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(54) Title: COATED ABRASIVE PRODUCTS CONTAINING AGGREGATES

(57) Abstract: A coated abrasive product includes a particulate material containing green, unfired abrasive aggregates having a generally spheroidal or toroidal shape, the aggregates formed from a composition comprising abrasive grit particles and a nanoparticle binder. Free abrasive products, bonded abrasive products, and the particulate material also contain aggregates.

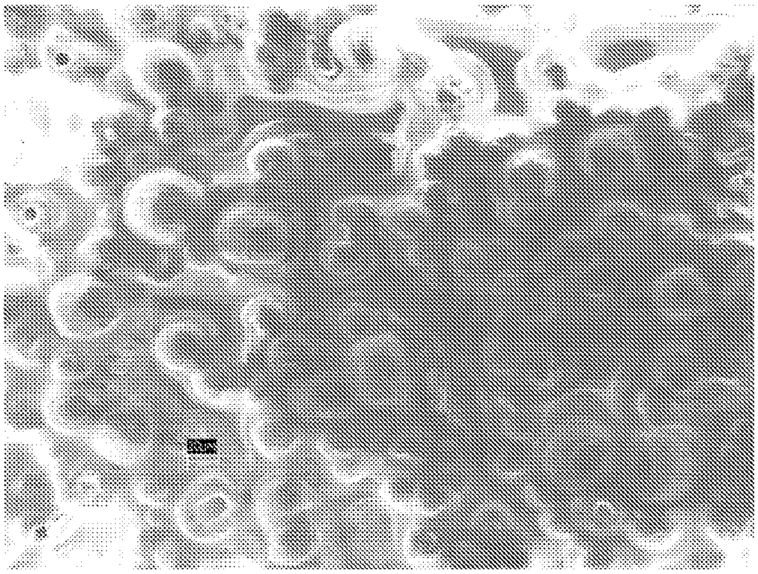

FIG. 1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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COATED ABRASIVE PRODUCTS CONTAINING AGGREGATES

TECHNICAL FIELD

The present disclosure is generally directed to abrasive particulate material, abrasive products incorporating abrasive particulate material, and methods for machining workpieces.

BACKGROUND ART

Abrasive products are generally contain or formed from abrasive particulate material. Such abrasive particulate material can be used as a free abrasive, such as in the form of a slurry, or a fixed abrasive, typically either a coated abrasive or a bonded abrasive article. Abrasive products are used in various industries to machine workpieces, such as by lapping, grinding, or polishing. Machining utilizing abrasive articles spans a wide industrial scope from optics industries, automotive paint repair industries, dental applications, to metal fabrication industries. Machining, such as by hand or with use of commonly available tools such as orbital polishers (both random and fixed axis), and belt and vibratory sanders, is also commonly done by consumers in household applications. In each of these examples, abrasives are used to remove bulk material and/or affect surface characteristics of products (e.g., planarity, surface roughness).

Surface characteristics include shine, texture, and uniformity. For example, manufacturers of metal components use abrasive articles to fine polish surfaces, and oftentimes desire a uniformly smooth surface. Similarly, optics manufacturers desire abrasive articles that produce defect free surfaces to prevent light diffraction and scattering. Hence, the abrasive surface of the abrasive article generally influences surface quality.

Abrasive particle formation, such as through chemical synthesis routes or through bulk material processing routes (e.g., fusion and comminution), is considered a fairly well developed and mature art area. Accordingly, notable developmental resources have been dedicated to development of macrostructures, such as development of engineered abrasives products within the context of coated abrasives and particular three-dimensional structures and formulations in the context of bonded abrasives. Despite continued developments, a need continues to exist in the art for improved particulate material.

Particulate materials include essentially single phase inorganic materials, such as alumina, silicon carbide, silica, ceria, and harder, high performance superabrasive grains such as cubic boron nitride and diamond. Enhanced and even more sophisticated abrasive properties have been achieved through development of composite particulate materials. Such materials include formation of aggregates, which can be formed through slurry processing pathways that include removal of the liquid carrier through volatilization or evaporation, leaving behind green agglomerates, followed by high temperature treatment (i.e., firing) to form usable, fired agglomerates.

Such composite agglomerates have found commercial use in various abrasive product deployments. However, the industry continues to demand even further improved particulate materials, and particularly composite aggregates that may offer enhanced machining performance.

DISCLOSURE OF INVENTION

According to one embodiment, a coated abrasive product includes a substrate and particulate material bonded thereto, the particulate material containing green, unfired abrasive aggregates having a generally spheroidal or toroidal shape, the aggregates formed from a composition comprising abrasive grit particles, a nanoparticle binder.

According to another embodiment, an abrasive slurry includes green, unfired abrasive aggregates provided in suspension, the aggregates having a generally spheroidal or toroidal shape, the aggregates comprising an abrasive grit particles and a nanoparticle binder.

According to another embodiment, a fixed abrasive in the form of a bonded abrasive includes green, unfired abrasive aggregates that are fixed in position with respect to each other with an inter-aggregate binder, the aggregates having a generally spheroidal or toroidal shape, the aggregates comprising an abrasive grit particles and a nanoparticle binder.

According to another embodiment, a method for forming abrasive particulate material includes forming a slurry comprising a liquid carrier, abrasive grit particles and a nanoparticle binder; and spray drying the slurry to form green, unfired aggregates containing the abrasive grit particles and the nanoparticle binder. Further, the aggregates are classified for use in an abrasive product

According to another embodiment, a method for machining a workpiece includes providing a workpiece having an initial surface roughness Ra_i, abrading the workpiece with a single abrasive product to remove material from the workpiece, whereby the workpiece has a final surface roughness Ra_f and Ra_f is not greater than $0.2Ra_i$.

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.

Figs 1 – 3 are photomicrographs taken with a scanning electron microscope showing abrasive aggregates including diamond grit combined with silica nanoparticles in a coating on a substrate according to one embodiment of the present disclosure.

Figs 4 – 6 are photomicrographs taken with a scanning electron microscope showing abrasive aggregates including silicon carbide grit combined with silica nanoparticles in a coating on a substrate according to another embodiment of the present disclosure.

Fig. 7 represents the results of Thermal Gravimetric Analysis (TGA) of examples according to embodiments.

Fig. 8 shows the consequence of post-synthesis heat treatment of diamond containing aggregate corresponding to an embodiment.

Figs. 9-16 show various aggregates formed in accordance with different formulations or processing parameters.

Figs. 17 and 18 include magnified images of an abrasive product using a porous substrate material.

The use of the same reference symbols in different drawings indicates similar or identical items.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

According to an embodiment, abrasive aggregates are provided that are particularly suitable for machining operations, in which abrasion is carried out to remove material and improve surface quality. Abrasive aggregates can be formed through slurry-based processing. Here, embodiments may take advantage of spray drying, where a slurry containing the constituent materials of the aggregates and a liquid carrier, such as water, are mixed together, nebulized into droplets, and dried. In more detail, certain embodiments combine an abrasive grit, which may be in the form of microparticles, a binder, which may be in the form of a nanoparticles, and a liquid carrier, which can be water for ease of handling and processing. Various embodiments further include a plasticizer, also known as a dispersant, in the slurry to promote dispersion of the abrasive grit within the thus formed, spray dried aggregates.

As used herein, the term “microparticle” may be used to refer to a particle having an average particle size of from about 0.1 microns to about 50 microns, preferably not less than 0.2 microns, 0.5 microns, or 0.75 microns, and not greater than about 20 microns, such as not greater than 10 microns. Particular embodiments have an average particle size from about 0.5 microns to about 10 microns.

As used herein, the term “nanoparticle” may be used to refer to a particle having an average particle size of from about 5 nm to about 150 nm, typically less than about 100 nm, 80 nm, 60 nm, 50 nm, or less than about 40 nm. Typical average particle sizes of nanoparticles lie within a range of about 20 nm to about 50 nm

As used herein, the term “aggregate” may be used to refer to a particle made of a plurality of smaller particles that have been combined in such a manner that it is relatively difficult to separate or disintegrate the aggregate particle into smaller particles by the application of pressure or agitation. This is in contrast to the term “agglomerate” used herein to refer to a particle made of a plurality of smaller particles which have been combined in such a manner that it is relatively easy to separate the aggregate particle or disintegrate the particle back into the smaller particles, such as by the application of pressure or hand agitation. According to present embodiments, the aggregates have a composite structure, including both abrasive grits that have a size within the microparticle range, and a nanoparticle binder that provides the matrix of the aggregate in which the abrasive grits are embedded or contained. As will be described in more detail, aggregates according to embodiments have notable morphology, characterized by uniform distribution of the abrasive grits in the nanoparticle binder.

Of notable consequence, aggregates according to various embodiments are in the green, unfired state. Here, the aggregates are utilized as or in an abrasive product without notable post-formation heat treatment, such as calcining, sintering, or recrystallization, that alter the crystallite size, grain size, density, tensile strength, young’s modulus, and the like of the aggregates. Such heat treatment processes are commonly carried out in ceramic processing to provide usable products, but are not utilized herein. Such heat treatment steps are generally carried out in excess of 400°C, generally 500°C and above. Indeed, temperatures can easily range from 800°C to 1200°C and above for certain ceramic species.

The abrasive grit particles generally have a Mohs hardness of greater than about 3, and preferably from about 3 to about 10. For particular applications, the abrasive grit particles have a Mohs hardness not less than 5, 6, 7, 8, or 9. The abrasive grit particles are generally believed to serve as the primary active grinding or polishing agent in the abrasive aggregates. Examples of suitable abrasive compositions include non-metallic, inorganic solids such as carbides, oxides, nitrides and certain carbonaceous materials. Oxides include silicon oxide (such as quartz, cristobalite and glassy forms), cerium oxide, zirconium oxide, aluminum oxide. Carbides and nitrides include, but are not limited to, silicon carbide, aluminum, boron nitride (including cubic boron nitride), titanium carbide, titanium nitride, silicon nitride. Carbonaceous materials include diamond, which broadly includes synthetic diamond, diamond-like carbon, and related carbonaceous materials such as fullerite and aggregate diamond nanorods. Materials may also include a wide range of naturally occurring mined minerals, such as garnet, cristobalite, quartz, corundum, feldspar, by way of example. Certain embodiments of the present disclosure, take advantage of diamond, silicon carbide, aluminum oxide, and /or cerium oxide materials, with diamond being shown to be notably effective. In addition, those of skill will appreciate that various other compositions possessing the desired hardness characteristics may be used as abrasive grit particles in the abrasive aggregates of the present disclosure. In addition, in certain embodiments according to the present disclosure, mixtures of two or more different abrasive grit particles can be used in the same aggregates.

As should be understood from the foregoing description, a wide variety of abrasive grit particles may be utilized in embodiments. Of the foregoing, cubic boron nitride and diamond are considered “superabrasive” particles, and have found widespread commercial use for specialized machining operations, including highly critical polishing operations. Further, the abrasive grit particles may be treated so as to form a metallurgical coating on the individual particles prior to incorporation into the aggregates. The superabrasive grits are particularly suitable for coating. Typical metallurgical coatings include nickel, titanium, copper, silver and alloys and mixtures thereof.

In general, the size of the abrasive grit particles lies in the microparticle range. It should be noted that the abrasive grit particles can be formed of abrasive aggregates of smaller particles such as abrasive aggregates nanoparticles, though more commonly the abrasive grits are formed of single particles within the microparticle range. For instance, a plurality of nano-sized diamond particles may be aggregated together to provide a microparticle of diamond grit. The size of the abrasive grit particles can vary depending upon the type of grit particles being used. For example, in certain embodiments of the present disclosure, diamond grit particles are preferably used having a size of about 0.5 to 2 microns, such as about 1 micron. In other embodiments of the present disclosure, silicon carbide grit particles are preferably used having a size of about 3 to about 8 microns. In still other embodiments of the present disclosure, aluminum oxide grit particles are preferably used having a size of about 3 to about 5 microns.

The abrasive grit particles may, in general, constitute between about 0.1 % to about 85% of the aggregates. The aggregates more preferably include between about 10% to about 50% of the abrasive grit particles.

In one embodiment according to the present disclosure, abrasive aggregates may be formed using a single size of abrasive grit particle, the size of the grit particle and the resultant aggregates both being tailored to the desired polishing application. In another embodiments, mixtures of two or more differently sized abrasive grit particles may be used in combination to form abrasive aggregates having advantageous characteristics attributable to each of the grit particle sizes.

The abrasive aggregates according to the present disclosure also include a nanoparticle binder material as stated above. The nanoparticle binder generally forms a continuous matrix phase that functions to form and hold the abrasive grit particles together within the abrasive aggregates in the nature of a binder. In this respect, it should be noted that the nanoparticle binder, while forming a continuous matrix phase, is itself generally made up of individually identifiable nanoparticles that are in intimate contact, interlocked and, to a certain extent, atomically bonded with each other. However, due to the green, unfired state of the thus formed aggregates, the individual nanoparticles are generally not fused together to form grains, as in the case of a sintered ceramic material. As used herein, description of nanoparticle binder extends to one or multiple species of binders.

While the grit material is believed to act as the primary abrasive, the nanoparticle material can also act as a secondary abrasive in some embodiments of the aggregates of the present disclosure. The size and polishing characteristics of the aggregates may be adjusted by varying parameters such as the composition of the nanoparticle binder material, the relative concentration ratio of nanoparticle binder material to abrasive grit particle, and the size of the abrasive grit particles. The nanoparticle binder material may itself comprise very fine ceramic and carbonaceous particles such as nano-sized silicon dioxide in a liquid colloid or suspension (known as colloidal silica). Nanoparticle binder materials may also include, but are not limited to, colloidal alumina, nano-sized cerium oxide, nano-sized diamond, and mixtures thereof. Colloidal silica is preferred for use as the nanoparticle binder in certain embodiments of the present disclosure. For example, commercially available nanoparticle binders that have been used successfully include the colloidal silica solutions BINDZEL 2040 BINDZIL 2040 (available from Eka Chemicals Inc. of Marietta, Georgia) and NEXSIL 20 (available from Nyacol Nano Technologies, Inc. of Ashland, Massachusetts).

Before the mixture is spray dried to form the aggregates, the mixture may include an amount of nanoparticle binder material ranging between about 0.1 % to about 80%, preferably ranging between about 10% to about 30% on a wet basis. In the formed abrasive aggregates, the nanoparticle binder material may constitute between about 1 % to about 90% of the aggregates, preferably between about 20% to about 80% of the aggregates, and most preferably between about 50% to about 75% of the aggregates, all on a dry weight basis.

