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(54) **Title:**
ABRASIVE ARTICLE WITH REPLICATED MICROSTRUCTURED BACKING AND METHOD OF USING SAME

(57) **Abstract:**
An abrasive article is provided that includes a flexible backing having opposed first and second major surfaces. The first major surface includes a plurality of abrasive particles in at least one binder disposed thereon. The second major surface includes replicated microstructures having recesses. The abrasive article also includes adhesive contained substantially in the recesses of the replicated microstructures. A rigid substrate can be in contact with at least a portion of the replicated microstructures. Also provide is a method of polishing a work-piece that uses the provided articles.

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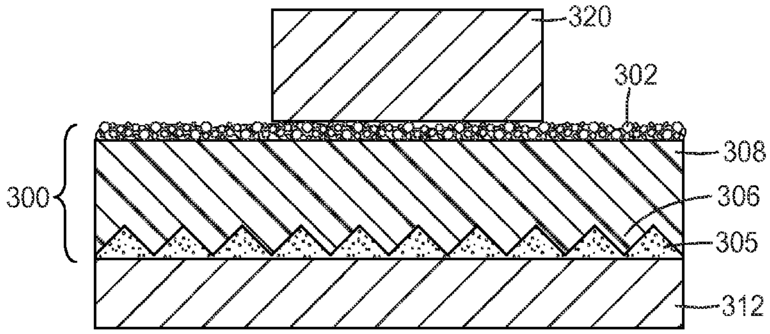

FIG. 3

(57) Abstract: An abrasive article is provided that includes a flexible backing having opposed first and second major surfaces. The first major surface includes a plurality of abrasive particles in at least one binder disposed thereon. The second major surface includes replicated microstructures having recesses. The abrasive article also includes adhesive contained substantially in the recesses of the replicated microstructures. A rigid substrate can be in contact with at least a portion of the replicated microstructures. Also provide is a method of polishing a work-piece that uses the provided articles.

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ABRASIVE ARTICLE WITH REPLICATED MICROSTRUCTURED BACKING AND METHOD OF USING SAME

Field

The present disclosure relates to abrasive articles useful for polishing complex materials.

Background

Work pieces, such as read/write heads for the hard disk drive (HDD) industry, have very hard and very soft, complex materials that are typically finished simultaneously by lapping and polishing with abrasive articles. The very soft materials that make up the read/write transducer are located at the edge of the very hard material, such as alumina titania carbide (AlTiC). Because high pressures are required to remove the hard AlTiC material, pressures of up to 40 pounds per square inch (psi) are applied. High loads on the work-piece can cause a displacement of the abrasive surface if the abrasive matrix is of sufficiently low modulus. This can result in a build up of abrasive material at the edges of the work-piece. The excess abrasive at the edge of the work-piece can cause accelerated removal of the edges or what is commonly called "crown" or "edge roll off". This crowning effect can damage a transducer that lies at the edge of the work-piece. Multilayer abrasive articles having compliant pressure sensitive adhesives can exacerbate the crowning of a read/write head.

Fig. 1 is an illustration of a typical prior art system of an abrasive article 10 having abrasive particles 12 dispersed in binder 13 (forming an abrasive layer) on first major surface 18a of flexible backing 18 having adhesive layer 14 coated on second major surface 18b of the abrasive article. The adhesive layer, such as, e.g., a pressure sensitive adhesive layer, secures the abrasive article to rigid support 22. When comparing the various components in the abrasive article 10, the adhesive layer is softer (i.e., having a lower Young's modulus) than the flexible backing and the abrasive particles.

As shown in Figs. 1 and 2, in use, typically work-piece 20 is exposed to an abrasive layer (that includes abrasive particles 18a and binder 13) under a load P. Under such circumstances, the work piece and the load applied thereon deform relatively soft adhesive layer 14. The contours of flexible substrate 18 and abrasive layer 13 tend to follow the deformation of the adhesive layer causing rounding or crowning of the edges of the work-piece. Additionally, high stresses at the edges of work-piece 20, may also cause rounding of the work-piece edges.

Summary

There is a need for solutions to the problem of crowning on work-pieces to be polished—particularly for work-pieces useful in sensitive electronics industries such as read-write heads for hard disk drives or thin hard disk drives, themselves. The abrasive articles and methods presented herein have the benefit of long use life, easy removal of material from the work-piece, ability to polish to a fine finish, and high removal rates. Additionally, they resist crowing of the edges of the work-pieces and produce a more desirable product.

In one aspect, an abrasive article is provided that includes a flexible backing having opposed first and second major surfaces, an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses, and an adhesive, wherein the adhesive is contained substantially in the recesses of the replicated microstructures. The article can further include a rigid substrate in contact with at least a portion of the replicated microstructures or a release liner in contact with at least a portion of the adhesive. The flexible backing can have a Young's modulus of greater than about 0.5 gigapascals (GPa) or even greater than 2 GPa, and can include rods, triangles, pyramids, truncated pyramids, cones, truncated cones, spheres, or spheroids among other possible shapes.

In another aspect, a method of polishing is provided that includes providing a work-piece, contacting the work-piece with an abrasive article that includes a flexible backing having opposed first and second major surfaces, an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses, an adhesive; and a rigid substrate in contact with at least a portion of the replicated microstructures, wherein the adhesive is contained substantially in the recesses of the replicated microstructures and moving the abrasive article relative to the work-piece. The

abrasive article is moved relative to the work-piece thereby polishing a surface of the work-piece. Typically, a load is applied to the work-piece.

The provided abrasive articles and methods are useful for polishing work-pieces that need to be very smooth and level across their dimensions. Flexible backings that include replicated microstructures allow a load that can be applied to the work-piece to be supported by a rigid substrate during polishing. The replicated microstructures bear part of the load, transferring at least part of the load to the rigid substrate, thereby reducing or eliminating adhesive deformation. The adhesive is substantially contained in the recesses of the replicated microstructures allowing direct contact of the replicated microstructures with the rigid substrate. The provided abrasive articles and methods allow for a finished work-piece having superior flatness that, in turn, provides the abrasive articles with the benefits of long life, easy application, easy removal, fine finish, and high removal rates with an advance over the art of reduced crowning.

The above summary is not intended to describe each disclosed embodiment of every implementation of the present invention. The brief description of the drawings and the detailed description which follows more particularly exemplify illustrative embodiments.

