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(54) **ABRASIVE TOOLS AND METHODS FOR FORMING SAME**

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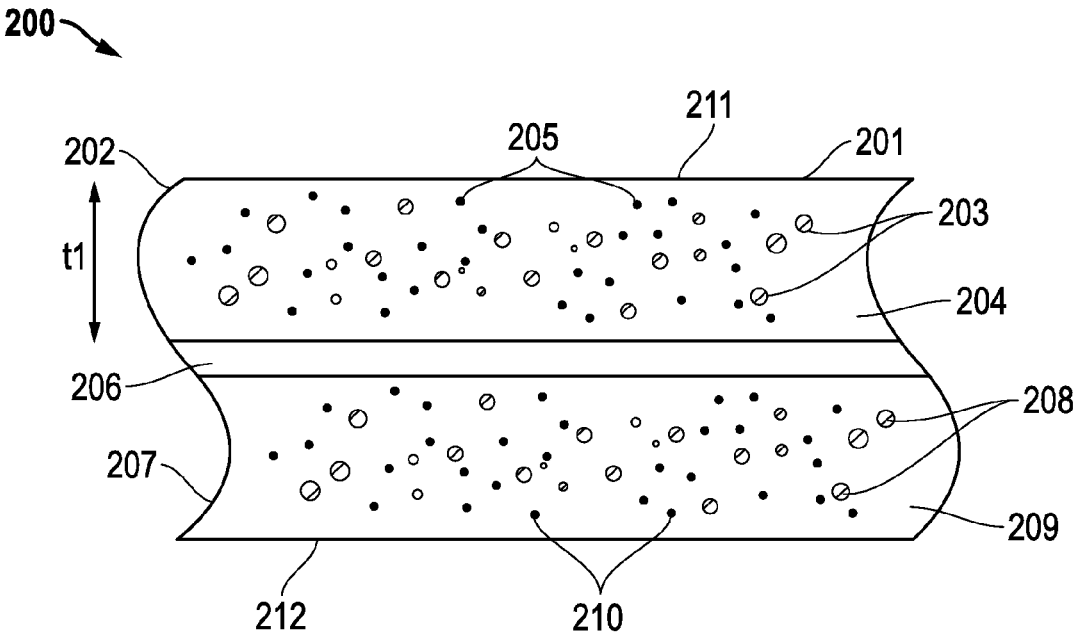
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CPC ***B24D 3/344*** (2013.01); ***B24D 5/02*** (2013.01); ***B24D 3/20*** (2013.01)

(57) **ABSTRACT**

An abrasive tool including a bonded abrasive including a body comprising abrasive particles contained within a three-dimensional matrix of bond material, the bond material including an organic material, the abrasive tool further including a first filler contained within the three-dimensional matrix of bond material including a silicate in a first content and a second filler contained within the three-dimensional matrix of bond material including a sulfate in a second content, and the first content is greater than the second content.



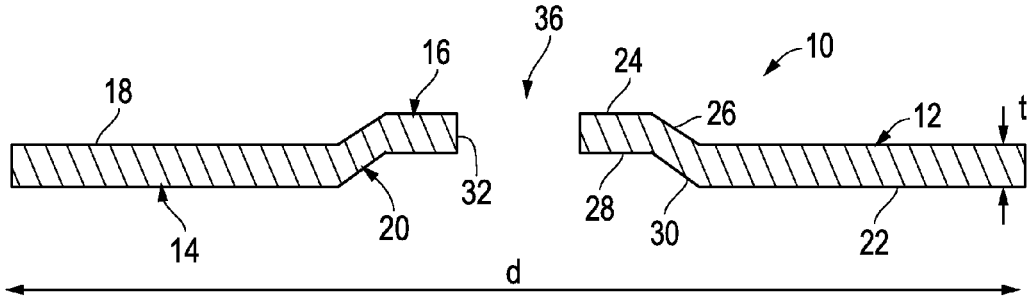

36
16
18
24
10
26
12
t
32
28
30
14
20
22
d

FIG. 1

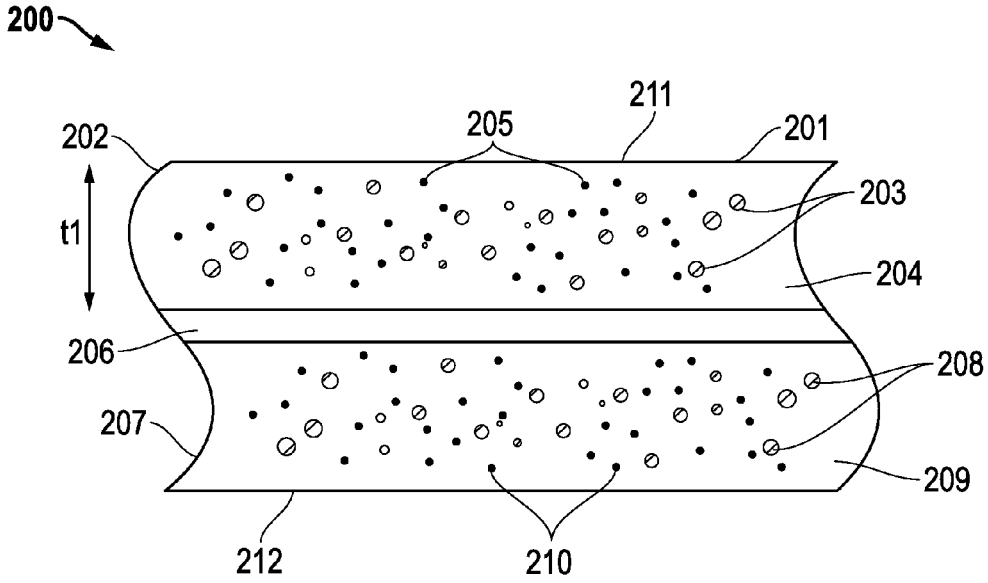

200
211
205
202
201
203
t1
204
206
208
207
209
212
210

FIG. 2

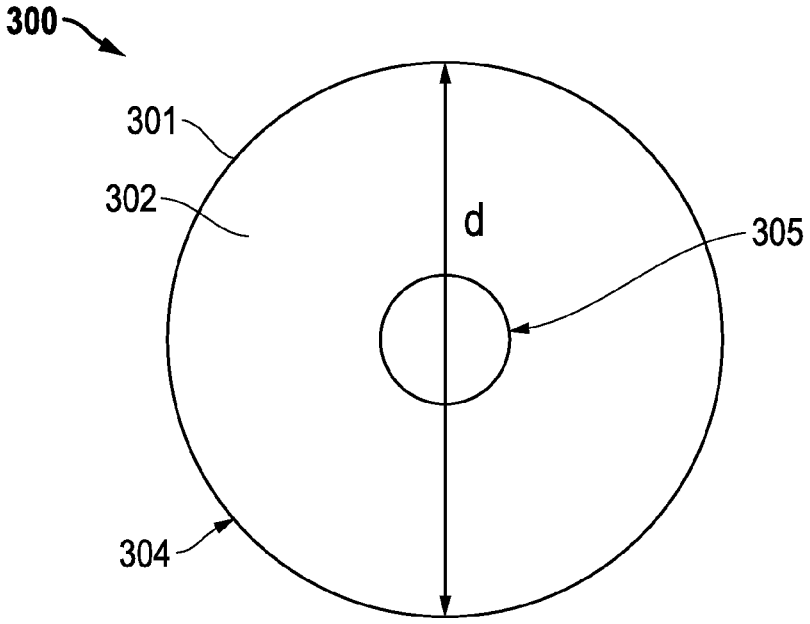


FIG. 3

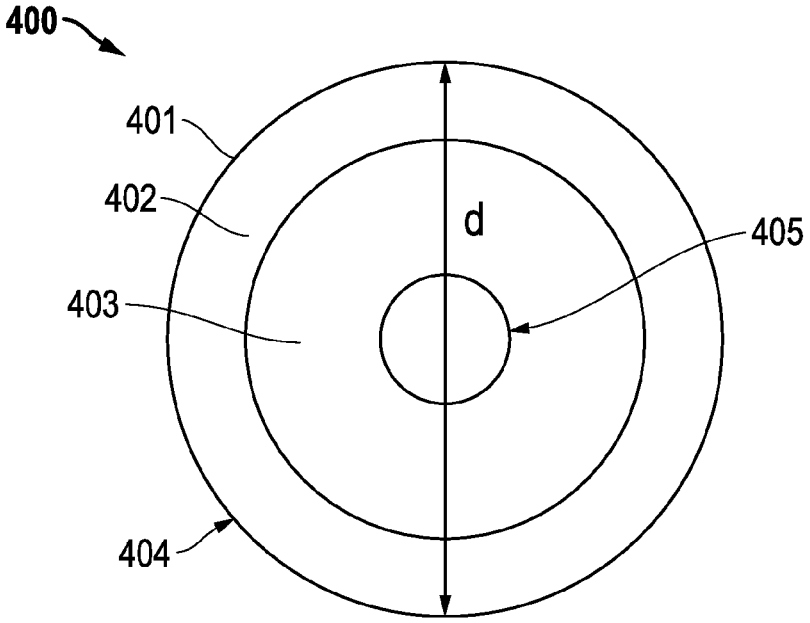


FIG. 4

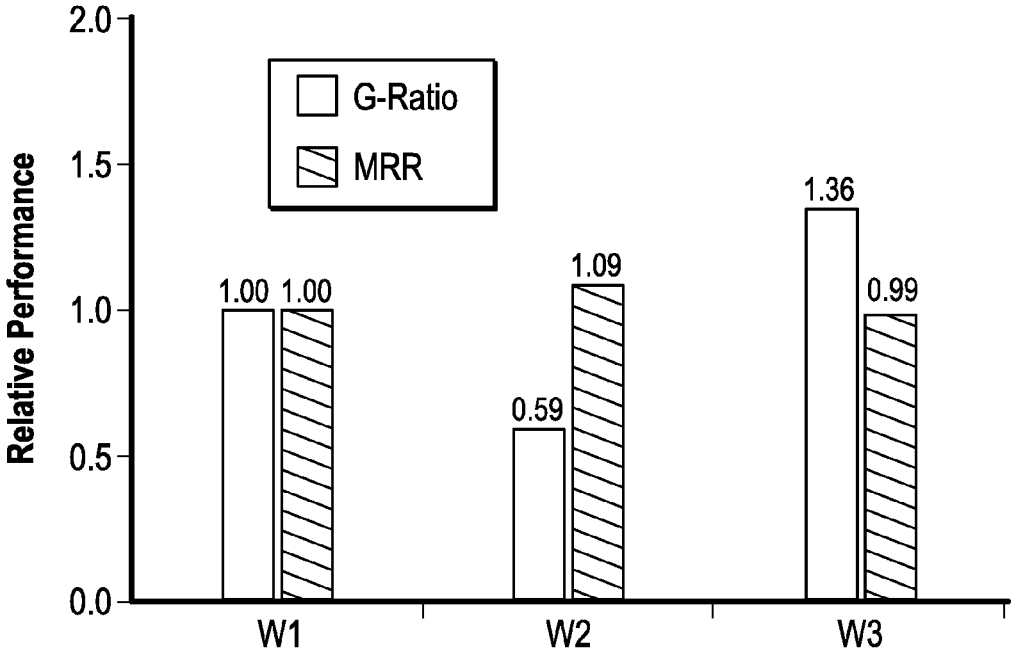

2.0
1.5
1.0
0.5
0.0
Relative Performance
G-Ratio
MRR
1.00
1.00
0.59
1.09
1.36
0.99
W1
W2
W3

