurseur de couche d'encollage.

7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel le champ magnétique agit sur les particules abrasives magnétisables (202) sensiblement dans une même direction qu'un champ gravitationnel et le champ magnétique et le champ gravitationnel poussent ensemble les particules abrasives magnétisables (202) à partir de l'outil de distribution (204) et influencent un passage des particules abrasives magnétisables (202) à travers l'espace (G) vers la première surface principale (220) du support (216).

8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel l'espace (G) est compris entre 0,254 mm et 25,4 mm (entre 0,010 pouces et 1,0 pouces) en étendue, tel que mesuré à partir d'un point le plus proche de l'outil de distribution (204) à la première surface principale (220) du support (216).

9. Procédé selon l'une quelconque des revendications 1 à 8, dans lequel une majorité des particules abrasives magnétisables (202) ont une surface plane principale disposée à un angle d'au moins 70 degrés par rapport à la première surface principale (220) du support (216) lors du transfert au support (216).

10. Système de positionnement de particules abrasives comprenant :
un outil de distribution (204) conçu pour conférer au moins l'un parmi une orientation et un alignement prédéterminés des particules abrasives magnétisables (202), l'outil de distribution (204) comprenant :

un élément porteur (203) ayant une surface de distribution (238) inversée et une surface arrière opposée à la surface de distribution, dans lequel l'élément porteur (203) a des cavités (230) formées dans celui-ci, dans lequel les cavités (230) s'étendent dans l'élément porteur (203) à partir de la surface de distribution (238) vers la surface arrière ;
des particules abrasives magnétisables (202) disposées de manière amovible à l'intérieur d'au moins certaines des cavités (230) et retenues à l'intérieur des cavités contre la force de gravité par une force F2, dans lequel la force F2 est conçue pour être supprimée ou modifiée avant ou simultanément avec le transfert des particules abrasives magnétisables (202) à partir de la pluralité de cavités (230) ;
un support (216) disposé adjacent à l'outil de distribution (204) et espacé de celui-ci par un espace (G), dans lequel l'espace (G) est au moins aussi grand qu'une dimension maximale des particules abrasives magnétisables (202), le support (216) ayant une première surface principale (220) faisant face à l'outil de distribution (204) et une seconde surface principale (256) opposée à la première surface principale (220) ; et
un aimant (250) disposé au-dessous du support (216) et faisant face à la seconde surface principale (256) du support (216), l'aimant (250) appliquant un champ magnétique pour exercer une première force magnétique **F1** sur les particules abrasives magnétisables afin d'influencer un transfert des particules abrasives magnétisables (202) à partir de l'outil de distribution (204) au support (216) de manière à aider à obtenir au moins l'un parmi une orientation et un alignement prédéterminés des particules abrasives magnétisables (202) sur une première surface principale (220) du support (216).

11. Système de positionnement de particules abrasives selon la revendication 10, dans lequel l'élément porteur (203) comprend un polymère et est flexible.

12. Système de positionnement de particules abrasives selon l'une quelconque des revendications 10 à 11, dans lequel l'outil de distribution (204) comprend une courroie sans fin.

