



US 20070243798A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2007/0243798 A1**
Annen et al. (43) **Pub. Date:** **Oct. 18, 2007**

(54) **EMBOSSED STRUCTURED ABRASIVE ARTICLE AND METHOD OF MAKING AND USING THE SAME**

(75) Inventors: **Michael J. Annen**, Hudson, WI (US);
Gregory A. Koehnle, Oakdale, MN (US)

Correspondence Address:
3M INNOVATIVE PROPERTIES COMPANY
PO BOX 33427
ST. PAUL, MN 55133-3427 (US)

(73) Assignee: **3M Innovative Properties Company**

(21) Appl. No.: **11/379,087**

(22) Filed: **Apr. 18, 2006**

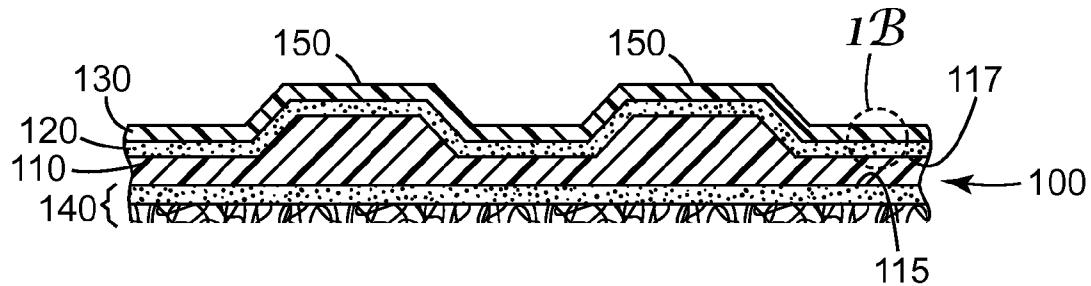
Publication Classification

(51) **Int. Cl.**
B24B 1/00 (2006.01)
B24D 11/00 (2006.01)

(52) **U.S. Cl.** **451/28; 451/527**

(57) **ABSTRACT**

An embossed structured abrasive article having an inelastic dense thermoplastic film backing and a structured abrasive layer. Both the backing and the structured abrasive layer have superposed embossed features. Methods of making and using embossed structured abrasive articles are also disclosed.