The slurry for forming the abrasive aggregates also can advantageously include another material which serves primarily as a plasticizer, also known as a dispersant, to promote dispersion of the abrasive grit within the thus formed aggregates. Due to the low processing temperatures used, the plasticizer is believed to remain in the thus formed aggregates, and has been quantified as remaining by thermal gravimetric analysis (TGA). The plasticizer might also assist in holding together the grit particles and nanoparticle binder material in an aggregate when the mixture is spray dried.

In this respect, Fig. 7 shows the results of TGA analysis on both SiC containing aggregates and diamond containing aggregates, showing residual plasticizer removal from 250°C to about 400°C. Of note, the diamond was found to burn out at high temperatures. It bears noting that the TGA analysis was done purely as a characterization tool, and the elevated temperatures to which the aggregates were exposed was not part of the process flow for forming aggregates.

Plasticizers include both organic and inorganic materials, including surfactants and other surface tension modifying species. Particular embodiments make use of organic species, such as polymers and monomers. In an exemplary embodiment, the plasticizer is a polyol. For example, the polyol may be a monomeric polyol or may be a polymeric polyol. An exemplary monomeric polyol includes 1,2-propanediol; 1,4-propanediol; ethylene glycol; glycerin; pentaerythritol; sugar alcohols such as malitol, sorbitol, isomalt, or any combination thereof; or any combination thereof. An exemplary polymeric polyol includes polyethylene glycol; polypropylene glycol; poly (tetramethylene ether) glycol; polyethylene oxide; polypropylene oxide; a reaction product of glycerin and propylene oxide, ethylene oxide, or a combination thereof; a reaction product of a diol and a dicarboxylic acid or its derivative; a natural oil polyol; or any combination thereof. In an example, the polyol may be a polyester polyol, such as a reaction products of a diol and a dicarboxylic acid or its derivative.
In another example, the polyol is a polyether polyol, such as polyethylene glycol, polypropylene glycol,

polyethylene oxide, polypropylene oxide, or a reaction product of glycerin and propylene oxide or ethylene oxide. In particular, the plasticizer includes polyethylene glycol (PEG).

The plasticizer, notably polyethylene glycols, can have a range of molecular weights. Suitable molecular weights lie within a range of about 10 to 3000, such as 50 to 1000, 50 to 500, or 50 to 400. PEG 200 has been found to be a particularly useful plasticizers according to certain embodiments of the present disclosure. Plasticizer concentrations in the mixture, before spray drying, may range between about 0.5% to about 40%, and preferably between about 0.5% to about 5%.

As should be clear, the composition used for forming the aggregates contains major species of abrasive grit, nanoparticle binder, and oftentimes a plasticizer. These species may be present in various relative contents in the composition for forming the aggregates. The relative solids content in the aggregates should mirror the solids content in the composition for forming the aggregates, though the final content of the plasticizer may be altered due to drying/volatilization during the spray drying process, though TGA analysis as shows plasticizer retention in the aggregates. The composition may include about 0.1 to about 85 weight percent of the abrasive grit particles, from about 0.1 to about 80 weight percent of the nanoparticle binder, and from about 0.5 to about 40 weight percent of the plasticizer, weight percents based on the total solids content of the composition. In certain embodiments, the composition can contain about 10 to 50 weight percent abrasive grit particles, about 50 to 90 weight percent nanoparticle binder, and about 0.5 to 15 weight percent plasticizer. Particular embodiments s about 15 to 40 weight percent abrasive grit particles and about 60 to 85 weight percent nanoparticle binder.

A volatile liquid is also included in the composition, which acts as a carrier and serves to liquefy or fluidize the mixture of the abrasive grit particles, the nanoparticle binder material, and the plasticizer, so that the mixture may be flowed into a spray dryer, nebulized into fine aggregate droplets, and dried therein. Preferably, the volatile liquid carrier is deionized water, although other volatile liquids may be used that will be driven off by typical spray drying temperatures and do not substantially alter the composition of the mixture. The liquefied mixture may include the abrasive grit particles, the nanoparticle binder material, and a plasticizer, the balance being a volatile liquid. The composition, in the form of a slurry, can be water-based and can include between about 7.5% to about 15% abrasive grit particles, between about 2.5% to about 7.5%, and between about 0.5% to about 1.5% plasticizer, percents based on total weight of the slurry.

During processing, it should be noted that in certain embodiments according to the present disclosure, it is preferred to substantially remove any accumulated static charges from the grit particles prior to their addition to the mixture. It has been observed that the stability of the aggregates formed in the spray drying step is substantially improved if the grit particles are substantially free of accumulated Coulombic charges. Once well mixed, the liquefied mixture, including the components of the abrasive grit particle, the nanoparticle binder material, and the plasticizer, is then processed in a spray dryer in order to form the abrasive aggregates.

Various spray drying apparatuses may be used, including a rotary atomizer, a single fluid nozzle atomizer, and a two-fluid nozzle atomizer. For mixtures having relatively smaller abrasive grit particles, and for forming relatively smaller aggregates, the spray dryer is preferably a rotary atomizer. For mixtures having relatively larger abrasive grit particles, particularly those larger than about 80 microns, and for forming relatively larger aggregates, particularly those larger than about 90 microns, a single fluid or two-fluid nozzle atomizer may be preferred.

The spray dryer apparatus will typically include at least two material collection points, one at the cyclone and one at the bottom of the main drying chamber. Aggregates formed according to the present disclosure can be collected from both locations; however, the aggregates collected from cyclone have been observed generally be smaller in size and lighter in weight while the aggregates collected from the main drying chamber have been observed to generally be larger in size and heavier in weight. Aggregates collected from the cyclone of the dryer have been observed to typically have a size of from about 5 to about 25 microns. On the other hand, aggregates collected from the main drying chamber have been observed to typically have a size of from about 20 to about 100 microns.

To commence spray drying, the slurry is pumped into the spray dry apparatus at a generally constant rate. The slurry then passes through an atomizer or nebulizer inside the spray dryer to form generally spheroidal droplets. While passing through the atomizer, these droplets are caught up in a vortex of hot air, in which the liquid portion of the slurry essentially instantly evaporates and the solid portion of the slurry forms an aggregate. The hot air that volatilizes the liquid fraction of the slurry, leaving behind solid particles, is typically not greater than 400° C, such as not greater than 375°C, 350°C, or 300°C. Typically, spray drying is carried out at a temperature greater than about 80° C, such as greater than about 90°C. Particular embodiments have been carried out at temperatures of about 90°C to about 250°C. It is noted that dwell times within the high temperature portion of the spray dryer are generally limited to seconds, such as 0.5 to 10 seconds, which is in stark contrast to typically heat treatment dwell times associated with sintering, calcination, or firing of typical ceramic products.

When the slurry enters the vortex of hot air the liquid is substantially driven off and the mixture is formed into a fine powder including numerous aggregates, each abrasive aggregate being generally spheroidal in shape. As used here in the term “spheroidal” refers to aggregates having a spherical shape, or a generally spherical shape, including ellipsoids and other spherical permutations, which are a consequent result of the spray drying process. Thus, spheroids include spheres, ellipsoids, truncated spheres and ellipsoids, but all generally have a rounded rather than blocky structure. As should be clear, the aggregates each contain the abrasive grit particles bound together by the nanoparticle binder material and any residue of the plasticizer that has not been evaporated. The final moisture content of the aggregates, the spray drying step, is generally from about 1 to about 3 percent by weight.

Advantageously, according the present disclosure, no further processing steps that notably modify the composition or morphology of the as-formed, unfired, green spray dried aggregates are required in order to produce usable abrasive aggregates. In fact, according to certain embodiments of the present disclosure, the method for making the aggregates consists essentially of only the aforementioned mixing and spray drying steps, and quite notably, heat treatment steps that would affect the morphology of the aggregates are avoided. In particular, no step is carried in which the materials are heated to extremely high temperatures in the range of from about 500°C to 1000°C or more in order to melt, sinter, or otherwise fuse the silica or other nanoparticle binder in the mixtures. Thus, in certain embodiments according to the present disclosure, all of the steps of the method of making the aggregates may be carried at temperatures of about 400°C or less.

This stands in contrast to conventional processes for making abrasive powders with aggregated particles which typically require a sintering step at very high temperatures of from about 500°C to 1000°C or more.

Although the aggregates are not believed to require a sintering or other similar high temperature treatment, the formed aggregates have been found to be highly durable. In particular, it has been observed that, once formed, the aggregates are resistant to dissolution in a wide variety of chemical solvents including methyl ethyl ketone (MEK), isopropyl alcohol (IPA), and 1,4-dioxane.

Once formed, the aggregates may be classified, or separated into various size ranges as desired before being applied to a substrate or otherwise utilized in a polishing operation. In addition to the abrasive aggregates, the resultant powder may include an amount of material smaller than the desired grain size. The particulate material composed of the thus formed aggregates generally has an average particle size within a range of about 10 to 150 microns. Typically, the material has an average particle size not less than about 20, such as not less than about 25 microns. Upper limits for average particle size are driven by process constraints and particular end use applications, and generally the material has an average particle size not greater than about 100 microns, such as not greater than about 90, 80, or even not greater than 70 microns. In certain embodiments, the average particle size of the aggregate material is preferably between about 20 microns and 50 microns. The size, and the size range, of the aggregates may be adjusted and may depend on many factors, including the composition of the mixture and the spray dryer feed rate. For example, abrasive aggregates of sizes including those of approximately 10 microns. 20 microns, 35 microns, 40 microns, and 45 microns have been successfully produced using a rotary atomizing spray dryer. These aggregates have included abrasive grit particles ranging from about 5 to about 8 microns.

When viewed under magnification, the aggregates have a generally spheroidal shape, being characterized as rounded or spherical as seen in the scanning electron micrographs of Figs. 4 – 6. In some instances, however, the aggregates may be observed to have an void near the center of the aggregate and thus exhibit a more toroid-or torus-like shape as seen in the scanning electron micrographs of Figs. 1 – 3. Individual particles of the abrasive grit material, such a diamond grit, may be observed to be dispersed over the surface of the aggregates and within the interior thereof, with relatively few instance of the individual grit particles clumping together on the surface of the aggregate.

It is noted that Figs. 1-6 show dispersed, individual aggregates that are bound together in a resin binder system.

Further study of the abrasive aggregates has revealed that certain embodiments are composed of hollow spheroids. Such particles can be analogized to thick-shelled racquet balls, having a wall thickness t_w within a range of about 0.08 to 0.4 times the average particle size of the aggregates. Process parameters and compositional parameters can be modified to effect different wall thicknesses, such as wall thicknesses not less than about 0.1, 0.15 times the average particle size of the aggregates. Upper limits for wall thickness may be on the order of 0.35, 0.30, 0.25, or 0.20 times the average particles size of the aggregates.

Additional studies show that specific surface areas (SSA)are generally greater than 2 m^2/g, such as greater than 10 m^2/g, greater than 10 m^2/g, or greater than 15 m^2/g. Maximum SSA has been observed to be not greater than 150 m^2/g, such as not greater than 100 m^2/g.

Once formed, the abrasive aggregates can be used ‘as-is’ with suitable classification to refine particle size distribution. While post-synthesis process steps such as excessive heat treatment are avoided, such that the aggregates are used in a green, unfired state, the aggregates can be coated with a metallurgical coating, in much the same fashion that individual abrasive grits can be coated. Metallurgical coatings nickel, titanium, copper, silver and alloys and mixtures thereof.

Once produced, the abrasive aggregates may be used directly as a loose or ‘free’ abrasive powder. In this context, the abrasive powder formed from the aggregates may be used as either a dry powder or a powder which has been wetted with a liquid such as water to create a slurry for improved performance. The abrasive powder may also be incorporated into a polishing paste or gel. The abrasive powder so produced may advantageously be used for the finishing and / or polishing of numerous other materials such as chemical mechanical planarization (CMP) used in the semiconductor industry, fine surface finishing of various materials, and polishing both natural and artificial dental materials. Alternatively, the aggregates are configured into a fixed abrasive, a term that broadly includes coated and bonded abrasive products.

In other embodiments of the present disclosure, however, the abrasive aggregates are preferably combined with a resin material used to adhere the aggregates onto a surface of a substrate. Processes for combining the aggregates with the resin bonding material include slurry formation, in which the aggregates, resin and other additives are combined together and coated on a substrate, or in a distinct processing pathway, aggregates are placed on a resin coated substrate through electrostatic attraction or simply through gravity (e.g., sprinkled on the substrate). The latter approach is well understood in the art, generally first depositing a ‘make coat’ on the substrate, aggregate application on the make coat, and subsequent deposition of a ‘size coat.’ Optionally, a supersize coat may be deposited over the size coat. Further, a compliant coat may be disposed between the make coat and the substrate. In another example, a back coat may be disposed over the substrate on a side opposite the make coat.

In connection with slurry coating a substrate, in addition to the aggregates, the slurry generally also includes a solvent such as water or an organic solvent and a polymeric resin material. Suitable polymeric resin materials include polyesters, epoxy resins, polyurethanes, polyamides, polyacrylates, polymethacrylates, poly vinyl chlorides, polyethylene, polysiloxane, silicones, cellulose acetates, nitrocellulose, natural rubber, starch, shellac, and mixtures thereof. Most preferably, the resin is a polyester resin. The slurry may additionally comprise other ingredients to form a binder system designed to bond the aggregate grains onto a substrate. The slurry composition is thoroughly mixing using, for example, a high shear mixer.

The slurry containing the aggregate grains is preferably applied to the substrate using a blade spreader to form a coating. Alternatively, the slurry coating may be applied using slot die, gravure, or reverse gravure coating methods. The coating thickness may range from about 1 to about 5 mils in thickness, after drying. As the substrate is fed under the blade spreader at a desired coat speed, the aggregate grain slurry is applied to the substrate in the desired thickness. The coat speed is preferably between about 10 to about 40 feet per minute.

The coated substrate is then heated in order to cure the resin and bond the aggregate grains to the substrate. In general, the coated substrate is heated to a temperature of between about 100°C to less than about 250°C during this curing process. In certain embodiments of the present disclosure, it is preferred that the curing step be carried at a temperature of less than about 200°C.

Once the resin is cured and the aggregate abrasive grains are bonded to the substrate, and the coated substrate may be used for a variety of stock removal, finishing, and polishing applications.

In an alternative embodiment of the present disclosure, the abrasive aggregates may be directly incorporated into the substrate. For instance, the aggregates may be mixed a polyester resin and this mixture of aggregates and polymer may then be formed into a substrate.

In a still alternative embodiment of the present disclosure, the abrasive aggregates may be applied to a substrate coated with an adhesive and then sealed. This coating technique is similar that typically used for traditional sandpaper, and is referenced above. In this embodiment, the abrasive aggregates are preferably not mixed into a slurry. Instead the abrasive powder containing the aggregates is preferably fed onto a substrate to which an adhesive has already been applied, the make coat, followed by sealing via the size coat. Optionally, the substrate may be pre-treated with a compliant coat or a back coat.