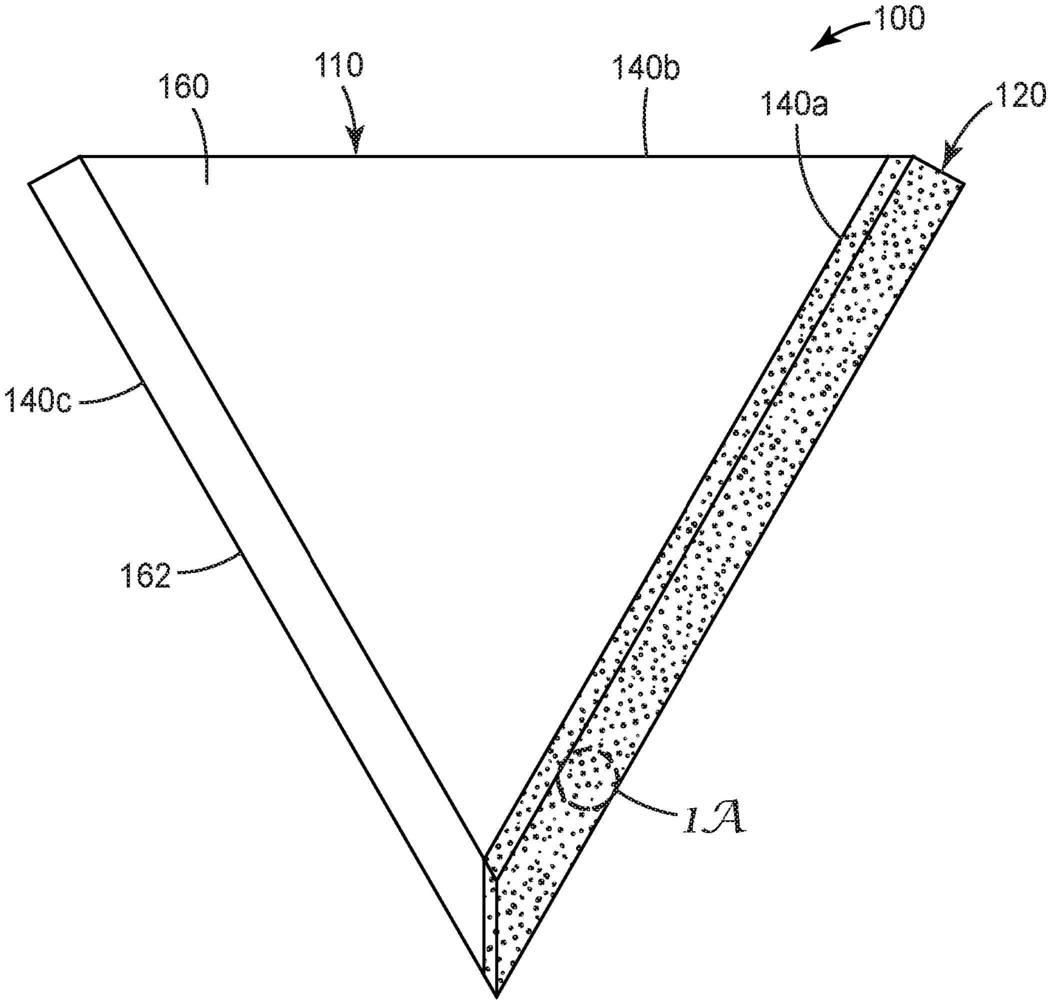

FIG. 1

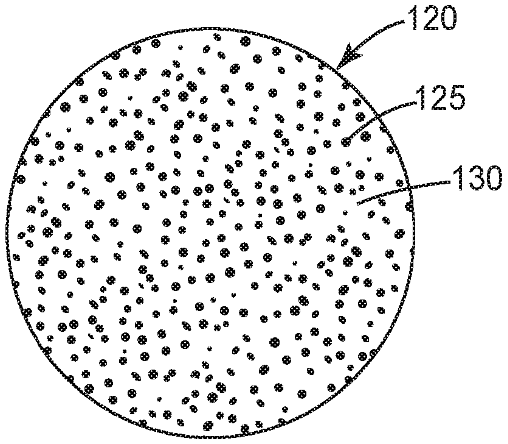

FIG. 1A

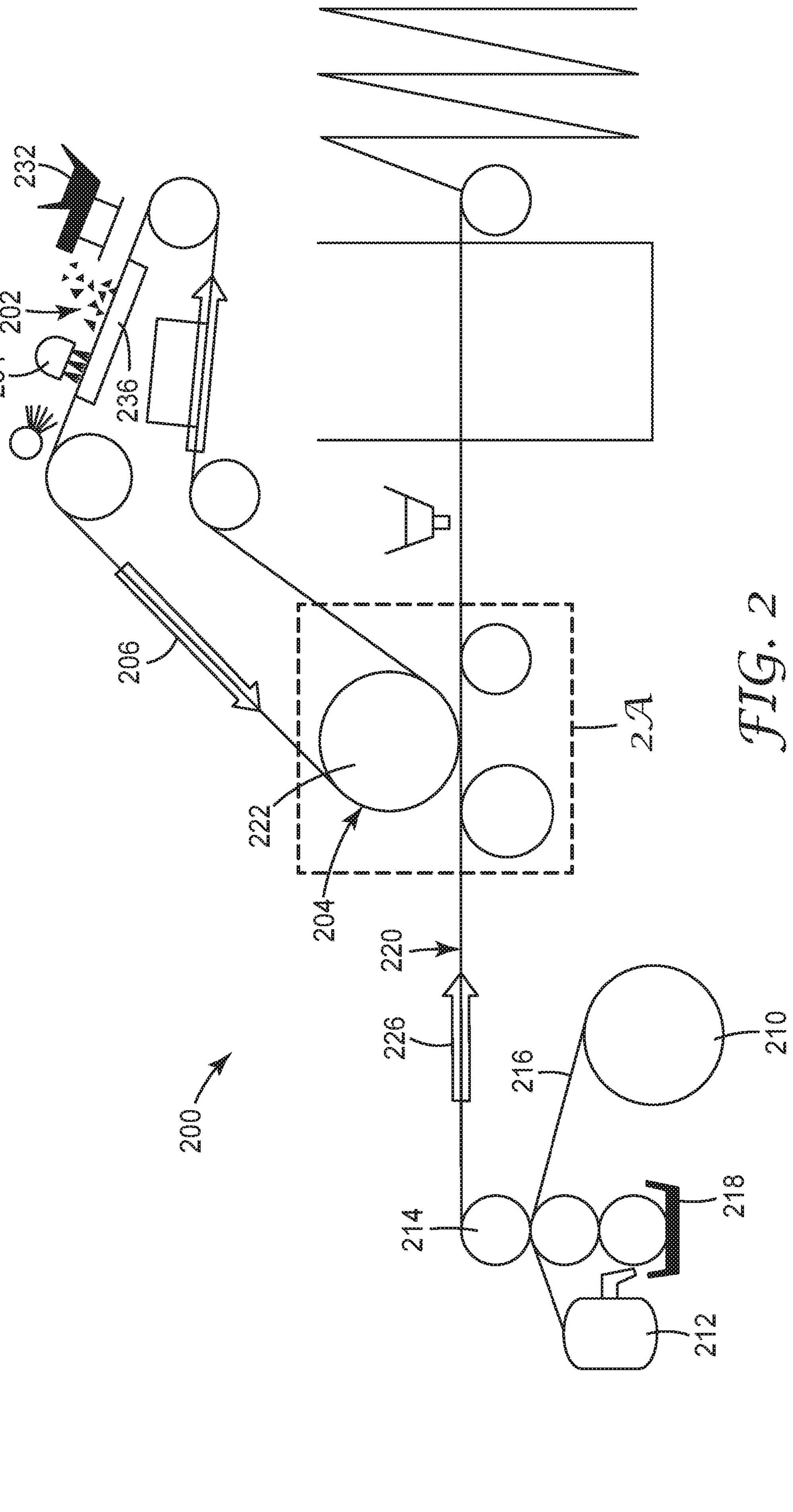