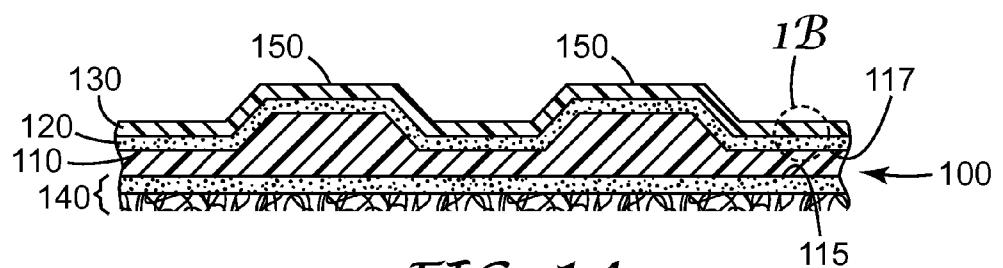


FIG. 1A

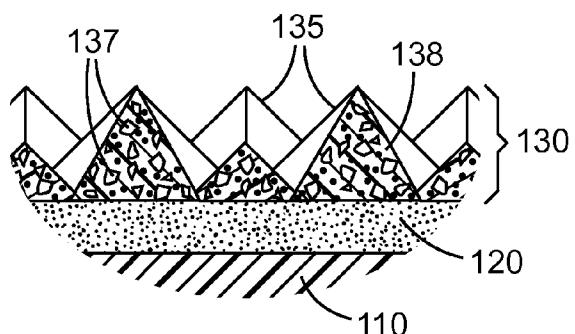


FIG. 1B

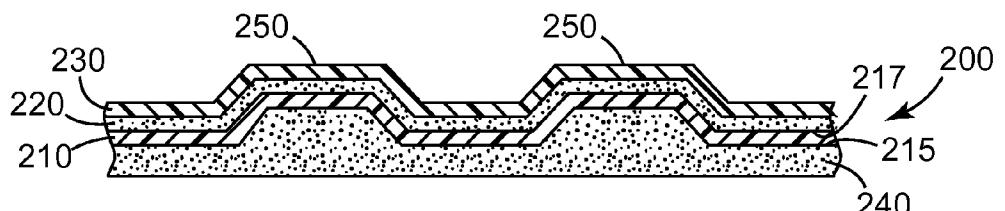


FIG. 2

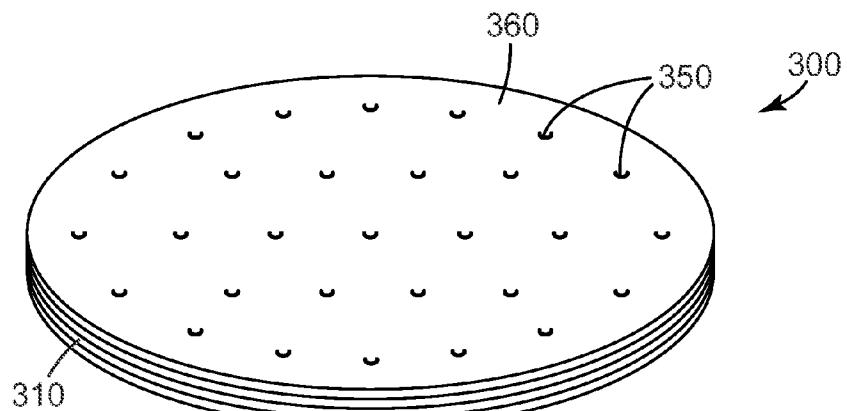


FIG. 3

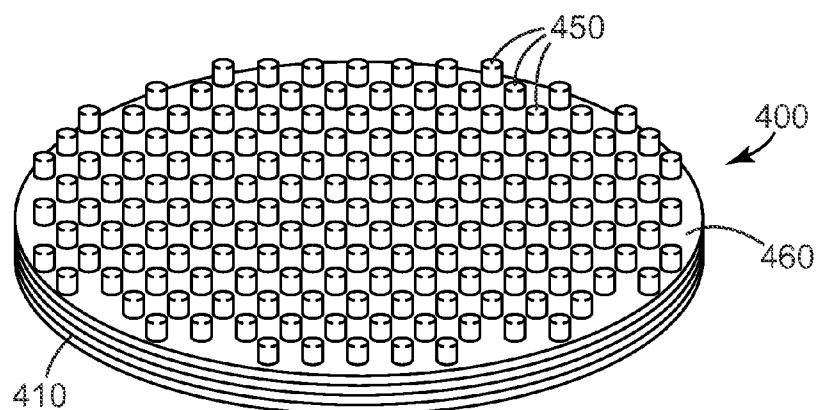


FIG. 4

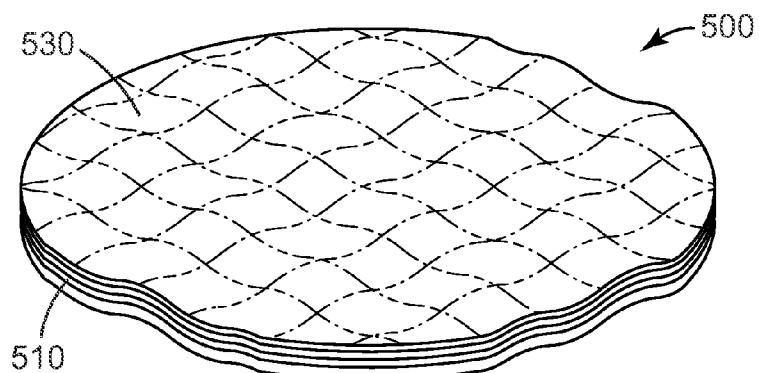


FIG. 5

EMBOSSED STRUCTURED ABRASIVE ARTICLE AND METHOD OF MAKING AND USING THE SAME**BACKGROUND**

[0001] The appearance of glossy surface finishes is important in the manufacture and repair of such articles having such surface finishes. Examples of finishes used to create glossy surfaces include automotive and marine clearcoat finishes, lacquer finishes, and the like. During application of such finishes, dust particles typically become accidentally included in the finish (commonly termed "dust nibs"). These dust nibs detract from the aesthetic appeal of the finish, and require one or more additional steps to reduce or remove them (i.e., denibbing).