In an alternative embodiment of the present disclosure, the abrasive aggregates could be applied to substrates or other materials by electroplating, electric-static, spray coating and spray powder coating methods.

The abrasive-coated substrate may them be used as a lapping film or a micro-finishing film for finishing and /or polishing other materials. Substrate materials which may be coated in this manner include, but are not limited to, polyester, polyurethane, polypropylene, polyimides such as KAPTON from DuPont, non-woven materials, woven materials, paper, and metals including foils of copper, aluminum, and steel. Polyester films are particularly preferred as the substrate material is certain embodiments of the present disclosure. Suitable substrates may have a thickness, before being coated, of from about 1 to about 14 mils.

In certain embodiments, the abrasive product may utilize a highly porous substrate material, such as a foam material. Porous substrates facilitate swarf removal during abrasive applications and may also prove useful in applications where a pliable material is suitable. The amount of porosity is typically on the order of at least about 40 vol%, and according to certain embodiments, at least about 50 vol%, 60 vol%, 70 vol%, 80 vol% or even at least about 90 vol%. Particular embodiments have a porosity within a range between about 50 vol% and 90 vol%.

Generally, the porosity in such substrates can be open, closed, or a combination thereof. Still, particular embodiments utilize porous substrate materials having a majority of open porosity. That is, the porosity is an interconnected network of pores extending through the physical, lattice structure of the substrate. A certain amount of open porosity may be desirable since the interconnected network of pores allows additives, coats, and particulate material to penetrate into the interior of the substrate material, which may be suitable for the formation of certain abrasive products.

In the context of porous substrates, some suitable materials can include organic materials. For example, synthesized organic materials such as polyolefins, and more particularly polymers including polystyrene, polyester, polyurethane, polypropylene, polyethylene, polymethacrylimide, polyamide, polylactic acid, polyacrylate, polysulphone, polyacetate, fluorinated polymers, and chlorinated polymers.

The formation of abrasive products using porous substrates can be completed in accordance with embodiments described herein. For example, the forming process can include any number of coats, such as a make coat, size coat, supersize coat, or even a back coat. In particular, binders or adhesives to which the particulate material is bonded to the substrate can include a spray coating application to assure penetration of the pores. Additionally, the particulate material may be applied using a similar process ensuring that a suitable amount particulate material is bonded to the substrate.

In some applications, a certain coating of particulate material on the available surface area of the lattice structure is desirable. For example, according to one embodiment, at least about 50% of the available surface area of the lattice structure is covered by the particulate material. In accordance with other embodiments, the particulate material covers a greater percentage of the available surface area of the lattice structure, such at least about 60%, 75%, 85% or even 95%. Certain embodiments utilize a coverage of particulate material on the available surface area within a range between about 50% and 100% and more particularly, between about 85% and 100%. FIG. 17 and 18 provide magnified images of portions of a highly porous substrate including particulate materials bonded to the lattice structure of the substrate.

Abrasive products utilizing a porous substrate may be useful in general abrading operations including polishing and grinding applications or alternatively in cleaning applications. Such products may be used in a variety of industries, including for example, commercial, automotive, household, personal use, and medical industries. In fact, in comparative tests, the present abrasive product has outperformed state of the art abrasive cleaning products. For example, one such state-of-the-art product is the Mr. Clean Magic Eraser® available from Proctor and Gamble.

Referring again more generally to the coated abrasive products independent of the type of substrate material, that is porous or non-porous, other additives may be provided in the abrasive product. Additives can be added to any of the previously mentioned coats such as the make coat, size coat, supersize coat, or back coat to give the abrasive product certain characteristics which may be suitable for certain applications. Such additives can include anti-loading agents, abrasive fillers, plasticizers, anti-static agents, lubricants, wetting agents, grinding aids, pigments, dyes, coupling agents, release agents, suspending agents, curing agents, aromatic materials, and antimicrobial agents.

Anti-loading agents aid swarf removal during grinding and polishing applications. Some such suitable anti-loading agents can include metal-containing or organic-containing materials, or a combination thereof. Particularly suitable organic-containing anti-loading agents can include polymers having organyl groups including at least 4 carbon atoms, and more particularly at least 8 carbon atoms, for example, quaternary ammonium salt compounds having from about 15 to 35 carbon atoms. Other suitable organic anti-loading agents can include acids, for example, saturated fatty acids having from about 4 to 22 carbon atoms. In some certain instances, partial esters may also be particularly suitable.

Additionally, particularly suitable metal-containing materials can include metal stearates, metal palmitates, a combination thereof, and the like. Certain other anti-loading agents can include salts, such as amine salts, lithium salts, combinations thereof and the like. Phosphoric-containing compounds, such as phosphoric acids, may also be suitable for use as anti-loading agents.

The abrasive products herein can include anti-loading agents having softening points greater than about 50°C. Other anti-loading agents may have higher softening points depending upon the intended application, such as at least about 60°C, 75°C, 90°C, and more particularly, within a range between about 50°C and 100°C. The anti-loading agent can be applied to the abrasive product within one of the forming coats, such as the make coat, size coat, supersize coat, or back coat, but it will be appreciated that such an additive can be applied in a different manner. For example, the anti-loading agent can be applied directly to the substrate, in a separate application, such that it bonded to the substrate. In other embodiments, the anti-loading agent can be bonded to the particulate material, for example, it may be contained within the particulate material, such as bonded to the nanoparticle binder, or alternatively, within the hollow or interior space of the particulate material.

In the context of a supersize coat containing an anti-loading agent, generally the anti-loading agent is present in an amount between about 50 wt% and 100 wt% of the total weight of the supersize coat. In the context of an anti-loading agent bonded to the substrate or contained within the particulate material, the amount of anti-loading agent may be the same, or in some certain instances, it can be present in minor amounts.

In certain embodiments, it may be suitable to incorporate an anti-loading agent prior to the final formation of the particulate material. That is, the anti-loading agent can be provided during the formation of the particulate material. According to one particular embodiment, the anti-loading agent is provided in a binder or plasticizer used to form the particles, such as prior to a spray drying process.

In further reference to particular additives, the abrasive product can include an anti-static agent that reduces the tendency of the abrasive product to accumulate static electricity during a grinding or polishing application. Suitable anti-static agents can include hygroscopic materials. For example, the anti-static agent can include an organic material, such as amines, carboxyls, and hydroxyls, a combination thereof, and the like. Additionally, an anti-static agent can include a metal, and more particularly, oxides of metals, such as vanadium oxide. Other embodiments may use an anti-static agent including carbon. Carbon-containing anti-static agents can include graphite or carbon black, which is typically formed by partial combustion of hydrocarbons.

Application of the anti-static agent to the abrasive product can be in a manner similar to that as described with respect to the anti-loading agent. That is, it may be included within a coat overlying and bonded to the substrate and or particulate material, such as the make coat, size coat, supersize coat, or even the back coat. Alternatively, the anti-static agent may be contained within a backing material attached to a surface of a substrate. In still another embodiment, the anti-static agent can be bonded to the particulate material, that is, it may be contained within and bonded to the nanoparticle binder material, or contained within an interior space of the hollow particulate material. In the particular context of providing an anti-static agent that is bonded to the particulate material, it may be suitable to provide such an agent while forming the particulate material. For example, the anti-static agent can be added as part of a binder or plasticizer material used to form the particles.

Incorporation of an anti-static agent within the abrasive product can result in a low surface resistivity product. In accordance with one embodiment, the surface resistivity of the abrasive product including the anti-static agent is not greater than about 1E8 ohm/square. Other embodiments may have lower surface resistivities, such as on the order of not greater than about 1E7 ohm/square, 1E6 ohm/square, or even not greater than about 1E5 ohm/square. Certain embodiments utilize an abrasive product having a surface resistivity within a range between about 1E4 ohm/square and about 1E8 ohm/square.

In particular reference to other additives, the substrate can include an aromatic material such that an aroma or scent is released upon use of the abrasive product. Generally, reference to aromatic materials is reference to materials capable of releasing a fragrance, often a pleasing fragrance, such as those associated with floral, musk, or citrus smelling agents. The aromatic material can include notes akin to perfumes, such that it may include a base note, top note, or middle note, and any combination thereof. Additionally, certain aromatic materials can include essential oils such as those found naturally and associated with certain fragrances, or alternatively, synthetic materials developed to mimic naturally occurring fragrances of essential oils. In accordance with a particular embodiment, the aromatic material is an organic material, and can include compounds such as alcohols, aldehydes, amines, esters, ethers, ketones, lactones, terpenes, and thiols.

Provision of an aromatic material within the abrasive product allows for the release of a pleasant fragrance upon use of the abrasive product. Accordingly, the provision of such aromatic materials within the abrasive product may be suitable for use in household or personal applications where pleasant fragrances are associated with a level of cleanliness. Like the other additives discussed herein, the aromatic material can be applied to the abrasive product within a coat, such as the size coat, make coat, supersize coat, or even the back coat. In accordance with a particular embodiment, the aromatic material is bonded to the substrate, and more particularly, may be contained within a coat overlying a portion of the substrate and particulate material. In accordance with an alternative embodiment, the aromatic material is contained within the particulate material, such that it can be contained and bonded to the nanoparticle binder, or alternatively contained within an interior space of the hollow particulate material. In the particular context of an aromatic material that is bonded to the particulate material, it may be suitable to provide such a material during the formation of the particulate material. For example, the anti-static agent can be added as part of a binder or plasticizer material used to form the particles.

In accordance with another particular embodiment, the abrasive product may include an antimicrobial agent useful in commercial, industrial, and household products, which is released upon the worksurface during the use of the abrasive product thereby sterilizing the work surface. Suitable antimicrobial agents can include sterilants, sanitizers, disinfectants, and fungicides. More particularly, suitable antimicrobial agents typically include materials such as alcohol, phenolics, peroxide, ammonium-containing compounds, iodine-containing compounds, and chlorine-containing compounds. It will be appreciated that an antimicrobial agent can include one or a combination of any of the above mentioned chemical compounds, including more common examples such as chlorhexadine, trichlosan, bleach, and quaternary ammonium chloride.

Provision of antimicrobial agents within the abrasive product can be done in such a manner that they are provided in one of various coats used to form the final product, including the make coat, size coat, supersize coat, or back coat. In accordance with a particular embodiment, the antimicrobial agent may be bonded to the substrate, and more particularly, overlying a portion of the substrate and bonded to the particulate material such that upon conducting an abrasive process the antimicrobial agent is released at the worksurface. In accordance with a particular embodiment, the antimicrobial agent can be bonded to the particulate material, such that it is contained within the nanoparticle binder, or alternatively contained within an interior space of the hollow particulate materials. In certain instances, where an antimicrobial agent is bonded to the particulate material, the agent may be provided within a plasticizer or binder during the formation of the particulate material.

Further, the abrasive aggregates may also be incorporated into bonded abrasives, such as diamond grinding wheels and other grinding wheels. Bonded abrasives may also used to provide high traction, non-slip materials which may be applied, for example, to ladder rungs. Here, typically bonded abrasives are three dimensional structures rather than the generally planar structure of a coated abrasive, and includes a 3 dimensional matrix of bonding material in which the aggregates are embedded. That is, the bond material fixes position of the aggregates with respect to each other, and is present as an inter-agglomerate phase. While bonded abrasives utilize a wide variety of bonding agents, such as resin, glass, and metals, certain agents such as glass and metal bond materials require high temperature processing. Accordingly, to preserve the green structure of the aggregates, generally resin systems are used that do not require high cure temperatures, or which can be cured with actinic radiation such as UV.

In one embodiment according to the present disclosure, the abrasive product may be used for finishing and polishing telecommunications cables, particularly fiber optic cables. Fiber optic cables are capable of transmitting vast amounts of data at very high speed in the form of light pulses. To allow these light pulses to be effectively transmitted between interconnected fiber optic cables or between a fiber optic cable and a connected electronic device, however, the ends of the fiber optic connectors must be cleanly cut or cleaved and then highly polished to produce an extremely smooth surface and appropriate tip geometry. Abrasive substrate film produced according to the present disclosure and generally cut into disk or sheet form may be used for this purpose and have been observed to be highly effective for the polishing of the ends of fiber optic connectors.

When used for polishing fiber optic connectors, the abrasive substrate films are preferably produced from aggregates formed from diamond grit combined with silica nanoparticle binder. The grit particles preferably have a size of about 1 micron, and the overall size of the aggregates is preferably from about 30 to about 80 microns. These aggregates are preferably bonded to a polyester film substrate. Polishing of the fiber optic connector ends may be carried out on a fiber optic polishing machine. A suitable 12 connector polishing machine is available from Domaille Engineering of Rochester, Minnesota and may be used with the abrasive substrate films of the present disclosure for polishing fiber optic connectors at, for example, a speed of about 60 rpm and with an applied pressure of about 8 psi.

In another embodiment according to the present disclosure, the abrasive product may be used for stock removal, finishing and polishing hard metal surfaces such as steel. When used for polishing metal surfaces, the abrasive substrate films are preferably produced from aggregates formed from diamond grit combined with a silica nanoparticle binder. The grit particles preferably have a size of about 1 micron, and the overall size of the aggregates is preferably from about 30 to about 80 microns. These aggregates are preferably bonded to polyester film substrate. Using this abrasive product, polishing of the surfaces may be carried out, for example, using a Struers metal polishing machine (available from Struers, Inc. of Westlake, Ohio) operating at a speed of 600 rpm and with an applied force of 15 newtons. Alternatively, hard metal surfaces may also be polished using abrasive aggregates formed from silicon carbide grit combined with silica.

In another embodiment according to the present disclosure, the abrasive product may be used for stock removal, finishing and polishing softer metal surfaces such as copper or brass. When used for polishing metal surfaces, the abrasive substrate films are preferably produced from aggregates formed from diamond grit combined with a silica nanoparticle binder. The grit particles preferably have a size of about 3 to 5 microns, and the overall size of the aggregates is preferably from about 30 to about 80 microns. These aggregates are preferably bonded to polyester film substrate. Using this abrasive product, polishing of the surfaces may be carried out, for example, using a Struers metal polishing machine (available from Struers, Inc. of Westlake, Ohio) operating at a speed of 150 rpm and with an applied force of 45 newtons. Alternatively, soft metal surfaces may also be polished using abrasive aggregates formed from silicon carbide grit combined with silica.

In still another embodiment according to the present disclosure, the abrasive substrate may be used for finishing and polishing coated surfaces, such as painted surfaces. In particular, the abrasive substrate film may be used to buff or polished painted automotive surfaces. When used for polishing painted automotive surfaces, the abrasive substrate films are preferably produced from aggregates formed from silicon carbide grit embedded within a silica nanoparticle binder. The grit particles preferably have a size of from about 3 to about 8 microns, and the overall size of the aggregates is preferably from about 30 to about 50 microns. These aggregates are preferably bonded to a polyester film substrate.