FIG. 2

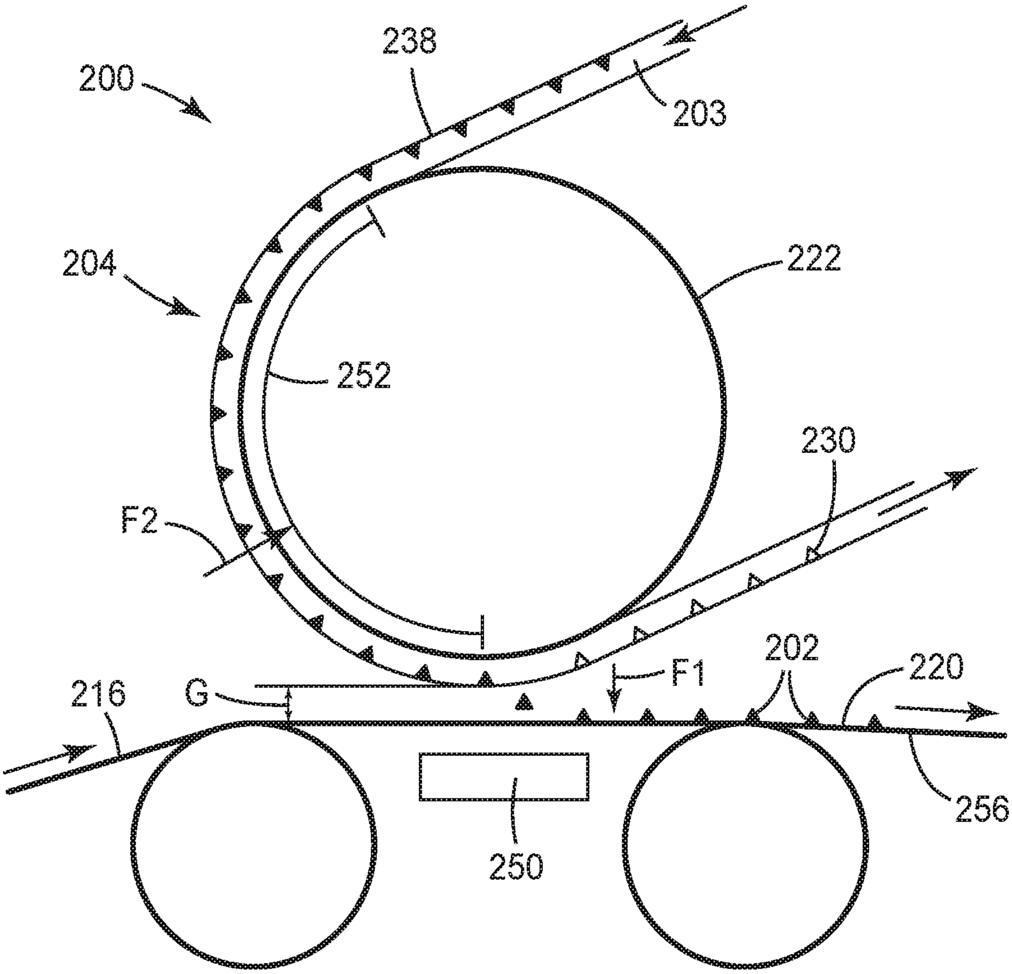
200
238
203
204
222
252
230
F2
202
F1
220
216
G
256
250