[0002] For years, a class of abrasive articles known generally as "structured abrasive" articles has been sold commercially for use in the manufacture and repair of glossy surface finishes; for example, as they relate to automobiles, trucks, boats, and the like. Structured abrasive articles have a structured abrasive layer affixed to a backing, and are typically used in conjunction with a liquid such as, for example, water, optionally containing surfactant. The structured abrasive layer has a plurality of shaped abrasive composites (typically having minute size), each having abrasive particles and a binder. In many cases, the shaped abrasive composites are precisely shaped, for example, according to various geometric shapes (e.g., pyramids). Examples of such structured abrasive articles include those marketed under the trade designation "TRIZACT" by 3M Company, St. Paul, Minn.

[0003] In many cases, conventional structured abrasive articles have problems with "stiction", i.e., the tendency for the abrasive surface to stick to a workpiece, when used in damp abrading processes typical of industry, unless special design or process steps are taken to alleviate the problem. Stiction makes it difficult to control abrading processes by requires more force to move and control conventional structured abrasive articles, leading to erratic control of any abrading tool to which it is mounted, and which could ultimately lead to damage of the workpiece (e.g., a car) if the abrading tool strikes an unintended area such as a side-view mirror or body molding. Stiction is often broken in an uncontrolled manner, often by a sudden release of the structured abrasive article from the surface of the abrading substrate. This is commonly accompanied by a period in which the structured abrasive article releases and easily glides over the surface of the workpiece with little actual abrading being done.

[0004] Structured abrasive articles (e.g., discs) are often used in combination with a compressible back up pad (e.g., foam or nonwoven) mounted to a tool (e.g., a disc sander). In such applications, structured abrasive articles typically have an attachment interface layer (e.g., a hooked fabric or adhesive) that is used to affix them to the backup pad during use. The compressibility of the backup pad provides a degree of conformability to the abrasive articles that may aid, for example, in abrading curved surfaces. In the case of handheld structured abrasive articles (e.g., denibbing discs), a foam layer has sometimes been included in the construction of the article itself to provide conformability. However, the presence of compressible layers such as foams or non-

wovens can result in the structured abrasive article riding over surface defects such as dust nibs, and merely rounding them off instead of removing them.

[0005] Further, during abrading with structured abrasive articles having the structured abrasive layer affixed to a foam layer, the abrasive article may be subjected to harsh forces that result in failure at a time when the abrasive layer is otherwise usable. Such premature failure may occur, for example, by separation of the abrasive layer from the foam backing and/or by damage caused to the foam backing.

SUMMARY

[0006] In one aspect, the present invention relates to an embossed structured abrasive article consisting of:

[0007] a backing having first and second major surfaces and comprising an inelastic dense thermoplastic film;

[0008] an optional adhesive layer in contact and coextensive with, and affixed to, the first major surface;

[0009] a structured abrasive layer in contact and coextensive with, and affixed to, either the first surface of the backing or the optional adhesive layer, wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder, and wherein both the backing and the structured abrasive layer have superposed embossed features; and

[0010] an optional attachment interface layer affixed to the second major surface;

[0011] wherein the embossed structured abrasive article is free of porous resilient components.

[0012] In another aspect, the present invention relates to a method of abrading a workpiece, the method comprising:

[0013] a) providing an embossed structured abrasive article according to the present invention;

[0014] b) providing a workpiece having a hardened polymeric layer thereon;

[0015] c) frictionally contacting at least a portion of the structured abrasive layer with the polymeric layer; and

[0016] d) moving at least one of the workpiece and the structured abrasive layer relative to the other to abrade at least a portion of the polymeric layer.

