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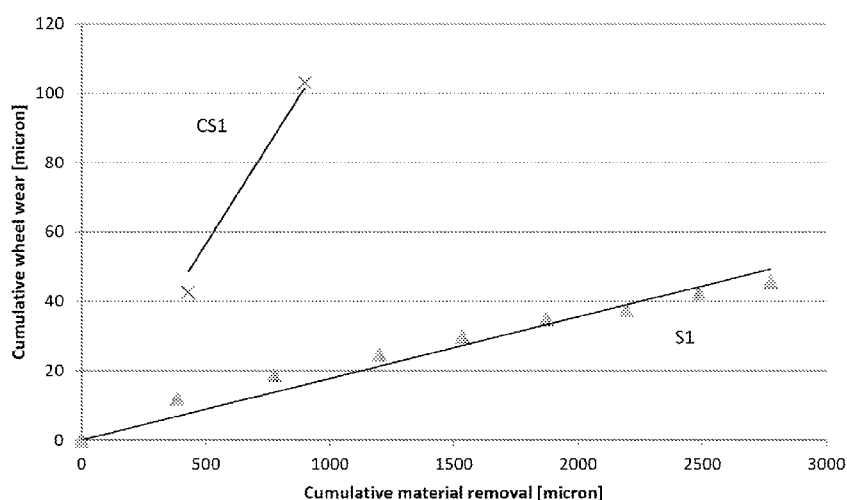


FIG. 1

(57) Abstract: An abrasive article including a bonded abrasive body including a bond material having a metal, abrasive particles contained within the bond material, and a filler blend including fine filler particles and coarse filler particles and defining a filler particle size ratio (F_f/F_c) of not greater than about 0.97, where F_f represents the average particle of the fine filler particles and F_c represents the average particle size of the coarse filler particles.

ABRASIVE ARTICLE AND METHOD OF FORMING

TECHNICAL FIELD

The following is directed to methods of forming abrasive articles, and particularly, bonded
5 abrasive articles.

BACKGROUND ART

A variety of abrasive tools have been developed over the past century for various industries
for the general function of removing material from a workpiece, including for example, sawing,
drilling, polishing, cleaning, carving, and grinding. In the production of electronic devices, the back
10 surface of a semiconductor wafer having a plurality of circuits such as IC's and LSI's is ground to a
predetermined thickness by a grinding machine before it is divided into individual chips. To grind the
back surface of the semiconductor wafer efficiently, a grinding machine equipped with a rough
grinding unit and a finish grinding unit is generally used. Generally, the article utilize to conduct the
rough grinding process is a bonded abrasive body or grindstone, which is obtained by bonding
15 together diamond abrasive grains having a relatively large size with a vitrified bond or metal bond
material. A resin bond grindstone having diamond abrasive grains of a median particle size of 2
microns or more contained in a resin bond is typically used for finish grinding operations. Smaller
sizes of diamonds generally cannot be utilized in resin bonded articles.

In some cases, the content of the inorganic bonding agent is reduced and the content of
20 porosity is increased, which is considered to reduce glazing or clogging of the surface of the vitrified
grindstone, chipping of the abrasive structure, poor dressability of the grindstone, and other
drawbacks. Generally, high-porosity grindstone bodies are accomplished by the use of foaming
agents during forming, which create bubbles and thus porosity in the finally-formed abrasive product.

Still, the industry continues to demand improved grindstone materials, capable of achieving
25 improved grinding performance.

SUMMARY

According to a first aspect, an abrasive article includes a bonded abrasive body including a
bond material comprising a metal, abrasive particles contained within the bond material, and a filler
blend including fine filler particles and coarse filler particles and defining a filler particle size ratio
30 (Ff/Fc) of not greater than about 0.97, wherein the Ff represents the average particle of the fine filler
particles and Fc represents the average particle size of the coarse filler particles.

In another aspect, an abrasive article includes a bonded abrasive body having a bond material
comprising a metal, abrasive particles contained within the bond material, a filler blend including fine
filler particles contained in the bond material having a Mohs hardness of not greater than about 4 and
35 coarse filler particles contained in the bond material having a Mohs hardness of not greater than about
6. The bonded abrasive body further includes a porosity of not greater than about 15 vol%.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG 1 includes a plot of cumulative wheel wear of the bonded abrasive body in microns versus cumulative material removed from the workpiece in microns.

FIG. 2 includes a plot of percent maximum power versus time for the backgrinding operation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The following is directed towards fixed abrasive articles, and more particularly bonded abrasive articles including a plurality of abrasive particles contained within a three dimensional matrix of bond material. The bonded abrasive article may be suitable for grinding a workpiece and material removal operations. In certain instances, the bonded abrasive article may be particularly suited for grinding of hard materials, and more particularly, hard, single crystalline materials, such a sapphire wafers.

In accordance with an embodiment, the process of forming a bonded abrasive article can include the formation of a mixture. The mixture may be in a wet or dry form. Furthermore, the mixture may include certain components, including but not limited to, a bond material, abrasive particles, and a filler blend. It will be appreciated that other components may be added to the mixture to facilitate proper dispersion of the components within each other and further processing to form the finally-formed bonded abrasive article.

After properly forming the mixture, the process of forming the bonded abrasive body can include forming a green body, which can be an unsintered body, which may undergo further treatment to form the finally-formed abrasive article. Suitable methods of forming the green body can include molding, pressing, casting, punching, and a combination thereof. Optionally, forming of the green body may include drying of the green body to facilitate removal of volatiles and prepare the body for further processing.

After forming the green body, the process of forming the bonded abrasive article can continue by heating the green body to form a finally-formed bonded abrasive body. Heating of the green body may facilitate a phase transformation of one or more components of the body, including for example a bond material. In certain instances, heating up the body can be conducted at a temperature of at least about 375°C to about 700°C. In more particular instances, the forming process may include hot pressing, which can include applying heat and pressure to the green body, which may be applied separately or simultaneously. In accordance with one embodiment, the pressure applied can be at least about 0.5 tons/in² and not greater than about 3 tons/in².

After processing, the finally-formed abrasive article can include a bonded abrasive body including a certain content of bond material, a certain content of abrasive particles contained within the bond material, a filler blend contained within the bond material, and some porosity extending

throughout the volume of the bonded abrasive body. In accordance with an embodiment, the filler blend can include fine filler particles and coarse filler particles that can be distinct from each other.