Brief Description of the Drawings

The present disclosure can be further defined with reference to the figures, wherein:

Fig. 1 is a schematic cross-section of a prior art abrasive system;

Fig. 2 is a schematic cross-section of the prior art abrasive system of Fig. 1 where a load has been applied to a work-piece;

Fig. 3 is a schematic cross-section of an embodiment of a provided abrasive article wherein the replicated microstructures are a part of the second surface of the flexible backing and include pyramids or pyramidal ridges;

Fig. 4 is a schematic cross-section of an embodiment of a provided abrasive article wherein the replicated microstructures are structurally attached to the second surface of the flexible backing and include pyramids or pyramidal ridges;

Fig. 5 is a schematic cross-section of another embodiment of a provided abrasive article wherein the replicated microstructures include truncated pyramids or pyramidal ridges; and

Fig. 6 is a schematic cross-section of yet another embodiment of a provided abrasive article wherein the replicated microstructures include square ridges.

Fig. 7 is a cross-sectional view of a microstructured roll surface used in an exemplary embodiment of the provided abrasive article.

Fig. 8 is a cross-sectional or cross-web view of an exemplary backing microstructure produced using the microstructured roll surface in Fig. 7.

Detailed Description

In the following description, reference is made to the accompanying set of drawings that form a part of the description hereof and in which are shown by way of illustration several specific embodiments. It is to be understood that other embodiments are contemplated and may be made without departing from the scope or spirit of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense.

Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein. The use of numerical ranges by endpoints includes all numbers within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range.

Flexible Backing

The provided abrasive articles and methods include a flexible backing having opposed first and second major surfaces. Suitable flexible backings that can be used in the provided abrasive articles are typically those known in the abrasive art. They include polymeric substrates, e.g. polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene; metal foils including aluminum, copper, tin and bronze; and papers, including densified kraft paper and poly-coated paper.

The material of the flexible backing includes replicated microstructures on at least a portion of its second major surface. In some embodiments, a separate backing that includes a replicated microstructure can be selected to provide an abrasive construction that exhibits uniform material removal across the work-piece, i.e., good uniformity and planarity which includes flatness. It is important that the material properties of the flexible backing and the replicated microstructure features contained thereon have material properties that allow the surface of a work-piece to be smooth across all of its dimensions—particularly at the edges of the work-piece.

Abrasive Layer

The provided abrasive articles include an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses. Suitable abrasive particles that can be used in the provided articles and methods include fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicon carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond (both natural and synthetic, including polycrystalline diamond), silica, iron oxide, chromia, ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive particles and the like. Examples of sol gel abrasive particles can be found in U. S. Pat. Nos. 4,314,827 (Leitheiser et al.); 4,623,364 (Cottringer et al); 4,744,802 (Schwabel); 4,770,671 (Monroe et al.) and 4,881,951 (Wood et al.).

As used herein, the term abrasive particle also encompasses single abrasive particles bonded together with a polymer, a ceramic, a metal or a glass to form abrasive agglomerates. The term abrasive agglomerate includes, but is not limited to, abrasive/silicon oxide agglomerates that may or may not have the silicon oxide densified by an annealing step at elevated temperatures. Abrasive agglomerates are further described in U. S. Pat. Nos. 4,311,489 (Kressner); 4,652,275 (Bloecher et al.); 4,799,939

(Bloecher et al.), 5,500,273 (Holmes et al.), 6,645,624 (Adefris et al.); 7,044,835 (Mujumdar et al.). Alternatively, the abrasive particles may be bonded together by inter-particle attractive forces as describe in U. S. Pat. No. 5,201,916 (Berg et al.). Typical abrasive agglomerates include agglomerates having diamond as the abrasive particle and silicon oxide as the bonding component. When an agglomerate is use, the size of the single abrasive particle contained within the agglomerate can range from 0.1 to 50 micrometer (μm) (0.0039 to 2.0 mils), preferably from 0.2 to 20 μm (0.0079 to 0.79 mils) and most preferably between 0.5 to 5 μm (0.020 to 0.20 mils).

The average particle size of the abrasive particles can be less than 150 μm (5.9 mils), typically less than 100 μm (3.9 mils), or even less than 50 μm (2.0 mils). The size of the abrasive particle is typically specified to be its longest dimension. Typically, there will be a range distribution of particle sizes. In some instances, the particle size distribution can be tightly controlled such that the resulting abrasive article provides a consistent surface finish on the work piece being abraded.

Yet another useful type of abrasive particle is a metal-based abrasive particle having a substantially spheroid metal containing matrix having a circumference and a super-abrasive materials having an average diameter of less than 50 μm, preferably less than 8 μm, at least partially embedded in the circumference of the metal containing matrix. Such abrasive particles can be made by charging into a vessel, metal-containing matrix (predominantly spheroids), super-abrasive particles, and grinding media. The vessel can then be then rolled for a period of time, typically at room temperature. Although not being bound by theory, it is believed that the milling process forces the super abrasive material to penetrate into, attach to, and protrude from the metal containing matrix. The circumference of the metal containing matrix changes from pure metal or metal alloy to a composite of super abrasive and metal or metal alloy. The subsurface of the metal containing matrix near the circumference also contains the super abrasive material, which would be considered as being embedded in the metal containing matrix. This metal-based abrasive particle is disclosed in assignee's co-pending U. S. Pat. App. Pub. No. 2010/0000160 (Lugg et al.).

Abrasive particles can be coated with materials to provide the particles with desired characteristics. For example, materials applied to the surface of an abrasive particle have been shown to improve the adhesion between the abrasive particle and the binder. Additionally, a material applied to the surface of an abrasive particle may improve the adhesion of the abrasive particles when a softened particulate curable binder material is used as the binder. Alternatively, surface coatings can alter and improve the cutting characteristics of the resulting abrasive particle. Such surface coatings are described, for example, in U.S. Pat. Nos. 5,011,508 (Wald et al.); 3,041,156 (Rowse et al.); 5,009,675 (Kunz et al.); 4,997,461 (Markhoff-Matheny et al.); 5,213,591 (Celikkaya et al.); 5,085,671 (Martin et al.) and 5,042,991 (Kunz et al.).

Provided abrasive articles and methods can include conventional coated abrasive articles, coatings (make coat, size coat and super size coat) and materials. Exemplary coated abrasive articles are described in U. S. Pat. No. 5,378,252 (Follensbee), U. S. Pat. No. 5,834,109 (Follett et.al.) and U. S. Pat. No. 6,979,713 (Barber). Provided abrasive articles and methods can include abrasive coatings that are shaped or structured. By shaped or structured it is meant that the abrasive coating has raised portions and recessed portions. Exemplary abrasive articles that include shaped or structured abrasive coatings are available under the trade designation TRIZACT from 3M Company, St. Paul, MN. They are generally described in U. S. Pat. No. 5,152,917 (Pieper et al.). Other lapping materials useful as abrasive articles in the provided abrasive articles and methods are also described in U. S. Pat. No. 5,489,235 (Gagliardi et al.).