[0017] In yet another aspect, the present invention relates to a method of making an embossed structured abrasive article, the method comprising:

[0018] providing backing having first and second major surfaces and comprising an inelastic dense thermoplastic film;

[0019] affixing an adhesive layer in contact and coextensive with the first major surface;

[0020] affixing a structured abrasive layer in contact and coextensive with the adhesive layer, wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder;

[0021] embossing the backing and structured abrasive layer to provide superposed embossed features in the backing and structured abrasive layer;

[0022] optionally affixing an attachment interface layer to the second major surface; and

[0023] thereby providing an embossed structured abrasive article that is free of porous resilient components.

[0024] In yet another aspect, the present invention provides a method of making an embossed structured abrasive article, the method comprising:

[0025] providing an inelastic dense thermoplastic film backing having first and second major surfaces;

[0026] affixing a structured abrasive layer to the backing, wherein the structured abrasive layer contacts and is coextensive with the adhesive layer, and wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder;

[0027] embossing the backing and structured abrasive layer to provide superposed embossed features in the backing and structured abrasive layer;

[0028] optionally affixing an attachment interface layer to the second major surface; and

[0029] thereby providing an embossed structured abrasive article that is free of porous resilient components.

[0030] Structured abrasive articles according to the present invention typically exhibit a combination of abrasive and stiction properties that makes them suitable for deburring of glossy finishes.

[0031] In this application:

[0032] "Affixed" as applied to any two components means that the components are not readily separable.

[0033] "Embossed features", as it relates to the abrasive layer or backing, refers to features that appear raised or depressed relative to the adjacent surface of the abrasive layer or backing, respectively, and does not include features due solely to the shape of individual abrasive composites themselves.

[0034] "Embossed" means formed by a process in which a patterned surface of a tool is pressed against an object with sufficient pressure, and optionally at sufficient temperature, to impart a recognizable inverse pattern into that object.

[0035] "Dense" means substantially free of enclosed voids or pores. Dense films may have perforations at predetermined locations.

[0036] "Inelastic" means not easily resuming original shape after being stretched or expanded by at least 10 percent.

[0037] "Precisely shaped abrasive composites" refers to abrasive composites wherein the shape of the abrasive composites is defined by relatively smooth surfaced sides that are bounded and joined by well-defined edges having distinct edge lengths with distinct endpoints, for example, as defined by the intersections of the various sides. The terms "bounded" and "boundary" refer to the exposed surfaces and edges of each abrasive composite that delimit and define the

actual three-dimensional shape of each abrasive composite. These boundaries are readily visible and discernible when a cross-section of an abrasive article is viewed under a scanning electron microscope. These boundaries separate and distinguish one precisely shaped abrasive composite from another even if the composites abut each other along a common border at their bases. By comparison, in an abrasive composite that does not have a precise shape, the boundaries and edges are not well defined (e.g., where the abrasive composite sags before completion of its curing).

[0038] "Resilient" means capable of returning to an original shape or position, as after having been compressed.

BRIEF DESCRIPTION OF THE DRAWING

[0039] FIG. 1A is a schematic side view of an exemplary embossed structured abrasive article according to one embodiment of the present invention;

[0040] FIG. 1B is an enlarged view of a portion of abrasive layer 130;

[0041] FIG. 2 is a schematic side view of an exemplary embossed structured abrasive article according to one embodiment of the present invention;

[0042] FIG. 3 is a schematic perspective view of an exemplary embossed structured abrasive article according to one embodiment of the present invention;

[0043] FIG. 4 is a schematic perspective view of another exemplary embossed structured abrasive article according to one embodiment of the present invention; and

[0044] FIG. 5 is a schematic perspective view of yet another exemplary embossed structured abrasive article according to one embodiment of the present invention.