In accordance with an embodiment, the fine filler particles can include a material incorporated into the finally-formed abrasive body. For example, in certain instances, the fine filler particles may be a permanent material, which may be present as a particulate material in the finally-formed abrasive article. Moreover, in certain instances, the fine filler particles may not necessarily be removed during processing, such as a pore-forming material. In accordance with one embodiment, the fine filler particles may include an inorganic material. More particularly, the fine filler particles may include a carbon-containing material. For example, the fine filler particles can include a carbon-base material, wherein at least about 51 % of the material of the fine filler particles includes carbon. In accordance with one particular embodiment, the fine filler particles can include graphite, and more particularly, may consist essentially of graphite.

In certain instances, the fine filler particles can have an average particle size that is not greater than about 120 microns. For example, the fine filler particles can have an average particle size that is not greater than about 110 microns, not greater than about 100 microns, not greater than about 90 microns, not greater than about 80 microns, not greater than about 70 microns, not greater than about 60 microns, not greater than about 50 microns, not greater than about 40 microns, not greater than about 30 microns, not greater than about 20 microns, or even not greater than about 10 microns. Still, the fine filler particles may have any average particle size that can be at least about 0.1 microns, such as at least about 1 micron, at least about 5 microns, or even at least about 10 microns. It will be appreciated that the fine filler particles can have an average particle size within a range between any of the minimum and maximum values noted above.

In accordance with an embodiment, the fine filler particles may have a particular Mohs hardness to facilitate formation and performance of the bonded abrasive body. For example, the fine filler particles contained within the bond material may have a Mohs hardness of not greater than about 4. In other embodiments, the fine filler particles contained within the bond material may have a Mohs hardness of not greater than about 3.5, or even not greater than about 3. Still, the fine filler particles contained within the bond material may have a Mohs hardness of at least about 1, such as at least about 1.5, or even at least about 2. It will be appreciated that the fine filler particles can have a Mohs hardness within a range between any of the minimum and maximum values noted above.

The fine filler particles may have a certain morphology that facilitates performance of the bonded abrasive article. For example, the fine filler particles can have a shape selected from the group consisting of circular, ellipsoidal, needle-like, irregular, and platelet. In one particular embodiment, the fine filler particles can have a platelet shape. More particularly, the fine filler particles may have an aspect ratio (l:t) of length (l), which is the greatest dimension of the particle to

thickness (t) which is the smallest dimension of the particle, of at least about 1:2, such as at least about 1:3, or even at least about 1:4.

In accordance with another embodiment, the coarse filler particles can include a material incorporated into the finally-formed abrasive body. In certain instances, the coarse filler particles may be a permanent material, which may be present as a particulate material in the finally-formed abrasive article. Moreover, the coarse filler particles may not necessarily be removed during processing, such as a pore-forming material. In accordance with one embodiment, the coarse filler particles may include an inorganic material. In at least one aspect, the coarse filler particles may include a carbon-containing material. For example, the coarse filler particles can include a carbon-base material, wherein at least about 51 % of the material of the coarse filler particles includes carbon. In accordance with one particular embodiment, the coarse filler particles can include graphite, and more particularly, may consist essentially of graphite.

In certain instances, the fine filler particles and coarse filler particles may include a same element, composition, or material. For example, the fine filler particles and coarse filler particles may include a same carbon-containing material, wherein the fine filler particle includes at least 51 % carbon and the coarse filler particle includes at least about 51 % carbon. In one aspect, the fine filler particles and coarse filler particles may include a same carbon-based material. For example, in one embodiment, the fine filler particles and coarse filler particles may include graphite, and more particularly, the fine filler particles can consist essentially of graphite and the coarse filler particles can consist essentially of graphite.

In certain instances, the coarse filler particles may have a particular average particle size. For example, the coarse filler particles can have an average particle size of not greater than about 200 microns, such as not greater than about 190 microns, not greater than about 180 microns, not greater than about 170 microns, not greater than about 160 microns, not greater than about 150 microns, not greater than about 140 microns, not greater than about 130 microns. In still another non-limiting embodiment, the coarse filler particles can have an average particle size of at least about 15 microns, such as at least about 20 microns, at least about 30 microns, at least about 40 microns, at least about 50 microns, at least about 60 microns, at least about 70 microns, at least about 80 microns, at least about 90 microns, or even at least about 100 microns. It will be appreciated that the coarse filler particles can have an average particle size within a range between any of the minimum and maximum values noted above.

In accordance with an embodiment, the coarse filler particles may have a particular hardness to facilitate formation and performance of the bonded abrasive body. For example, the coarse filler particles can have a Mohs hardness of not greater than about 6, such as not greater than about 5.5, not greater than about 5, or even not greater than about 4, not greater than about 3.5. Still, in at least one non-limiting embodiment, the coarse filler particles contained in the bond material can have a Mohs

hardness of at least about 1, such as at least about 1.5, or even at least about 2. It will be appreciated that the coarse filler particles contained in the bond material can have a Mohs hardness within a range between any of the minimum and maximum values noted above.

The coarse filler particles may have a certain morphology that facilitates performance of the bonded abrasive article. For example, the coarse filler particles can have a shape selected from the group consisting of circular, ellipsoidal, needle-like, irregular, and platelet. In one particular embodiment, the coarse filler particles can have a platelet shape. More particularly, the coarse filler particles may have an aspect ratio (l:t) of length (l), which is the greatest dimension of the particle to thickness (t) which is the smallest dimension of the particle, of at least about 1:2, such as at least about 1:3, or even at least about 1:4.

In one aspect, the fine filler particles may have an average particle size (F_f) that is distinct from the average particle size of the coarse filler (F_c). More particularly, the filler blend may include a particular filler particle size ratio (F_f/F_c) that may be not greater than about 0.97. For example, in one embodiment, the filler particle size ratio (F_f/F_c) can be not greater than about 0.95, such as not greater than about 0.93, not greater than about 0.9, not greater than about 0.88, not greater than about 0.85, not greater than about 0.83, not greater than about 0.8, not greater than about 0.78, not greater than about 0.75, not greater than about 0.73, not greater than about 0.7, not greater than about 0.68, not greater than about 0.65, not greater than about 0.63, not greater than about 0.6, not greater than about 0.58, not greater than about 0.55, not greater than about 0.53, not greater than about 0.5, not greater than about 0.48, not greater than about 0.45, not greater than about 0.43, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2, or even not greater than about 0.1. Still, in another non-limiting embodiment, the filler particle size ratio (F_f/F_c) can be at least about 0.3, such as at least about 0.5, at least about 0.8, at least about 0.1, at least about 0.13, at least about 0.15, at least about 0.18, at least about 0.2, at least about 0.23, at least about 0.25, at least about 0.28, at least about 0.3, at least about 0.33, at least about 0.35, at least about 0.38, at least about 0.4, at least about 0.43, at least about 0.45, at least about 0.48, at least about 0.5, at least about 0.53, at least about 0.55, at least about 0.58, at least about 0.6, at least about 0.63, at least about 0.65, at least about 0.68, at least about 0.7, at least about 0.73, at least about 0.75, at least about 0.78, at least about 0.8, or even at least about 0.9. It will be appreciated that the filler particle size ratio can be within a range between any of the above minimum and maximum values.