The abrasive particles can be partially embedded into the first opposing surface of the flexible backing and can be held in place by the flexible backing. The abrasive articles can also be bonded to the flexible backing by thermal bonding, ultrasonic welding, or microwave-activated bonding. Alternatively, a binder can be used to hold the abrasive particles onto the first surface of the flexible backing. Useful binders for holding abrasive particles onto the first surface of the flexible backing are well known to those of ordinary skill in the art and adhesives.

Suitable binder precursors are typically, in an uncured or uncrosslinked state, flowable at or near ambient conditions. The binder precursor is then typically exposed to conditions (typically an energy source) that at least partially cure or crosslink (i.e., free-radical polymerization) the binder precursor, thereby converting it into a binder capable of retaining the dispersed abrasive particles. Exemplary energy sources include: e-beam, ultraviolet radiation, visible radiation, infrared radiation, gamma radiation, heat, and combinations thereof.

Useful poly(meth)acrylates include monomers and/or oligomers that have at least two (meth)acrylate groups; for example, tri(meth)acrylates, and tetra(methacrylates). Exemplary poly(methacrylates) include: di(meth)acrylates such as, for example, 1,3-butylene glycol di(meth)acrylate, 1,4-butanediol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, 1,6-hexanediol mono(meth)acrylate mono(meth)acrylate, ethylene glycol di(meth)acrylate, alkoxylated aliphatic di(meth)acrylate, alkoxylated cyclohexanedimethanol di(meth)acrylate, alkoxylated hexanediol di(meth)acrylate, alkoxylated neopentyl glycol di(meth)acrylate, caprolactone modified neopentyl glycol hydroxypivalate di(meth)acrylate, caprolactone modified neopentyl glycol hydroxypivalate di(meth)acrylate, cyclohexanedimethanol di(meth)acrylate, diethylene glycol di(meth)acrylate, dipropylene glycol di(meth)acrylate, ethoxylated (10) bisphenol A di(meth)acrylate, ethoxylated (3) bisphenol A di(meth)acrylate, ethoxylated (30) bisphenol A di(meth)acrylate, ethoxylated (4) bisphenol A di(meth)acrylate, hydroxypivalaldehyde modified trimethylolpropane di(meth)acrylate, neopentyl glycol di(meth)acrylate, polyethylene glycol (200) di(meth)acrylate, polyethylene glycol (400) di(meth)acrylate, polyethylene glycol (600) di(meth)acrylate, propoxylated neopentyl glycol di(meth)acrylate, tetraethylene glycol di(meth)acrylate, tricyclodecanedimethanol di(meth)acrylate, triethylene glycol di(meth)acrylate, tripropylene glycol di(meth)acrylate; tri(meth)(meth)acrylates such as glycerol tri(meth)acrylate, trimethylolpropane tri(meth)acrylate, ethoxylated tri(meth)acrylates (e.g., ethoxylated (3) trimethylolpropane tri(meth)acrylate, ethoxylated (6) trimethylolpropane tri(meth)acrylate, ethoxylated (9) trimethylolpropane tri(meth)acrylate, ethoxylated (20) trimethylolpropane tri(meth)acrylate), pentaerythritol tri(meth)acrylate, propoxylated tri(meth)acrylates (e.g., propoxylated (3) glyceryl tri(meth)acrylate, propoxylated (5.5) glyceryl tri(meth)acrylate, propoxylated (3) trimethylolpropane tri(meth)acrylate, propoxylated (6) trimethylolpropane tri(meth)acrylate), trimethylolpropane tri(meth)acrylate, tris(2-hydroxyethyl)isocyanurate tri(meth)acrylate; and higher functionality (meth)acryl containing compounds such as ditrimethylolpropane tetra(meth)acrylate, dipentaerythritol penta(meth)acrylate, ethoxylated (4) pentaerythritol tetra(meth)acrylate, pentaerythritol tetra(meth)acrylate, caprolactone modified dipentaerythritol hexa(meth)acrylate; oligomeric (meth)acryl compounds such as, for example, polyester (meth)acrylates, epoxy (meth)acrylates; and combinations thereof. Such compounds are widely available from vendors such as, for example, Sartomer Co. of Exton, PA; UCB Chemicals Corporation of Smyrna, GA; and Aldrich Chemical Company of Milwaukee, WI.

The binder precursor may comprise an effective amount of at least one photoinitiator; for example, in an amount of from 0.1, 1, or 3 percent by weight, up to 5, 7, or even 10 percent by weight, or more. Useful photoinitiators include those known as useful for free-radically photocuring (meth)acrylates. Exemplary photoinitiators include benzoin and its derivatives such as alpha-methylbenzoin; alpha-phenylbenzoin; alpha-allylbenzoin; alpha-benzylbenzoin; benzoin ethers such as benzil dimethyl ketal (available as IRGACURE 651 from Ciba Specialty Chemicals, Tarrytown, NY), benzoin methyl ether, benzoin ethyl ether, benzoin n-butyl ether; acetophenone and its derivatives such as 2-hydroxy-2-methyl-1-phenyl-1-propanone (available as DAROCUR 1173 from Ciba Specialty Chemicals) and 1-hydroxycyclohexyl phenyl ketone (available as IRGACURE 184 from Ciba Specialty Chemicals); 2-methyl-1-[4-(methylthio)phenyl]-2-(4-morpholinyl)-1-propanone (available as IRGACURE 907 from Ciba Specialty Chemicals); 2-benzyl-2-(dimethylamino)-1-[4-(4-morpholinyl)phenyl]-1-butanone (available as IRGACURE 369 from Ciba Specialty Chemicals); and phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide (available as IRGACURE 819 from Ciba Specialty Chemicals, NY. Other useful photoinitiators include mono- and bis-acylphosphines (available, for example, from Ciba Specialty Chemicals as IRGACURE 1700, IRGACURE 1800, IRGACURE 1850, and DAROCUR 4265).

The binder precursor may comprise an effective amount of at least one thermal initiator; for example, in an amount of from 0.1, 1, or 3 percent by weight, up to 5, 7, or even 10 percent by weight, or more. Exemplary thermal free-radical initiators include: azo compounds such as, for example, 2,2-azo-bisisobutyronitrile, dimethyl 2,2'-azobis(isobutyrate), azobis(diphenyl methane), 4,4'-azobis-(4-cyanopentanoic acid), (2,2'-azobis(2,4-dimethylvaleronitrile (available as VAZO 52 from E. I. du Pont de Nemours and Co. of Wilmington, DE); peroxides such as, for example, benzoyl peroxide, cumyl peroxide, tert-butyl peroxide, cyclohexanone peroxide, glutaric acid peroxide, and dilauryl peroxide; hydrogen peroxide; hydroperoxides such as, for example, tert butyl hydroperoxide and cumene hydroperoxide; peracids such as, for example, peracetic acid and perbenzoic acid; potassium persulfate; and peresters such as, for example, diisopropyl percarbonate.