DETAILED DESCRIPTION

[0045] Referring now to FIGS. 1A and 1B, exemplary embossed structured abrasive article 100 consists of an inelastic dense thermoplastic film backing 110, having first and second major surfaces, 117 and 115, respectively. Optional adhesive layer 120 contacts and is affixed to and coextensive with first major surface 117. Structured abrasive layer 130 contacts and is affixed to and coextensive with, either first major surface 117 of film backing 110 (if optional adhesive layer 120 is not present) or optional adhesive layer 120 (if present). Structured abrasive layer 130 consists of outwardly protruding precisely shaped abrasive composites 135 (shown in FIG. 1B) comprising abrasive particles 137 and a binder 138. Both film backing 110 and the structured abrasive layer have superposed embossed features 150. Optional attachment interface layer 140 is affixed to second major surface 115. Embossed structured abrasive article 100 is free of porous resilient components.

[0046] Another exemplary embossed structured abrasive article is shown in FIG. 2. Exemplary embossed structured abrasive article 200 consists of an inelastic dense thermoplastic film backing 210, having first and second major surfaces, 217 and 215, respectively. Optional adhesive layer 220 contacts and is affixed to and coextensive with first major surface 217. Structured abrasive layer 230 contacts and is affixed to and coextensive with, either first major surface 217 of film backing 210 (if optional adhesive layer 220 is not present) or optional adhesive layer 220 (if

present). Structured abrasive layer 230 consists of outwardly protruding precisely shaped abrasive composites 135 (shown in FIG. 1B) comprising abrasive particles 137 and a binder 138. Both film backing 210 and structured abrasive layer 230 have superposed embossed features 250. Optional attachment interface layer 240 is affixed to second major surface 215. Embossed structured abrasive article 200 is free of porous resilient components.

[0047] Various shaped features may be embossed into the abrasive layer to create embossed structured abrasive articles according to the present invention. In general, the structured abrasive layer is continuous; however, depending on the scale of the embossed features and their sharpness, the abrasive layer may be only substantially continuous having fine stress cracks therein or substantially vertical discontinuities, for example, as a result of the embossing step.

[0048] In one embodiment (shown in FIG. 3), exemplary embossed structured abrasive article 300 has structured abrasive layer 360 with superposed dimples 350 embossed into structured abrasive layer 360 and inelastic dense thermoplastic film backing 310 (not shown in detail).

[0049] In another embodiment (shown in FIG. 4), exemplary embossed structured abrasive article 400 has structured abrasive layer 460 and superposed posts 450 embossed into structured abrasive layer 460 and inelastic dense thermoplastic film backing 410 (not shown in detail).

[0050] In yet another embodiment (shown in FIG. 5), exemplary embossed structured abrasive article 500 has structured abrasive layer 530 with an undulating superposed topography embossed into structured abrasive layer 530 and inelastic dense thermoplastic film backing 510 (not shown in detail).

[0051] Embossed structured abrasive articles according to the present invention are free of resilient compressible layers, such as for example, foams. Advantageously, this eliminates problems of delamination between the resilient compressible layer and other layers such as for example, the structured abrasive member during some abrading processes; a problem that continues to plague such abrasive articles.

[0052] The backing is an inelastic dense thermoplastic film that includes a thermoplastic polymer, which may contain various additive(s). Examples of suitable additives include colorants, processing aids, reinforcing fibers, heat stabilizers, UV stabilizers, and antioxidants. Examples of useful fillers include clays, calcium carbonate, glass beads, talc, clays, mica, wood flour, and carbon black. The backing may be a composite film, for example a coextruded film having two or more discrete layers.

[0053] Suitable thermoplastic polymers include, for example, polyolefins (e.g., polyethylene, and polypropylene), polyesters (e.g., polyethylene terephthalate), polyamides (e.g., nylon-6 and nylon-6,6), polyimides, polycarbonates, and combinations and blends thereof.

[0054] Typically, the average thickness of the backing is in a range of from at least 1 mil (25 micrometers) to 100 mils (2500 micrometers), although thicknesses outside of this range may also be used. Of course, the thickness of the backing may vary, for example, as a result of embossing.