In further instances, the filler blend may include a particular filler content ratio (C_f/C_c) of at least about 0.1, wherein C_f represents the volume percent of fine filler particles for the total volume of the bonded abrasive body and C_c represents the volume percent of the coarse filler particles for the total volume of the bonded abrasive body. In one embodiment, the filler content ratio can be at least about 0.05, such as at least about 0.1, at least about 0.2, at least about 0.3, at least about 0.4, at least about 0.5, at least about 0.6, at least about 0.7, at least about 0.8, at least about 0.9, at least about 1, at

least about 1.1, at least about 1.2, at least about 1.3, at least about 1.4, or even at least about 1.5. In still another non-limiting embodiment, the filler content ratio of the bonded abrasive body can be not greater than about 10, such as not greater than about 9, not greater than about 8, not greater than about 7, not greater than about 6, not greater than about 5, not greater than about 4, not greater than about 3, not greater than about 2, not greater than about 1, not greater than about 0.95, not greater than about 0.9, not greater than about 0.8, not greater than about 0.7, not greater than about 0.6, not greater than about 0.5, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2, not greater than about 0.1. It will be appreciated that the bonded abrasive body may have a filler content ratio within a range between any of the minimum and maximum values noted above.

In more particular instances, the bonded abrasive body may include a particular content of the filler blend to facilitate the characteristics of the embodiments herein. For example, in one embodiment the bonded abrasive body may include at least 1 vol.% filler blend for the total volume of the bonded abrasive body. In other instances, the content of the filler blend within the bonded abrasive body can be greater, such as at least about 3 vol.%, at least about 5 vol.%, at least about 8 vol.%, at least about 10 vol.%, at least about 13 vol.%, at least about 15 vol.%, or even at least about 18 vol.% for the total volume of the bonded abrasive body. Still, in other non-limiting embodiments, the bonded abrasive body may include not greater than about 50 vol.% of the filler blend, such as not greater than about 45 vol.%, not greater than about 40 vol.%, not greater than about 35 vol.%, not greater than about 30 vol.%, not greater than about 28 vol.%, not greater than about 25 vol.%, or even not greater than about 22 vol.% for the total volume of the bonded abrasive body. It will be appreciated that the bonded abrasive body may include a content of filler blend within a range between any of the minimum and maximum percentages noted above.

In still another embodiment, the bonded abrasive body may include a certain content of the fine filler for the total volume of the bonded abrasive body. For example, the bonded abrasive body may include at least about 1 vol.%, such as at least about 2 vol.%, at least about 3 vol.%, at least about 4 vol.%, at least about 5 vol.%, at least about 6 vol.%, at least about 7 vol.%, or even at least about 8 vol.% fine filler particles for the total volume of the bonded abrasive body. In another non-limiting embodiment, the bonded abrasive body may include not greater than about 25 vol.%, such as not greater than about 22 vol.%, not greater than about 20 vol.%, not greater than about 18 vol.%, not greater than about 16 vol.%, not greater than about 13 vol.%, or even not greater than about 10 vol.% of the fine filler particles for the total volume of the bonded abrasive body. It will be appreciated that the total content of the fine filler particles for the total volume of the bonded abrasive body can be within range between any of the minimum and maximum percentages noted above.

In still another aspect, the bonded abrasive body may include a particular content of coarse filler particles for the total volume of the bonded abrasive body. For example, the bonded abrasive body may include at least 1 vol.%, such as at least about 2 vol.%, at least about 3 vol.%, at least about

4 vol.%, at least about 5 vol.%, at least about 6 vol.%, at least about 7 vol.%, or even at least about 8 vol.% coarse filler particles for the total volume of the bonded abrasive body. In still other instances, the bonded abrasive body may include not greater than about 25 vol.%, not greater than about 22 vol.%, not greater than about 20 vol.%, not greater than about 18 vol.%, not greater than about 16 vol.%, not greater than about 13 vol.%, or even not greater than about 10 vol.% coarse filler particles for the total volume of the bonded abrasive body. It will be appreciated that the bonded abrasive body may include content of coarse filler particles for the total volume of the bonded abrasive body within a range between any of the minimum and maximum percentages noted above.

In another embodiment, the bonded abrasive body may include a particular content of abrasive particles for the total volume of the bonded abrasive body. For example, in certain instances, the bonded abrasive body may include not greater than about 85 vol.%, such as not greater than about 82 vol.%, not greater than about 80 vol.%, not greater than about 75 vol.%, not greater than about 70 vol.%, not greater than about 65 vol.%, or even not greater than about 60 vol.% abrasive particles for the total volume of the bonded abrasive body. In yet another non-limiting embodiment, the bonded abrasive body may include at least about 10 vol.%, such as at least about 15 vol.%, at least about 20 vol.%, at least about 25 vol.%, at least about 30 vol.%, at least about 35 vol.%, at least about 40 vol.%, or even at least about 45 vol.% abrasive particles for the total volume of the bonded abrasive body. It will be appreciated that the content of abrasive particles for the total volume of the bonded abrasive body may be within a range between any of the minimum and maximum percentages noted above.

In accordance with an embodiment, the bonded abrasive body may be formed of particular size of abrasive particles. For example, the abrasive particles may have an average particle size of not greater than about 200 microns. In other embodiments, the average particle size of the abrasive particles may be not greater than about 180 microns, such as not greater than about 150 microns, not greater than about 130 microns, not greater than about 110 microns, not greater than about 100 microns, not greater than about 80 microns, not greater than about 70 microns, not greater than about 65 microns, not greater than about 60 microns, not greater than about 55 microns, not greater than about 50 microns, or even not greater than about 45 microns. In still other embodiments, the abrasive particles may have an average particle size of at least about 0.5 microns, such as at least about 1 micron, at least about 2 microns, at least about 5 microns, at least about 8 microns, at least about 10 microns, at least about 15 microns, at least about 20 microns, at least about 25 microns, or even at least about 30 microns. It will be appreciated that the abrasive particles can have an average particle size within a range between any of the minimum and maximum values noted above.