In some embodiments, it may be desirable to include one or more monoethylenically unsaturated free-radically polymerizable compounds in the binder precursor; for example, to reduce viscosity and/or or reduce crosslink density in the resultant binder. Exemplary monoethylenically unsaturated free-radically polymerizable compounds include: mono(meth)acrylates include hexyl (meth)acrylate, 2-ethylhexyl acrylate, isononyl (meth)acrylate, isobornyl (meth)acrylate, phenoxyethyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate, dodecyl (meth)acrylate, methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, n-butyl (meth)acrylate, n-octyl (meth)acrylate, isobutyl (meth)acrylate, cyclohexyl (meth)acrylate, or octadecyl (meth)acrylate; N-vinyl compounds such as, for example, N-vinylformamide, N-vinylpyrrolidinone, or N-vinylcaprolactam; and combinations thereof.

In some embodiments, the abrasive layer may also include one or more additives. The additives can include one or more of an antioxidant, a colorant, a heat and/or light stabilizer, or a filler (the filler having substantially no impact on abrading performance). Accordingly, the binder may be prepared from a binder precursor comprising the abrasive particles, the surfactant, and additives in which the abrasive particles are dispersed (e.g., as a slurry).

Microstructures

The provided abrasive articles include a flexible backing having opposed first and second major surfaces. At least a portion of the second major surface of the flexible backing includes replicated microstructures having recesses. The replicated microstructures are integral to the flexible backing. By integral it is meant that the replicated microstructures are a part of the flexible backing (e.g., the second surface of the flexible backing). The replicated microstructures can extend from a common base (i.e., the flexible backing), be disposed on a separate backing, and combinations thereof, thereby forming protrusions (distal end of the replicated microstructures) and recesses. In some embodiments, the replicated microstructures can be an extension of the flexible backing material as in the case, e.g., when the replicated microstructures are formed, molded, or embossed, simultaneously with the flexible substrate or grown directly on the flexible substrate.

In some embodiments, the replicated microstructures form recesses in the second surface of the flexible backing, i.e., they form a textured surface on the flexible backing as a result of a texturizing process, e.g., embossing. Useful flexible backings are presented above and include polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene; metal foils including aluminum, copper, tin and bronze; and papers, including densified kraft paper and poly-coated paper.

Alternatively, the replicated microstructures can be disposed or formed on a separate backing. The separate backing can be flexible or rigid. The separate backing can then be structurally attached to the second side of the flexible backing. Any separate backing can be used, however the separate backing needs to not significantly change the overall modulus of the flexible backing—particularly near the top surface where the abrasive elements can be formed. When a separate backing is used, the replicated microstructures on the second backing can be structurally attached to the flexible backing using a variety of mechanisms including, e.g., an adhesive composition (such as a structural adhesive), sonic welding, heat welding, mechanical fasteners, and combinations thereof.

The replicated microstructures may have a shape. Examples of such shapes include rods, triangles, pyramids, truncated pyramids, cones, truncated cones, cube corners, cuboids, spheres, or spheroids. The replicated microstructures can have elongated shapes that form ridges. In some embodiments the ridges have the cross-sections of triangles or truncated triangles (triangles with a flat top). In other embodiments, the ridges can have cross-sections that are rectangular, square, or trapezoidal. Alternatively, the replicated microstructures may be randomly shaped. Since the replicated microstructures are replicas, it is typical that the three-dimensional shape of the replicated microstructures or the two-dimensional cross-sections of the replicated microstructures have side walls that are at an angle with respect to the plane of the second major surface of the flexible backing that is about 90^{o} or higher. In other words, the shape of the replicated microstructures does not typically include an undercut portion that cannot be easily removed from a mold while preserving the features of the replicated microstructures.

As defined herein, "replicated microstructures" are microstructures that can be created by a replicated or repeated process. These processes include replication processes well known to those of ordinary skill in replicating microstructures such as, for example, embossing, injection molding, cast-and-cure, heat-forming or screen printing.

The replicated microstructures can be formed according to a variety of methods including, e.g., molding, extruding, embossing and combinations thereof. Useful methods of forming microstructure elements are described, e.g., in U. S. Pat. Nos. 5,897,930 (Calhoun et al.); 5,183,597 (Lu); 4,588,258 (Hoopman); 4,576,850 (Martens); and 4,374,077 (Kerfeld). Other useful methods for making replicated microstructures include the general methods of making three-dimension abrasive articles disclosed in U.S. Pat. No. 5,958,794 (Bruxvoort et al.). The replicated microstructures can also be made by various other methods. For example, the replicated microstructures can be transferred from a master tool to other media such as a belt or a web of polymeric material, by a cast and cure process from the master tool to form a production tool. This production tool can then be used to make the microreplicated structure that includes replicated microstructures using any of the above mentioned methods of replication. Other methods such as electroforming can be used to copy the master tool.

Another alternate method to make replicated microstructures is to directly cut or machine the second major surface of the flexible backing material to form the replicated microstructures. Techniques such as chemical etching, laser ablating, bead blasting, or other stochastic surface modification techniques can be utilized for this purpose. It is contemplated that when microstructures are directly cut into the second major surface of the flexible backing that they are to be considered "replicated microstructures" if the process is automated to repeatedly direct a cutting tool, such as an ablative laser, under control of some type of computer system to produce multiple flexible backings having replicated microstructures. Additional disclosure for making flexible backings having replicated microstructures can be found, for example, in U. S. Pat. Appl. Publ. No. 2010/0277802 (Gardiner et al.).

Adhesive

The provided abrasive articles and methods include an adhesive that provides tack between the flexible backing and a rigid substrate. In some embodiments, the adhesive can be in contact with a release liner. Any adhesive that can provide tack is suitable for use in the present disclosure. The adhesive is contained substantially in the recesses of the replicated microstructures. By "substantially contained" it is meant that the adhesive occupies a substantial volume of the recesses in the replicated microstructures on the opposed second major surface of the flexible backing. When a rigid substrate is present, the volume of the recesses is the volume defined by the walls of the recesses and the rigid substrate. When a rigid substrate is not present the volume of the recesses is the volume defined by the walls of the recesses and a plane across the distal ends of the replicated microstructures. In the provided articles and methods, the adhesive can occupy greater than about 15 volume percent, greater than about 25 volume percent, or even greater than about 35 volume percent of the volume of the recesses. In some embodiments, the volume of the adhesive may be greater than the volume of the recesses, 110%, 120% or even 130% of the volume of the recesses, typically no more than 150% of the volume of the recesses. In addition, the adhesive can just about occupy the volume of the recesses, or can occupy less than about 85 volume percent, less than about 75 volume percent, or even less than about 65 volume percent of the volume of the recesses.