In the context of coated surfaces, it has been observed that the abrasive products herein are useful for changing the appearance of painted surfaces. In particular, it is noted that the abrasive products are suitable for reducing the surface roughness of painted surfaces, and thereby increasing the gloss of a painted surface. Upon abrading a painted surface having a dull or semi-glossy paint with the abrasive product, the surface roughness is reduced such that the gloss of the treated surface is increased to a final gloss, G_f that is greater than an initial gloss, G_i. Such measured changes in glossiness appear more prevalently at certain angles, such as at 60° or 85°. In accordance with an embodiment, the change in gloss is a notable change such that the final gloss G_f is at least two times greater than the initial gloss G_i as measured by a gloss meter BYK Micro Trigloss Meter 4430 according to ASTM standard test D2457. In other embodiments, the change between the initial gloss and the final gloss is greater, such that the final gloss G_f is at least 4 times the initial gloss G_f, and more particularly within a range between about 2 times to about 4 times of the initial gloss G_i measured at angle of about 60°.

At greater angles, the change in the gloss between the final gloss G_f and initial gloss G_i may be greater. In accordance with one embodiment, the final gloss G_f measured at an angle of 85° is at least about 3 times the initial gloss G_i, and more particularly within a range between about 2 times and 6 times the initial gloss G_i measurement.

Other embodiments can particularly include finishing in dental applications. Here, an abrasive product such as a coated abrasive, containing green, unfired aggregates as described herein can be utilized quite successfully for finishing tooth and dental prosthetics.

Typically the polishing of materials such as those described above is carried out in a multi-step, incremental process. The surface is first polished with a relatively coarse abrasive material and then polished again with a somewhat finer grit abrasive material. This process may be repeated several times, which each successive re-polishing being carried out with a progressively finer grit abrasive until the surface is polished to the desired degree of smoothness. This type of multi-step polishing procedure has conventionally been required as typically the grains of an abrasive must be on the same scale as the size of the scratches which they are to remove. Certain polishing protocols use successively finer products having a grit size, and attendant Ra (with respect to both the abrasive product and on the workpiece post-machining step) reduced by a factor of three. That is, successively finer products are generally limited to reduction by a factor of three (e.g., from 9 micron, to 6 micron, to 3 micron grit sizes), in order to ensure defect removal from the preceding machining step.

In contrast to the conventional multi-step procedure, however, it has been quite surprisingly and unexpectedly observed that a wide variety of workpieces, from materials such as fiber optic connectors, metals surfaces, and painted automotive surfaces, and dental prosthetics, may be polished in a *single* step process using *single*, rather than multiple abrasive product, such as a coated abrasive product according to the present disclosure. This result is quite surprising and highly advantageous. It is been observed that when abrasive substrates according to the present disclosure are used, the entire polishing may be carried out using only one abrasive. This results in a considerable reduction in the time needed to achieve a desired degree of polishing smoothness, as well as marked reduction in costs.

Without being bound by theory, it is believed that the advantage may be derived from the unique properties observed in the aggregates of the present disclosure. The average roughness, or $R_{a,}$ of a surface is a measure of the degree of variations in the overall height profile of a surface. A lower roughness value is generally indicative of a surface which is smoother and has smaller variations in overall height between differing locations on the surface. When the roughness value of abrasive materials is measured, the roughness values observed can typically be correlated to the average size of the abrasive particles. For example, with conventional diamond grit abrasives, the size of the diamond grit and the expected roughness values for the abrasives are typically as follows:

Diamond grit size (microns)	Typical roughness value (R_a) (microns)
30	2.5
15	1.6
9	1.0
6	0.8
3	0.6
1	0.3

To finish or polish a surface to a desired final maximum roughness (i.e. to a desired final minimum degree of smoothness), conventionally an abrasive must be employed having a corresponding maximum degree of roughness.

The aggregates of the present disclosure, however, have been observed have a roughness value in excess of what would typically be expected for a grit particle having a comparable size. Thus, while a typical 30 micron diamond grit particle would generally have a roughness values of about 2.5 microns (as noted above), 30 micron aggregates formed from 1 micron diamond grit and a silica nanoparticle binder according to the present disclosure have been observed to have a roughness value of from about 5 to about 6 microns.

Even more surprisingly, despite this high roughness value, it has been observed that these same aggregates according to the present disclosure may be used for the fine polishing of surfaces. A finished surface smoothness corresponding to a roughness value of well below 1 micron may be achieved using the aforementioned diamond grit and silica aggregates which, again, have been measured to roughness values of from about 5 to about 6 microns. Conventionally, a grit particle having a size of about 1 micron or less would be required to polish a surface to this degree of smoothness.

More concretely, based upon testing of numerous embodiments, it has been found that initial surface roughness of a work piece can be machined and polished in a single step, utilizing a single abrasive product, well beyond the capability of a conventional single abrasive product. For example, for a workpiece having an initial surface roughness Ra_i, embodiments herein have shown the capability of reducing the initial surface roughness Ra_i to a final surface roughness as a result of abrading the workpiece, the final surface roughness Ra_f being not greater than 0.2 Ra_i, such as not greater than 0.1 Ra_i. The foregoing achievement in the reduction of surface roughness by utilizing a *single* product bears notable attention, as state of the art abrasive products are generally quite limited in surface roughness reduction utilizing a single product. Indeed, surface roughness reductions have been measured to values not greater than 0.5 Ra_i, and even not greater than about 0.01 Ra_i, representing a notable 2 order of magnitude reduction in surface roughness Ra.

While it is not completely understood as to the precise reasons why embodiments herein have demonstrated such machining efficacy, oftentimes spanning more than one order of magnitude reduction in Ra on a work piece, it is theorized that the present green, unfired aggregates having notable composite structure is responsible for machining through complementary simultaneous pathways. For example, it is believed that the aggregate size is responsible for large defect reduction (e.g., removal of 6 to 7 micron scratches in a work piece). Meanwhile, the primary abrasive grit is believed to be responsible for simultaneous reduction in medium sized defects, driving the Ra value of the workpiece even further downward. And moreover, it is believed that the nanoparticle binder contributes to ultra-fine polishing of the workpiece, driving Ra values of the workpiece down into the nanometer regime, such as on the order of 10 to 20 nanometers, observed for certain work pieces.

It is emphasized that the green, unfired state of the aggregates contributes to the notable machining efficacy described above. By maintaining the aggregates in the green, unfired state, it is understood that the nanoparticle binder, while composed of particles interlocked and to some extent atomically bonded together, nevertheless retains the desirable ultra-fine polishing properties of the nanoparticle *particles*, which properties would be destroyed through higher temperature heat treatment. That is, the multi-action nature of the aggregates is maintained through controlled process conditions, notably preventing the aggregates from being exposed to high temperatures over any sort of notable duration. Here, it is noted that it is likely not just temperature alone, but also dwell time which would be responsible for high temperature aggregate degradation. For example, during spray drying, droplets containing the solids fraction forming the aggregates are typically exposed to elevated temperatures, such as up to about 400° C, for a mere few seconds, while conventional high temperature ceramic processes such as sintering, calcination or the like generally utilize dwell times on the order of 15 minutes to multiple hours. Accordingly, it is feasible that the aggregates according to the present embodiments may maintain their green state even upon exposure to elevated temperatures, provided that such elevation is restricted to the order of seconds. Such would be the case to the extent that higher temperatures for spray drying processes were utilized.

It is also noted, that based on comparative testing, incorporation of a plasticizer in the slurry composition can be highly result effective. More specifically, in testing of diamond/colloidal silica containing aggregates, removal of plasticizer had a notable, negative impact. The plasticizer helps maintain dispersion of the abrasive grits in suspension or slurry form, and stabilizes the suspension during processing. Upon spray drying, it was observed that the abrasive grits remain very well distributed. When the plasticizer is removed from the slurry composition, the resultant aggregates at first appeared not different, and had requisite green strength for handling. However, upon deployment into an abrasive product, machining results were poor, with observed aggregate failure. Without wishing to be bound by any particular theory, it is believed that the plasticizer enable the formation of a more structurally sound aggregate, by maintaining grit dispersion in the slurry and uniform distribution in the aggregate. In contrast, comparative examples absent plasticizer had localized clumps of grits, forming a weak area of the aggregate, subject to failure upon application of working pressures.

The uniform distribution of aggregates can easily be seen in Fig. 8, which is an example that was exposed to TGA described above, showing diamond grit burnout due to high temperature volatilization. The void areas shown in Fig. 8 illustrate diamond grit positions. It is also noted that the material left behind, heat treated nanoparticle binder, clearly forms a self supporting, continuous matrix. Of course, in the high temperature form shown in Fig. 8, the particulate nature of the binder has been lost due to grain growth and sintering.

A further advantage may be found in the surprising durability of abrasives made from the aggregates of the present disclosure. Abrasives typically wear down and gradually lose their effectiveness in removing stock material from a surface being polished or finished with the abrasive. Abrasives incorporating the aggregates of the present disclosure, however, have been observed to have significantly improved durability as compared to conventional abrasives materials. When used in comparable applications, abrasives incorporating the aggregates of the present disclosure have been observed to retain their effectiveness for more than twice as long as conventional abrasive materials, and in some instances, up to 20 times as long.

The properties and advantage of the present disclosure are illustrated in further detail in the following nonlimiting examples. Unless otherwise indicated, temperatures are expressed in degrees Celsius, and concentrations are expressed in weight percentages based upon the overall dry weight of the abrasive aggregates.

EXAMPLE 1

A powder of fine abrasive aggregates including diamond grit combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with diamond grit having an average particle size of 1.1 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica ($Si0_2$) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Pounds in mixture
Diamond grit	6.6
BINDZIL 2040 silica sol	13.2
PEG 200	0.9
Deionized water	45

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 20 % solids in water.

The mixture was then spray dried using a Niro SD6.3 rotary atomizer spray dryer with an FF-1 atomizer available from Niro, Inc. of Columbia, Maryland. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 152°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 85 % of the aggregate particles were collected from the dryer cyclone unit and about 15 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the diamond grit. The average size of the aggregates collected from the cyclone was measured to be about 20 microns. The average size of the aggregates collected from the main drying chamber was about 40 microns.

EXAMPLE 2

A powder of fine abrasive aggregates including diamond grit combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica solution (BINDZIL 2040) was mixed with diamond grit having an average particle size of 1.0 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The components were mixed in the following amounts:

Component	Pounds in mixture
Diamond grit	15.75
BINDZIL 2040 silica sol	40
PEG 200	2.2
Deionized water	52.5

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 52 % solids in water.

The mixture was then spray dried using the same Niro brand spray dryer. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 170°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates. The aggregates produced were collected for analysis with about 50 % of the particles being collected from the dryer cyclone unit and about 50 %

being collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the diamond grit. The typical size of the aggregates was measured to be about 35 to about 45 microns.

EXAMPLE 3

A powder of fine abrasive aggregates including diamond grit combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica solution (BINDZIL 2040) was mixed with silicon carbide grit (NGC 2500, available from Nanko Abrasives, Inc. of Tokyo, Japan) having an average particle size of 8 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The components were mixed in the following amounts:

Component	Pounds in mixture
Silicon carbide grit	75
BINDZIL 2040 silica sol	190
PEG 200	10.5
Deionized water	25

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 60 % solids in water.

The mixture was then spray dried using the same Niro brand spray dryer. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 132°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates. About 150 pounds of the aggregates were collected with about 50 % of the particles being collected from the dryer cyclone unit and about 50 % being collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the silicon carbide grit. The average size of the aggregates was measured to be about 40 microns.

EXAMPLE 4

In this example, a powder of silicon carbide and silica aggregates produced as described in Example 3 above, was coated and bonded to a substrate. In order to apply the aggregate powder to the substrate, a coating slurry was first prepared including the aggregate powder, a polyester resin (VITEL 3301 available from Bostik, Inc. of Wauwatos, Wisconsin), a crosslinking agent, and methyl ethyl ketone solvent (available from Quaker City Chemicals, Inc. of Philadelphia, Pennsylvania) in the following amounts:

Component	Pounds in mixture
Silicon carbide aggregates	81.6
Polyester resin	50
Crosslinking agent	24.9
MEK solvent	75

The composition was mixed in order to provide a substantially uniform slurry mixer.

A roll of MYLAR Type A polyester brand film (available from DuPont) was used as the substrate. The film had a thickness of 3 mils. A coating of the slurry was applied to the upper surface of the substrate film using a blade coating system. The film was advanced through the blade coating station at a rate of 40 feet per minute and the slurry was coated onto the substrate film at an initial thickness of about 3 mils.

As the coated substrate exited the blade coater, the film was advanced through an extended heating unit. The length of the heating section within the unit was about 37 feet and this heating section was maintained at a temperature of about 340°C. The coated will was advanced in the heating unit at a speed of 40 feet per minute. As the coated film passed through the heating unit, the resin in the slurry underwent a crosslinking (i.e. curing) reaction. Upon exiting the heating unit, this reaction was substantially complete and the aggregates were substantially bonded to the substrate film by the crosslinked resin.

The finished, aggregate-bonded substrate film was then allowed to cool and thereafter was cut into a plurality of abrasive discs. The surface profile of an abrasive disc sample was then analyzed using a Mahr profilometer instrument from Mahr Federal Inc. of Providence, Rhode Island in order to determine the roughness value (R_a) of the abrasive disc. The roughness value was measured to be 5.85 microns.

EXAMPLE 5

In this example, a lapping film substrate was coated with a combination of two aggregate powders. The first was a powder made from diamond grit and silica aggregates as described in Example 1 above. The second was a powder made from silicon carbide and silica aggregates produced as described in Example 3 above. In order to apply the aggregate powder to the substrate, a coating slurry was first prepared including the two aggregate powders, a polyester resin (available from Bostik, Inc. of Wauwatos, Wisconsin), a crosslinking agent, and methyl ethyl ketone solvent (available from Quaker City Chemicals, Inc. of Philadelphia, Pennsylvania) in the following amounts:

Component	Pounds in mixture
Silicon carbide aggregates	15.21
Diamond aggregates	35.3
Polyester resin	60
Crosslinking agent	0.6
MEK solvent	45

The composition was mixed in order to provide a substantially uniform slurry mixer.

A roll of MYLAR Type A polyester brand film was used as the substrate. The film had a thickness of about 3 mils. A coating of the slurry was applied to the upper surface of the substrate film using a blade coating system. The film was advanced through the blade coating station at a rate of 25 feet per minute and the slurry was coated onto the substrate film at an initial thickness of about 2.5 mils.