Furthermore, the abrasive particles can have a particular hardness with respect to the fine filler particle. For example, the abrasive particles can have a hardness that is greater than the fine filler particle. In certain instances, the abrasive particles can have a hardness that is at least about 7

with respect Mohs hardness. In other embodiments, the abrasive particles can have a Mohs hardness of about 7.5, such as at least about 8, at least about 8.5, or even at least about 9.

The abrasive article may use an abrasive particle hardness-to-fine filler particle hardness ratio (Hap/Hff), wherein Hap represents the Mohs hardness of the abrasive particles and Hff represents the Mohs hardness of the fine filler particles. In at least one embodiment, the abrasive particle hardness-to-fine filler particle hardness ratio (Hap/Hff) can be at least about 1, such as at least about 1.05, at least about 1.1, at least about 1.2, at least about 1.3, at least about 1.4, at least about 1.5, at least about 1.6, at least about 1.7, at least about 1.8, at least about 1.9, at least about 2, at least about 2.1, at least about 2.2, at least about 2.5, at least about 2.7, at least about 3. Still, in one non-limiting embodiment, the abrasive particle hardness-to-fine filler particle hardness ratio (Hap/Hff) can be not greater than about 10, such as not greater than about 9, not greater than about 8, not greater than about 7, not greater than about 6, not greater than about 5, not greater than about 4, or even not greater than about 3. It will be appreciated that the abrasive particle hardness-to-fine filler particle hardness ratio (Hap/Hff) can be within a range between any of the above minimum and maximum values.

Moreover, the abrasive particles may have a particular hardness with respect to the coarse filler particle. For example, the abrasive particles can have a hardness that is greater than the coarse filler particle. In one particular embodiment, the abrasive article may incorporate a specific abrasive particle hardness-to-coarse filler particle hardness ratio (Hap/Hcf), wherein Hap represents the Mohs hardness of the abrasive particles and Hcf represents the Mohs hardness of the coarse filler particles.

In at least one embodiment, the abrasive particle hardness-to-coarse filler particle hardness ratio (Hap/Hff) can be at least about 1, such as at least about 1.05, at least about 1.1, at least about 1.2, at least about 1.3, at least about 1.4, at least about 1.5, at least about 1.6, at least about 1.7, at least about 1.8, at least about 1.9, at least about 2, at least about 2.1, at least about 2.2, at least about 2.5, at least about 2.7, at least about 3. Still, in one non-limiting embodiment, the abrasive particle hardness-to-coarse filler particle hardness ratio (Hap/Hff) can be not greater than about 10, such as not greater than about 9, not greater than about 8, not greater than about 7, not greater than about 6, not greater than about 5, not greater than about 4, or even not greater than about 3. It will be appreciated that the abrasive particle hardness-to-coarse filler particle hardness ratio (Hap/Hff) can be within a range between any of the above minimum and maximum values.

In certain instances, the bonded abrasive body may include abrasive particles that are formed of an inorganic material. More particularly, the abrasive particles can include a naturally occurring material or mineral. In yet another embodiment, the abrasive particles may include a synthesized material. Accordingly to at least one embodiment, the abrasive particles can include materials such as oxides, carbides, nitrides, borides, oxycarbides, oxynitrides, oxyborites, carbon-containing materials, diamond, cubic boron nitride, and a combination thereof. For example, in one particular instance, the

abrasive particles can include a super abrasive material such as diamond or cubic boron nitride. More particularly, in at least one aspect, the abrasive particles can consist essentially of diamond.

For embodiments utilizing abrasive particles including diamond, the abrasive particles may have a particular content of polycrystalline diamond. For example, the content of poly-crystalline diamond for the total content of abrasive particles may be at least about 20%, such as at least about 25%, at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, or even at least about 90%. In at least one embodiment, essentially, essentially all of the diamond of the abrasive particles is a polycrystalline diamond material.

In certain instances, the bonded abrasive body can include a bond material including a metal or metal alloy. In particular embodiments, the bond material may include a transition metal element, and more particularly, may include a transition metal element, such as copper, tin, silver, nickel, and a combination thereof. In at least one embodiment, the bond material can include bronze including a combination of copper and tin. For example, the bond material including bronze may include a content of copper that is not less than a content of tin. In still other alternative embodiments, the bronze may include a content of copper that is greater than a content of tin.

In one aspect, the bonded abrasive body can include a bond material including bronze having a copper-to-tin ratio (Cu/An) of at least about 0.2. In other embodiments, the bronze can include a copper-to-tin ratio of at least about 0.23, such as at least about 0.25, at least about 0.28, at least about 0.3, at least about 0.33, at least about 0.35, at least about 0.38, at least about 0.4, at least about 0.43, at least about 0.45, at least about 0.48, at least about 0.5, at least about 0.53, at least about 0.55, at least about 0.58, at least about 0.6, at least about 0.63, at least about 0.65, at least about 0.68, at least about 0.7, at least about 0.73, at least about 0.75, at least about 0.78, at least about 0.8, or even at least about 0.9. In another non-limiting embodiment, the bond material can include bronze having a copper-to-tin ratio of not greater than about 0.93, not greater than about 0.9, not greater than about 0.88, not greater than about 0.85, not greater than about 0.83, not greater than about 0.8, not greater than about 0.78, not greater than about 0.75, not greater than about 0.73, not greater than about 0.7, not greater than about 0.68, not greater than about 0.65, not greater than about 0.63, not greater than about 0.6, not greater than about 0.58, not greater than about 0.55, not greater than about 0.53, not greater than about 0.5, not greater than about 0.48, not greater than about 0.45, not greater than about 0.43, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2. It will be appreciated that the bond material can include bronze having a copper-to-tin ratio within a range between any of the minimum and maximum values noted above.