Additionally, "substantially contained" means that the adhesive is not substantially present on the distal ends or projections of the replicated microstructures that form the second major surface of the flexible backing. Typically, when a rigid substrate is present, the rigid substrate is in direct contact with at least a portion of the replicated microstructures. It is important to the operation of the provided abrasive articles and methods that there is some direct contact between the flexible backing and the rigid support in order to bear the load of the work-piece when it is under a load during polishing or lapping. This important feature can resist or prevent crowning or edge-rounding from occurring when the work-piece is polished using the provided abrasive articles and methods. Typically, the adhesive is not substantially present on the distal ends or projections of the replicated microstructures that form the second major surface of the flexible backing. In some embodiments there is virtually no adhesive on the distal ends or projections of the replicated microstructures. In other embodiments, the average amount of adhesive that can be present on the distal ends or projections of the microstructures is less than about 10 μm, less than about 5 μm, or even less than about 3 μm in thickness. It is important that less adhesive is present than that which will alter the overall mechanical properties and preserve the overall modulus of the abrasive article. The load from the work-piece on the abrasive article needs to be supported through to the rigid support during polishing in order to avoid crowning.

Useful adhesives for securing the abrasive article to the rigid substrate are well known to those of ordinary skill in the art. Suitable adhesives include, pressure sensitive adhesives (PSAs), hot melt adhesives and liquid adhesives that can be cured and/or vitrified by ordinary means including, radiation curable, e.g. photo curable, UV curable, E-beam curable, gamma curable; heat curable, moisture curable, and the like. Hot melt adhesives are those adhesives that can flow upon heating at a temperature above the glass and/or melting transition temperature of the adhesive. Upon cooling below the transition temperature, the hot melt adhesive solidifies. Some hot melt adhesive may flow upon heating and then solidify due to further curing of the adhesive.

Useful adhesives include, e.g., pressure sensitive adhesives, hot melt adhesives, and glue. Suitable pressure sensitive adhesives include a wide variety of pressure sensitive adhesives including, e.g., natural rubber-based adhesives, (meth)acrylate polymers and copolymers, AB or ABA block copolymers of thermoplastic rubbers, e.g., styrene/butadiene or styrene/isoprene block copolymers available under the trade designation KRATON (Shell Chemical Co., Houston, Tex.) or polyolefins. Suitable hot melt adhesives include, e.g., polyester, ethylene vinyl acetate (EVA), polyamides, epoxies, and combinations thereof. The adhesive typically has sufficient cohesive strength and peel resistance to maintain the components of the abrasive article in fixed relation to each other during use, and should be resistant to chemical degradation under conditions of use. Exemplary adhesives include epoxy resins such as those available from 3M Company, St. Paul, MN., under the trade designation SCOTCH-WELD such as 3M SCOTCH-WELD Epoxy Adhesives 1838, 2158, 2216, and 3501.

Rigid Substrate

The term "rigid" describes a substrate that is at least self-supporting, i.e., it does not substantially deform under its own weight. By rigid, it is not meant that the substrate is absolutely inflexible. Rigid substrates may be deformed or bent under an applied load but offer very low compressibility. In one embodiment, the rigid substrates comprise materials having a modulus of rigidity of 1×10^6 pound per square inch (psi) (7×10^4

kg/cm^2) or greater. In another embodiment, the rigid substrates comprise material having a modulus of rigidity of 10x10^6 psi (7 x 10^5 kg/cm^2) or greater.

Suitable materials that can function as the rigid substrate include metals, metal alloys, metal-matrix composites, metalized plastics, inorganic glasses and vitrified organic resins, formed ceramics, and polymer matrix reinforced composites. The rigid substrate can be a platen on which the provided abrasive articles can be mounted during polishing of a substrate.

Suitable rigid substrate materials include, e.g., organic polymers, inorganic polymers, ceramics, metals, composites of organic polymers, and combinations thereof. Suitable organic polymers can be thermoplastic or thermoset. Suitable thermoplastic materials include polycarbonates, polyesters, polyurethanes, polystyrenes, polyolefins, polyperfluoroolefins, polyvinyl chlorides, and copolymers thereof. Suitable thermosetting polymers include, e.g., epoxies, polyimides, polyesters, and copolymers thereof (i.e., polymers containing at least two different monomers including, e.g., terpolymers and tetrapolymers).

The polymer of the rigid substrate may be reinforced. The reinforcement can be in the form of fibers or particulate material. Suitable materials for use as reinforcement include, e.g., organic or inorganic fibers (e.g., continuous or staple), silicates, e.g., mica or talc, silica-based materials, e.g., sand and quartz, metal particulates, glass, metallic oxides and calcium carbonate, or a combination thereof.

Particularly useful rigid substrates can also include poly(ethylene terephthalate), polycarbonate, glass fiber reinforced epoxy boards, aluminum, steel, stainless steel. Metal sheets or plates can also be used as the rigid substrate. Suitable metals include, e.g., aluminum, stainless steel, copper, nickel, and chromium. Multi-layer metal plates can also be used, e.g. tin over steel or tin over aluminum.

The provided articles and methods can be further illustrated by the figures and drawings accompanying this disclosure. Fig. 3 is a schematic cross-section of an embodiment of a provided abrasive article wherein the microstructures are a part of the second surface of the flexible backing and include pyramids or pyramidal ridges. Fig. 3 is an embodiment of abrasive article 300 that includes flexible backing 308. Abrasive layer 302 (that includes abrasive particles retained in a binder) is disposed upon a first major surface of flexible backing 308. On at least a portion of its second major surface, flexible backing 308 includes microstructures 306 having recesses. Adhesive 305 is located substantially in the recesses. In this embodiment, the cross-section of the microstructures is V-shaped as defined by the recesses. Work-piece 320, which includes a surface to be polished, contacts abrasive layer 302, and is moved relative to abrasive article 300 to polish work-piece 320. A load P is applied to work-piece 320 as shown in Fig. 2. The load P is supported by direct contact of at least a portion of microstructures 306 with rigid substrate 312 thereby minimizing, if not eliminating, deformation in the adhesive layer and reducing, if not eliminating crowning or rounding of the edges of work-piece 320.