FIG. 5

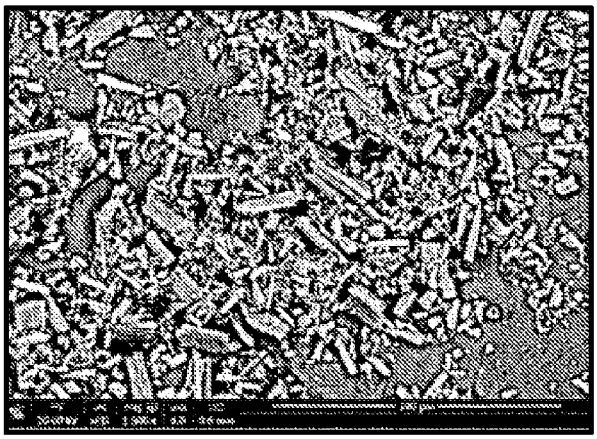


FIG. 6A

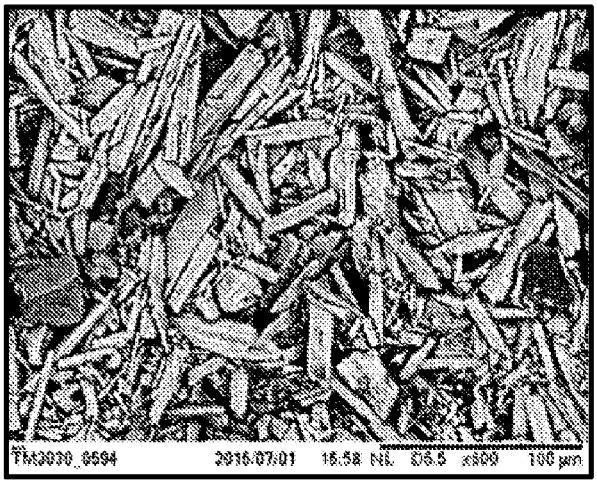


FIG. 6B

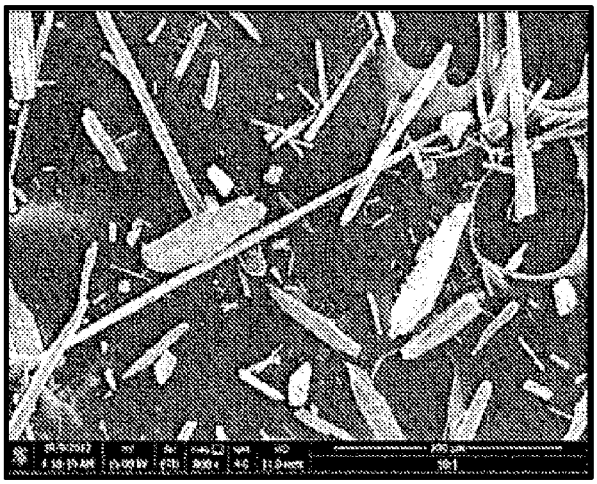


FIG. 6C

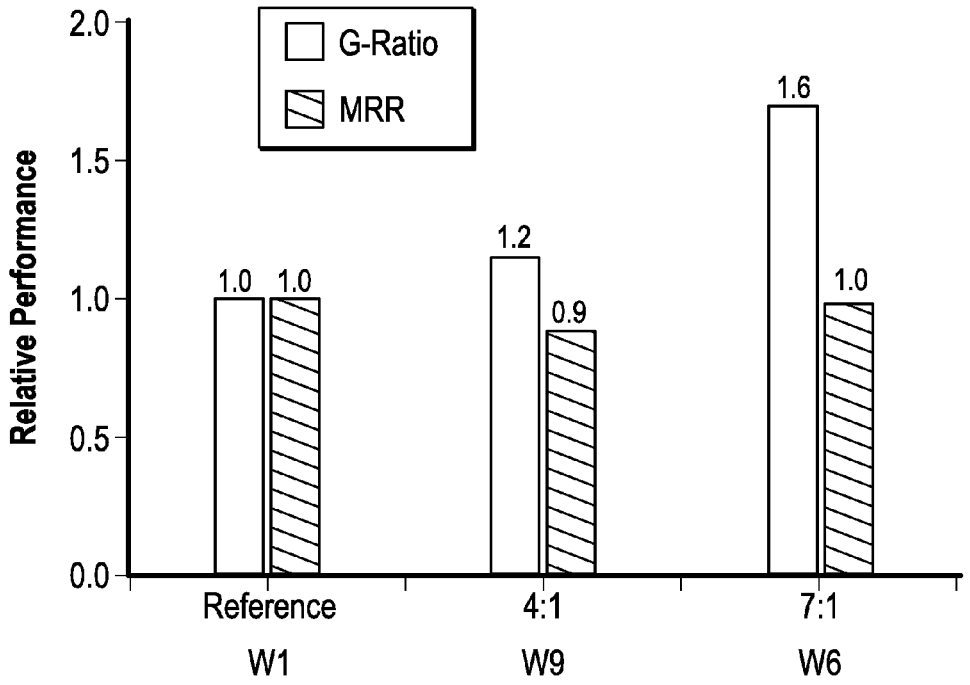

G-Ratio
MRR
Relative Performance
2.0
1.5
1.0
0.5
0.0
1.0
1.0
1.2
0.9
1.6
1.0
Reference
W1
4:1
W9
7:1
W6

FIG. 7

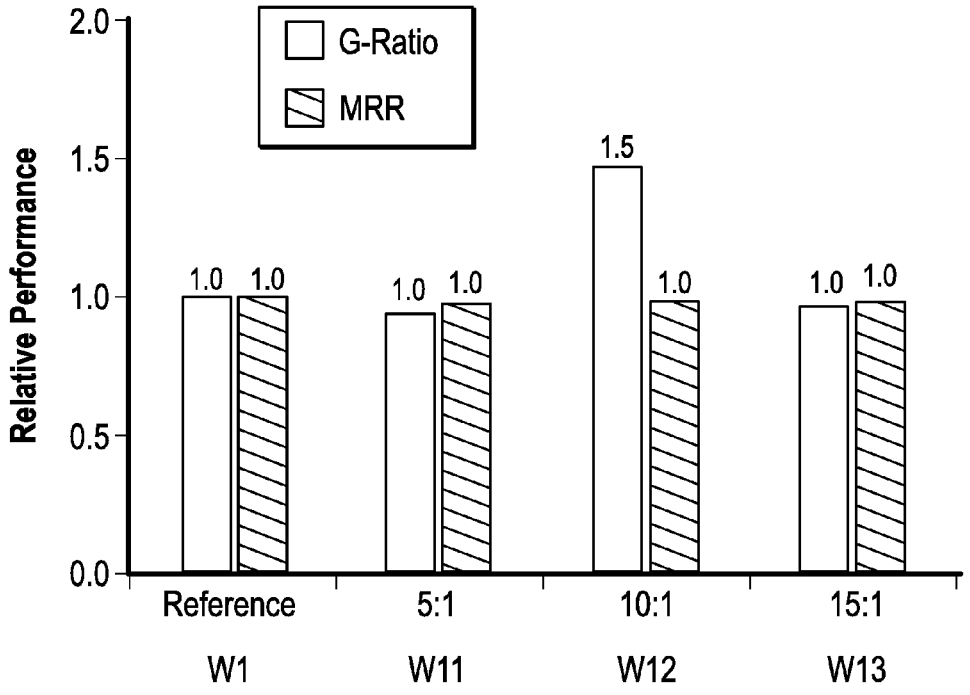

G-Ratio
MRR
Relative Performance
2.0
1.5
1.0
0.5
0.0
1.0
1.0
1.0
1.0
1.5
1.0
1.0
1.0
Reference
W1
5:1
W11
10:1
W12
15:1
W13

FIG. 8

ABRASIVE TOOLS AND METHODS FOR FORMING SAME

FIELD OF THE DISCLOSURE

[0001] The present invention relates in general to abrasive tools and, in particular, to a bonded abrasive.

DESCRIPTION OF RELATED ART

[0002] Bonded abrasive articles can be prepared by blending abrasive grains with a bond and optional additives and shaping the resulting mixture, using, for instance, a suitable mold. The mixture can be shaped to form a green body which can be thermally processed, for example, by curing, to produce an article in which the abrasive grains are held in a three dimensional bond matrix. Among bonded abrasive tools, various bond matrix materials exist, including for example organic materials, such as resin. A need for improved abrasive articles continues to exist.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Embodiments are illustrated by way of example and are not limited in the accompanying figures.

[0004] FIG. **1** includes a cross-sectional view of an abrasive tool in accordance with an embodiment described herein.

[0005] FIG. **2** includes a cross-sectional view of a portion of an abrasive tool in accordance with an embodiment.

[0006] FIG. **3** includes a top down view of an abrasive tool according to an embodiment.

[0007] FIG. **4** includes a top down view of an abrasive tool according to an embodiment.

[0008] FIG. **5** includes a histogram of grinding ratio of abrasive tool samples having different compositions.

[0009] FIG. **6**A includes an image of a filler having a certain aspect ratio according to an embodiment.

[0010] FIG. **6**B includes an image of a filler having an aspect ratio according to an embodiment.

[0011] FIG. **6**C includes an image of a filler having an aspect ratio according to an embodiment.

[0012] FIG. **7** includes a histogram of grinding ratio of abrasive tool samples.

[0013] FIG. **8** includes a histogram of grinding ratio of abrasive tool samples.

[0014] Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the invention.

DETAILED DESCRIPTION

[0015] Embodiments disclosed herein are related to abrasive tools including a bonded abrasive that may include one or more abrasive regions. The abrasive tools may be in the form of thin wheels, utilized for grinding, cutting, and general material removal operations. The bonded abrasive can include a body including abrasive particles contained within a bond material. In an embodiment, the barrier layer can be bonded to a major surface of the body.

[0016] FIG. **1** includes a cross-sectional illustration of a portion of an abrasive tool according to an embodiment. The abrasive tool **10** can include a body including a rear (top) face **12** and a front (bottom) face **14**. In certain instances, such as illustrated in FIG. **1**, the abrasive tool can have a rear face **12** that may include a raised hub region **16** and outer flat rear wheel region **18**. The front face **14** can include a depressed center region **20** and outer flat front wheel region **22**. In turn, raised hub region **16** can have raised hub surface **24** and back sloping (or slanted) surface **26**; depressed center region **20** can include depressed center **28** and front sloping (or slanted) surface **30**. The body of the abrasive tool **10** can have central opening **32** for mounting the abrasive tool **10** on the rotating spindle of a tool, e.g., a hand-held angle grinder. During operation, the abrasive tool **10** can be secured by mounting hardware such as, for instance, a suitable flange system. The abrasive tool **10** can also be part of an integrated arrangement that includes mounting hardware.

[0017] The abrasive tools of the embodiments herein can include any suitable type of abrasive wheel as known in the art, including thin disc shaped abrasive articles. For example, the abrasive tool can be a depressed center wheel, such as, for example, ANSI (American National Standards Institute) Type 27, Type 28 or Type 29 wheels, or European Standard (EN 14312) Type 42 wheel. In particular embodiments, the abrasive tool may include a Type 41 or Type 1 wheel, which may be referred to as straight wheels, having no depression in the interior but having the same contour and extending along the same plane along the length of the diameter of the wheel. Still, essentially any bonded abrasive wheel construction may be utilized with the present embodiments. Moreover, the abrasive tools may be in the form of cut-off wheels.

[0018] The body of the abrasive tool **10** can have a thickness "t" that can be measured at various positions, including at the periphery of the bonded abrasive body. The thickness (t) of the body of the abrasive tool **10** can be the same or essentially the same along a radial direction from the central opening **36** to the outer edge (periphery) **38** of the abrasive tool **10**. In other designs, the thickness (t) of the body can vary (can increase or decrease) along a radial distance from the central opening **36** to the periphery **38**. Reference herein to a thickness can be reference to an average thickness of the abrasive tool **10**. For example, the body of the abrasive tool **10** can have a thickness (t) of not greater than 10 mm, such as not greater than 9.5 mm or not greater than 9 mm or not greater than 8.5 mm or not greater than 8 mm or not greater than 7.5 mm or not greater than 7 mm or not greater than 6.5 mm or not greater than 6 mm or not greater than 5.5 mm or not greater than 5 mm or not greater than 4.5 mm or not greater than 4 mm. Still, in at least one non-limiting embodiment, the thickness (t) of the abrasive tool **10** can be at least 0.3 mm, such as at least 0.5 mm or at least 0.8 mm or at least 1 mm or at least 1.3 mm or even at least 1.5 mm. It will be appreciated that the body of the abrasive tool **10** can have a thickness (t) within a range including any of the minimum and maximum values noted above, including for example, within a range including at least 0.3 mm to not greater than 10 mm, such as within a range including at least 0.3 mm to not greater than 9 mm, or even within range including at least 0.5 mm to not greater than 8 mm.

[0019] Further, the body of the abrasive tool **10** of the embodiments herein can include a diameter (d), which defines the length of extending between two points on the perimeter and through the center of the body. In a non-limiting embodiment, the diameter (d) can be at least 10 mm, such as at least 25 mm or at least 50 mm or at least 55 mm

or at least 60 mm or at least 65 mm or at least 70 mm or at least 75 mm or at least 80 mm or at least 90 mm, or even at least 100 mm. In another non-limiting embodiment, the diameter (d) may be not greater than 400 mm, such as not greater than 350 mm or not greater than 300 mm or not greater than 275 mm or not greater than 250 mm, or even not greater than 230 mm. It will be appreciated that the diameter (d) of the bonded abrasive body can be within a range including any of the minimum to maximum values noted above, for example, within a range including at least mm 10 mm to not greater than 400 mm, such as within a range including at least 50 mm to not greater than 300 mm, or even within a range including at least 50 mm to not greater than 230 mm.

[0020] The body of the abrasive tool **10** may have a particular aspect ratio, which is a ratio of the diameter (d) of the body to the thickness (t) of the body (diameter:thickness) that may facilitate certain abrasive operations. For example, the body can have an aspect ratio of at least 10:1 or at least 15:1 or at least 20:1 or at least 35:1 or at least 50:1 or at least 75:1 or at least 100:1, or even at least 125:1. In other instances, the body of the abrasive tool **10** can have an aspect ratio (diameter:thickness) of not greater than 1000:1, such as not greater than 800:1 or not greater than 500:1 or not greater than 400:1 or not greater than 350:1 or not greater than 300:1 or not greater than 250:1, or even not greater than 200:1. The ratio can be within a range including any of the above minimum and maximum values, such as within a range including at least 10:1 to not greater than 1000:1, such as within a range including at least 10:1 and not greater than 500:1, or even within a range including at least 10:1 and not greater than 200:1.

[0021] The abrasive tools of the embodiments herein can have various constructions. The abrasive tools of the embodiments herein may be monolithic articles formed of a single material, having a single construction, having a substantially uniform grade and structure throughout the volume of the body of the abrasive tool. Alternatively, the body of the embodiments herein can be composite bodies having one or more elements (e.g., abrasive regions, abrasive layers, reinforcing members, etc.), wherein at least two of the elements are different from each other based on a characteristic such as, abrasive particle type, content of abrasive particles, porosity type (e.g., closed or open), content of porosity, type of bond material, content of bond material, distribution of abrasive particles, hardness, flexibility, filler content, type of filler materials including individual filler materials and filler compositions as a whole (i.e., taking into account all of the filler materials, such as a first filler, a second filler, a third filler, and the like), shape of the layer, size (e.g., thickness, width, diameter, circumference, or length) of the layer, construction of the layer (e.g., solid, woven, non-woven, etc.) and a combination thereof.