In at least one aspect, the bonded abrasive body may include a particular content of bond material for the total volume of the bonded abrasive body. For example, the bonded abrasive body may include at least about 10 vol.% bond material, such as at least about 15 vol.%, at least about 20 vol.%, at least about 25 vol.%, at least about 30 vol.%, at least about 35 vol.%, at least about 40

vol.%, or even at least about 45 vol.% for the total volume of the bonded abrasive body. Still, in another non-limiting embodiment, the bonded abrasive body may include not greater than about 85 vol.% bond material, such as not greater than about 82 vol.%, not greater than about 80 vol.%, not greater than about 75 vol.%, not greater than about 70 vol.%, or even not greater than about 65 vol.% bond material for a total volume of the bonded abrasive body. It will be appreciated that the bonded abrasive body may include a content of bond material within a range between any of the minimum and maximum percentages noted above.

The bonded abrasive body may include a limited content of certain materials, including for example phosphorous, zinc, antimony, chromium, cobalt, silicon, and a combination thereof. For example, in one embodiment, the content of phosphorous can be not greater than about 1 vol.%, such as not greater than about 0.08 vol.%, such as not greater than about 0.05 vol.%, or even not greater than about 0.01 vol.% for the total volume of the bond material. Still, in certain non-limiting embodiments, the bond material may include a trace amount, such as at least about 0.001 vol.% for the total volume of the bond material.

In accordance with an embodiment, the bonded abrasive body may have a certain content of porosity to facilitate performance characteristics. For example, the porosity of the body may be not greater than about 15 vol.% for the total volume of the body. In other instances, the body may include a porosity of not greater than about 14 vol.%, such as not greater than about 13 vol.%, not greater than about 12 vol.%, not greater than about 11 vol.%, not greater than about 10 vol.%, not greater than about 9 vol.%, not greater than about 8 vol.%, not greater than about 7 vol.%, not greater than about 6 vol.%, not greater than about 5 vol.%, not greater than about 4 vol.%, not greater than about 3 vol.%. Still, in at least one non-limiting embodiment, the porosity of the body can be at least about 0.1 vol.%, such as at least about 0.5 vol.%, at least about 1 vol.%, or even at least about 1.5 vol.%. It will be appreciated that the body can have a content of porosity within a range between any of the minimum and maximum percentages noted above.

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

Item 1. An abrasive article comprising: a bonded abrasive body including: a bond material comprising a metal; abrasive particles contained within the bond material; a filler blend including fine filler particles and coarse filler particles and defining a filler particle size ratio (F_f/F_c) of not greater than about 0.97, wherein the F_f represents the average particle of the fine filler particles and F_c represents the average particle size of the coarse filler particles.

Item 2. An abrasive article comprising: a bonded abrasive body including: a bond material comprising a metal; abrasive particles contained within the bond material; a filler blend comprising:

fine filler particles contained in the bond material having a Mohs hardness of not greater than about 4; coarse filler particles contained in the bond material having a Mohs hardness of not greater than about 6; and a porosity of not greater than about 15 vol%.

Item 3. The abrasive article of any of items 1 and 2, wherein the body comprises a porosity of not greater than about 14 vol% for a total volume of the bonded abrasive body, not greater than about 13 vol%, not greater than about 12 vol%, not greater than about 11 vol%, not greater than about 10 vol%, not greater than about 9 vol%, not greater than about 8 vol%, not greater than about 7 vol%, not greater than about 6 vol%, not greater than about 5 vol%, not greater than about 4 vol%, not greater than about 3 vol%, and at least about 0.1 vol%.

Item 4. The abrasive article of any of items 1 and 2, wherein the fine filler particles comprise an inorganic material, wherein the fine filler particles comprise a carbon-containing material, wherein the fine filler particles comprise a carbon-based material, wherein the fine filler particles comprise graphite, wherein the fine filler particles consist essentially of graphite.

Item 5. The abrasive article of any of items 1 and 2, wherein the coarse filler particles comprise an inorganic material, wherein the coarse filler particles comprise a carbon-containing material, wherein the coarse filler particles comprise a carbon-based material, wherein the coarse filler particles comprise graphite, wherein the coarse filler particles consist essentially of graphite.

Item 6. The abrasive article of any of items 1 and 2, wherein the fine filler particles and the coarse filler particles comprise a same element, wherein the fine filler particles and the coarse filler particles comprise a same carbon-containing material, wherein the fine filler particles and coarse filler particles comprise a same carbon-based material, wherein the fine filler particles and the coarse filler particles comprise graphite, wherein the fine filler particles and the coarse filler particles consist essentially of the same material.

Item 7. The abrasive article of any of items 1 and 2, wherein fine filler particles comprise an average particle size of not greater than about 120 microns, and at least about 5 microns.

Item 8. The abrasive article of any of items 1 and 2, wherein coarse filler particles comprise an average particle size of not greater than about 200 microns, and at least about 15 microns.

Item 9. The abrasive article of item 2, further comprising a filler particle size ratio (Ff/Fc) of not greater than about 0.97, wherein the Ff represents the average particle of the fine filler particles and Fc represents the average particle size of the coarse filler particles.

Item 10. The abrasive article of any of items 1 and 29, wherein the filler particle size ratio (Ff/Fc) is not greater than about 0.95, not greater than about 0.93, not greater than about 0.9, not greater than about 0.88, not greater than about 0.85, not greater than about 0.83, not greater than about 0.8, not greater than about 0.78, not greater than about 0.75, not greater than about 0.73, not greater than about 0.7, not greater than about 0.68, not greater than about 0.65, not greater than about 0.63, not greater than about 0.6, not greater than about 0.58, not greater than about 0.55, not greater than

about 0.53, not greater than about 0.5, not greater than about 0.48, not greater than about 0.45, not greater than about 0.43, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2, not greater than about 0.1.

Item 11. The abrasive article of any of items 1 and 9, wherein the filler particle size ratio (Ff/Fc) is at least about 0.03, at least about 0.05, at least about 0.08, at least about 0.1, at least about 0.13, at least about 0.15, at least about 0.18, at least about 0.2, at least about 0.23, at least about 0.25, at least about 0.28, at least about 0.3, at least about 0.33, at least about 0.35, at least about 0.38, at least about 0.4, at least about 0.43, at least about 0.45, at least about 0.48, at least about 0.5, at least about 0.53, at least about 0.55, at least about 0.58, at least about 0.6, at least about 0.63, at least about 0.65, at least about 0.68, at least about 0.7, at least about 0.73, at least about 0.75, at least about 0.78, at least about 0.8, at least about 0.9.