As the coated substrate exited the blade coater, the film was advanced through an extended heating unit. The length of the heating section within the unit was about 37 feet and this heating section was maintained at a temperature of about 340 °C. The coated will was advanced in the heating unit at a speed of 25 feet per minute for a total heating time of about two minutes. As the coated film passed through the heating unit, the resin in the slurry underwent a crosslinking (i.e. curing) reaction. Upon exiting the heating unit, this reaction was substantially complete and the aggregates were substantially bonded to the substrate film by the crosslinked resin.

The finished, aggregate-bonded substrate film was then allowed to cool and thereafter was cut into a plurality of abrasive discs. The surface profile of an abrasive disc sample was then analyzed using a Mahr profilometer instrument in order to determine the roughness value (Ra) of the abrasive disc. The roughness value was measured to be 11.13 microns.

EXAMPLE 6

A powder of fine abrasive aggregates including aluminum oxide grit held within silica was produced by the following method. An aqueous colloidal silica was mixed with aluminum oxide grit having an average particle size of 3.27 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica (Si02) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Pounds in mixture
Alum. Oxide grit	24
BINDZIL 2040 silica sol	62
PEG 200	3.8
Deionized water	210

The components were thoroughly mixed using a high shear mixer for 15 minutes to provide a uniform aqueous dispersion.

The mixture was then spray dried using the same Niro brand spray dryer. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 240°C. The outlet temperature of the spray dryer was measured to be about 120°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates. About 15 pounds of the aggregates were collected from the cyclone section during a 1.5 hour run of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica and PEG with particles of the aluminum oxide grit imbedded thereon. The average size of the aggregates was measured using a Microtrack size distribution analysis, using both wet and dry sample methods. The average size was measured to be 17.08 microns by the wet sample method and 19.12 microns by the dry sample method. The final moisture content of the aggregates, after spray drying, was 1.4 weight percent.

EXAMPLE 7

A powder of fine abrasive aggregates including aluminum oxide grit held within silica was produced by the following method. An aqueous colloidal silica solution (BINDZIL 2040) was mixed with an aluminum oxide grit having an average particle size of 3.27 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The components were mixed in the following amounts:

Component	Pounds in mixture
Alum. Oxide grit	24
BINDZIL 2040 silica sol	62
PEG 200	3.8
Deionized water	210

The components were thoroughly mixed using a high shear mixer for 15 minutes to provide a uniform aqueous dispersion.

The mixture was then spray dried using the same Niro brand spray dryer. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 343°C. The outlet temperature of the spray dryer was measured to be about 150°C. The spray dryer was operated at 350 Hertz. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates. A total of about 26 pounds of the aggregates were collected during a 2 hour run of the spray dryer apparatus, with about 8 pounds of aggregates being collected from the main drying chamber and about 18 pounds of aggregates being collected from the cyclone. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica and PEG with particles of the aluminum oxide grit imbedded thereon. The average size of the aggregates was measured using a Microtrack size distribution analysis, using both wet and dry sample methods. For the cyclone aggregates, the average size was measured to be 20.38 microns by the wet sample method and 22.4 microns by the dry sample method. For the drying chamber aggregates, the average size was measured to be 45.97 microns by the wet sample method and 45.91 microns by the dry sample method. The final moisture content of the aggregates, after spray drying, was 1.76 weight percent for the cyclone aggregates and 1.54 for the drying chamber aggregates.

EXAMPLE 8 (Diamond 1 Chamber)

A powder of fine abrasive aggregates including diamond grit combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with diamond grit having an average particle size of 1.1 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica ($Si0_2$) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Pounds in mixture
Diamond grit	6.6
BINDZIL 2040 silica sol	13.2
PEG 200	0.9
Deionized water	45

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 20 % solids in water.

The mixture was then spray dried using a Niro SD6.3 rotary atomizer spray dryer with an FF-1 atomizer available from Niro, Inc. of Columbia, Maryland. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 152°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 85 % of the aggregate particles were collected from the dryer cyclone unit and about 15 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the diamond grit. The average size of the aggregates collected from the chamber was measured to be about 40-50 microns, SSA = 72 m^2/g. The aggregates are shown in Fig. 9.

EXAMPLE 9 (Diamond 1 Cyclone)

A powder of fine abrasive aggregates including diamond grit combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with diamond grit having an average particle size of 1.1 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica ($Si0_2$) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10.

The components were mixed in the following amounts:

Component	Pounds in mixture
Diamond grit	6.6
BINDZIL 2040 silica sol	13.2
PEG 200	0.9
Deionized water	45

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 20 % solids in water.

The mixture was then spray dried using a Niro SD6.3 rotary atomizer spray dryer with an FF-1 atomizer available from Niro, Inc. of Columbia, Maryland. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 152°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 85 % of the aggregate particles were collected from the dryer cyclone unit and about 15 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the diamond grit. The average size of the aggregates collected from the cyclone was measured to be about 25 microns, SSA = 71 m2/g. The aggregates are shown in Fig. 10.

EXAMPLE 10 (NGC 2500 Chamber)

A powder of fine abrasive aggregates including NGC 2500 combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with NGC 2500 grit having an average particle size of 8 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica ($Si0_2$) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Pounds in mixture
NGC 2500	75
BINDZIL 2040 silica sol	190
PEG 200	10.5
Deionized water	25

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 54% solids in water.

The mixture was then spray dried using a Niro SD6.3 rotary atomizer spray dryer with an FF-1 atomizer available from Niro, Inc. of Columbia, Maryland. The mixture was heated and fed into the inlet of the spray dryer at a temperature of about 342°C. The outlet temperature of the spray dryer was measured to be about 152°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 50 % of the aggregate particles were collected from the dryer cyclone unit and about 50 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the NGC grit. The average size of the aggregates collected from the chamber was measured to be about 40-50 microns, SSA 63 m2/g. The aggregates are shown in Fig. 11.

EXAMPLE 11 (CBN 9 micron Chamber)

A powder of fine abrasive aggregates including CBN combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with CBN grit having an average particle size of 9 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40% silica ($Si0_2$) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
CBN 9 micron	204.3
BINDZIL 2040 silica sol	454
PEG 200	27.24
Deionized water	72.64

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 54% solids in water.

The mixture was then spray dried using a Pentronix Model 370 rotary atomizer spray dryer. The mixture was fed at room temperature into the inlet of the spray dryer at a temperature of about 220°C. The outlet temperature of the spray dryer was measured to be about 98°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 5 % of the aggregate particles were collected from the dryer cyclone unit and about 95 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the CBN grit. The average size of the aggregates collected from the chamber was measured to be about 80 microns, SSA = 62 m2/g. The aggregates are shown in Fig. 12

EXAMPLE 12 (Nickel coated CBN 15 micron Chamber)

A powder of fine abrasive aggregates including CBN combined with silica nanoparticles was produced by the following method. An aqueous colloidal silica was mixed with Nickel coated CBN grit having an average particle size of 15 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The silica sol used was BINDZIL 2040, available from Eka Chemicals Inc. of Marietta, Georgia, which is believed to be aqueous colloidal silica solution was used having about 40%

silica (SiO_2) by weight, a silica particle size of about 20 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
Nickel coated CBN 15 micron	1200
BINDZIL 2040 silica sol	454
PEG 200	29
Deionized water	63

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 81% solids in water.

The mixture was then spray dried using a Pentronix Model 370 rotary atomizer spray dryer. The mixture was fed at room temperature into the inlet of the spray dryer at a temperature of about 220°C. The outlet temperature of the spray dryer was measured to be about 98°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 5 % of the aggregate particles were collected from the dryer cyclone unit and about 95 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of silica nanoparticles and PEG combined with particles of the CBN grit. The average size of the aggregates collected from the chamber was measured to be about 70 microns, SSA 23 m2/g. The aggregates are shown in Fig. 13.

EXAMPLE 13 (NG C 2500)

A powder of fine abrasive aggregates including NGC 2500 combined with Ceria nanoparticles was produced by the following method. An aqueous Nano Ceria was mixed with NGC 2500 grit having an average particle size of 8 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The Nano Ceria used was by Degussa AG, Advanced Nanomaterials, which is believed to be aqueous Ceria solution was used having about 40% Ceria) by weight, a silica particle size of about 38 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
NGC 2500	168
Nano Ceria	454
PEG 200	27.54
Deionized water	63

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 53% solids in water.

The mixture was then spray dried using a Pentronix Model 370 rotary atomizer spray dryer. The mixture was fed at room temperature into the inlet of the spray dryer at a temperature of about 220°C. The outlet temperature of the spray dryer was measured to be about 98°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 5 % of the aggregate particles were collected from the dryer cyclone unit and about 95 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of ceria nanoparticles and PEG combined with particles of the NGC grit. The average size of the aggregates collected from the chamber was measured to be about 50 microns, SSA = 8 m2/g. The aggregates are shown in Fig. 14.

EXAMPLE 14 (NG C 2500)

A powder of fine abrasive aggregates including NGC 2500 combined with Alumina nanoparticles was produced by the following method. An aqueous Soft Alumina was mixed with NGC 2500 grit having an average particle size of 8 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The Alumina used was by Saint Gobain, which is believed to be aqueous Alumina solution was used having about 40% Alumina) by weight, a silica particle size of about 38 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
NGC 2500	168
Alumina	454
PEG 200	27.54
Deionized water	63

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 53% solids in water.

The mixture was then spray dried using a Pentronix Model 370 rotary atomizer spray dryer. The mixture was fed at room temperature into the inlet of the spray dryer at a temperature of about 220°C. The outlet temperature of the spray dryer was measured to be about 98°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 5 % of the aggregate particles were collected from the dryer cyclone unit and about 95 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of Alumina nanoparticles and PEG combined with particles of the NGC 2500 grit. The average size of the aggregates collected from the chamber was measured to be about 70 microns, SSA 56 m2/g. The aggregates are shown in Fig. 15.

EXAMPLE 15 (NG C 2500)

A powder of fine abrasive aggregates including NGC 2500 combined with silica nanoparticles was produced by the following method. An aqueous Mega Sil was mixed with NGC 2500 grit having an average particle size of 5 microns, along with a polyethylene glycol (PEG) 200 plasticizer and deionized water. The Mega Sil used was by Moyco Technologies, which is believed to be aqueous Mega sil (Silica) solution was used having about 40% Silica) by weight, a silica particle size of about 100 nm, and a base-stabilized pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
NGC 2500	168
Mega Sil	454
PEG 200	27.54
Deionized water	63

The components were thoroughly mixed using a high shear mixer to provide a uniform aqueous dispersion having about 53% solids in water.

The mixture was then spray dried using a Pentronix Model 370 rotary atomizer spray dryer. The mixture was fed at room temperature into the inlet of the spray dryer at a temperature of about 220°C. The outlet temperature of the spray dryer was measured to be about 98°C. The spray drying process substantially removed the water from the mixture and the remaining components were observed to form a powder of small, generally round aggregates which were collected for analysis. About 5 % of the aggregate particles were collected from the dryer cyclone unit and about 95 % were collected from the main drying of the spray dryer apparatus. No further sintering or heating was required to form the aggregates.

The aggregates were examined under magnification and observed to be formed of a phase of Silica nanoparticles and PEG combined with particles of the NGC grit. The average size of the aggregates collected from the chamber was measured to be about 50 microns, SSA = 52 m2/g.

EXAMPLE 16

A powder of fine abrasive aggregates including NGC 2500 combined with silica nanoparticles was produced by the following method. An aqueous Mega Sil was mixed with NGC 2500 grit having an average particle size of approximately 5 microns, along with polyethyleneglycol (PEG) 200 plasticizer in deionized water. The Mega Sil was by Moyco Technologies, believed to be an aqueous Mega Sil (silica) solution having about 40% silica by weight, a silica particle size of about 100 nm and a base stabilizer pH of about 10. The components were mixed in the following amounts:

Component	Grams in mixture
NGC 2500	168
Mega Sil	454
PEG 200	27.54
Deionized water	63

The components were mixed and formed a slurry having about 53% solids in the deionized water. The mixture was spray dried using a Pentronix Model 370 rotary atomizer spray drier, wherein the mixture was fed at room temperature into an inlet of the spray drier having a temperature of about 220°C and released at an outlet having an outlet temperature of approximately 98°C. The spray drying process resulted in the formation of aggregates having substantially spherical shapes including the abrasive grit contained within the nanoparticle binder as illustrated in images described herein. No further sintering or heating was required to form the aggregates.

A variety of different abrasive products were then formed on different substrate materials including dense, solid cloth substrate materials and porous, foam substrate materials. Each of the substrate materials were coated with an adhesive via an in-line roll process, after which, the formed aggregates were coated on the substrate containing the adhesive material via a slotted conveyer as the substrates passed underneath. Each of the samples were treated at 260°C for at approximately 15 seconds to dry the adhesive and bind the aggregate particles to the substrate.

Each of the samples were then used to abrade a painted surface having a Sherwin Williams PROMAR 200 Interior Latex Semigloss BWI W 2206 6403-54262 applied to the surface having an initial gloss of approximately 2.1 measured at an angle of 60°, and 3.8 measured at an angle of 85° in accordance with ASTM D2457 using a BYK Micro Trigloss Meter 4430. Each of the samples were abraded on the painted surface for several seconds and the gloss measurement of the surface after abrading was measured again using the same process at angles of 60° and 85° as provided below in Table 1.

Table 1

	Initial Gloss (Gi)		**Final Gloss (Gf)**	
Sample	**60°**	**85°**	**60°**	**85°**
1 (NCM300199HD)	2.1	3.8	3.3	7
2 (NCS38CH)	2.1	3.8	5.3	17
3 (Blue Topo)	2.1	3.8	5.7	16.9
4 (NCF40CH)	2.1	3.8	9.1	9.9
5 (NCE360070)	2.1	3.8	5.7	15
6 (NCS40100)	2.1	3.8	5.6	16.9
7 (Blue Dot)	2.1	3.8	3.1	7.8
8 (NC392953)	2.1	3.8	5.5	16.1
9 (NCEG430)	2.1	3.8	4.2	9.5
10 (NCE392953)	2.1	3.8	6	18.6
11 (ZMELAMINE)	2.1	3.8	7.1	16.8
12 (ZMELAMINE UNCOATED)	2.1	3.8	5.1	9.7
13 (NCS40100)	2.1	3.8	7.6	20.4
Average	2.1	3.8	5.6	14.0
Gf/Gi			2.7	3.7

As illustrated in Table 1, after conducting the abrading process on the painted surface, all 13 samples demonstrate an increase in the gloss at angles of 60° and 85°. With regard to the measurements taken at a 60° angle, the change in the gloss between the average initial gloss and the average final gloss is approximately 2.7 times the initial gloss reading. With regard to the change in the gloss readings measured at the 85° angle, the painted surface had an average increase in the gloss across the 13 samples, such that the final gloss was 3.7 times greater than the initial gloss as calculated from the averages of the initial gloss and final gloss of the 13 samples. The results of Table 1 demonstrate that the abrasive product, provided on various different substrates, is capable of reducing the surface roughness of a painted surface and selectively increasing the glossiness of an abraded region.