Fig. 4 is a schematic cross-section of another embodiment of a provided abrasive article. Abrasive article 400 includes flexible backing 408. Abrasive layer 402 (that includes abrasive particles retained in a binder) is disposed upon a first major surface of flexible backing 408. On at least a portion of its second major surface, flexible backing 408 includes replicated microstructures 406 having recesses. Adhesive 405 is located substantially in the recesses. The shape of the microstructures is identical to that of the embodiment shown in Fig. 3. However, in the embodiment shown in Fig. 4, replicated microstructures 406 have been formed on a separate backing (not shown) and then integrally bonded to flexible backing 408. Work-piece 420, which includes a surface to be polished, contacts abrasive layer 402 which is moved relative to abrasive article 400 to polish work-piece 420. A load P is applied to work-piece 420 as shown in Fig. 2. The load P is supported by direct contact of at least a portion of replicated microstructures 406 with rigid substrate 412 thereby minimizing, if not eliminating, deformation in the adhesive layer and reducing, if not eliminating crowning or rounding of the edges of work-piece 420.

Fig. 5 is a schematic cross-section of another embodiment of a provided abrasive article wherein the replicated microstructures include truncated pyramids or pyramidal ridges. Fig. 5 is an embodiment of abrasive article 500 that includes flexible backing 508. Abrasive layer 502 (that includes abrasive particles retained in a binder, not shown) is disposed upon a first major surface of flexible backing 508. On at least a portion of its second major surface, flexible backing 508 includes replicated microstructures 506 having recesses. Adhesive 505 is located substantially in the recesses. In this embodiment, the cross-section of the replicated microstructures is truncated V-shaped as defined by the recesses. The truncated microstructures have a flat plateau that increases the area of contact between flexible backing 508 and rigid substrate 512. This provides more load-bearing support during polishing. Work-piece 520, which includes a surface to be polished, contacts abrasive layer 502 is moved relative to abrasive article 500 to polish work-piece 520. A load P is applied to work-piece 520 as shown in Fig. 2. The load P is supported by direct contact of at least a portion of replicated microstructures 506 with rigid substrate 512 thereby minimizing, if not eliminating, deformation in the adhesive layer and reducing, if not eliminating crowning or rounding of the edges of work-piece 520.

Fig. 6 is a schematic cross-section of yet another embodiment of a provided abrasive article wherein the replicated microstructure is a cuboid or cuboidal ridge. The cross-section of the replicated microstructures is rectangular shaped as defined by the recesses. Fig. 6 is an embodiment of abrasive article 600 that includes flexible backing 608. Abrasive layer 602 (that includes abrasive particles retained in a binder) is disposed upon a first major surface of flexible backing 608. On at least a portion of its second major surface, flexible backing 608 includes replicated microstructures 606 having recesses. Adhesive 605 is located substantially in recesses. The cuboidal microstructures have a flat plateau that increases the area of contact between flexible backing 608 and rigid substrate 612. This provides more load-bearing support during polishing. Work-piece 620, which includes a surface to be polished, contacts abrasive layer 602 which is moved relative to abrasive article 600 to polish work-piece 620. A load P is applied to work-piece 620 as shown in Fig. 2. The load P is supported by direct contact of at least a portion of replicated microstructures 606 with rigid substrate 612 thereby minimizing, if not eliminating, deformation in the adhesive layer and reducing, if not eliminating crowning or rounding of the edges of work-piece 620.

Objects and advantages of this invention are further illustrated by the following examples, but the particular materials and amounts thereof recited in these examples, as well as other conditions and details, should not be construed to unduly limit this invention.

Examples

Test Methods

Lapping Procedure

The simultaneous lapping of three AlTiC coupons, 2.40 cm x 0.20 cm x 0.5 cm, was conducted using a lapping tool, a Lapmaster model 15 (available from Lapmaster International LLC, Mount Prospect, Illinois). The platen with attached abrasive article was mounted to the base of the tool. A 15 cm diameter x 1 mm AlTiC wafer was mounted to the top surface of the 5.5 inch (14.0 cm) diameter ring of the Lapmaster model 15 using an adhesive, SCOTCHWELD DP100 two part epoxy adhesive (available from 3M Company, St. Paul, Minnesota). Three AlTiC coupons were mounted to the AlTiC wafer surface using the same epoxy adhesive. The coupons were mounted along a 4.5 mm radius of the wafer, being spaced uniformly, i.e. about 120 ° apart from one another with their length being perpendicular to the radius. The coupons were mounted such that a 2.40 cm x 0.20 cm surface was mounted to the wafer. Lapping conditions were 20 rpm head rotation, 40 rpm platen rotation and a lapping time of 3 hours. During the first hour, a 2 kg load was applied to the head; during the second hour, a 4 kg load was applied and during the third hour, a 6 kg load was applied. The AlTiC coupons rotated in a path that was within the outer diameter and inner diameter of the abrasive covered platen. A lapping fluid was used, anhydrous ethylene glycol was dripped onto the platen at a rate of 0.36 g/min throughout the 3 hour process.

Crown Measurement Procedure

Measurement of the flatness of the AlTiC coupons after lapping was conducted using a Model P16 Profilometer, (available from KLA-Tencor Corporation, Milpitas, California). Four profilometer scans were taken across the 0.2 cm width of each coupon. The four scans were taken at about 0.5 cm increments along the length of the coupon. The crown is defined as the difference between the maximum and minimum height of a given profilometer scan. The twelve measurements taken from the three coupons were then averaged to obtain an average crown value.

Fabrication of Backing Having Microstructures with Recess

A steel roll having a width of 25.25 inch (64.1 cm) and a diameter of 12 inch (30.5 cm) with copper surface was cut on a diamond turning machine to make a surface having a series of microstructures with recess between the microstructures. A cross-sectional view of microstructure roll surface, 700, of a small section of roll, 740, is shown in Fig. 7. Recesses, 710, were cut such that they were along the circumference of the roll, running perpendicular to roll axis direction, 730, illustrated by dotted two-headed arrow 730. This produced a series of microstructure features, 720, that also ran along the circumference of the roll. The average depth of recesses 710 was 1.3 mils (33.0 μm). The average width of the base of microstructured features 720 was 1.0 mil (15.4 μm). The average distance between bases of microstructured features 720 was 0.48 mils (12.1 μm). The microstructured features 720 were trapezoidal in shape with an average internal angle measured at the top of the features of about 110 degrees. After cutting on the diamond turning machine, the roll was degreased with isopropyl alcohol and an alkaline solution was used to clean the surface. Using an electroless nickel plating process, the copper surface of the steel roll was nickel plated to protect the surface from oxidation.