[0022] FIG. **2** includes a cross-sectional view of a portion of an abrasive tool according to an embodiment. As illustrated, the abrasive tool **200** can be a bonded abrasive having a body **201** including a first abrasive region **202**, which can include abrasive particles **203** contained within a three-dimensional matrix of bond material **204**. The first abrasive region may also include fillers **205** contained within the bond material **204**. As will be described herein, in certain embodiments, the fillers **205** can include one or more elements or compositions, including for example, a particular combination of a first filler, a second filler, a third filler, and the like that may define a filler composition for the first abrasive region **202**.

[0023] As further illustrated, the body **201** of the abrasive tool **200** can include a second abrasive region **207**, which can include abrasive particles **208** contained within a three-dimensional matrix of bond material **209**. The second abrasive region **207** may also include fillers **210** contained within the three-dimensional matrix of the bond material **209**. As noted herein, the first and second abrasive regions **202** and **207** can have include the same features or different features, including but not limited to, abrasive particle type, content of abrasive particles, porosity type (e.g., closed or open), content of porosity, type of bond material, content of bond material, distribution of abrasive particles, hardness, flexibility, filler content, type of filler materials including individual filler materials and filler compositions as a whole (i.e., taking into account all of the filler materials, such as a first filler, a second filler, a third filler, and the like), shape of the layer, size (e.g., thickness, width, diameter, circumference, or length) of the layer, construction of the layer (e.g., solid, woven, non-woven, etc.) and a combination thereof. In at least one embodiment, the first abrasive region **202** and second abrasive region **207** can be in the form of layers that are axially spaced apart from each other within the body **201**. The layers can extend for the entire diameter of the body **201** with the exception of an arbor hole or opening at the center of the body as described herein. In still other instances, the body of the abrasive tool can be formed such that the first abrasive region and second abrasive region define distinct annular regions within the body that are radially spaced apart from each other within the body.

[0024] According to one embodiment, as illustrated in FIG. **2**, the body **201** may also include a reinforcing member **206** disposed between the first and second abrasive regions **202** and **207**. While FIG. **2** depicts a particular arrangement of the first and second abrasive regions **202** and **207** relative to each other and relative to the reinforcing member **206**, it will be appreciated that other constructions of the abrasive tool are within the scope of the embodiments herein. The abrasive tools may include a plurality of abrasive regions, which may be in the form of layers, extending for at least a portion of the diameter of the abrasive tool. The plurality of abrasive regions can be separated from each other by one or more reinforcing members. Additionally, the body **201** can include first and second major surfaces **211** and **212**, which may generally correspond to surface **18** and **22**, which can define the exterior surfaces of the body **201**. In certain instances, one or more layers of material, including for example, a reinforcing member or paper backing with indicia may be applied to the first and second major surfaces **211** and **212** of the body **201**.

[0025] According to one embodiment, the first abrasive region **202** can include filler **205**, which can include a first filler. The first filler may be distinct from the abrasive particles with regard to at least one of average particle size, hardness, composition, shape, and the like. The first filler may include a silicate. For example, the first filler may include calcium, and more particularly, may include a calcium silicate compound. In one instance, the first filler can include an inosilicate compound, which may be a single chain inosilicate. An inosilicate compound includes interlocking chains of silicate tetrahedral. According to a particular embodiment, the first filler comprises wollastonite,

and more particularly, can consist essentially of wollastonite ($CaSiO_3$). Utilization of a first filler may facilitate improved performance of the abrasive tool **200** as the first filler may be configured to provide suitable mechanical reinforcement to the bond material **204**. Moreover, in more particular instances, the first filler can be a reinforcing agent configured to reduce the wear and/or fracture of the bond during grinding operations.

[0026] In certain embodiments, the first filler may have a particular median particle size (D50), which may facilitate improved performance of the abrasive tool **10**. For example, the first filler can have a median particle size of at least 1 micron, such at least 2 microns or at least 3 microns or at least 4 microns or at least 5 microns or at least 6 microns or at least 7 microns or at least 8 microns or at least 9 microns or at least 10 microns or at least 11 microns or at least 12 microns, or even at least 13 microns. Still, in another non-limiting embodiment, the first filler can have a median particle size (D50) of not greater than 100 microns, such as not greater than 95 microns or not greater than 90 microns or not greater than 85 microns or not greater than 80 microns or not greater than 75 microns or not greater than 70 microns or not greater than 65 microns or not greater than 60 microns or not greater than 55 microns or not greater than 50 microns or not greater than 45 microns or not greater than 40 microns or not greater than 35 microns or not greater than 30 microns or not greater than 25 microns. It will be appreciated that the median particle size of the first filler can be within a range including any of the minimum and maximum values noted above. Moreover, in certain instances, reference to the foregoing median particle size may be reference to a maximum particle size, depending upon the sieving technique and the shape of the first filler particle.

[0027] According to one embodiment, the first filler may have a particular shape, which may make it more suitable for use in the abrasive tools of the embodiments herein. Furthermore, the shape of the first filler may facilitate improved performance of the abrasive tools of the embodiments herein. According to one embodiment, the first filler can have an aspect ratio (length:width) when viewing the first filler using a suitable two-dimensional image of at least 1.2:1, such as at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2:1, or even at least 3:1. In a further embodiment, the first filler can have an aspect ratio greater than 5:1, such as at least 5.5:1 or at least 6:1 or at least 6.5:1 or even at least 7:1. Still, in one non-limiting embodiment, the first filler can have an aspect ratio of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1. Still, in another non-limiting embodiment, the first filler can have an aspect ratio less than 15:1, such as not greater than 14.5:1, or not greater than 14:1, or not greater than 13.5:1, or not greater than 13:1, or not greater than or not greater than 12:1, or not greater than 11.5:1, or even not greater than 10:1. It will be appreciated that the aspect ratio of the first filler can be within a range including any of the minimum and maximum ratios noted above. For example, the aspect ratio of the first filler can be greater than 5:1 and less than 15:1, such as within a range from at least 5.5:1 to not greater than 14.5:1, or within a range from at least 6:1 to not greater than 13:1, or within a range from at least 7:1 to not greater than 10:1.

[0028] In certain situations, the first filler may be present in a particular content that may facilitate improved performance of the abrasive tool. For example, the first filler can be present in the first abrasive region **202** in a first content. According to one embodiment, the first content can be at least 0.1 wt % of the total weight of the first abrasive region **202**, such as at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt % or at least 2.2 wt % or at least 2.4 wt % or at least 2.6 wt % or at least 2.8 wt % or at least 3 wt % or at least 3.2 wt % or at least 3.4 wt % or at least 3.6 wt % or at least 3.8 wt % or at least 4 wt %, such as at least 4.2 wt % or at least 4.5 wt % or at least 5 wt %. Still, in another non-limiting embodiment, the first content can be not greater than 19 wt % of the total weight of the first abrasive region **202**, such as or not greater than 18 wt % or not greater than 17 wt % or not greater than 16 wt % or not greater than 15 wt % or not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7.8 wt % or not greater than 7.5 wt % or not greater than 7 wt % or not greater than 6 wt % or not greater than 5.5 wt %, or even not greater than 5 wt %. It will be appreciated that the first content can be within a range including any of the minimum and maximum ratios noted above, including for example, at least 0.2 wt % and not greater than 20 wt % for a total weight of the first abrasive region **202**, or within a range including at least 2 wt % and not greater than 12 wt %. In a particular example, the first content can be within a range including at least 2.8 wt % and not greater than 8 wt %.

[0029] According to another embodiment, the first abrasive region **202** can include a filler **205**, which may include a first filler and a second filler, wherein the second filler is distinct from the first filler. Provision of a second filler as part of the filler composition of the abrasive tool may facilitate improved performance. Some suitable examples of fillers that may be used as a second filler can include powders, granules, spheres, fibers, or a combination thereof. In another embodiment, the second filler can include an inorganic material, an organic material, or a combination thereof. For example, suitable fillers for use as the second filler can include sand, silicon carbide, bubble alumina, bauxite, chromites, magnesite, dolomites, bubble mullite, borides, titanium dioxide, carbon products (e.g., carbon black, coke or graphite), wood flour, clay, talc, hexagonal boron nitride, molybdenum disulfide, feldspar, nepheline syenite, glass fibers, glass spheres, chlorides (e.g., $MgCl_2$ and $CaCl_2$), fluorides (e.g., CaF_2, KBF_4), cryolite (Na_3AlF_6), potassium cryolite (K_3AlF_6), pyrites, ZnS, copper sulfide, mineral oil, carbonates, calcium carbonate, sulphates, dechlorane, and a combination thereof. In a further embodiment, the second filler can include an antistatic agent, a metal oxide, a lubricant, a porosity inducer, a coloring agent, or a combination thereof. Examples of the lubricants can include stearic acid, glycerol monostearate, graphite, carbon, molybdenum disulfide, wax beads, calcium carbonate, calcium fluoride, or any combination thereof. Examples of the metal oxides can include lime, zinc oxide, magnesium oxide, or any combination thereof. Note that the second filler may be functional, such as, grinding aids, lubricants, and porosity inducers. In alternative instances, the second filler can be used for functional and/or

aesthetics, such as a coloring agent. According to an embodiment, the second filler can be distinct from the abrasive particles, including primary abrasive particles and secondary abrasive particles. In one particular embodiment, the second filler can include a sulfate. In more particular instances, the second filler can include potassium, and may be a compound including potassium. For one particular embodiment, the second filler may include a potassium sulfate compound, and even more particularly, may consist essentially of potassium sulfate.

[0030] In one embodiment, the second filler may have a particular median particle size (D50), which may facilitate improved performance of the abrasive tool. For example, the second filler can have a median particle size of at least 0.1 microns, such at least 0.5 microns or at least 1 micron or at least 1.5 microns or at least 2 microns, or even at least 5 microns. Still, in another non-limiting embodiment, the second filler can have a median particle size (D50) of not greater than 500 microns, such as not greater than 450 microns or not greater than 400 microns or not greater than 350 microns or not greater than 300 microns or not greater than 275 microns or not greater than 250 microns or not greater than 200 microns or not greater than 175 microns or not greater than 150 microns, or even not greater than 100 microns. It will be appreciated that the median particle size of the second filler can be within a range including any of the minimum and maximum values noted above. Moreover, in certain instances, reference to the foregoing median particle size may be reference to a maximum particle size, depending upon the sieving technique and the shape of the second filler particle.

[0031] In certain instances, the second filler may have a particular aspect ratio (length:width), which may facilitate improved performance of the abrasive tool. The second filler may have an aspect ratio that is substantially the same as the aspect ratio of the first filler. Still, in at least one other embodiment, the second filler can have an aspect ratio that is different compared to the aspect ratio of the first filler. For example, the second filler can have an aspect ratio (length: width) when viewing the second filler using a suitable two-dimensional image of at least 1.1:1, such as at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1, or even at least 2:1. Still, in one non-limiting embodiment, the second filler can have an aspect ratio of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1, or not greater than 10:1 or not greater than 5:1, or even not greater than 2:1. In at least one embodiment, the second filler may be substantially equiaxed having an aspect ratio of approximately 1:1. It will be appreciated that the aspect ratio of the second filler can be within a range including any of the minimum and maximum ratios noted above.

[0032] In certain situations, the second filler may be present in a particular content that may facilitate improved performance of the abrasive tool. For example, the second filler can be present in the first abrasive region **202** in a second content. According to one embodiment, the second content can be at least 0.01 wt % of the total weight of the first abrasive region **202**, such as at least 0.1 wt % or at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt %, or even at least 2.2 wt %. Still, in another non-limiting embodiment, the second content can be not greater than 15 wt % of the total weight of the first abrasive region **202**, such as not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7 wt % or not greater than 6 wt % or not greater than 5 wt % or not greater than 4.5 wt % or not greater than 4 wt % or not greater than 3.5 wt % or not greater than 3 wt % or not greater than 2.8 wt % or not greater than 2.5 wt %, or even not greater than 2.2 wt %. It will be appreciated that the second content can be within a range including any of the minimum and maximum ratios noted above, including for example, at least 0.01 wt % and not greater than 15 wt % for a total weight of the first abrasive region **202**, or within a range including at least 1 wt % and not greater than 4 wt %, or within a range including at least 1.5 wt % and not greater than 2.5 wt %.

[0033] The first abrasive region **202** may utilize particular contents of the first filler and second filler with respect to each other, which may facilitate improved operation of the abrasive tool **200**. In certain instances, the first content of the first filler and second content of the second filler can be substantially the same with respect to each other. In still other instances, the first content of the first filler and second content of the second filler can be different with respect to each other. According to one embodiment, the first abrasive region **202** can include a ratio (C1:C2) of the first content (C1) to the second content (C2) as measured in wt % of the first filler and second filler, respectively. According to one embodiment, the first abrasive region **202** can have a ratio (C1:C2) of at least 1.1:1, such as at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2.1:1 or at least 2.4:1 or even at least 2.5:1. Still, in a non-limiting embodiment, the first abrasive region **202** can have a ratio (C1:C2) of the first content (C1) to the second content (C2) of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 8:1 or not greater than 6:1 or not greater than 5:1 or not greater than 4:1 or not greater than 3.9:1 or not greater than 3.5:1 or not greater than 3.2:1 or not greater than 3:1 or even not greater than 2.5:1. It will be appreciated that the ratio (C1:C2) can be within a range including any of the minimum and maximum ratios noted above, including for example, at least 1.5:1 and not greater than 3.5:1, or within a range including at least 2.4:1 and not greater than 3.2:1.