Item 12. The abrasive article of any of items 1 and 2, wherein the filler blend comprises a filler content ratio (Cf/Cc) of at least about 0.05, wherein Cf represents the volume percent of fine filler particles for the total volume of the bonded abrasive body and Cc represents the volume percent of the coarse filler particles for the total volume of the bonded abrasive body, wherein the filler content ratio is at least about 0.1, at least about 0.2, at least about 0.3, at least about 0.4, at least about 0.5, at least about 0.6, at least about 0.7, at least about 0.8, at least about 0.9, at least about 1, at least about 1.1, at least about 1.2, at least about 1.3, at least about 1.4, at least about 1.5.

Item 13. The abrasive article of any of items 1 and 2, wherein the filler blend comprises a filler content ratio (Cf/Cc) of not greater than about 10, wherein Cf represents the volume percent of fine filler particles for the total volume of the bonded abrasive body and Cc represents the volume percent of the coarse filler particles for the total volume of the bonded abrasive body, wherein the filler content ratio is not greater than about 9, not greater than about 8, not greater than about 7, not greater than about 6, not greater than about 5, not greater than about 4, not greater than about 3, not greater than about 2, not greater than about 1, not greater than about 0.95, not greater than about 0.9, not greater than about 0.8, not greater than about 0.7, not greater than about 0.6, not greater than about 0.5, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2, not greater than about 0.1.

Item 14. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% of the filler blend for the total volume of the bonded abrasive body, at least about 3 vol%, at least about 5 vol%, at least about 8 vol%, at least about 10 vol%, at least about 13 vol%, at least about 15 vol%, at least about 18 vol%.

Item 15. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises not greater than about 50 vol% of the filler blend for the total volume of the bonded abrasive body, not greater than about 45 vol%, not greater than about 40 vol%, not greater than about

35 vol%, not greater than about 30 vol%, not greater than about 28 vol%, not greater than about 25 vol%, not greater than about 22 vol%.

Item 16. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% of the fine filler particles for the total volume of the bonded abrasive body, at least about 2 vol%, at least about 3 vol%, at least about 4 vol%, at least about 5 vol%, at least about 6 vol%, at least about 7 vol%, at least about 8 vol%.

Item 17. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises not greater than about 25 vol% of the fine filler particles for the total volume of the bonded abrasive body, not greater than about 22 vol%, not greater than about 20 vol%, not greater than about 18 vol%, not greater than about 16 vol%, not greater than about 13 vol%, not greater than about 10 vol%.

Item 18. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% of the coarse filler particles for the total volume of the bonded abrasive body, at least about 2 vol%, at least about 3 vol%, at least about 4 vol%, at least about 5 vol%, at least about 6 vol%, at least about 7 vol%, at least about 8 vol%.

Item 19. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises not greater than about 25 vol% of the coarse filler particles for the total volume of the bonded abrasive body, not greater than about 22 vol%, not greater than about 20 vol%, not greater than about 18 vol%, not greater than about 16 vol%, not greater than about 13 vol%, not greater than about 10 vol%.

Item 20. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises not greater than about 85 vol% of the abrasive particles for the total volume of the bonded abrasive body, not greater than about 82 vol%, not greater than about 80 vol%, not greater than about 75 vol%, not greater than about 70 vol%, not greater than about 65 vol%, not greater than about 60 vol%.

Item 21. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises at least about 10 vol% of the abrasive particles for the total volume of the bonded abrasive body, at least about 15 vol%, at least about 20 vol%, at least about 25 vol%, at least about 30 vol%, at least about 35 vol%, at least about 40 vol%, at least about 45 vol%.

Item 22. The abrasive article of any of items 1 and 2, wherein the abrasive particles comprise an average particle size of not greater than about 200 microns, not greater than about 180 microns, not greater than about 150 microns, not greater than about 130 microns, not greater than about 110 microns, not greater than about 100 microns, not greater than about 80 microns, not greater than about 70 microns, not greater than about 65 microns, not greater than about 60 microns, not greater than about 55 microns, not greater than about 50 microns, not greater than about 45 microns.

Item 23. The abrasive article of any of items 1 and 2, wherein the abrasive particles comprise an average particle size of at least about 0.5 microns, at least about 1 micron, at least about 2 microns, at least about 5 microns, at least about 8 microns, at least about 10 microns, at least about 15 microns, at least about 20 microns, at least about 25 microns, at least about 30 microns.

5 Item 24. The abrasive article of any of items 1 and 2, wherein the abrasive particles have a hardness greater than the fine filler particle, wherein the abrasive particles have a hardness greater than the coarse filler particle, wherein the abrasive particles have a Mohs hardness of at least about 7, at least about 8, at least about 9.

10 Item 25. The abrasive article of any of items 1 and 2, wherein the abrasive particles comprise an inorganic material, wherein the abrasive particles comprise a naturally occurring material, wherein the abrasive particles comprise a synthesized material, wherein the abrasive particles comprise a material selected from the group consisting of oxides, carbides, nitrides, borides, oxycarbides, oxynitrides, oxyborides, carbon-containing materials, diamond, and a combination thereof.

15 Item 26. The abrasive article of any of items 1 and 2, wherein the abrasive particles comprise a superabrasive material, wherein the abrasive particles comprise a diamond, wherein the abrasive particles comprise cubic boron nitride, wherein the abrasive particles consist essentially of diamond, wherein the abrasive particles comprise having a content of polycrystalline diamond.

20 Item 27. The abrasive article of any of items 1 and 2, wherein the bond material comprises a transition metal element, wherein the bond material comprises a transition metal element selected from the group consisting of copper, tin, silver, nickel, and a combination thereof.

25 Item 28. The abrasive article of any of items 1 and 2, wherein the bond material comprises bronze including copper (Cu) and tin (Sn), wherein the bronze comprises a content of copper that is not less than a content of tin, wherein the bronze comprises a content of copper that is greater than a content of tin, wherein the bronze comprises a copper/tin ratio (Cu/Sn) of at least about 0.2, at least about 0.23, at least about 0.25, at least about 0.28, at least about 0.3, at least about 0.33, at least about 0.35, at least about 0.38, at least about 0.4, at least about 0.43, at least about 0.45, at least about 0.48, at least about 0.5, at least about 0.53, at least about 0.55, at least about 0.58, at least about 0.6, at least about 0.63, at least about 0.65, at least about 0.68, at least about 0.7, at least about 0.73, at least about 0.75, at least about 0.78, at least about 0.8, at least about 0.9.