Accordingly, it is expected that such an abrasive product may be particularly useful for improving or changing the aesthetic appeal of painted surfaces. For example, painted surfaces around light fixtures to improve the reflective capabilities of the painted surface at low angles relative to a light source, or alternatively use in more artistic endeavors, such as the creation of glossy appearing stencils on dull or semi-glossy painted backgrounds.

In addition to being used as abrasives, in some embodiments of the present disclosure, the aggregates may also be used in application other than abrasives for polishing and finishing of materials. For instance, it is believed that the aggregates of the present disclosure may be incorporated into lubricant formulations. The aggregates may also incorporated into composite materials for the purpose of enhancing the strength of the composites. In addition, it is believed that the aggregates may also be employed as a heat sink material in certain applications. The aggregates are shown in Fig. 16.

The foregoing description of preferred embodiments for this invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiments are chosen and described in an effort to provide the best illustrations of the principles of the invention and its practical application, and to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS:

1. An coated abrasive product, comprising:
a substrate; and
particulate material bonded to the substrate, the particulate material comprising green, unfired abrasive aggregates having a generally spheroidal or toroidal shape, the aggregates formed from a composition comprising abrasive grit particles and a nanoparticle binder.

2. The coated abrasive product of claim 1, wherein the substrate comprises a foam material.

3. The coated abrasive product of any of claims 1 and 2, wherein the substrate is a non-woven material.

4. The coated abrasive product of any of claims 1, 2, and 3, wherein the substrate comprises an organic material.

5. The coated abrasive product of any of claims 1, 2, 3, and 4, wherein the substrate is a porous material.

6. The coated abrasive product of claim 5, wherein the substrate has a porosity of at least about 40 vol%.

7. The coated abrasive product of claim 6, wherein the substrate has a porosity within a range between about 50 vol% and about 90 vol%.

8. The coated abrasive product of claim 5, wherein a majority of the porosity is open porosity.

9. The coated abrasive product of claim 5, wherein the substrate comprises a lattice structure defining a network of open porosity extending through the lattice structure.

10. The coated abrasive product of claim 9, wherein the particulate material is bonded to the lattice structure.

11. The coated abrasive product of claim 9, wherein the lattice structure comprises available surface area and at least about 50% of the available surface area is covered by the particulate material.

12. The coated abrasive product of any of claims 1, 2, 3, 4, and 5, wherein the substrate comprises a polymer.

13. The coated abrasive product of claim 12, wherein the substrate comprises a polyolefin.

14. The coated abrasive product of claim 12, wherein the substrate comprises a polymer selected from the group of polymers consisting of polystyrene, polyester, polyurethane, polypropylene, polyethylene, polymethacrylimide, polyamide, polylactic acid, polyacrylate, polysulfone, polyacetate, fluorinated polymers, and chlorinated polymers.

15. The coated abrasive product of any of claims 1, 2, 3, 4, 5, and 12 further comprising a backing material attached to a surface of the substrate.

16. The coated abrasive product of any of claims 1, 2, 3, 4, 5, 12, and 15, further comprising a supersize coat overlying the substrate.

17. The coated abrasive product of claim 16, wherein the supersize coat is bonded to the particulate material.

18. The coated abrasive product of claim 16, wherein the supersize coat comprises an additive selected from the group of additives consisting of anti-loading agents, abrasive fillers, plasticizers, anti-static agents, lubricants, wetting agents, grinding aids, pigments, dyes, coupling agents, release agents, suspending agents, curing agents, aromatic materials, and antimicrobial agents.

19. The coated abrasive product of any of claims 1, 2, 3, 4, 5, 12, 15, and 16, wherein the substrate comprises an anti-loading agent.

20. The coated abrasive product of claim 19, wherein the anti-loading agent is bonded to the substrate.

21. The coated abrasive product of claim 19, wherein the anti-loading agent is contained in a coat overlying portion of the substrate and the particulate material.

22. The coated abrasive product of claim 19, wherein the anti-loading agent is bonded to the particulate material.

23. The coated abrasive product of claim 19, wherein the anti-loading agent is contained within the particulate material.

24. The coated abrasive product of claim 23, wherein the anti-loading agent is bonded to the nanoparticle binder.

25. The coated abrasive product of claim 23, wherein the particulate material is hollow and the anti-loading agent is contained within an interior space of the particulate material.

26. The coated abrasive product of claim 19, wherein the anti-loading agent comprises a metal.

27. The coated abrasive product of claim 19, wherein the anti-loading agent comprises an acid.

28. The coated abrasive product of claim 19, wherein the anti-loading agent comprises an organic material.

29. The coated abrasive product of claim 28, wherein the anti-loading agent comprises an organyl group including at least 4 carbon atoms.

30. The coated abrasive product of claim 19, wherein the anti-loading agent is selected from the group of materials consisting of metal stearates, metal plamitates, fatty acids, phosphoric acids, partial esters, amine salts, and ammonium salts.

31. The coated abrasive product of claim 19, wherein the anti-loading agent has a softening point greater than about 50ºC.

32. The coated abrasive product of any of claims 1, 2, 3, 4, 5, 12, 15, 16, and 19, wherein the substrate comprises an anti-static agent.

33. The coated abrasive product of claim 32, wherein the surface resistivity of the abrasive product containing the anti-static agent is not greater than about 1E8 Ω/square.

34. The coated abrasive product of claim 32, wherein the anti-static agent is bonded to the substrate.

35. The coated abrasive product of claim 32, wherein the anti-static agent is contained within a coat overlying a portion of the substrate and particulate material.

36. The coated abrasive product of claim 32, wherein the anti-static agent is contained within a backing attached to a surface of the substrate.

37. The coated abrasive product of claim 32, wherein the anti-static agent is bonded to the particulate material.

38. The coated abrasive product of claim 32, wherein the anti-static agent is contained within the particulate material.

39. The coated abrasive product of claim 38, wherein the anti-static agent is bonded to the nanoparticle binder.

40. The coated abrasive product of claim 38, wherein the particulate material is hollow and the anti-static agent is contained within an interior space of the particulate material.

41. The coated abrasive product of claim 32, wherein the anti-static agent comprises a hygroscopic material.

42. The coated abrasive product of claim 32, wherein the anti-static agent comprises an organic material.

43. The coated abrasive product of claim 32, wherein the anti-static agent comprises a compound selected from the group consisting of amines, carboxyls, and hydroxyls.

44. The coated abrasive product of claim 32, wherein the anti-static agent comprises a metal.

45. The coated abrasive product of claim 32, wherein the anti-static agent comprises carbon.

46. The coated abrasive product of claim 32, wherein the substrate comprises an aromatic material.

47. The coated abrasive product of claim 46, wherein the aromatic material comprises a base note.

48. The coated abrasive product of claim 46, wherein the aromatic material comprises a top note.

49. The coated abrasive product of claim 46, wherein the aromatic material comprises a middle note.

50. The coated abrasive product of claim 46, wherein the aromatic material comprises an essential oil.

51. The coated abrasive product of claim 46, wherein the aromatic material comprises an organic material selected from the group of materials consisting of alcohols, aldehydes, amines, esters, ethers, ketones, lactones, terpenes, and thiols.

52. The coated abrasive product of claim 46, wherein the aromatic material is bonded to the particulate material.

53. The coated abrasive product of claim 52, wherein the aromatic material is contained within a coat overlying a portion of the substrate and the particulate material.

54. The coated abrasive product of claim 46, wherein the aromatic material is contained within the particulate material.

55. The coated abrasive product of claim 54, wherein the aromatic material is bonded to the nanoparticle binder.

56. The coated abrasive product of claim 54, wherein the particulate material is hollow and the aromatic material is contained within an interior space of the particulate material.

57. The coated abrasive product of any of claims 1, 2, 3, 4, 5, 12, 15, 16, 19, and 32, wherein the substrate comprises an antimicrobial agent.

58. The coated abrasive product of claim 57, wherein the antimicrobial agent comprises a material selected from the group consisting of sterilants, sanitizers, disinfectants, and fungicides.

59. The coated abrasive product of claim 57, wherein the antimicrobial agent includes a material selected from the group consisting of alcohol, phenolics, peroxide, ammonium-containing compounds, iodine-containing compounds, chlorine-containing compounds, and phenolic compounds.

60. The coated abrasive product of claim 59, wherein the antimicrobial agent is contained within a coat overlying a portion of the substrate and particulate material.

61. The coated abrasive product of claim 57, wherein the antimicrobial agent is bonded to the particulate material.

62. The coated abrasive product of claim 61, wherein the antimicrobial agent is contained within the particulate material.

63. The coated abrasive product of claim 62, wherein the antimicrobial agent is bonded to the nanoparticle binder.

64. The coated abrasive product of claim 62, wherein the particulate material is hollow and the antimicrobial agent is contained within an interior space of the particulate material.

65. A method for machining a painted surface comprising:
providing a painted surface having an initial surface roughness Ra_i;
abrading the painted surface with a single abrasive product to remove material from the painted surface and reduce the surface roughness to a final surface roughness Ra_f, the final surface roughness Ra_f being achieved with said single product without use of another abrasive product.

66. The method of claim 65, wherein the painted surface has an initial gloss G_i and abrading the painted surface includes changing the gloss of the surface to a final gloss G_f, wherein G_f is at least about $2G_i$ measured at an angle of at least about 60°.

67. The method of claim 66, wherein G_f is within a range between about $2G_i$ and about $4G_i$ measured at an angle of about 60°.

68. The method of claim 66, wherein G_f is at least about $3G_i$ measured at an angle of about 85°.

69. The method of claim 68, wherein G_f is within a range between about $2G_i$ and about $6G_i$ measured at an angle of about 85°.