[0034] According to another embodiment, the first abrasive region **202** can include a filler **205**, which may include a first filler and a third filler, wherein the third filler can be distinct from the first filler. Provision of a third filler as part of the filler composition of the abrasive tool may facilitate improved performance. Note that reference herein to a third filler does not necessitate the inclusion of a second filler, but reference to third filler is a convention to distinguish one filler (e.g., first filler) from another filler (e.g., the third filler). Some suitable examples of fillers that may be used as a third filler can include powders, granules, spheres, fibers, or a combination thereof. In another embodiment, the third filler can include an inorganic material, an organic material,

or a combination thereof. For example, suitable materials for use as the third fillers can include sand, silicon carbide, bubble alumina, bauxite, chromites, magnesite, dolomites, bubble mullite, borides, titanium dioxide, carbon products (e.g., carbon black, coke or graphite), wood flour, clay, talc, hexagonal boron nitride, molybdenum disulfide, feldspar, nepheline syenite, glass fibers, glass spheres, chlorides (e.g., $MgCl_2$ and $CaCl_2$), fluorides (e.g., CaF_2, KBF_4), cryolite (Na_3AlF_6), potassium cryolite (K_3AlF_6), pyrites, ZnS, copper sulfide, mineral oil, carbonates, calcium carbonate, sulphates, dechlorane, and a combination thereof. In a further embodiment, the third filler can include an antistatic agent, a metal oxide, a lubricant, a porosity inducer, a coloring agent, or a combination thereof. Examples of the lubricants can include stearic acid, glycerol monostearate, graphite, carbon, molybdenum disulfide, wax beads, calcium carbonate, calcium fluoride, or any combination thereof. Examples of the metal oxides can include lime, zinc oxide, magnesium oxide, or any combination thereof. Note that the third filler may be functional, such as, grinding aids, lubricants, and porosity inducers. In alternative instances, the third filler can be used for functional and/or aesthetics, such as a coloring agent. According to an embodiment, the third filler can be distinct from the abrasive particles, including primary abrasive particles and secondary abrasive particles. In at least one embodiment, the third filler can include a halide-containing compound. In more particular instances, the third filler can include sodium. Moreover, the third filler may include aluminum. In one particular embodiment, the third filler can include sodium hexafluoroaluminate (Na_3AlF_6) and more particularly, can consist essentially of hexafluoroaluminate (Na_3AlF_6).

[0035] In one embodiment, the third filler may have a particular median particle size (D50), which may facilitate improved performance of the abrasive tool. For example, the third filler can have a median particle size of at least 0.1 microns, such at least 0.5 microns or at least 1 micron or at least 1.5 microns or at least 2 microns, or even at least 5 microns. Still, in another non-limiting embodiment, the third filler can have a median particle size (D50) of not greater than 500 microns, such as not greater than 200 microns or not greater than 100 microns or not greater than 90 microns or not greater than 80 microns or not greater than 70 microns or not greater than 60 microns or not greater than 50 microns or not greater than 40 microns or even not greater than 30 microns. It will be appreciated that the median particle size of the third filler can be within a range including any of the minimum and maximum values noted above. Moreover, in certain instances, reference to the foregoing median particle size may be reference to a maximum particle size, depending upon the sieving technique and the shape of the third filler particle.

[0036] In certain instances, the third filler may have a particular aspect ratio (length:width), which may facilitate improved performance of the abrasive tool. The third filler may have an aspect ratio that is substantially the same as the aspect ratio of the first filler and/or second filler. Still, in at least one other embodiment, the third filler can have an aspect ratio that is different compared to the aspect ratio of the first filler and/or second filler. For example, the third filler can have an aspect ratio (length:width) when viewing the second filler using a suitable two-dimensional image of at least 1.1:1, such as at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1, or even at least 2:1. Still, in one non-limiting embodiment, the third filler can have an aspect ratio of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1, or not greater than 10:1 or not greater than 5:1, or even not greater than 2:1. In at least one embodiment, the third filler may be substantially equiaxed having an aspect ratio of approximately 1:1. It will be appreciated that the aspect ratio of the third filler can be within a range including any of the minimum and maximum ratios noted above.

[0037] In certain situations, the third filler may be present in a particular content that may facilitate improved performance of the abrasive tool. For example, the third filler can be present in the first abrasive region **202** in a third content. According to one embodiment, the third content can be at least 0.01 wt % of the total weight of the first abrasive region **202**, such as at least 0.1 wt % or at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt %, or even at least 2.2 wt % or at least 2.4 wt % or at least 2.6 wt % or at least 2.8 wt % or at least 3 wt % or at least 3.1 wt % or at least 3.2 wt %. Still, in another non-limiting embodiment, the third content can be not greater than 18 wt % of the total weight of the first abrasive region **202**, such as not greater than 17 wt % or not greater than 16 wt % or not greater than 15 wt % or not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7 wt % or not greater than 6 wt %, not greater than 5 wt % or not greater than 4 wt % or even not greater than 3.5 wt %. It will be appreciated that the third content can be within a range including any of the minimum and maximum ratios noted above, including for example, at least 0.01 wt % and not greater than 18 wt % for a total weight of the first abrasive region **202**, or within a range including at least 2.6 wt % and not greater than 4 wt %.

[0038] The first abrasive region **202** may utilize particular contents of the first filler and third filler with respect to each other, which may facilitate improved operation of the abrasive tool. In certain instances, the first content of the first filler and third content of the third filler can be substantially the same with respect to each other. In still other instances, the first content of the first filler and third content of the third filler can be different with respect to each other. For example, according to an embodiment, the third content of the third filler may be greater than the first content of the first filler, or in another instance, the third content of the third filler may be smaller than the first content of the first filler. According to one embodiment, the first abrasive region **202** can include a ratio (C1:C3) of the first content (C1) to the third content (C3) as measured in wt % of the first filler and third filler, respectively. According to one embodiment, the first abrasive region **202** can have a ratio (C1:C3) of at least 1.1:1, such as at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or even at least 2:1. Still, in a non-limiting embodiment, the first abrasive region **202** can have a ratio (C1:C3) of the first content (C1) to the third content (C3) of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater

than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 8:1 or not greater than 6:1 or not greater than 5:1 or not greater than 4:1 or not greater than 3:1 or not greater than 2.5:1 or not greater than 2.2:1 or even not greater than 1.9:1. It will be appreciated that the ratio (C1:C3) can be within a range including any of the minimum and maximum ratios noted above, for instant including at least 1.1:1 and not greater than 2.5:1.

[0039] Moreover, the first abrasive region **202** may utilize particular contents of the second filler and third filler with respect to each other, which may facilitate improved operation of the abrasive tool. In certain instances, the second content of the second filler and third content of the third filler can be substantially the same with respect to each other. In still other instances, the second content of the second filler and third content of the third filler can be different with respect to each other. According to one embodiment, the first abrasive region **202** can include a ratio (C3:C2) of the third content (C2) to the second content (C2) as measured in wt % of the third filler and second filler, respectively. According to one embodiment, the first abrasive region **202** can have a ratio (C3:C2) of at least 1.1:1, such as at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or even at least 2:1. Still, in a non-limiting embodiment, the first abrasive region **202** can have a ratio (C3:C2) of the third content (C1) to the second content (C2) of not greater than 100:1, such as not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 8:1 or not greater than 6:1 or not greater than 5:1 or not greater than 4:1 or not greater than 3:1 or not greater than 2.5:1 or even not greater than 2:1. It will be appreciated that the ratio (C3:C2) can be within a range including any of the minimum and maximum ratios noted above.

[0040] It will be appreciated that reference herein to a filler including a first filler, second filler, and third filler is not to be interpreted as limited to only three fillers. Other filler compositions may be utilized that include more than two or three fillers as noted herein. Still, in at least one embodiment, the abrasive tool **200** may include one or more abrasive layers consisting essentially of the first filler, second filler, and third filler.

[0041] One or more of the filler materials of the embodiments herein can include a coating. The coating can overlie at least a portion of the surfaces of one or more types of fillers (i.e., the first filler, second filler, third filler, etc.) contained in the body. The coating can be a material distinct from the bond material. In particular instances, the first filler comprises a coating, and may be the only filler material having a coating within the body. The coating can be selected from a group of materials including an inorganic material, an organic material, a resin, an epoxy, or a combination thereof. In one particular instance, the coating can include a silane, and more particularly, may include a silane-based material including a majority content of silane. In some cases, the coating may facilitate improved bonding between the filler and the bond material, which may facilitate improved performance of the abrasive tool.

[0042] According to an embodiment herein, the body **201** can include a first abrasive region **202** that may have a particular content of bond material relative to the content of one of the fillers, which may facilitate improved performance. For example, the body **201** can have a ratio (Cff/Cb) of at least 0.2, wherein Cff represents a content of the first filler (wt %) for the first abrasive region **202** and Cb represents a content of the bond material (wt %) for the first abrasive region **202**. In other instances, the ratio (Cff/Cb) at least 0.22, such as at least 0.24 or at least 0.26 or even at least 0.28. Still, in other non-limiting embodiments, the ratio (Cff/Cb) can be not greater than 1, such as not greater than 0.9 or not greater than 0.8 or not greater than 0.7 or not greater than 0.6 or not greater than 0.5 or even not greater than 0.4. It will be appreciated that the ratio (Cff/Cb) can be within a range between any of the minimum and maximum values noted above.

[0043] The filler, including each of the first filler, second filler, and third filler can be substantially uniformly distributed throughout the thickness (t**1**) of the first abrasive region **202**. In other embodiments, it is contemplated that a non-uniform distribution of the filler may be utilized with respect to the thickness. For example, in certain instances, the content of the filler in the first abrasive region **202** at the major surface **211** may be significantly different compared to the content of filler at the interface of the first abrasive region **202** and the reinforcing member **206**. The filler content in the first abrasive region **202** can define a content gradient that is gradually changing along the axis defined by the thickness (i.e., the axial direction) of the abrasive tool **200**.

[0044] FIG. **3** includes a top-down view of an abrasive tool according to an embodiment. As illustrated, the abrasive tool **300** includes a body **301** that can include a bonded abrasive as described herein. The body **301** can include an annular region **302** defined between the inner annual edge **305** and outer peripheral edge **304**. According to one embodiment, at least one filler, such as the first filler, can be substantially uniformly radially distributed throughout the entire volume of the bond material. That is, for a given abrasive region within the body **301**, the content of the filler (e.g., first filler) at the inner annular edge **305** to the outer peripheral edge **304** can be substantially the same in a radial direction. In one particular embodiment, the body **301** can include an abrasive region wherein the first filler is substantially uniformly radially distributed throughout the entirety of the first abrasive region, which can extend between the inner annular edge **305** to the outer peripheral edge **304**. It will be appreciated that such a uniform distribution can exist for any and all components of the body, including any and all fillers and the abrasive particles. Moreover, while certain abrasive tools may utilize a substantially uniform radial distribution of at least one filler, it will be appreciated that such uniformity may be attributed to one or more abrasive layers of the body **301**. Furthermore, an abrasive article may utilize at least one filler that has a substantially uniform radial distribution within one abrasive region, and a non-uniform distribution within another, different abrasive region of the body. The non-uniform distribution may extend axially (i.e., in the direction of the thickness of the body), radially, or both.

[0045] FIG. **4** includes a top-down view of an abrasive tool according to an embodiment. As illustrated, the abrasive tool **400** can have a body **401** that can include a bonded abrasive as described herein. As illustrated, the body **401** may include different annular regions, including for example, an inner annular region **403** including the inner annular edge **405** of the body **401**, which may define the

opening **406**. The body **401** may also include an outer annular region **402** including the outer peripheral edge **404** of the body **401**. It will be appreciated that the inner annular region **403** and outer annular region **402** can be any size and shape as suitable for forming and function of the abrasive tool **400**.

[0046] According to one embodiment, at least one filler (e.g., the first filler) can have a difference in content (wt %) in the inner annular region **403** compared to the outer annular region **402**. For example, in certain instances, the inner annular region **403** can have a different content (wt %) of at least one filler (e.g., the first filler) compared to the content (wt %) of the same filler in the outer annular region **402**. In a more particular embodiment, the content of at least one filler, such as the first filler, can be greater in the outer annular region **402** compared to the content of the same filler (e.g., the first filler) in the inner annular region **403**. In yet another embodiment, the content of a filler, such as the first filler can be less in the outer annular region **402** compared to the content of the same filler in the inner annular region **403**.

[0047] According to an embodiment, any one of the abrasive regions of the body can have one or more annular regions, including an inner annular region and outer annular region as illustrated in FIG. **4**. Moreover, the body of an abrasive tool may utilize multiple abrasive regions, wherein each of the abrasive regions may have the same arrangement of one or more annular regions or a different arrangement of one or more annular regions compared to each other. According to one embodiment, the body of the abrasive tool can have a first abrasive region and a second abrasive region distinct from the first abrasive region, wherein the first abrasive region and the second abrasive region have at least one of 1) a first content of abrasive particles in the first abrasive region different than a second content of abrasive particles in the second abrasive region or 2) a first type of abrasive particles in the first abrasive region different than a second type of abrasive particles in the second abrasive region or 3) a first content of the first filler in the first abrasive region different than a first content of the first filler in the second abrasive region or 4) a first filler composition in the first abrasive region different than a second filler composition in the second abrasive region or 5) a first content of bond material in the first abrasive region different than a second content of bond material in the second abrasive region or 6) a first type of bond material in the first abrasive region different than a second type of bond material in the second abrasive region or 7) a second content of a second filler in the first abrasive region different than a second content of the second filler in the second abrasive region or 8) a third content of a third filler in the first abrasive region different than a third content of the third filler in the second abrasive region, or a combination thereof.