This roll was used as the tool in a continuous cast and cure process to make a microstructure surface, ridges, having recesses on a backing. In this cast and cure process, a 23 inch (58.4 cm) wide by 0.005 inch (127 microns) thick, polyester film was used as the backing. A photopolymerizable acrylate resin was applied to the tool, coating a width of about 20 inches (50.8 cm) along the length of the roll. The acrylate resin was 75 wt. % aliphatic urethane diacrylate (available unde the trade designation PHOTOMER 6210 from Cognis Corporation, Cincinnati, OH), 24 wt. % 1,6 hexanediol diacrylate (available under the trade desigantion SR238 from Sartomer Company, Inc., Exton, PA) and 1wt. % photoinitiator (available under the trade designation LUCIRIN TPO from BASF Corp., Charlotte, NC). The backing was subsequently applied to the acrylate coated section of the tool. The acrylate resin was UV cured through the backing while still in the recesses of the roll microstructure. The backing was then peeled from the tool. The cured acrylic resin adhered to the backing and released from the tool, producing a microstructure surface. A cross-sectional view, which corresponds to a cross-web view, of the backing microstructure is shown in Figure 8. Figure 8 shows microstructure backing surface, 800, with recesses, 810, and microstructure features, 820, on the surface of the backing, 840.

The cross web direction, 830, is indicated. The replicated microstructure surface of the backing has the inverse microstructure as that of the tool. The average depth of recesses 810 was 1.3 mils (33.0 μm). The average width of the base of microstructured features 820 was 1.0 mil (15.4 μm). The average distance between bases of microstructured features 720 was 0.48 mils (12.1 μm). The microstructured features 720 were trapezoidal in shape with an average external angle measured at the bottom of the features of about 100 degrees. The microstructures and corresponding recesses between them followed the down-web direction of the web.

Example

A 20 inch (50.8 cm) x 20 inch (50.8 cm) sheet of the above backing with microstructure surface was taped onto an 18 inch (45.7 cm) x 21 inch (53.3 cm) x 0.625 inch (0.159 cm) aluminum plate, with the microstructure surface facing the aluminum plate. A solution of 1g of 3M SCOTCH-WEL Epoxy B/A Adhesive (available from the 3M Company, St Paul, MN) mixed according to the supplier specification and 3g of methyl ethyl ketone (MEK) was prepared. The solution was poured onto the polyester backing and spread over the surface of the backing using a rubber roller. The surface was rolled repeatedly as the solvent evaporated and the epoxy adhesive covered the surface in a uniform manner. Ten grams of abrasive composite particles comprising 1 micron diamond/silica 50/50 wt. % prepared according to U. S. Pat. No. 6,645,624 (Adefris et. al.) and sieved to a size of less than 38 micron were poured onto the epoxy adhesive in a line along the edge. The aluminum plate and the coated backing were held at a 45° angle and tapped gently to cause the particles to roll and coat the tacky resin. The procedure was repeated until the backing contained a complete coating. The sheet was then held perpendicular and tapped rigorously to dislodge loose particles. The bound abrasive was then covered with a sheet of silicone release liner and rolled with a rubber hand roller to press the particles into the epoxy adhesive in a single plane. The coating was allowed to cure for 12 hrs at room temperature and then an additional 2 hrs at 70° C.

The abrasive layer was then spray coated with a securing size coating of resin. The size coating resin solution consisted of 4g of a phenoxy resin solution, 30 wt. % in 2-butanone (available under the trade designation of YP-50S from Tohto Kasei Co. Lt. Inabata America Corp, NY, NY); 2.3g of a polyester polyurethane resin solution, 35 wt.

% in MEK (synthesized internally from neopentyl glycol, 21 wt. %, poly caprolactone, 29 wt. %, and a methylene diisocyanate 50 wt. %); 1.1g of polymeric isocyanate (available under the trade designation Mondur MRS from Bayer Chemical, Pittsburgh, PA.); 40g MEK and 10g of cyclohexanone. The size coating resin solution was placed in an aerosol container. The abrasive surface was sprayed with the size coating solution in a well ventilated hood for about 60 seconds or until the surface looked wet. The aluminum plate and abrasive article were then heated in an oven at 70° C for 17 hrs. After cooling, the film with microstructure was turned over, so that the abrasive surface contacted the aluminum plate and the microstructure surface was exposed. A layer of non-crosslinked, acrylate based, pressure sensitive adhesive having a 0.0009 inch (22.9 micron) nominal thickness, coated on a siliconized kraft paper release liner, was then hand laminated to the microstructure surface of the backing using a rubber roller. The release liner of the abrasive article was removed and the abrasive article was hand laminated using a rubber roller to a flat annular shaped, aluminum platen having a 16 inch (40.6 cm) outside diameter, an 8 inch (20.3 cm) inside diameter and a 1.5 inch (3.8 cm) thickness, which was fabricated using standard CNC cutting techniques.

The platen with the abrasive article was then place abrasive face down onto a quartz sheet, 23 inch (58.4 cm) x 18 inch (45.7 cm) x 3/8 inch (0.95 cm). An identical platen, weighing 10.7 kg, was placed on top of the first platen with attached abrasive and the entire stack was heated in an oven for 70 °C for 48 hrs. The stack was removed from the oven, the 2nd platen was removed from the stack and the platen with attached abrasive article was allowed to cool while the abrasive was still in contact with the quartz plate. The abrasive article was trimmed with a razor blade to fit the dimensions of the platen. Following the lapping procedure and the crown measurement procedure described above, the average crown of the three AlTiC coupons was 0.9 micro-inches (0.0229 μm).

Various modifications and alterations to this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention. It should be understood that this invention is not intended to be unduly limited by the illustrative embodiments and examples set forth herein and that such examples and embodiments are presented by way of example only with the scope of the invention intended to be limited only by the claims set forth herein as follows. All references cited in this disclosure are herein incorporated by reference in their entirety.

Following are exemplary embodiments of an abrasive article with replicated microstructured backing and method of using same according to aspects of the present invention.

Embodiment 1 is an abrasive article comprising: a flexible backing having opposed first and second major surfaces, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses; an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing; and an adhesive, wherein the adhesive is contained substantially in the recesses of the replicated microstructures.

Embodiment 2 is an abrasive article according to embodiment 1, further comprising: a rigid substrate in contact with at least a portion of the replicated microstructures.

Embodiment 3 is an abrasive article according to embodiment 1, further comprising: a release liner in contact with at least a portion of the adhesive.

Embodiment 4 is an abrasive article according to embodiment 1, wherein the flexible backing is selected from the group consisting of densified kraft paper, poly-coated paper, metal foils, and polymeric substrate.

Embodiment 5 is an abrasive article according to embodiment 4, wherein the metal foils are selected from aluminum, copper, tin, and bronze.