FIG. 2A

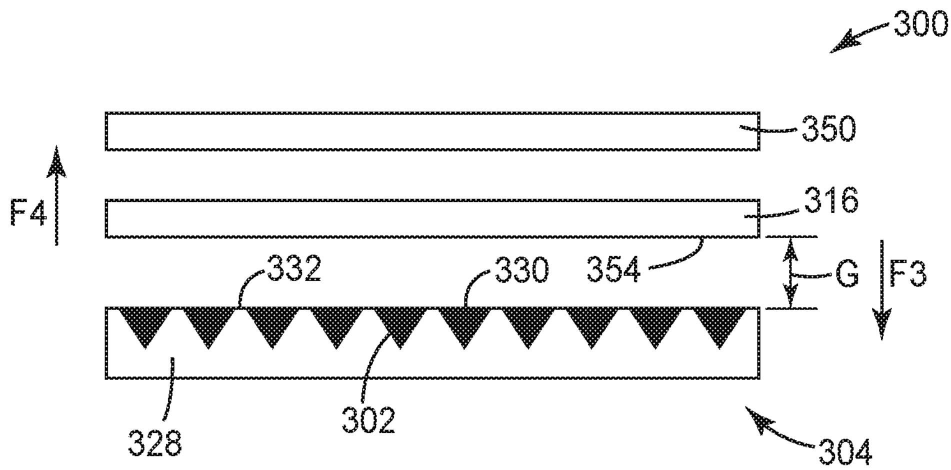
300
350
F4
316
332
330
354
G
F3
328
302
304