[0048] In further reference to certain aspects of the abrasive articles of the embodiments herein, the abrasive particles of the abrasive tool may include inorganic materials, organic materials, naturally occurring materials (e.g., minerals), superabrasive materials, synthesized materials (e.g., polycrystalline diamond compacts) or a combination thereof. Some exemplary abrasive particles can include oxides, carbides (e.g., silicon carbide), carbon-based materials, nitrides, borides, oxycarbides, oxynitrides, oxyborides, agglomerated particles, non-agglomerated particles, shaped abrasive particles, non-shaped abrasive particles, or a combination thereof. In at least one embodiment, the abrasive particles can include alumina-based abrasive particles. As used herein, the term "alumina," "Al_2O_3" and "aluminum oxide" are used interchangeably. Specific examples of suitable alumina-based abrasive grains that can be employed in the present invention include white alundum grain, or pink alundum, mono-crystalline alumina, brown fused alumina, heat-treated alumina, alumina-zirconia abrasive particles, and a combination thereof.

[0049] Other abrasive particles can include seeded or unseeded sintered sol gel alumina, with or without chemical modification, such as rare earth oxides, MgO, and the like can be utilized. In yet another embodiment, the abrasive particles can include silica, zirconia, alumina-zirconia, silicon carbide, garnet, boron-alumina, diamond, cubic boron nitride, aluminum-oxynitride, ceria, titanium dioxide, titanium diboride, boron carbide, tin oxide, tungsten carbide, titanium carbide, iron oxide, chromia, flint, emery, bauxite, and utilized combination thereof. Furthermore, it will be appreciated that the abrasive particles can include a blend of one or more different types of abrasive particles as described herein. In one particular embodiment, the abrasive tool includes a blend of different types of abrasive particles, including a first type comprising alumina and a second type including silicon carbide. The abrasive particles of the embodiments herein can consist essentially of any one or more compositions provided herein.

[0050] As noted herein, the abrasive particles can include shaped abrasive particles. Shaped abrasive particles can have a well-defined and regular arrangement (i.e., non-random) of edges and sides, thus defining an identifiable and controlled shape from particle-to-particle. Moreover, shaped abrasive particles are distinct from traditional crushed or non-shaped abrasive particles as the shaped abrasive particles have substantially the same shape with respect to each other, wherein traditional crushed abrasive particles vary significantly in their shape with respect to each other. For example, a shaped abrasive particle may have a polygonal shape as viewed in a plane defined by any two dimensions of length, width, and height (e.g., viewed in a plane defined by a length and a width). Some exemplary polygonal shapes can be triangular, quadrilateral (e.g., rectangular, square, trapezoidal, parallelogram), a pentagon, a hexagon, a heptagon, an octagon, a nonagon, a decagon, and the like. Additionally, the shaped abrasive particle can have a three-dimensional shape defined by a polyhedral shape, such as a prismatic shape or the like. Further, the shaped abrasive particles may have curved edges and/or surfaces, such that the shaped abrasive particles can have convex, concave, ellipsoidal shapes. Exemplary shaped abrasive particles are disclosed in U.S. Pat. No. 8,758,461, which is incorporated herein in its entirety.

[0051] The size of abrasive particles can be expressed as a grit size, and charts showing a relation between a grit size and its corresponding average particle size, expressed in microns or inches, are known in the art as are correlations to the corresponding United States Standard Sieve (USSS) mesh size. Particle size selection depends upon the application or process for which the abrasive tool is intended and may range from 10 to 325 as per ANSI grit size designation. Specifically, grit sizes may range from 16 to 120 or 16 to 80.

[0052] According to one particular embodiment, the abrasive particles can have an average particle size (D50) of at least 1 micron, such as at least 10 microns or at least 20

microns or at least 30 microns or at least 40 microns. Still, in another non-limiting embodiment, the abrasive particles can have an average particle size of not greater than 2 mm, such as not greater than 1 mm or not greater than 800 microns or not greater than 600 microns or not greater than 500 microns or not greater than 400 microns or not greater than 300 microns or not greater than 280 microns or not greater than 250 microns or not greater than 200 microns. It will be appreciated that the abrasive particles can have an average particle size within a range including any of the minimum and maximum values noted above, including for example, within a range between 1 micron and 2 mm, within a range between 10 microns and 1 mm, or even within a range between 20 microns and 200 microns.

[0053] In at least one embodiment, an abrasive region of the abrasive tool may include a particular content of abrasive particles, which may facilitate improved performance. For example, the content of abrasive particles in the first abrasive region **202** can be at least 1 wt % of the total weight of the first abrasive region **202**, such as at least 5 wt % or at least 10 wt % or at least 20 wt % or at least 30 wt % or at least 40 wt % or at least 50 wt % or at least 60 wt % or at least 65wt % or at least 70 wt %. Still, in another non-limiting embodiment, the content of abrasive particles in the first abrasive region **202** can be not greater than 90 wt % of the total weight of the first abrasive region **202**, such as not greater than 85 wt % or not greater than 83 wt % or not greater than 80 wt % or not greater than 78 wt % or even not greater than 75 wt %. It will be appreciated that the content of abrasive particles can be within a range including any of the minimum and maximum ratios noted above, including for example, at least 30 wt % and not greater than 90 wt % for a total weight of the first abrasive region **202**.

[0054] The bond material of one or more abrasive regions of the abrasive tool can include an organic material. In specific implementations, the bond material can be a polymeric or resin material, which may be formed into the finally-formed bond material by curing. An example of an organic bond material that can be employed to fabricate bonded abrasive articles can include a phenolic resin. Such resins can be obtained by polymerizing phenols with aldehydes, in particular, formaldehyde, paraformaldehyde or furfural. In addition to phenols, cresols, xylenols and substituted phenols can be employed. Comparable formaldehyde-free resins also can be utilized. Examples of other suitable organic bond materials include epoxy resins, polyester resins, polyurethanes, polyester, rubber, polyimide, polybenzimidazole, aromatic polyamide, modified phenolic resins (such as: epoxy modified and rubber modified resins, or phenolic resin blended with plasticizers, etc.), and so forth, as well as mixtures thereof.

[0055] In at least one embodiment, an abrasive region of the abrasive tool may include a particular content of bond material, which may facilitate improved performance. For example, the content of bond material in the first abrasive region **202** can be at least 1 wt % of the total weight of the first abrasive region **202**, such as at least 5 wt % or at least 10 wt % or at least 12 wt % or at least 13 wt % or at least 14 wt %. In another non-limiting embodiment, the content of bond material in the first abrasive region can be at least 20 wt %, such as at least 30 wt % or at least 40 wt % or at least 50 wt % or at least 60 wt % or at least 65wt % or at least 70 wt %. Still, in another non-limiting embodiment, the content of bond material in the first abrasive region **202** can be not greater than 90 wt % of the total weight of the first abrasive region **202**, such as not greater than 85 wt % or not greater than 83 wt % or not greater than 80 wt % or not greater than 78 wt % or even not greater than 75 wt %. In yet another non-limiting embodiment, the content of bond material may be not greater than 60 wt %, such as not greater than 50 wt % or not greater than 40 wt % or not greater than 30 wt % or not greater than 20 wt % or not greater than 18 wt % or not greater than 16 wt %. It will be appreciated that the content of bond material can be within a range including any of the minimum and maximum ratios noted above.

[0056] Among phenolic resins, resoles can be obtained by a one-step reaction between aqueous formaldehyde and phenol in the presence of an alkaline catalyst. Novolac resin, also known as a two-stage phenolic resin, can be produced under acidic conditions and during milling process blended with a cross-linking agent, such as hexamethylenetetramine (often also referred to as "hexa"). Exemplary phenolic resins can include resole and novolac. Resole phenolic resins can be alkaline catalyzed and have a ratio of formaldehyde to phenol of greater than or equal to one, such as from 1:1 to 3:1. Novolac phenolic resins can be acid catalyzed and have a ratio of formaldehyde to phenol of less than one, such as from 0.5:1 to 0.8:1.

[0057] The bond material can contain more than one phenolic resin, including for example or at least one resole and at least novolac-type phenolic resin. In many cases or at least one phenol-based resin is in liquid form. Suitable combinations of phenolic resins are described, for example, in U.S. Pat. No. 4,918,116 to Gardziella, et al., the entire contents of which are incorporated herein by reference.

[0058] An epoxy resin can include an aromatic epoxy or an aliphatic epoxy. Aromatic epoxies components include one or more epoxy groups and one or more aromatic rings. An example aromatic epoxy includes epoxy derived from a polyphenol, e.g., from bisphenols, such as bisphenol A (4,4'-isopropylidenediphenol), bisphenol F (bis[4-hydroxyphenyl]methane), bisphenol S (4,4'-sulfonyldiphenol), 4,4'-cyclohexylidenebisphenol, 4,4'-biphenol, 4,4'-(9-fluorenylidene)diphenol, or any combination thereof. The bisphenol can be alkoxylated (e.g., ethoxylated or propoxylated) or halogenated (e.g., brominated). Examples of bisphenol epoxies include bisphenol diglycidyl ethers, such as diglycidyl ether of Bisphenol A or Bisphenol F. A further example of an aromatic epoxy includes triphenylolmethane triglycidyl ether, 1,1,1-tris(p-hydroxyphenyl)ethane triglycidyl ether, or an aromatic epoxy derived from a monophenol, e.g., from resorcinol (for example, resorcin diglycidyl ether) or hydroquinone (for example, hydroquinone diglycidyl ether). Another example is nonylphenyl glycidyl ether. In addition, an example of an aromatic epoxy includes epoxy novolac, for example, phenol epoxy novolac and cresol epoxy novolac. Aliphatic epoxy components have one or more epoxy groups and are free of aromatic rings. The external phase can include one or more aliphatic epoxies. An example of an aliphatic epoxy includes glycidyl ether of C2-C30 alkyl; 1,2 epoxy of C3-C30 alkyl; mono or multi-glycidyl ether of an aliphatic alcohol or polyol such as 1,4-butanediol, neopentyl glycol, cyclohexane dimethanol, dibromo neopentyl glycol, trimethylol propane, polytetramethylene oxide, polyethylene oxide, polypropylene oxide, glycerol, and alkoxylated aliphatic alcohols; or polyols. In one embodiment, the aliphatic epoxy includes one or more cycloaliphatic ring structures. For example, the aliphatic

epoxy can have one or more cyclohexene oxide structures, for example, two cyclohexene oxide structures.

[0059] An example of an aliphatic epoxy comprising a ring structure includes hydrogenated bisphenol A diglycidyl ether, hydrogenated bisphenol F diglycidyl ether, hydrogenated bisphenol S diglycidyl ether, bis(4-hydroxycyclohexyl)methane diglycidyl ether, 2,2-bis(4-hydroxycyclohexyl)propane diglycidyl ether, 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexanecarboxylate, 3,4-epoxy-6-methylcyclohexylmethyl-3,4-epoxy-6-methylcyclohexanecarboxylate, di(3,4-epoxycyclohexylmethyl) hexanedioate, di(3,4-epoxy-6methylcyclohexylmethyl) hexanedioate, ethylenebis(3,4-epoxycyclohexanecarboxylate), ethanedioldi(3,4-epoxycyclohexylmethyl) ether, or 2-(3,4-epoxycyclohexyl-5,5-spiro-3,4-epoxy)cyclohexane-1,3-dioxane.

[0060] An exemplary multifunctional acrylic can include trimethylolpropane triacrylate, glycerol triacrylate, pentaerythritol triacrylate, methacrylate, dipentaerythritol pentaacrylate, sorbitol triacrylate, sorbital hexacrylate, or any combination thereof. In another example, an acrylic polymer can be formed from a monomer having an alkyl group having from 1-4 carbon atoms, a glycidyl group or a hydroxyalkyl group having from 1-4 carbon atoms. Representative acrylic polymers include polymethyl methacrylate, polyethyl methacrylate, polybutyl methacrylate, polyglycidyl methacrylate, polyhydroxyethyl methacrylate, polymethyl acrylate, polyethyl acrylate, polybutyl acrylate, polyglycidyl acrylate, polyhydroxyethyl acrylate and mixtures thereof.

[0061] Curing or cross-linking agents that can be utilized depend on the bonding material selected. For curing phenol novolac resins, for instance, a typical curing agent is hexa. Other amines, e.g., ethylene diamine; ethylene triamine; methyl amines and precursors of curing agents, e.g., ammonium hydroxide which reacts with formaldehyde to form hexa, also can be employed. Suitable amounts of curing agent can be within the range, for example, of from 5 to 20 parts, or 8 parts to 15 parts, by weight of curing agent per hundred parts of total novolac resin. It will be appreciated that the ratio can be adjusted based on various factors, including for example the particular types of resins used, the degree of cure needed, and the desired final properties for the articles, such as strength, hardness, and grinding performance.

[0062] As noted herein and according to one embodiment, the bonded abrasive can be reinforced with one or more reinforcing members, which may be in the form of layers, partial layers, discrete bundles of material distributed throughout the body, and a combination thereof. As used herein, the term "reinforcing member" can refer to a discrete component that can be made of a material that is different from the bond material and abrasive particles utilized to make the abrasive layers within the bonded abrasive body. In an embodiment, the reinforcing member does not include abrasive particles. With respect to the thickness of the bonded abrasive, a reinforcing member can be embedded within the body of the bonded abrasive and such bonded abrasives may be referred to as "internally" reinforced. A reinforcing member also can be close to, or attached to the front and/or back face of the body of the bonded abrasive. Several reinforcing members can be disposed at various depths through the thickness of the bonded abrasive.