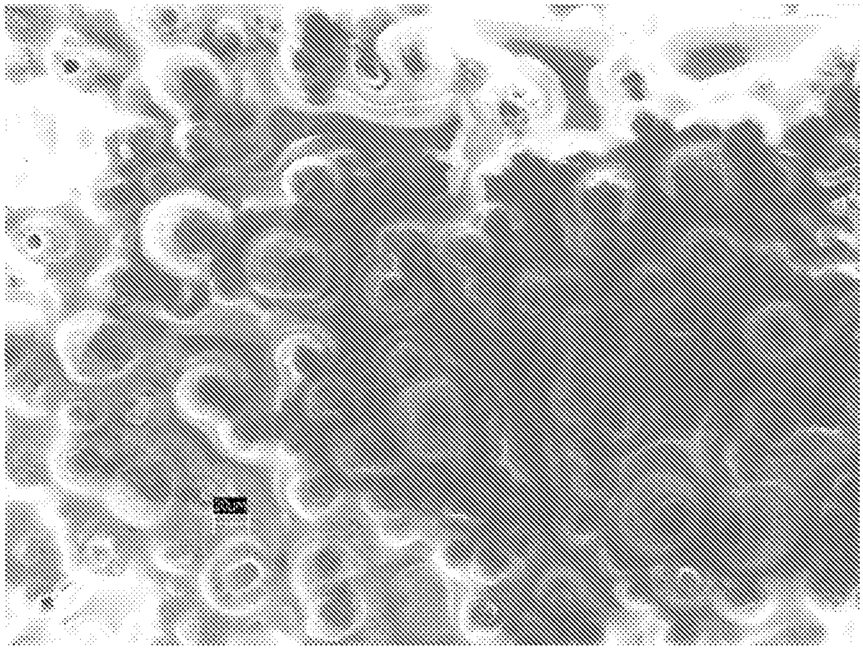


FIG. 1

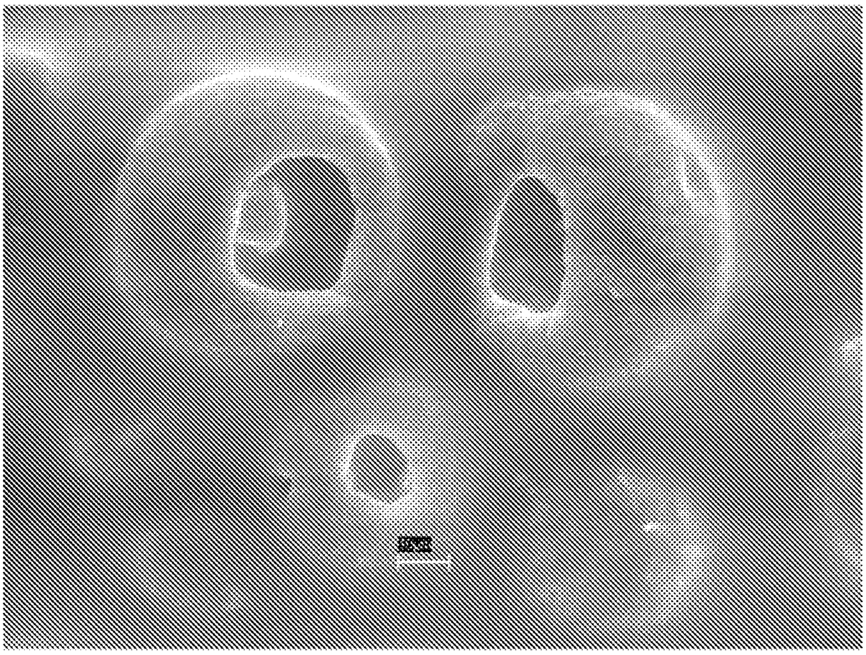


FIG. 2

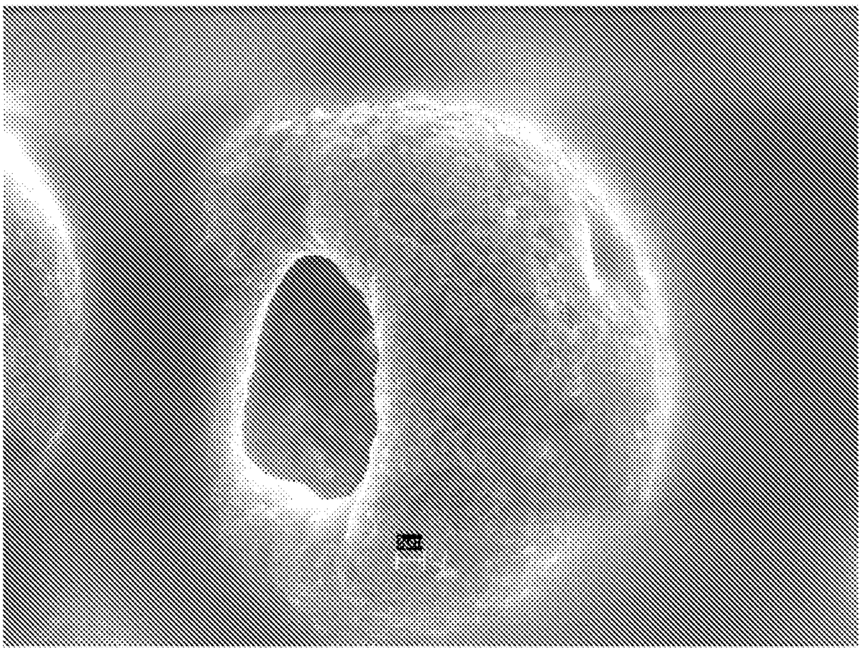


FIG. 3

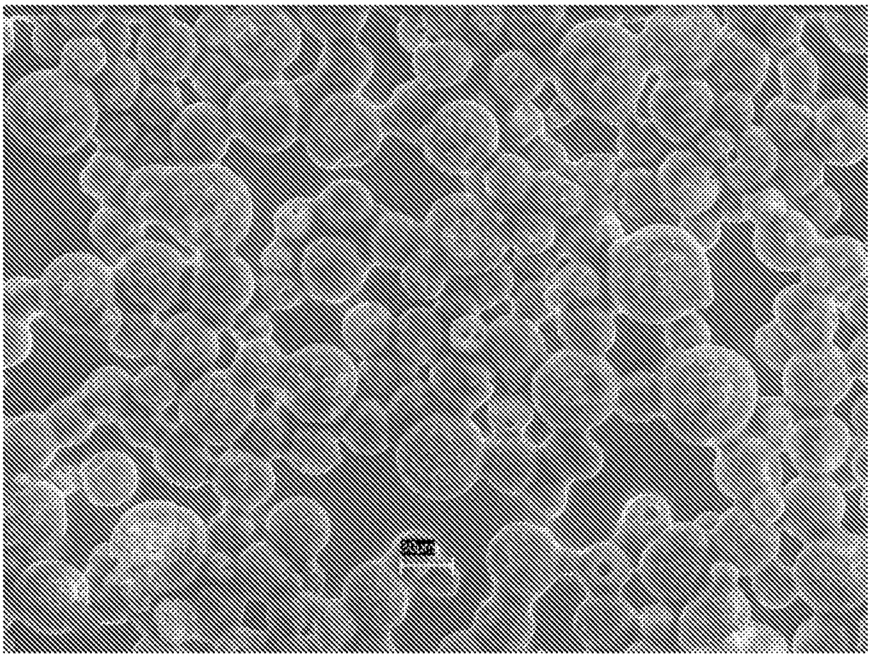


FIG. 4

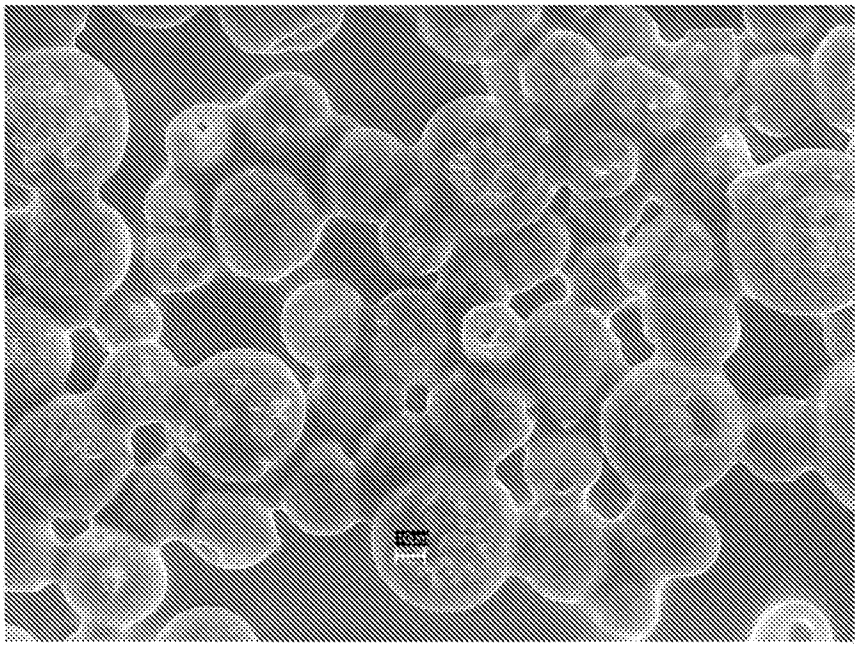


FIG. 5

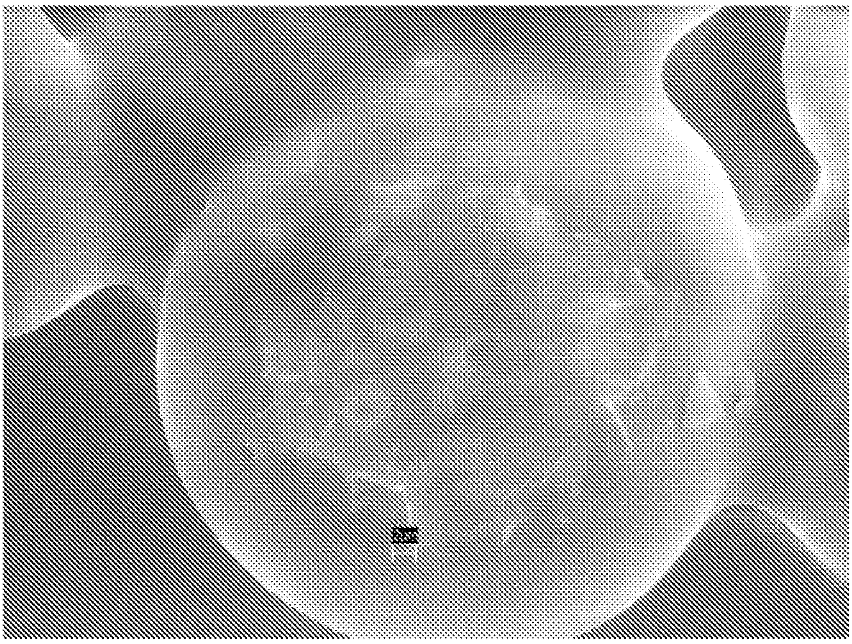


FIG. 6

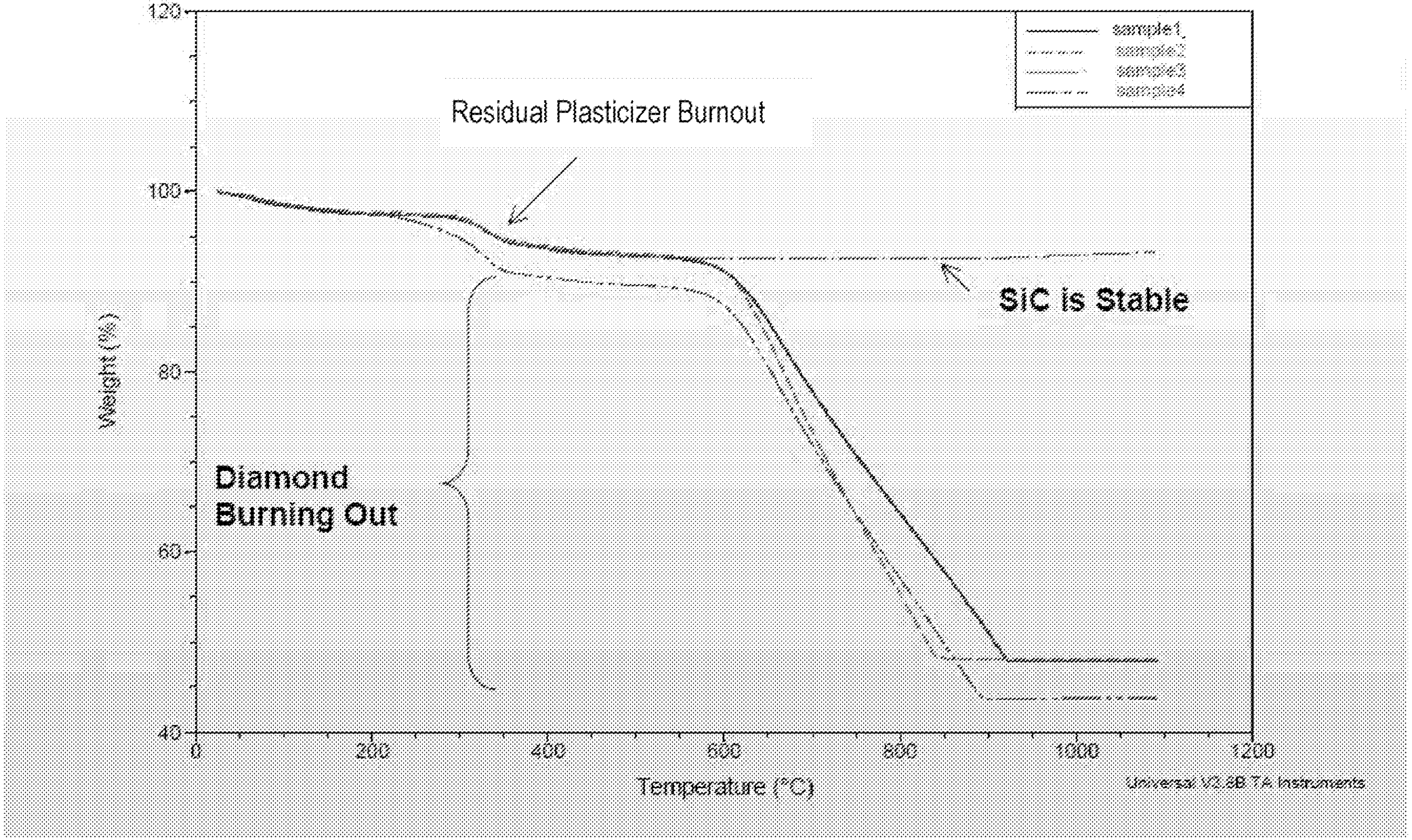

sample1
sample2
sample3
sample4
Residual Plasticizer Burnout
SiC is Stable
Diamond Burning Out
Weight (%)
120
100
80
60
40
Temperature (°C)
0
200
400
600
800
1000
1200
Universal V2.5B TA Instruments

FIG. 7

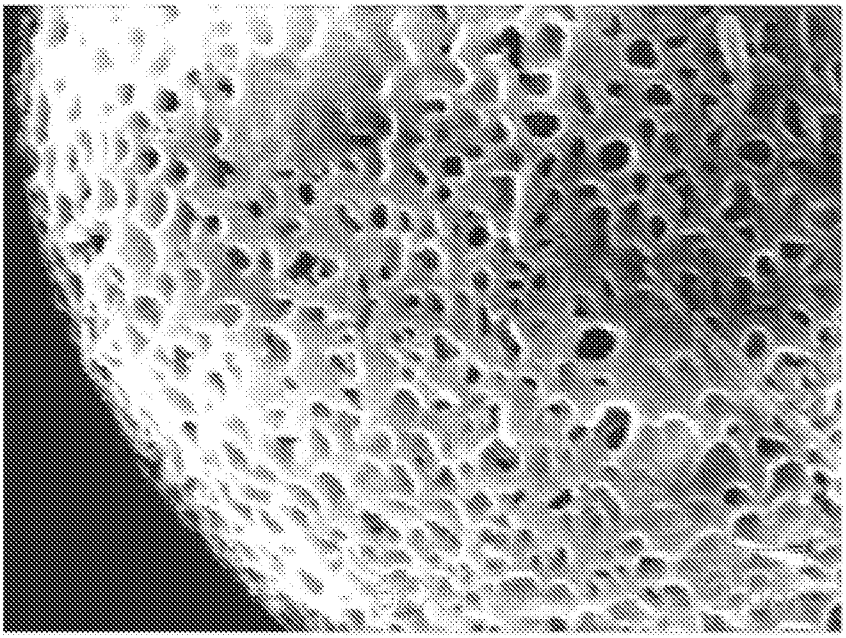


FIG. 8

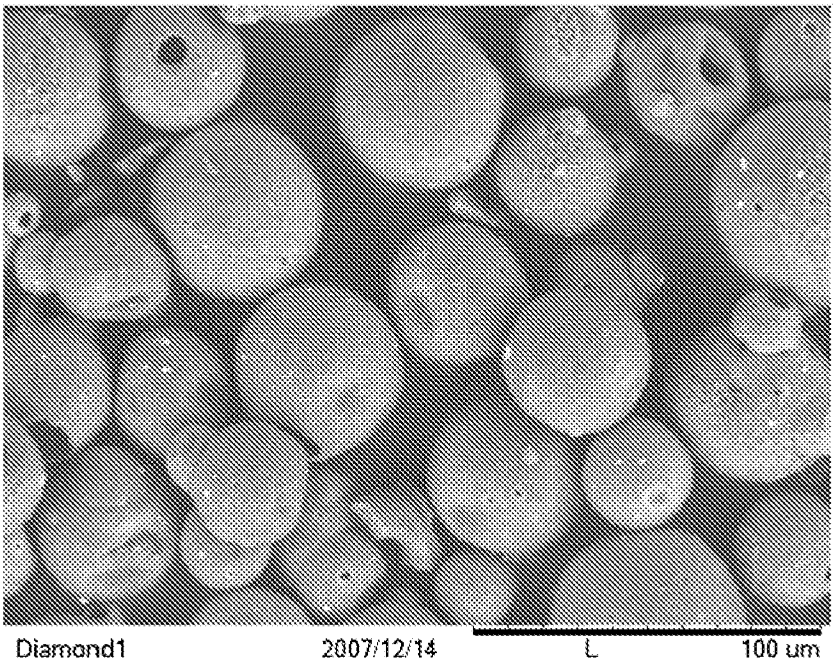
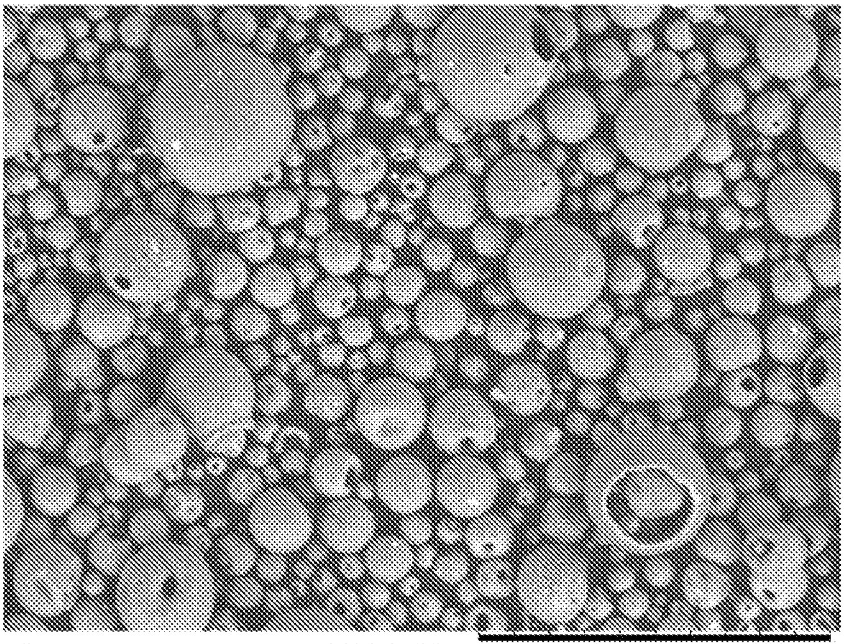