FIG. 3

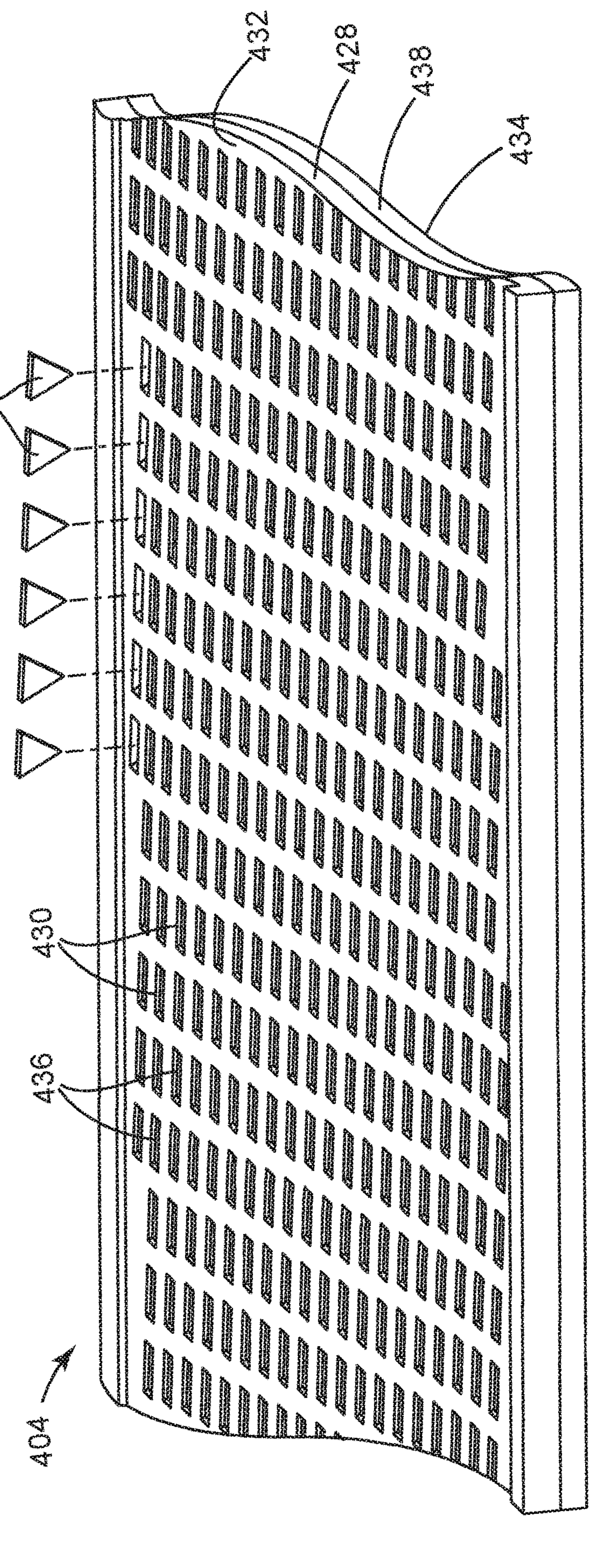

FIG. 4

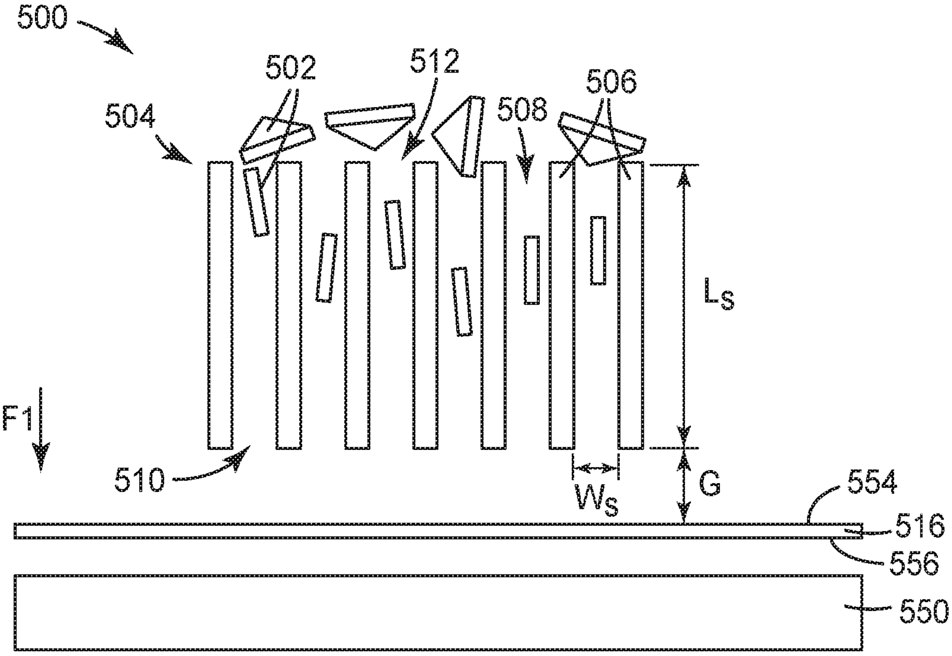
500
502
512
506
504
508
Ls
F1
510
G
Ws
554
516
556
550