[0063] Certain reinforcing members may have a circular geometry. The outer periphery of the reinforcing member also can have a square, hexagon or another polygonal geometry. An irregular outer edge also can be used. Suitable non-circular shapes that can be utilized are described in U.S. Pat. Nos. 6,749,496 and 6,942,561, incorporated herein by reference in their entirety. In certain instances wherein the bonded abrasive is in the form of a wheel or disc, the reinforcing member can extend from the inner diameter (edge of the central opening) to the outermost edge (i.e., peripheral surface) of the bonded abrasive body. Partial reinforcing members can be employed and in such cases, the reinforcing member may extend, for example, from the mounting hole to at least 30% along the radius or, for non-circular shapes, along the equivalent of the largest "radius" of the bonded abrasive body. For example, a partial reinforcing member can extend for at least 60% or at least 70% or at least 75% or at least 80% or at least 85% or at least 90% or at least 95%, or even at least 99% along the radius or, for non-circular shapes, along the equivalent of the largest "radius" of the body of the bonded abrasive. In another non-limiting embodiment, the partial reinforcing member may extend for not greater than 100%, such as not greater than 99% or not greater than 97% or not greater than 95% or not greater than 90% or not greater than 85% or not greater than 80% or not greater than 70%, or even not greater than 60% along the radius or the equivalent of the largest "radius" of the bonded abrasive body. It will be appreciated that the partial reinforcing member can extend within a range including any of the minimum and maximum values noted above. For instance, the partial reinforcing member can extend within a range of 60% to 100%, such as, within a range of 70% to 99%, or within a range of 80% to 90% along the radius or the equivalent of the largest "radius" of the bonded abrasive body

[0064] The reinforcing member can include various materials, including a single material or more than one type of material, such as a composite material. Moreover, the abrasive tool of the embodiments herein can use a single type of reinforcing member or may use different types of reinforcing members, which can employ different materials with respect to each other. Some suitable reinforcing member materials can include woven materials or non-woven materials. In at least one embodiment, the reinforcing member can include a glass material, including but not limited to a fiberglass material. In yet other embodiments, the reinforcing member can include, a fiber (e.g., Kevlar®), basalt, carbon, fabric organic materials (e.g., elastomers, rubbers), combinations of materials and so forth. An exemplary reinforcing member can include a polymeric film (including primed films) including for example, a polyolefin film (e.g., polypropylene including biaxially oriented polypropylene), a polyester film (e.g., polyethylene terephthalate), a polyamide film, a cellulose ester film, a metal foil, a mesh, a foam (e.g., natural sponge material or polyurethane foam), a cloth (e.g., cloth made from fibers or yams comprising fiberglass, polyester, nylon, silk, cotton, poly-cotton, or rayon), a paper, a vulcanized paper, a vulcanized rubber, a vulcanized fiber, a nonwoven material, or any combination thereof, or treated versions thereof. A cloth backing can be woven or stitch bonded. In particular examples, the reinforcing member can be selected from a group consisting of paper, polymer film, cloth, cotton, poly-cotton, rayon, polyester, poly-nylon, vulcanized rubber, vulcanized fiber, fiberglass fabric, metal foil

or any combination thereof. In other examples, the reinforcing member includes a woven fiberglass fabric. In a particular example, the bonded abrasive can include one more layers of fiberglass between which a blend abrasive grains or particles are bound in a bond material such as a polymer matrix. Using reinforcing members also can allow for shear at the interface between the reinforcing member and adjacent region(s) of the bonded abrasive (which contain abrasive grains or particles distributed in a three dimensional bond material matrix). It will be appreciated that a reinforcing member can consist essentially of any of the foregoing materials or consists essentially of two or more of the foregoing materials noted above.

[0065] In specific examples, the body can include at least one or more fiberglass reinforcing members, provided, for instance, in the form of fiberglass web(s). Fiberglass webs can include fiberglass woven from very fine fibers of glass. Fiberglass web can include leno or plain woven. The fiberglass utilized can include E-glass (alumino-borosilicate glass with less than 1 wt % alkali oxides). Other types of fiberglass can include, for example, A-glass (alkali-lime glass with little or no boron oxide), E-CR-glass (alumino-lime silicate with less than 1 wt % alkali oxides, with high acid resistance), C-glass (alkali-lime glass with high boron oxide content, used for example for glass staple fibers), D-glass (borosilicate glass with high dielectric constant), R-glass (alumino silicate glass without MgO and CaO with high mechanical requirements), or S-glass (alumino silicate glass without CaO but with high MgO content with high tensile strength).

[0066] Fiberglass webs can be arranged in the bonded abrasive such as a bonded abrasive wheel in any suitable manner. In certain implementations, placement of a glass fiber web at the working face of the wheel may be avoided. Any of the embodiments herein can be reinforced with at least one fiberglass web having a hole corresponding to the central opening or arbor hole of the wheel and the same diameter as the wheel. Partial web reinforcing members that extend from the mounting hole through some but not the total radius of the wheel also can be used, as can be other web reinforcement placements.

[0067] The abrasive tools of the embodiments herein, with or without one or more reinforcing members, can be prepared by forming a mixture of the components, including but not limited to abrasive particles, a bond material, e.g., an organic material (resin) or an inorganic material, and in many cases other ingredients, such as, for instance, fillers, processing aids, lubricants, crosslinking agents, antistatic agents and so forth.

[0068] The various ingredients can be added in any suitable order and blended using known techniques. The resulting mixture can be used to form a green body. As used herein, the term "green" refers to a body which maintains its shape during the next process step, but generally does not have enough strength to maintain its shape permanently. Green may also refer to a body that is unfinished, or that there are further processes yet to be completed before transforming the green body to a finally-formed abrasive tool. For example, a resin bond present in the green body is in an uncured or unpolymerized state. The green body preferably is molded in the shape of the desired article.

[0069] One or more reinforcing members can be incorporated in the green body. For example, a first portion of a mixture can be placed and distributed at the bottom of an appropriate mold cavity and then covered with a first reinforcing member. A second portion of the mixture can then be disposed and distributed over the first reinforcing member. Additional reinforcing members and/or bond/abrasive mixture layers can be provided, if so desired. The amounts of mix added to form a particular layer thickness can be modified as suitable for the intended purposes of the abrasive article. Other suitable sequences and/or techniques can be employed to shape the reinforced green body. For instance, a piece of paper or a fiberglass mesh or web or a piece of paper with a fiber glass mesh or web may be inserted in the mold cavity before the first mixture.

[0070] As noted herein, the body can be formed of one or more abrasive regions, which may be in the form of layers, which can have the same or different characteristics, such as, layer thickness, layer formulation (e.g., amounts and or types of ingredients being employed, grit size, grit shape, porosity), filler materials, bond composition, bond content, abrasive content, abrasive particle composition, porosity, pore size, porosity distribution, porosity type (i.e., closed and/or open porosity) and the like.

[0071] The bonded abrasive body described herein can be fabricated to have a certain porosity. The porosity can be set to provide a particular performance of the abrasive tool, including parameters such as hardness, strength, and initial stiffness, as well as chip clearance and swarf removal. Porosity can be uniformly or non-uniformly distributed throughout the body of the bonded abrasive and can be intrinsic porosity, obtained by the arrangement of grains within the bond matrix, shape of the abrasive grains and/or bond precursors being utilized, pressing conditions, curing conditions and so forth, or can be generated by the use of pore inducers. Both types of porosity can be present.

[0072] The porosity can be closed and/or interconnected (open). In "closed" type of porosity, the pores are generally discrete with respect to each other and are not interconnected. In contrast, "open" porosity presents pores that are interconnected to one another creating an interconnected network of channels.

[0073] In one embodiment, an abrasive region of the abrasive tool may contain porosity of at least 0.1 vol % for a total volume of the abrasive region, such as at least 1 vol % or at least 2 vol % or at least 3 vol % or even at least 5 vol %. In another non-limiting embodiment, the porosity may be not greater than 40 vol %, such as not greater than 35 vol % or not greater than 30 vol % or not greater than 25 vol %, or not greater than 20 vol % or not greater than 15 vol % or not greater than 10 vol %, or even not greater than 5 vol % for the total volume of abrasive layers within the body of the bonded abrasive. It will be appreciated that the porosity of the bonded abrasive can be within a range including any of the minimum and maximum values noted above, such as within the range of from 1 vol % to 40 vol %.

[0074] Various techniques can be used to produce the abrasive tools, including for example cold pressing, warm pressing, or hot pressing. In accordance with a particular embodiment the process of forming the abrasive articles herein can include cold pressing. In cold pressing, the materials in the mold are maintained at approximately ambient temperature, such as less than 30° centigrade (C). Force can be applied to the materials in the mold. For example, the applied force can be at least 40 tons. The applied force may be not greater than 2000 tons. The applied

force can be within a range of 100 tons to 2000 tons. Alternatively, pressure can be applied to the materials by suitable means, such as a hydraulic press. The pressure applied can be, for example, in the range of 4.2 kg/cm2 (60 psi or 0.03 tsi), 8.4 kg/cm2 (120 psi or 0.06 tsi) 70.3 kg/cm2 (0.5 tsi) to 2109.3 kg/cm2 (15 tsi), or in the range of 140.6 kg/cm2 (1 tsi) to 843,6 kg/cm2 (6 tsi). The holding time within the press can be, for example, within the range of from less than 2.5 seconds to 1 minute.

[0075] Wheels may be molded individually or large "bats" can be molded, from which individual wheels are later cored out. The various abrasive mix layers, which comprise abrasive grain, resin and fillers), fiberglass reinforcement and barrier layer material are sequentially placed into a mold cavity in the appropriate configuration. The barrier layer can serve as the outermost layers of the stack. The full stack can be pressed using forces commensurate with the pressures described above. The barrier layer can adhere to the abrasive mixture, and thus ultimately be bonded in-situ to the abrasive wheel as a result of the curing process.

[0076] It will be appreciated however that warm pressing or hot pressing may be utilized to form the abrasive articles. Warm pressing and hot pressing are similar to cold pressing operations, except that higher temperatures may be utilized during the application of pressure.

[0077] In the embodiments employing an organic bond material, the bonded abrasive can be formed by curing the organic bond material. As used herein, the term "final cure temperature" is the temperature at which the molded article is held to effect polymerization, e.g., cross-linking, of the organic bond material, thereby forming the final composition of the bond material, although cross-linking can begin at lower temperatures. The curing temperature may be utilized during other processes, such as during the cold pressing operation. Alternatively, certain processes of the embodiments herein, can utilize a separate curing step, which can be separate from other processes such as the cold pressing operation. In such instances, the pressing operation may be first conducted, and the uncured abrasive article may be removed from the press and placed in a temperature-controlled chamber to facilitate curing. As used herein, "cross-linking" refers to the chemical reaction(s) that take(s) place in the presence of heat and often in the presence of a cross-linking agent, such as "hexa" or hexamethylenetetramine, whereby the organic bond composition hardens. Generally, the molded article can be held at a final cure temperature for a period of time, such as between 6 hours and 48 hours, between 10 and 36 hours, or until the center of mass of the molded article reaches the cross-linking temperature and desired grinding performance (e.g., density of the cross-link).

[0078] Selection of a curing temperature depends, for instance, on factors such as the type of bonding material employed, strength, hardness, and grinding performance desired. According to certain embodiments, the curing temperature can be in the range including at least 100° C. to not greater than 250° C. In more specific embodiments employing organic bonds, the curing temperature can be in the range including at least 150° C. to not greater than 230° C. Polymerization of novolac-based resins may occur at a temperature in the range of including at least 110° C. and not greater than 225° C. Resole resins can polymerize at a temperature in a range of including at least 100° C. and not greater than 225° C. Certain novolac resins suitable for the embodiments herein can polymerize at a temperature in a range including at least 110° C. and not greater than 250° C.

Items

[0079] Item 1. An abrasive tool comprising a bonded abrasive including a body comprising abrasive particles contained within a three-dimensional matrix of bond material, the bond material comprising an organic material; a first filler contained within the three-dimensional matrix of bond material comprising a silicate in a first content; and a second filler contained within the three-dimensional matrix of bond material comprising a sulfate in a second content; and wherein the first content is greater than the second content.

[0080] Item 2. An abrasive tool comprising: a bonded abrasive including a body comprising: a first abrasive region including abrasive particles contained within a three-dimensional matrix of bond material, the bond material comprising an organic material, wherein the first abrasive region further comprises a first filler comprising a silicate contained within the three-dimensional matrix of bond material, wherein the first filler is substantially uniformly radially distributed throughout the first abrasive region; and a reinforcing member coupled to the first abrasive region.

[0081] Item 3. An abrasive tool comprising: a bonded abrasive including a body comprising: a diameter, a thickness, and a ratio of diameter:thickness of at least about 10:1; and a first abrasive region including abrasive particles contained within a three-dimensional matrix of bond material comprising an organic material, wherein the first abrasive region further comprises a first filler contained within the three-dimensional matrix of bond material comprising a silicate, wherein the first filler is substantially uniformly radially distributed throughout the first abrasive region.

[0082] Item 4. An abrasive tool comprising: a bonded abrasive including a body comprising: a first abrasive region including abrasive particles contained within a three-dimensional matrix of bond material comprising an organic material, wherein the first abrasive region further comprises a first filler contained within the three-dimensional matrix of bond material comprising a silicate, the first abrasive region comprising a ratio (Cff/Cb) of at least 0.2 and not greater than 1, wherein Cff represents a content of the first filler (wt %) for the first abrasive region and Cb represents a content of the bond material (wt %) for the first abrasive region; and a reinforcing member coupled to the first abrasive region.

[0083] Item 5. An abrasive tool comprising: a bonded abrasive including a body having a thickness not greater than 10 mm comprising: a first abrasive region including abrasive particles contained within a three-dimensional matrix of bond material, the bond material comprising an organic material, wherein the first abrasive region further comprises a first filler comprising a silicate contained within the three-dimensional matrix of bond material, wherein the first filler is substantially uniformly radially distributed throughout the first abrasive region, and wherein the first abrasive region comprises a content of wollastonite within a range including at least 0.2 wt % and not greater than 20 wt % for a total weight of the first abrasive region.