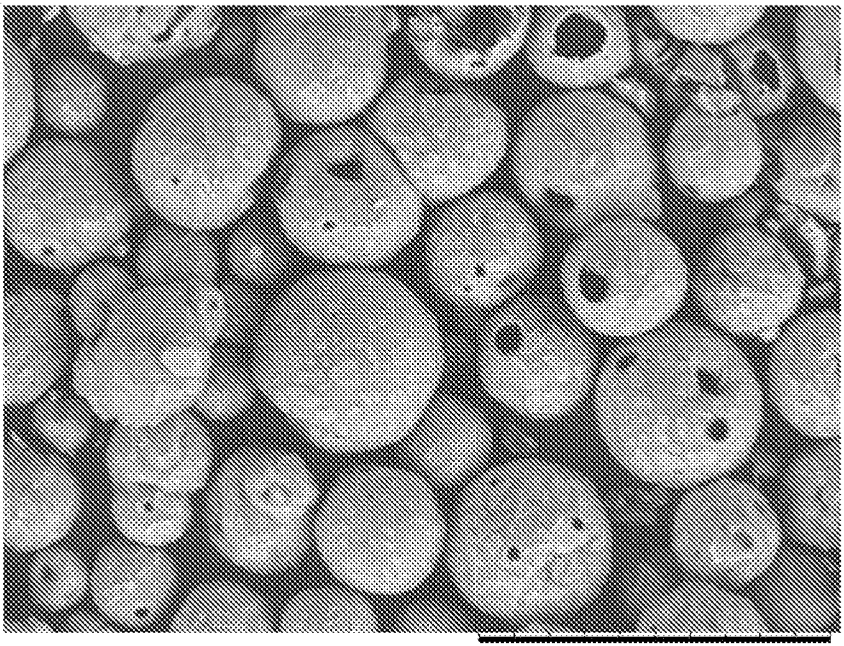
FIG. 9



Green 2008/01/03 L 100 um

Diamond Cyclone

FIG. 10



NGC 2500 2007/12/14 L 100 um

FIG. 11

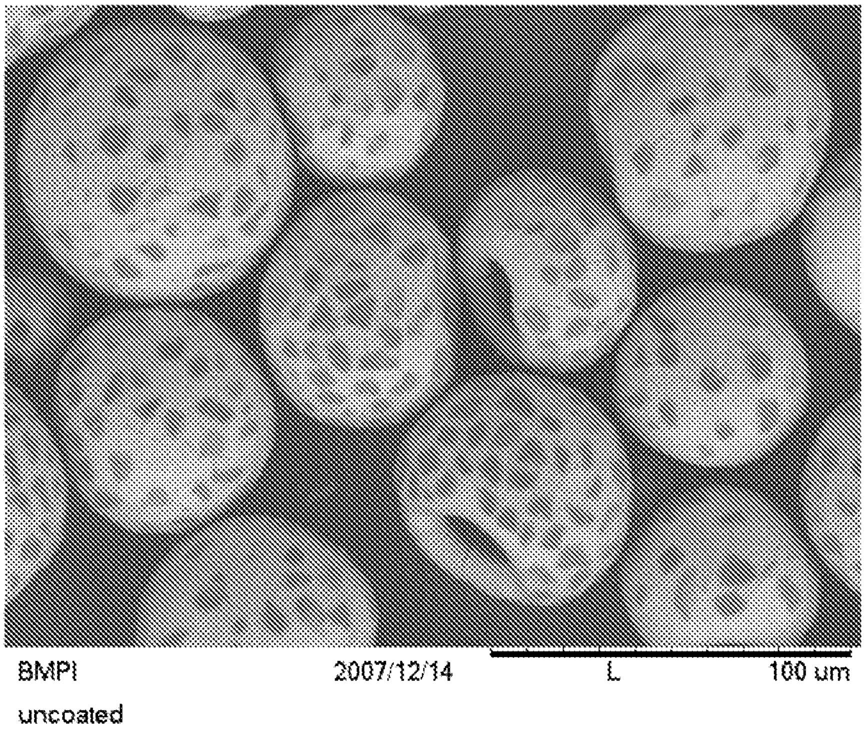


FIG. 12

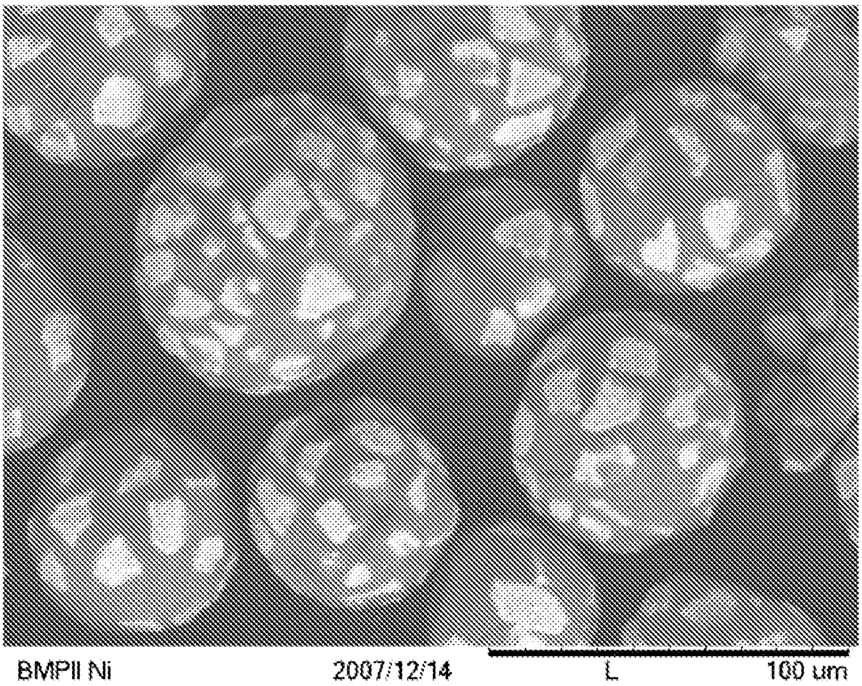
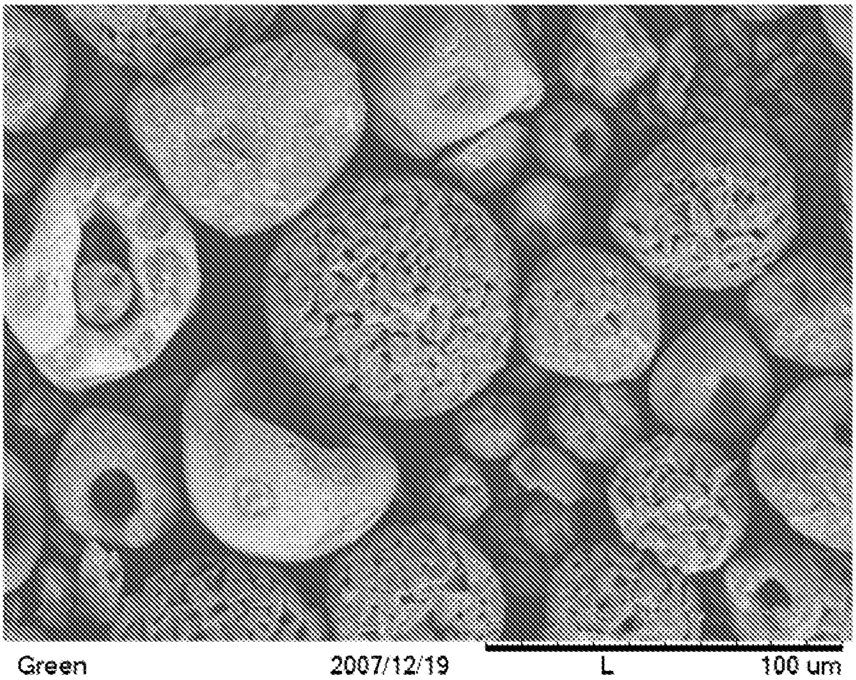
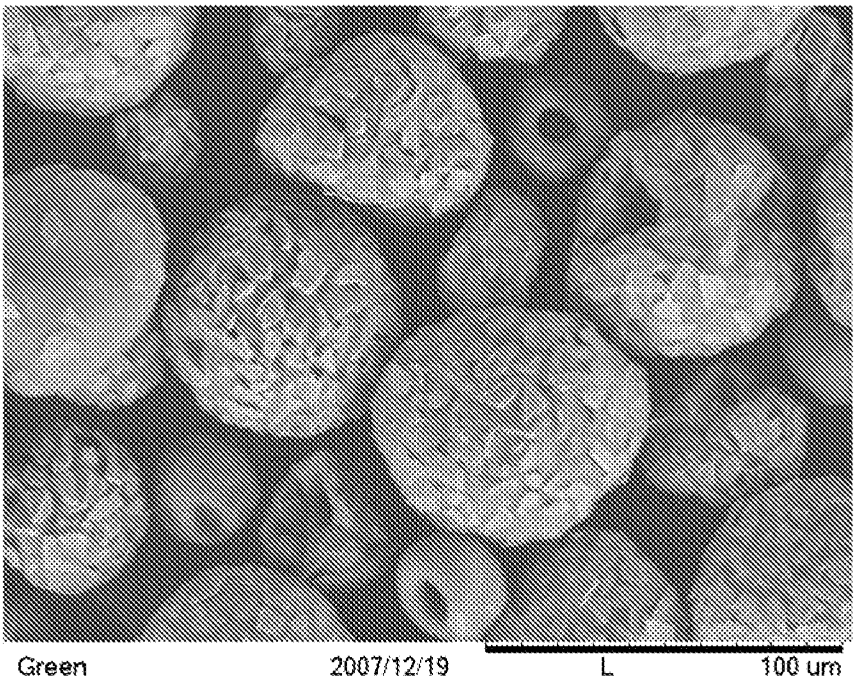


FIG. 13



NGC 2500 with cerium

FIG. 14



NGC 2500 with Alumina

FIG. 15

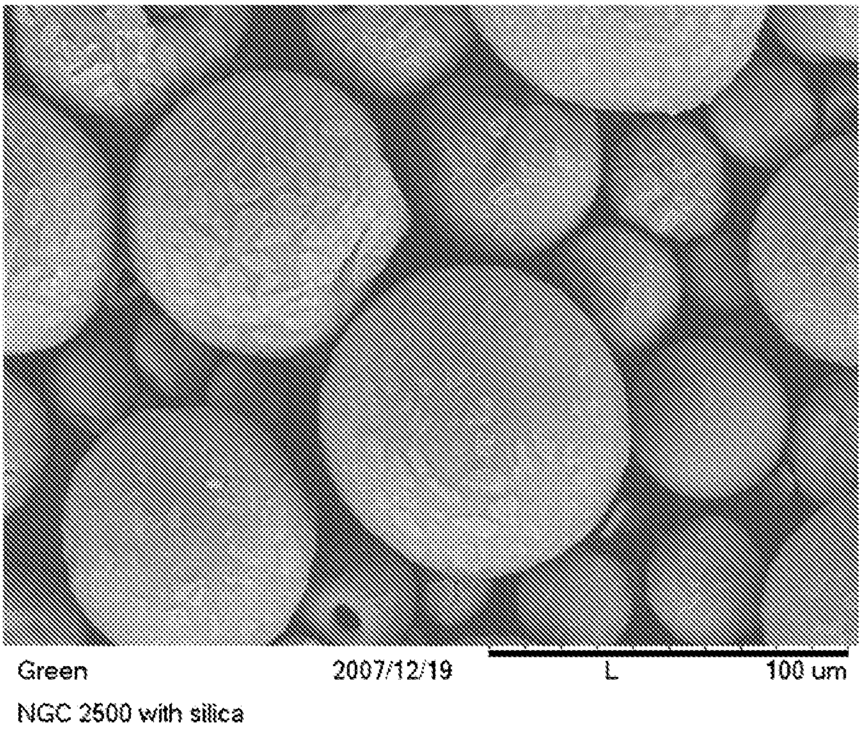


FIG. 16

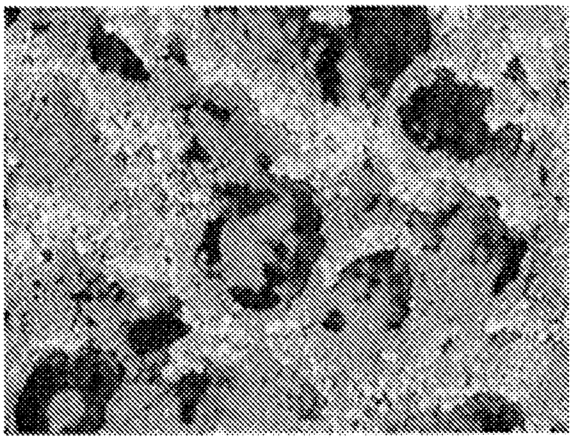


FIG. 17

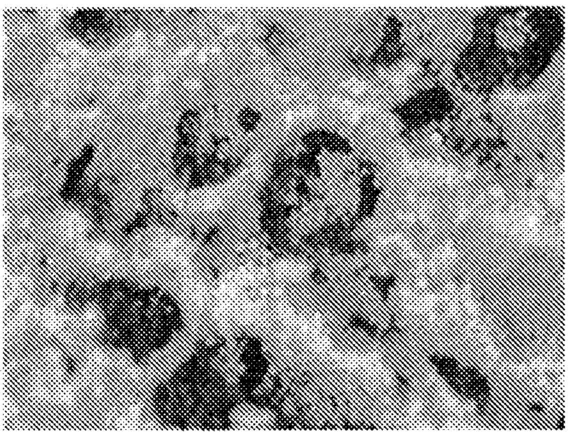


FIG. 18