Embodiment 6 is an abrasive article according to embodiment 4, wherein the polymeric substrate is selected from the group consisting of polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene.

Embodiment 7 is an abrasive article according to embodiment 1, wherein the abrasive particles are selected from the group consisting of fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicone carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond, silica, iron oxide, chromia, ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive particles, abrasive agglomerates, metal-based particulates, and combinations thereof.

Embodiment 8 is an abrasive article according to embodiment 1, wherein the flexible backing has a Young's modulus of greater than about 0.5 GPa.

Embodiment 9 is an abrasive article according to embodiment 8, wherein the flexible backing has a Young's modulus of greater than about 2.0 GPa.

Embodiment 10 is an abrasive article according to embodiment 1, wherein the replicated microstructures have a shape that comprises rods, triangles, pyramids, truncated pyramids, cones, truncated cones, cube corners, cuboids, spheres, or spheroids.

Embodiment 11 is an abrasive article according to embodiment 1, wherein the replicated microstructures have a shape that comprises ridges.

Embodiment 12 is an abrasive article according to embodiment 1, wherein the adhesive is selected from the group consisting of pressure-sensitive adhesives, hot melt adhesives and curable liquid adhesives.

Embodiment 13 is an abrasive article according to embodiment 1, wherein the adhesive occupies greater than about 25 volume percent and less than about 120 volume percent of the volume of the recesses of the replicated microstructures.

Embodiment 14 is a method of polishing comprising: providing a work-piece to be polished; contacting the work-piece with an abrasive article comprising: a flexible backing having opposed first and second major surfaces, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses; an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing; an adhesive; and a rigid substrate in contact with at least a portion of the replicated microstructures, wherein the adhesive is contained substantially in the recesses of the replicated microstructures; and moving the abrasive article relative to the work-piece.

Embodiment 15 is a method of polishing according to embodiment 14, wherein the abrasive particles are selected from the group consisting of fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicone carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond, silica, iron oxide, chromia, ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive particles, abrasive agglomerates, metal-based particulates, and combinations thereof.

Embodiment 16 is a method of polishing according to embodiment 14, wherein the replicated microstructures have a shape that comprises rods, triangles, pyramids, truncated pyramids, cones, truncated cones, cube corners, cuboids, spheres, or spheroids.

Embodiment 17 is a method of polishing according to embodiment 14, wherein the replicated microstructures have a shape that comprises ridges.

Embodiment 18 is a method of polishing according to embodiment 14, wherein the adhesive is selected from the group consisting of pressure-sensitive adhesives, hot melt adhesives and curable liquid adhesives.

Embodiment 19 is a method of polishing according to embodiment 14, wherein the adhesive occupies greater than about 25 volume percent and less than about 120 volume percent of the volume of the recesses of the replicated microstructures.

Embodiment 20 is a method of polishing according to embodiment 14, further comprising a release liner disposed on the adhesive.

Although specific embodiments have been illustrated and described herein for purposes of description of the preferred embodiment, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations calculated to achieve the same purposes may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. Those with skill in the mechanical, electro-mechanical, and electrical arts will readily appreciate that the present invention may be implemented in a very wide variety of embodiments. This application is intended to cover any adoptions or variations of the preferred embodiments discussed herein. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. An abrasive article comprising:

a flexible backing having opposed first and second major surfaces, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses;

an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing; and

an adhesive,

wherein the adhesive is contained substantially in the recesses of the replicated microstructures.

2. An abrasive article according to claim 1, further comprising:

a rigid substrate in contact with at least a portion of the replicated microstructures.

3. An abrasive article according to claim 1, further comprising:

a release liner in contact with at least a portion of the adhesive.

4. An abrasive article according to claim 1, wherein the flexible backing is selected from the group consisting of densified kraft paper, poly-coated paper, metal foils, and polymeric substrate.

5. An abrasive article according to claim 4, wherein the metal foils are selected from aluminum, copper, tin, and bronze.

6. An abrasive article according to claim 4, wherein the polymeric substrate is selected from the group consisting of polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene.

7. An abrasive article according to claim 1, wherein the abrasive particles are selected from the group consisting of fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicone carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond, silica, iron oxide, chromia,

ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive particles, abrasive agglomerates, metal-based particulates, and combinations thereof.

8. An abrasive article according to claim 1, wherein the flexible backing has a Young's modulus of greater than about 0.5 GPa.

9. An abrasive article according to claim 8, wherein the flexible backing has a Young's modulus of greater than about 2.0 GPa.

10. An abrasive article according to claim 1, wherein the replicated microstructures have a shape that comprises rods, triangles, pyramids, truncated pyramids, cones, truncated cones, cube corners, cuboids, spheres, or spheroids.

11. An abrasive article according to claim 1, wherein the replicated microstructures have a shape that comprises ridges.

12. An abrasive article according to claim 1, wherein the adhesive is selected from the group consisting of pressure-sensitive adhesives, hot melt adhesives and curable liquid adhesives.

13. An abrasive article according to claim 1, wherein the adhesive occupies greater than about 25 volume percent and less than about 120 volume percent of the volume of the recesses of the replicated microstructures.

14. A method of polishing comprising:
providing a work-piece to be polished;
contacting the work-piece with an abrasive article comprising:
a flexible backing having opposed first and second major surfaces, wherein at least a portion the second major surface of the flexible backing includes replicated microstructures having recesses;

an abrasive layer comprising a plurality of abrasive particles retained in at least one binder, the abrasive layer disposed on the first major surface of the flexible backing;

an adhesive; and

a rigid substrate in contact with at least a portion of the replicated microstructures, wherein the adhesive is contained substantially in the recesses of the replicated microstructures; and

moving the abrasive article relative to the work-piece.

15. A method of polishing according to claim 14, wherein the abrasive particles are selected from the group consisting of fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicone carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond, silica, iron oxide, chromia, ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive particles, abrasive agglomerates, metal-based particulates, and combinations thereof.

16. A method of polishing according to claim 14, wherein the replicated microstructures have a shape that comprises rods, triangles, pyramids, truncated pyramids, cones, truncated cones, cube corners, cuboids, spheres, or spheroids.

17. A method of polishing according to claim 14, wherein the replicated microstructures have a shape that comprises ridges.

18. A method of polishing according to claim 14, wherein the adhesive is selected from the group consisting of pressure-sensitive adhesives, hot melt adhesives and curable liquid adhesives.

19. A method of polishing according to claim 14, wherein the adhesive occupies greater than about 25 volume percent and less than about 120 volume percent of the volume of the recesses of the replicated microstructures.

20. A method of polishing according to claim 14, further comprising a release liner disposed on the adhesive.