[0084] Item 6. The abrasive tool of any of the items herein, wherein the first filler comprises calcium.

[0085] Item 7. The abrasive tool of any of the items herein, wherein the first filler comprises a calcium silicate compound.

[0086] Item 8. The abrasive tool of any of the items herein, wherein the first filler comprises an inosilicate compound.

[0087] Item 9. The abrasive tool of any of the items herein, wherein the first filler comprises wollastonite.

[0088] Item 10. The abrasive tool of any of the items herein, wherein the first filler consists essentially of wollastonite (CaSiO3).

[0089] Item 11. The abrasive tool of any of the items herein, wherein the first filler comprises a median particle size (D50) of at least 1 micron or at least 2 microns or at least 3 microns or at least 4 microns or at least 5 microns or at least 6 microns or at least 7 microns or at least 8 microns or at least 9 microns or at least 10 microns or at least 11 microns or at least 12 microns or at least 13 microns.

[0090] Item 12. The abrasive tool of any of the items herein, wherein the first filler comprises a median particle size (D50) of not greater than 100 microns or not greater than 95 microns or not greater than 90 microns or not greater than 85 microns or not greater than 80 microns or not greater than 75 microns or not greater than 7+0 microns or not greater than 65 microns or not greater than 60 microns or not greater than 55 microns or not greater than 50 microns or not greater than 45 microns or not greater than 40 microns or not greater than 35 microns or not greater than 30 microns or not greater than 25 microns.

[0091] Item 13. The abrasive tool of any of the items herein, wherein the first filler is a material distinct from the abrasive particles.

[0092] Item 14. The abrasive tool of any of the items herein, wherein the first filler is substantially uniformly distributed throughout the entire volume of the bond material.

[0093] Item 15. The abrasive tool of any of the items herein, wherein the first content of the first filler is substantially the same in an outer annular region of the body as compared to a content of the first filler in an inner annular region of the body.

[0094] Item 16. The abrasive tool of any of the items herein, wherein the first content of the first filler is substantially the same at a peripheral edge of the body as compared to an inner annular edge of the body.

[0095] Item 17. The abrasive tool of any of the items herein, wherein the first filler is substantially uniformly radially distributed throughout the first abrasive region;

[0096] Item 18. The abrasive tool of any of the items herein, wherein the first abrasive region comprises an inner annular region and an outer annular region, wherein the inner annular region has a different content (wt %) of the first filler compared to a content (wt %) of the first filler in the outer annular region.

[0097] Item 19. The abrasive tool of any of the items herein, wherein the content of the first filler is greater in the outer annular region compared to the inner annular region.

[0098] Item 20. The abrasive tool of any of the items herein, wherein the content of the first filler is less in the outer annular region compared to the inner annular region.

[0099] Item 21. The abrasive tool of any of the items herein, wherein the first filler is a reinforcing agent configured to reduce the wear of the bond during grinding operations.

[0100] Item 22. The abrasive tool of any of the items herein, wherein the first filler is a particle having an aspect ratio of length:width of at least 1.1:1.

[0101] Item 23. The abrasive tool of any of the items herein, wherein the aspect ratio is at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2:1.

[0102] Item 24. The abrasive tool of any of the items herein, wherein the aspect ratio is not greater than 100:1 or not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1.

[0103] Item 25. The abrasive tool of any of the items herein, wherein the body comprises a first abrasive region including abrasive particles contained within the three-dimensional matrix of bond material and the first filler is present in a first content within a range including at least 0.2 wt % and not greater than 20 wt % for a total weight of the first abrasive region.

[0104] Item 26. The abrasive tool of any of the items herein, wherein the first content is at least 0.1 wt % of the first abrasive region or at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt % or at least 2.2 wt % or at least 2.4 wt % or at least 2.6 wt % or at least 2.8 wt % or at least 3 wt % or at least 3.2 wt % or at least 3.4 wt % or at least 3.6 wt % or at least 3.8 wt % or at least 4 wt % or at least 4.2 wt %.

[0105] Item 27. The abrasive tool of any of the items herein, wherein the first content is not greater than 19 wt % of the first abrasive region or not greater than 18 wt % or not greater than 17 wt % or not greater than 16 wt % or not greater than 15 wt % or not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7 wt % or not greater than 6 wt % or not greater than 5 wt %.

[0106] Item 28. The abrasive tool of any of the items herein, further comprising a second filler contained within the three-dimensional matrix of bond material comprising a sulfate in a second content.

[0107] Item 29. The abrasive tool of any of the items herein, wherein the first content of the first filler is greater than the second content of the second filler.

[0108] Item 30. The abrasive tool of any of the items herein, wherein the second filler comprises potassium.

[0109] Item 31. The abrasive tool of any of the items herein, wherein the second filler comprises a potassium sulfate compound.

[0110] Item 32. The abrasive tool of any of the items herein, wherein the second filler consists essentially of potassium sulfate.

[0111] Item 33. The abrasive tool of any of the items herein, wherein the second filler comprises an average particle size of at least 0.1 microns.

[0112] Item 34. The abrasive tool of any of the items herein, wherein the second filler comprises an average particle size of not greater than 500 microns.

[0113] Item 35. The abrasive tool of any of the items herein, wherein the second filler is a particle having an aspect ratio of length:width of at least 1.1:1.

[0114] Item 36. The abrasive tool of any of the items herein, wherein the second filler has a different aspect ratio (length:width) compared to an aspect ratio (length:width) of the first filler.

[0115] Item 37. The abrasive tool of any of the items herein, wherein the body comprises a first abrasive region including abrasive particles contained within the three-dimensional matrix of bond material and the second filler present in the second content within a range including at least 0.01 wt % and not greater than 15 wt % for a total weight of the first abrasive region.

[0116] Item 38. The abrasive tool of any of the items herein, wherein the second content is at least 0.1 wt % or at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt % or at least 2.2 wt %.

[0117] Item 39. The abrasive tool of any of the items herein, wherein the second content is not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7 wt % or not greater than 6 wt % or not greater than 5 wt %.

[0118] Item 40. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C2) of the first content (C1) to the second content (C2) of at least 1.1:1 or at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2:1.

[0119] Item 41. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C2) of the first content (C1) to the second content (C2) of not greater than 100:1 or not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 8:1 or not greater than 6:1 or not greater than 5:1 or not greater than 4:1 or not greater than 3:1 or not greater than 2.5:1.

[0120] Item 42. The abrasive tool of any of the items herein, further comprising a third filler contained within the three-dimensional matrix of bond material comprising a halide-containing compound in a third content.

[0121] Item 43. The abrasive tool of any of the items herein, wherein the first content is greater than the third content.

[0122] Item 44. The abrasive tool of any of the items herein, wherein the third filler comprises sodium.

[0123] Item 45. The abrasive tool of any of the items herein, wherein the third filler comprises aluminum.

[0124] Item 46. The abrasive tool of any of the items herein, wherein the third filler comprises sodium hexafluoroaluminate (Na_3AlF_6).

[0125] Item 47. The abrasive tool of any of the items herein, wherein the third filler consists essentially of sodium hexafluoroaluminate (Na_3AlF_6).

[0126] Item 48. The abrasive tool of any of the items herein, wherein the third filler comprises a median particle size (D50) of at least 1 micron.

[0127] Item 49. The abrasive tool of any of the items herein, wherein the third filler comprises an average particle size of not greater than 50 microns.

[0128] Item 50. The abrasive tool of any of the items herein, wherein the third filler is a particle having a substantially equiaxed shape.

[0129] Item 51. The abrasive tool of any of the items herein, wherein the third filler has a substantially elongated shape.

[0130] Item 52. The abrasive tool of any of the items herein, wherein the third filler has a different aspect ratio (length:width) compared to an aspect ratio (length:width) of the first filler.

[0131] Item 53. The abrasive tool of any of the items herein, wherein the third filler has a different aspect ratio (length:width) compared to an aspect ratio (length:width) of a second filler.

[0132] Item 54. The abrasive tool of any of the items herein, wherein the third filler is present in a third content within a range including at least 0.01 wt % and not greater than 18 wt % for a total weight of the first abrasive region.

[0133] Item 55. The abrasive tool of any of the items herein, wherein the third content is at least 0.1 wt % or at least 0.5 wt % or at least 0.8 wt % or at least 1 wt % or at least 1.2 wt % or at least 1.4 wt % or at least 1.6 wt % or at least 1.8 wt % or at least 2 wt % or at least 2.2 wt % or at least or at least 2.4 wt % or at least 2.6 wt % or at least 2.8 wt % or at least 3 wt % or at least 3.2 wt %.

[0134] Item 56. The abrasive tool of any of the items herein, wherein the third content is not greater than 17 wt % or not greater than 16 wt % or not greater than 15 wt % or not greater than 14 wt % or not greater than 13 wt % or not greater than 12 wt % or not greater than 11 wt % or not greater than 10 wt % or not greater than 9 wt % or not greater than 8 wt % or not greater than 7 wt % or not greater than 6 wt % or not greater than 5 wt % or not greater than 4 wt %.

[0135] Item 57. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C3) of the first content (C1) to the third content (C3) of at least 1.1:1 or at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2:1.

[0136] Item 58. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C3) of the first content (C1) to the second content (C2) of not greater than 100:1 or not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 5:1 or not greater than 3:1 or not greater than 2.5:1.

[0137] Item 59. The abrasive tool of any of the items herein, wherein the first abrasive region further includes a second filler contained within the three-dimensional matrix of bond material.

[0138] Item 60. The abrasive tool of any of the items herein, wherein the second filler present in a second content within a range including at least 0.01 wt % and not greater than 15 wt % for a total weight of the first abrasive region.

[0139] Item 61. The abrasive tool of any of the items herein, wherein the first abrasive region further comprises a third filler in a third content, and wherein the first abrasive region comprises a ratio (C3:C2) of the third content (C3) to the second content (C2) of at least 1.1:1 or at least 1.2:1 or at least 1.3:1 or at least 1.4:1 or at least 1.5:1 or at least 1.6:1 or at least 1.7:1 or at least 1.8:1 or at least 1.9:1 or at least 2:1.

[0140] Item 62. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C3:C2) of the third content (C3) to the second content (C2) of not greater than 100:1 or not greater than 90:1 or not greater than 80:1 or not greater than 70:1 or not greater than 60:1 or

not greater than 60:1 or not greater than 50:1 or not greater than 40:1 or not greater than 30:1 or not greater than 20:1 or not greater than 10:1 or not greater than 5:1 or not greater than 3:1 or not greater than 2.5:1.

[0141] Item 63. The abrasive tool of any of the items herein, wherein the abrasive particles include a material selected from the group consisting of oxides, nitrides, carbides, carbon-based materials, borides, oxynitrides, oxycarbides, oxyborides, naturally occurring minerals, agglomerated particles, non-agglomerated particles, and a combination thereof, and wherein the abrasive particles comprise shaped abrasive particles, wherein the abrasive particles comprise alumina.

[0142] Item 64. The abrasive tool of any of the items herein, wherein the abrasive particles comprise a blend of different types of abrasive particles, a first type including alumina and a second type including silicon carbide.

[0143] Item 65. The abrasive tool of any of the items herein, wherein the body comprises a first abrasive region including abrasive particles contained within the three-dimensional matrix of bond material, wherein the first abrasive region includes a content of abrasive particles within a range including at least 30 wt % and not greater than 90 wt % for a total weight of the first abrasive region.

[0144] Item 66. The abrasive tool of any of the items herein, wherein the body comprises at least one reinforcing member extending radially through at least a portion of the body, wherein the at least one reinforcing layer comprises a material selected from the group consisting of a fabric, a fiber, a film, a woven material, a non-woven material, a glass, a fiberglass, a ceramic, a polymer, a resin, a polymer, a fluorinated polymer, an epoxy resin, a polyester resin, a polyurethane, a polyester, a rubber, a polyimide, a polybenzimidazole, an aromatic polyamide, a modified phenolic resin, and a combination thereof.

[0145] Item 67. The abrasive tool of any of the items herein, wherein the body includes a first reinforcing member extending radially through at least a portion of the body at a first axial position and a second reinforcing member extending radially through at least a portion of the body at a second axial position different than the first axial position.

[0146] Item 68. The abrasive tool of any of the items herein, wherein the body comprises a diameter (D) extending radially across the body and a thickness (t) extending axially across the body, wherein the body comprises a ratio of diameter:thickness of at least about 10:1 or at least about 20:1 or at least about 50:1, or at least about 100:1.

[0147] Item 69. The abrasive tool of any of the items herein, wherein the three-dimensional matrix of bond material includes an organic material selected from the group consisting of a resin, an epoxy, a polymer, and a combination thereof, wherein the bond material comprises a phenolic resin.

[0148] Item 70. The abrasive tool of any of the items herein, wherein the body comprises a first abrasive region including abrasive particles contained within the three-dimensional matrix of bond material, wherein the first abrasive region includes a content of the three-dimensional matrix of bond material within a range including at least 1 wt % and not greater than 40 wt % for a total weight of the first abrasive region.

[0149] Item 71. The abrasive tool of any of the items herein, wherein the body comprises a first abrasive region and a second abrasive region distinct from the first abrasive region, wherein the first abrasive region and the second abrasive region comprise at least one of:

[0150] a. a first content of abrasive particles in the first abrasive region different than a second content of abrasive particles in the second abrasive region;

[0151] b. a first type of abrasive particles in the first abrasive region different than a second type of abrasive particles in the second abrasive region;

[0152] c. a first content of the first filler in the first abrasive region different than a first content of the first filler in the second abrasive region;

[0153] d. a first filler composition in the first abrasive region different than a second filler composition in the second abrasive region;

[0154] e. a first content of bond material in the first abrasive region different than a second content of bond material in the second abrasive region;

[0155] f. a first type of bond material in the first abrasive region different than a second type of bond material in the second abrasive region;

[0156] g. a second content of a second filler in the first abrasive region different than a second content of the second filler in the second abrasive region;

[0157] h. a third content of a third filler in the first abrasive region different than a third content of the third filler in the second abrasive region;

[0158] Item 72. The abrasive tool of any of the items herein, wherein the first abrasive region and second abrasive region are layers that are axially spaced apart from each other within the body.