FIG. 5

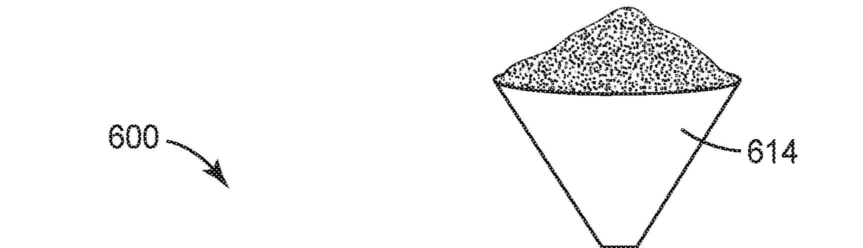
614
600
604
608
A
G
602
610
616

FIG. 6

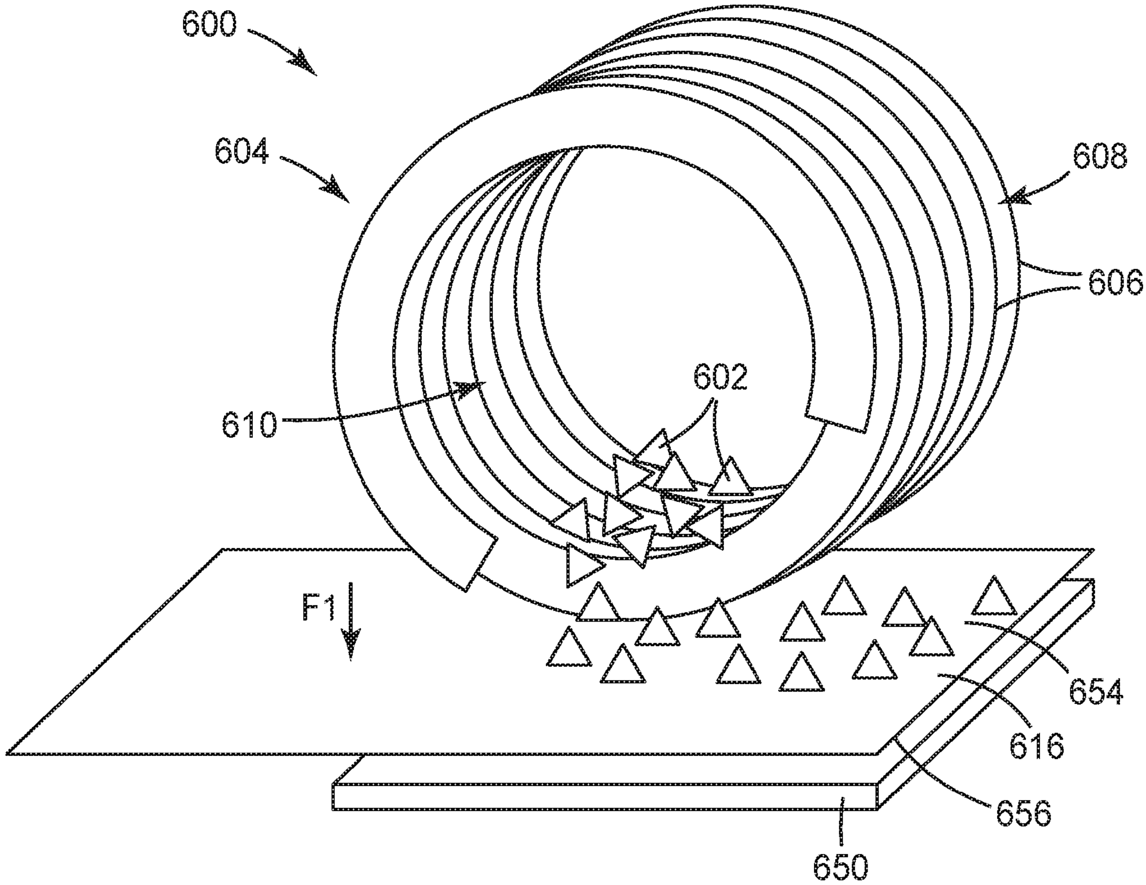

FIG. 6A

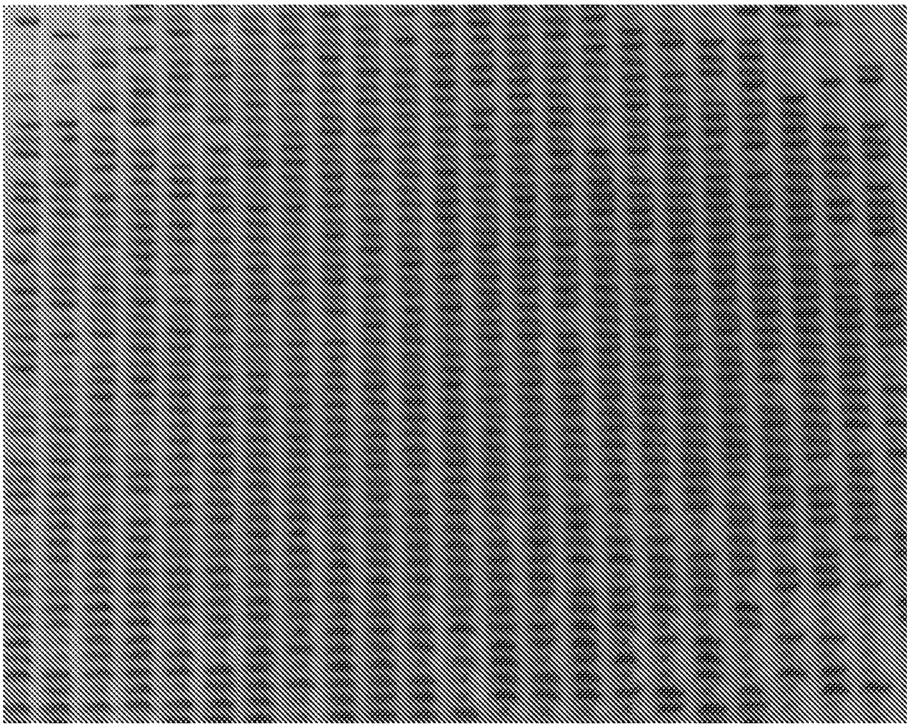

FIG. 7

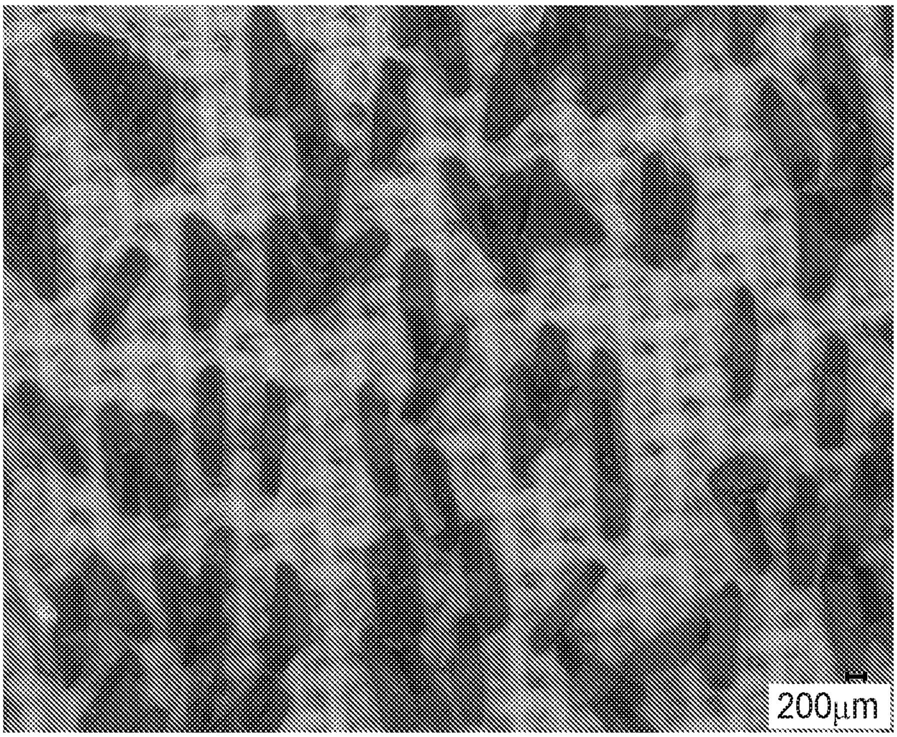

FIG. 8

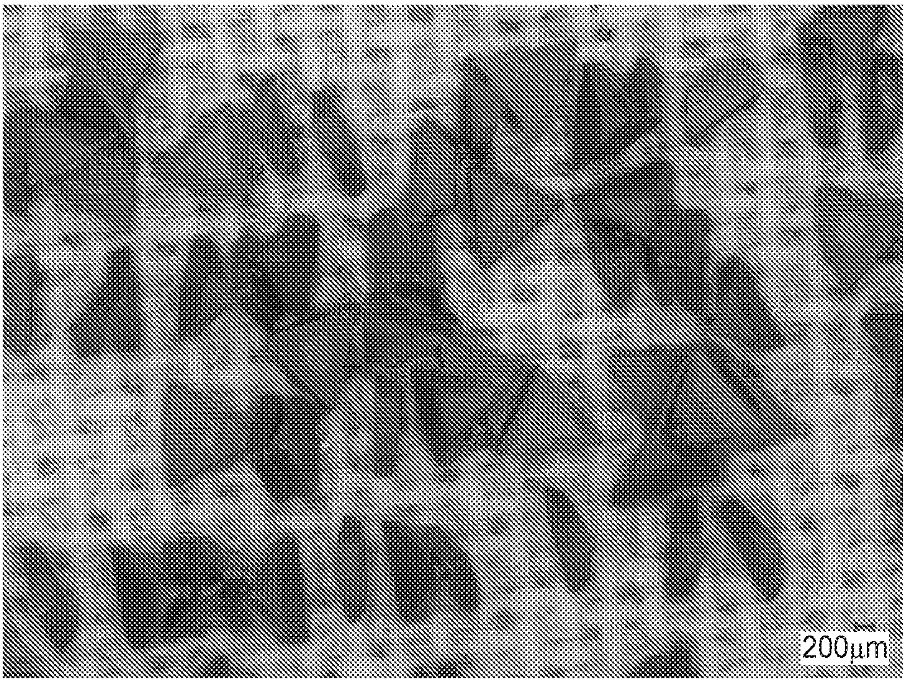

FIG. 9

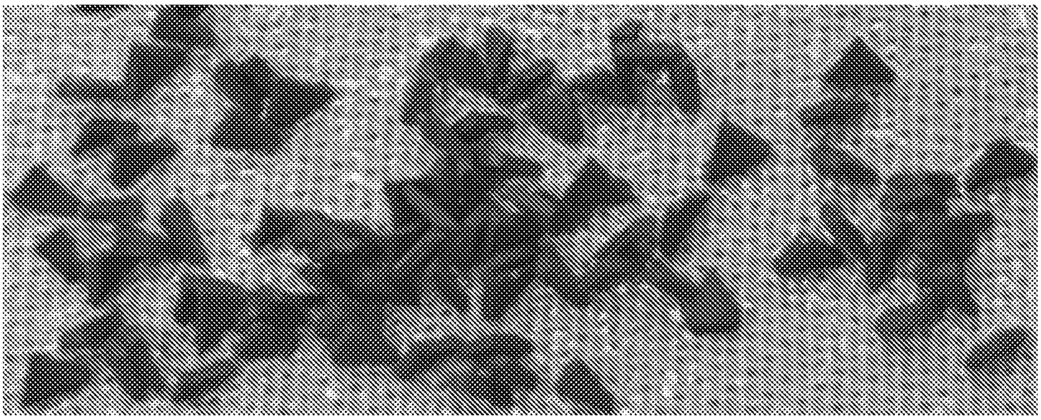

FIG. 10

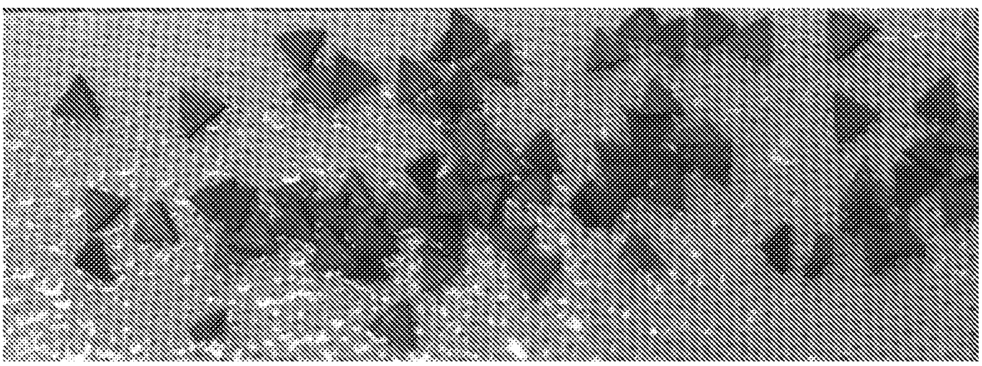

FIG. 11

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2012112305 A2, Keipert **[0004]**
- US 2014290147 A1 **[0005]**
- US 62412402 A **[0048]**
- US 62412405 B **[0048]**
- US 62412411 B **[0048]**