30 Item 29. The abrasive article of any of items 1 and 2, wherein the bond material comprises bronze including copper (Cu) and tin (Sn), wherein the bronze comprises a copper/tin ratio (Cu/Sn) of not greater than about 0.93, not greater than about 0.9, not greater than about 0.88, not greater than about 0.85, not greater than about 0.83, not greater than about 0.8, not greater than about 0.78, not greater than about 0.75, not greater than about 0.73, not greater than about 0.7, not greater than about 0.68, not greater than about 0.65, not greater than about 0.63, not greater than about 0.6, not greater than about 0.58, not greater than about 0.55, not greater than about 0.53, not greater than about 0.5,

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not greater than about 0.48, not greater than about 0.45, not greater than about 0.43, not greater than about 0.4, not greater than about 0.3, not greater than about 0.2.

Item 30. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises at least about 10 vol% of the bond material for the total volume of the bonded abrasive body, at least about 15 vol%, at least about 20 vol%, at least about 25 vol%, at least about 30 vol%, at least about 35 vol%, at least about 40 vol%, at least about 45 vol%. [target is between 50-80]

Item 31. The abrasive article of any of items 1 and 2, wherein the bonded abrasive body comprises not greater than about 85 vol% of the bond material for the total volume of the bonded abrasive body, not greater than about 82 vol%, not greater than about 80 vol%, not greater than about 75 vol%, not greater than about 70 vol%, not greater than about 65 vol%.

Example 1

Two samples were formed for comparative testing. A first sample, CS1, represents a conventional sample formed from a mixture including 4.8 wt% diamond abrasive particles, 89.4 wt% pre-alloyed bronze (copper/tin ratio of 1) metal bond material, and 5.8 wt% graphite filler material having an average particle size of approximately 125 microns. Sample CS1 was molded into a green article, hot pressed at a temperature of approximately 375°C to about 700°C at a pressure from about 0.5 tons/in² to 4 tons/in² to form a bonded abrasive body having about 5 vol% diamond abrasive particles, 20 vol% graphite filler material, and about 75 vol% bronze bond material.

The second sample, S2, represents a sample of an embodiment, and is formed from a mixture including 19.5 wt% diamond abrasive particles, 75.6 wt% pre-alloyed bronze (copper/tin ratio of 1) metal bond material, and 4.8 wt% of a filler blend including 2.4 wt% of graphite fine filler particles having an average particle size of about 15 microns, and 2.4 wt% of graphite coarse filler particles having an average particle size of about 125 microns. Sample S2 was formed into a bonded abrasive body using essentially the same process as used to form sample CS1. Sample S2 had 19 vol% diamond abrasive particles, 20 vol% graphite filler blend including 10 vol% fine filler particles and 10 vol% coarse filler particles, and approximately 51 vol% bronze bond material.

Samples CS1 and S2 were used in a backgrinding operation of c-plane sapphire substrates according to the following conditions.

FIG 1 includes a plot of cumulative wheel wear of the bonded abrasive body in microns versus cumulative material removed from the workpiece in microns. As illustrated, sample S2 demonstrated significantly less wheel wear as compared to sample CS1 over a greater range of cumulative material removed. That is, Sample CS1 demonstrated significantly less total material removed as compared to sample S2 and also demonstrated significantly greater wear for the limited amount of material removed..

FIG. 2 includes a plot of percent maximum power versus time for the backgrinding operation. As illustrated in FIG. 2, sample CS2 demonstrated regular spikes in the percentage maximum power

utilized, indicated regimes of inefficient grinding and high forces on the bonded abrasive body during the backgrinding operation. By contrast, sample S2, demonstrated no significant localized spikes during the backgrinding operation and thus demonstrated significantly more uniform and efficient grinding throughout the use of the bonded abrasive body as compared to sample CS1.

5 The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the true scope of the present invention. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing
10 detailed description.

 The Abstract of the Disclosure is provided to comply with Patent Law and is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description of the Drawings, various features may be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This
15 disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter may be directed to less than all features of any of the disclosed embodiments. Thus, the following claims are incorporated into the Detailed Description of the Drawings, with each claim standing on its own as defining separately claimed subject matter.

WHAT IS CLAIMED IS:

1. An abrasive article comprising:
a bonded abrasive body including:
 - a bond material comprising a metal;
 - abrasive particles contained within the bond material;
 - a filler blend including fine filler particles and coarse filler particles and defining a filler particle size ratio (F_f/F_c) of not greater than about 0.97, wherein the F_f represents the average particle of the fine filler particles and F_c represents the average particle size of the coarse filler particles.
2. An abrasive article comprising:
a bonded abrasive body including:
 - a bond material comprising a metal;
 - abrasive particles contained within the bond material;
 - a filler blend comprising:
 - fine filler particles contained in the bond material having a Mohs hardness of not greater than about 4;
 - coarse filler particles contained in the bond material having a Mohs hardness of not greater than about 6; and
 - a porosity of not greater than about 15 vol%.
3. The abrasive article of any of claims 1 and 2, wherein the body comprises a porosity of not greater than about 14 vol% for a total volume of the bonded abrasive body.
4. The abrasive article of any of claims 1 and 2, wherein the fine filler particles and the coarse filler particles comprise a same element.
5. The abrasive article of any of claims 1 and 2, wherein fine filler particles comprise an average particle size of at least about 5 microns and not greater than about 120 microns.
6. The abrasive article of any of claims 1 and 2, wherein coarse filler particles comprise an average particle size of at least about 15 microns and not greater than about 200 microns.
7. The abrasive article of claim 1, wherein the filler particle size ratio (F_f/F_c) is at least about 0.03 and not greater than about 0.95.
8. The abrasive article of any of claims 1 and 2, wherein the filler blend comprises a filler content ratio (C_f/C_c) of at least about 0.05 and not greater than about 10, wherein C_f represents the volume percent of fine filler particles for the total volume of the bonded abrasive body and C_c represents the volume percent of the coarse filler particles for the total volume of the bonded abrasive body.

9. The abrasive article of any of claims 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% and not greater than about 50 vol% of the filler blend for the total volume of the bonded abrasive body.

10. The abrasive article of any of claims 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% and not greater than about 25 vol% of the fine filler particles for the total volume of the bonded abrasive body.

11. The abrasive article of any of claims 1 and 2, wherein the bonded abrasive body comprises at least about 1 vol% and not greater than about 25 vol% of the coarse filler particles for the total volume of the bonded abrasive body.