[0159] Item 73. The abrasive tool of any of the items herein, wherein the first abrasive region and second abrasive region define distinct annular regions within the body that are radially spaced apart from each other within the body.

[0160] Item 74. The abrasive tool of any of the items herein, wherein the body comprises a thickness not greater than 10 mm or not greater than 9.5 mm or not greater than 9 mm or not greater than 8.5 mm or not greater than 8 mm or not greater than 7.5 mm or not greater than 7 mm or not greater than 6.5 mm or not greater than 6 mm or not greater than 5.5. mm or not greater than 5 mm or not greater than 4.5 mm or not greater than 4 mm, and wherein the body comprises a thickness of at least 0.3 mm or at least 0.5 mm or at least 0.8 mm or at least 1 mm.

[0161] Item 75. The abrasive tool of any of the items herein, wherein the first filler comprises a coating overlying at least a portion of the surface of the first filler, wherein the coating is selected from the group consisting of an inorganic material, an organic material, a resin, an epoxy, and a combination thereof.

[0162] Item 76. The abrasive tool of any of the items herein, wherein the coating comprises silane.

[0163] Item 77. The abrasive tool of any of the items herein, wherein the first filler is a particle having an aspect ratio of length:width greater than 5:1.

[0164] Item 78. The abrasive tool of any of the items herein, wherein the first filler is a particle having an aspect ratio of length:width less than 15:1.

[0165] Item 79. The abrasive tool of any of the items herein, wherein the first filler is a particle having an aspect ratio within a range of greater than 5:1 to less than 15:1.

[0166] Item 80. The abrasive tool of any of the items herein, wherein the first filler is a particle having an aspect ratio within a range of at least 7:1 to 10:1.

[0167] Item 81. The abrasive tool of any of the items herein, wherein the first filler is present in a first content within a range including at least 0.2 wt % and not greater than 20 wt % for a total weight of the first abrasive region.

[0168] Item 82. The abrasive tool of any of the items herein, wherein the first filler is present in the first content within a range including at least 2 wt % and not greater than 12 wt % for a total weight of the first abrasive region.

[0169] Item 83. The abrasive tool of any of the items herein, wherein the first filler is present in the first content within a range including at least 2.8 wt % and not greater than 8 wt % for a total weight of the first abrasive region.

[0170] Item 84. The abrasive tool of any of the items herein, wherein the second content of the second filler is within a range including 1 wt % and not greater than 4 wt % for a total weight of the first abrasive region.

[0171] Item 85. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C2) of the first content (C1) to the second content (C2) of at least 1.5:1 and not greater than 3.5:1.

[0172] Item 86. The abrasive tool of any of the items herein, wherein the third filler is present in the third content within a range including at least 2.6 wt % and not greater than 4 wt %.

[0173] Item 87. The abrasive tool of any of the items herein, wherein the abrasive region comprises a ratio (C1:C3) of the first content (C1) to the third content (C3) in a range including at least 1.1:1 and not greater than 2.5:1.

EXAMPLE 1

[0174] A representative sample (S1) of an abrasive tool having a depressed center shape with an outer diameter of 230 mm, an inner diameter of approximately 22 mm, and an average thickness of approximately 6.5-7.5 mm was made using the following procedure. A mixture including the components provided in Table 1 was created and provided in a mold. Sample S1 was created to have the construction of a first reinforcing member of fiberglass (approximately 260 gsm), a first layer of the mixture overlying the first reinforcing member, a second reinforcing member of fiberglass (approximately 320 gsm) overlying the first layer, a second layer of the abrasive mixture overlying the second reinforcing member, and a third reinforcing member overlying the second layer. The sample (S1) was cold pressed including application of a pressure within a range of 90-160 bars at approximately room temperature. Then, the sample was cured in an oven at approximately 170-200° C. for at least 8 hours.

TABLE 1

INGREDIENT	Sample S1 Weight % in mix
Brown fused alumina (approximate average particle size of 1190 microns)	33.578
SiC (approximate average particle size of 1035 microns)	40.932
Resole	3.954
Novolac	10.690
Cryolite	3.565
Potassium sulfate	2.403
Wollastonite	4.411
Castor Oil	0.199
Titania	0.269

TABLE 1-continued

INGREDIENT	Sample S1 Weight % in mix
Potassium sulfate	2.403
Wollastonite	4.411
Castor Oil	0.199
Titania	0.269

EXAMPLE 2

[0175] Mixtures having a conventional composition W1 and compositions representative of embodiments herein, W2 and W3, were used to form abrasive tool samples in the same manner as described for Sample 51 in Example 1. The compositions are disclosed in Table 2 below. W1 did not include wollastonite, the mixture W2 included wollastonite, but had reduced contents of bond material, resole and novolac, as compared to W1. W3 included wollastonite, had similar contents of resin, but decreased contents of cryolite and potassium sulfate, as compared to W1. All of the ingredients added up to 100 wt % for each composition. Three samples for each composition were tested utilizing Bosch 9-inch Angle grinder on Grey Cast Iron plates having thickness of 15 mm. Grinding was performed at an angle of 30 to 45 degrees with 2.4 kW rated power (corresponding to an average of 4 to 6 kg normal force) and controlled current within 8 to 9 Amps. Average G-Ratio and MRR (material removal rate) for each of W2 and W3 compositions was used to compare to the average G-Ratio and MRR of W1, respectively. The relative G-Ratio and MRR of W1 is 1.00, respectively, and the relative G-Ratio and MRR of W2 and W3 samples are included in FIG. **5**. MRR of W2 and W3 was similar to that of W1. However, W2 demonstrated reduced G-Ratio with relative G-Ratio of 0.59, while W3 demonstrated increased G-Ratio with relative G-ratio of 1.36.

TABLE 2

Ingredient	W1 Weight % in mix	W2 Weight % in mix	W3 Weight % in mix
Brown fused alumina	33.639	32.821	33.578
SiC	41.006	40.008	40.932
Resole	3.961	3.729	3.954
Novolac	10.710	8.701	10.690
Cryolite	5.803	5.662	3.565
Potassium sulfate	4.413	4.305	2.403
Wollastonite	0.000	4.311	4.411
Castor oil	0.199	0.199	0.199
Titania	0.269	0.263	0.269

EXAMPLE 3

[0176] Mixtures having compositions W6, W9, W11, W 12, and W13, as disclosed in Table 3 below, were used to form additional representative abrasive tool samples. Samples of W1 were also formed. W6, W9, W11, W 12, and W13 included Wollastonite having aspect ratios of 7:1, 4:1, 5:1, 10:1, and 15:1, respectively. FIGS. **6**A to **6**C include images of wollastonite having aspect ratios of 4:1, 7:1, and 10:1, respectively.

TABLE 3

Ingredient	W6 Weight % in mix	W9 Weight % in mix	W11 Weight % in mix	W12 Weight % in mix	W13 Weight % in mix
Brown fused alumina	33.566	33.566	33.566	33.566	33.566
SiC	40.917	40.917	40.917	40.917	40.917
Resole	3.952	3.952	3.952	3.952	3.952
Novolac	10.686	10.686	10.686	10.686	10.686
Cryolite	3.118	3.118	3.118	3.118	3.118
Potassium sulfate	2.001	2.001	2.001	2.001	2.001
Wollastonite	5.291	5.291	5.291	5.291	5.291
Castor oil	0.199	0.199	0.199	0.199	0.199
Titania	0.269	0.269	0.269	0.269	0.269

[0177] Three samples for each of the compositions were formed, and all of the samples were tested utilizing Bosch 9-inch Angle grinder on Grey Cast Iron plates having thickness of 15 mm. Grinding was performed at an angle of 30 to 45 degrees with 2.4 kW rated power (corresponding to an average of 4 to 6 kg normal force) and controlled current within 8 to 9 Amps. Average G-Ratio and MRR (material removal rate) for each of compositions W6, W9, W11, W 12, and W13 was compared to the corresponding average of W1 samples. Relative G-Ratio and MRR of W1 is 1.00, respectively. Relative performance of G-Ratio and MRR of samples of W6 and W9 is included in FIG. **7**, and FIG. **8** includes relative performance for samples W11 to W13. Samples of W1, W6, and W9 demonstrated similar MRR. Samples of W9 had G-Ratio that was comparable to W1, while W6 demonstrated improved G-Ratio over W1 and W9. As disclosed in FIG. **7**, the relative G-Ratio of W6 is 1.6, while the relative G-Ratio of W9 is 1.2. As disclosed in FIG. **8**, MRR of samples of W1 and W11 to W13 were comparable, but G-ratio of W12 was improved over W1, W11, and W13. Samples of W11 and W13 demonstrated similar G-ratio as compared to W1. The relative G-ratio for W11 to W13 is 1.0, 1.5, and 1.0, respectively.

[0178] Note that not all of the activities described above in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed is not necessarily the order in which they are performed.

[0179] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

[0180] The specification and illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments. The specification and illustrations are not intended to serve as an exhaustive and comprehensive description of all of the elements and features of apparatus and systems that use the structures or methods described herein. Certain features, that are for clarity, described herein in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in a sub combination. Further, reference to values stated in ranges includes each and every value within that range. Many other embodiments may be apparent to skilled artisans only after reading this specification. Other embodiments may be used and derived from the disclosure, such that a structural substitution, logical substitution, or another change may be made without departing from the scope of the disclosure. Accordingly, the disclosure is to be regarded as illustrative rather than restrictive.

[0181] The description in combination with the figures is provided to assist in understanding the teachings disclosed herein, is provided to assist in describing the teachings, and should not be interpreted as a limitation on the scope or applicability of the teachings. However, other teachings can certainly be used in this application.

[0182] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or inherent to such method, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0183] Also, the use of "a" or "an" is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural, or vice versa, unless it is clear that it is meant otherwise. For example, when a single item is described herein, more than one item may be used in place of a single item. Similarly, where more than one item is described herein, a single item may be substituted for that more than one item.

[0184] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The materials, methods, and examples are illustrative only and not intended to be limiting. To the extent that certain details regarding specific materials and processing acts are not described, such details may include conventional approaches, which may be found in reference books and other sources within the manufacturing arts.

1. An abrasive tool comprising:

a bonded abrasive including a body comprising a first abrasive region including:

abrasive particles contained within a bond material, the bond material comprising an organic material;

a first filler contained within the bond material comprising a silicate in a first content; and

a second filler contained within the bond material comprising a sulfate in a second content; and

wherein the first content is greater than the second content.

2. The abrasive tool of claim **1**, wherein the first filler comprises a calcium silicate compound.

3. The abrasive tool of claim **2**, wherein the first filler comprises wollastonite.

4. The abrasive tool of claim **1**, wherein the first content is within a range including at least 0.2 wt % and not greater than 20 wt % for a total weight of the first abrasive region.

5. The abrasive tool of claim **4**, wherein the first content is within a range including at least 2.8 wt % and not greater than 8 wt % for a total weight of the first abrasive region.

6. The abrasive tool of claim **1**, the second filler comprises a potassium sulfate compound.

7. The abrasive tool of claim **6**, wherein the second filler consists essentially of potassium sulfate.

8. The abrasive tool of claim **1**, wherein the second content of the second filler is within a range including 1 wt % and not greater than 4 wt % for a total weight of the first abrasive region.

9. The abrasive tool of claim **1**, wherein the abrasive region comprises a ratio (C1:C2) of the first content (C1) to the second content (C2) of at least 1.5:1 and not greater than 3.5:1.

10. The abrasive tool of claim **1**, further comprising a third filler contained within the bond material comprising a halide-containing compound in a third content.

11. The abrasive tool of claim **10**, wherein the third filler comprises sodium hexafluoroaluminate (Na_3AlF_6).

12. The abrasive tool of claim **10**, wherein the third filler has a third content of at least 2.6 wt % and not greater than 4 wt %.

13. The abrasive tool of claim **1**, wherein the first filler is a particle having an aspect ratio of length:width within a range including greater than 5:1 and less than 15:1.

14. The abrasive tool of claim **13**, wherein the first filler is a particle having an aspect ratio within a range including at least 7:1 and not greater than 10:1.

15. An abrasive tool comprising:

a bonded abrasive including a body having a thickness not greater than 10 mm comprising:

a first abrasive region including abrasive particles contained within a bond material, the bond material comprising an organic material,

wherein the first abrasive region comprises a first filler in a first content comprising a silicate contained within the bond material, wherein the first filler is a particle having an aspect ratio of length:width of at least 1.5:1, and

a second filler contained within the bond material comprising a sulfate in a second content

16. The abrasive tool of claim **15**, wherein the abrasive region comprises a ratio (C1:C2) of the first content (C1) to the second content (C2) of at least 1.1:1.

17. The abrasive tool of claim **15**, wherein the first filler comprises an inosilicate compound.

18. The abrasive tool of claim **15**, wherein the first filler comprises an aspect ratio within a range including at least 7:1 and not greater than 10:1.

19. The abrasive tool of claim **15**, wherein the second filler comprises a potassium sulfate compound.

20. The abrasive tool of claim **15**, wherein the first abrasive region includes a content of abrasive particles within a range including at least 30 wt % and not greater than 90 wt % for a total weight of the first abrasive region.

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