- US 62412416 B **[0048]**
- US 62412427 B **[0048]**
- US 62412440 B **[0048]**
- US 62412459 B **[0048]**
- US 62412470 B **[0048]**
- US 4612242 A, Vesley **[0049]**
- US 7727931 B, Brey **[0049]**
- US 4314827 A, Leitheiser **[0051]**
- US 4623364 A, Cottringer **[0051]**
- US 4744802 A, Schwabel **[0051]**
- US 4770671 A, Monroe **[0051]**
- US 4881951 A, Monroe **[0051]**
- US 5201916 A, Berg **[0052]**
- US 5366523 A, Rowenhorst **[0052]**
- US 5984988 A, Berg **[0052]**
- US 8034137 B, Erickson **[0052]**
- WO 2015100020 A **[0061]**
- WO 2015100220 A **[0061] [0101]**
- WO 2015100018 A **[0061]**
- US 20080289262 A1, Gao **[0066]**
- US 2370636 A, Carlton **[0066]**
- US 2857879 A, Johnson **[0066]**
- US 3625666 A, James **[0066]**
- US 4008055 A, Phaal **[0066]**
- US 5181939 A, Neff **[0066]**
- GB 1477767 A **[0066]**
- WO 2017007714 A **[0097]**
- WO 2017007703 A **[0097]**
- WO 20162015267 A **[0097]**
- US 8142531 B, Adefris **[0101]**
- US 8698394 B, McCutcheon **[0102] [0107]**
- US 62182077 A **[0108]**

Non-patent literature cited in the description

- **BARBEE et al.** *Thin Solid Films*, 1979, vol. 63, 143-150 **[0102] [0107]**