12. The abrasive article of any of claims 1 and 2, wherein the bond material comprises a transition metal element selected from the group consisting of copper, tin, silver, nickel, and a combination thereof.

13. The abrasive article of any of claims 1 and 2, wherein the bond material comprises bronze including copper (Cu) and tin (Sn) and wherein the bronze comprises a content of copper that is not less than a content of tin.

14. The abrasive article of any of claims 1 and 2, wherein the bonded abrasive body comprises at least about 10 vol% of the bond material for the total volume of the bonded abrasive body.

15. The abrasive article of any of claims 1 and 2, wherein the bonded abrasive body comprises not greater than about 85 vol% of the bond material for the total volume of the bonded abrasive body.

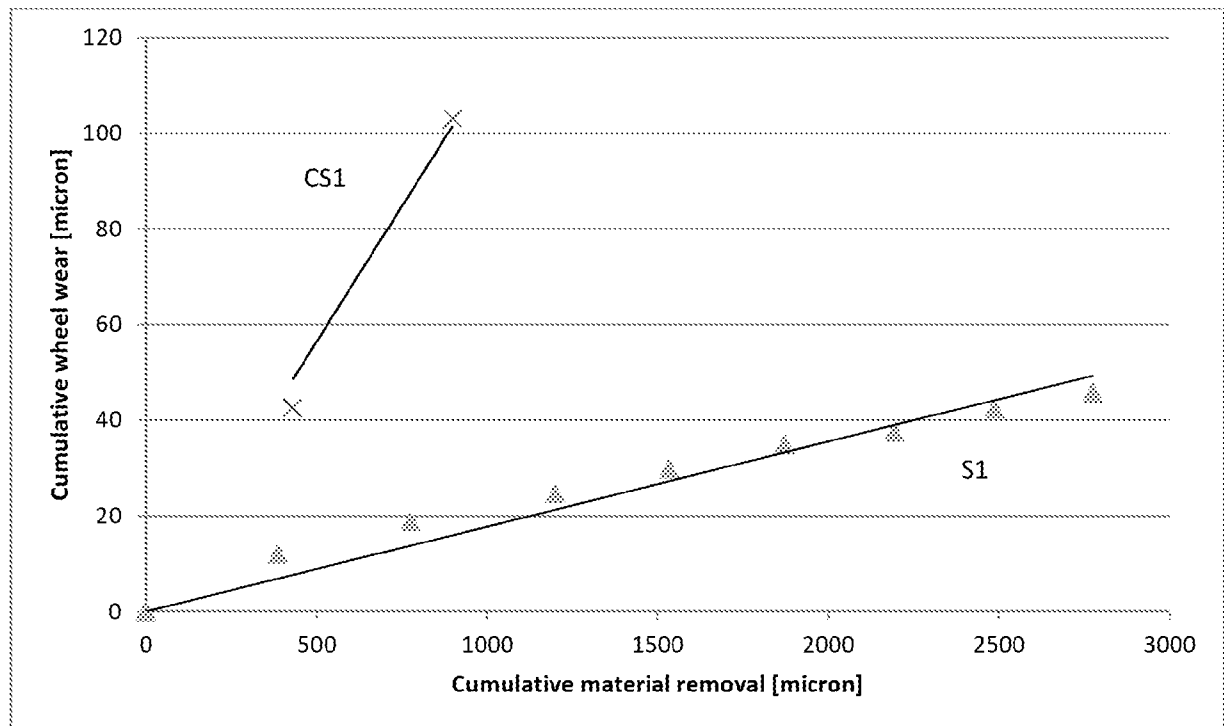


FIG. 1

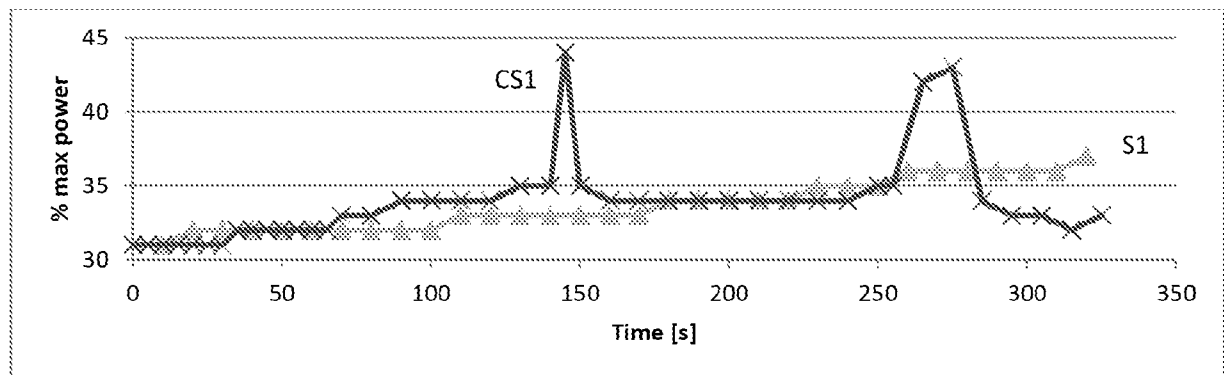


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/051623**A. CLASSIFICATION OF SUBJECT MATTER****B24D 3/06(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B24D 3/06; B24D 3/00; B24D 3/28; B24D 3/34; B24B 1/00; B24D 11/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: abrasive, particle, fine, coarse, porosity, size ratio, hardness

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5942015 A (CULLER et al.) 24 August 1999 See column 11, line 23 - column 13, line 23, column 15, line 2 - column 18, line 54; claims 1, 25; and figure 2.	1,4-8,12-13
Y		2-3,9-11,14-15
Y	US 5429648 A (WU, MIANXUE) 04 July 1995 See abstract; column 2, line 53 - column 4, line 58; and claim 9.	2-3,9-11,14-15
A	KR 10-2010-0057592 A (3M INNOVATIVE PROPERTIES COMPANY) 31 May 2010 See paragraphs [0027]-[0041]; claims 1-10; and figure 1.	1-15
A	US 8348723 B2 (WOO et al.) 08 January 2013 See abstract; column 2, line 18 - column 10, line 67; and claim 1.	1-15
A	US 2002-0026752 A1 (CULLER et al.) 07 March 2002 See abstract; claims 1-17; and figures 4-5.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 November 2014 (24.11.2014)

Date of mailing of the international search report

24 November 2014 (24.11.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/051623

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