[0055] The optional adhesive layer may be any adhesive material sufficiently strong to maintain adhesion of the abrasive layer to the backing during abrading process. Examples of suitable adhesives include hot melt adhesives, pressure sensitive adhesives (e.g., latex pressure sensitive adhesives or pressure sensitive adhesive transfer films), thermosetting thermoplastic adhesives, and glues.

[0056] The structured abrasive layer typically consists of outwardly protruding non-randomly shaped abrasive composites comprising abrasive particles and a binder. As used herein, the term "abrasive composite" refers to a body that includes abrasive particles dispersed in a binder. The structured abrasive layer may be continuous or discontinuous, for example, it may have regions, devoid of shaped abrasive composites. Typically, shaped abrasive composites are arranged on the backing according to a predetermined pattern or array, although this is not a requirement.

[0057] The shaped abrasive composites may have substantially identical shapes and/or sizes or a mixture of various shapes and/or sizes.

[0058] In some embodiments, at least a portion of the shaped abrasive composites may comprise "precisely shaped" abrasive composites. This means that the shaped abrasive composites are defined by relatively smooth surfaced sides that are bounded and joined by well-defined edges having distinct edge lengths with distinct endpoints defined by the intersections of the various sides. The terms "bounded" and "boundary" refer to the exposed surfaces and edges of each composite that delimit and define the actual three-dimensional shape of each shaped abrasive composite. These boundaries are readily visible and discernible when a cross-section of an abrasive article is viewed under a scanning electron microscope. These boundaries separate and distinguish one precisely shaped abrasive composite from another even if the composites abut each other along a common border at their bases. By comparison, in a shaped abrasive composite that does not have a precise shape, the boundaries and edges are not well defined (e.g., where the abrasive composite sags before completion of its curing).

[0059] The shaped abrasive composites may be arranged such that some of their work surfaces are recessed from the polishing surface of the structured abrasive layer.

[0060] Any abrasive particle may be included in the abrasive composites. Typically, the abrasive particles have a Mohs' hardness of at least 8, or even 9. Examples of such abrasive particles include aluminum oxide, fused aluminum oxide, ceramic aluminum oxide, white fused aluminum oxide, heat treated aluminum oxide, silica, silicon carbide, green silicon carbide, alumina zirconia, diamond, iron oxide, ceria, cubic boron nitride, garnet, tripoli, sol-gel derived abrasive particles, and combinations thereof.

[0061] Typically, the abrasive particles have an average particle size of less than or equal to 1500 micrometers, although average particle sizes outside of this range may also be used. For repair and finishing applications, useful abrasive particle sizes typically range from an average particle size in a range of from at least 0.01, 1, 3 or even 5 micrometers up to and including 35, 100, 250, 500, or even as much as 1,500 micrometers.

[0062] The abrasive particles are dispersed in a binder to form the abrasive composite. The binder can be a thermo-

plastic binder; however, it is typically a thermosetting binder. Examples of suitable binders that are useful in abrasive composites include phenolics, aminoplasts, urethanes, epoxies, acrylics, cyanates, isocyanurates, glue, and combinations thereof. Typically, the binder is prepared by at least partially curing (polymerizing) a corresponding binder precursor, usually in the presence of an appropriate curative (e.g., photoinitiator, thermal curative, and/or catalyst).

[0063] The binder is formed from a binder precursor. During the manufacture of the structured abrasive article, the thermosetting binder precursor is exposed to an energy source which aids in the initiation of the polymerization or curing process. Examples of energy sources include thermal energy and radiation energy which includes electron beam, ultraviolet light, and visible light.

[0064] After this polymerization process, the binder precursor is converted into a solidified binder. Alternatively for a thermoplastic binder precursor, during the manufacture of the abrasive article the thermoplastic binder precursor is cooled to a degree that results in solidification of the binder precursor. Upon solidification of the binder precursor, the abrasive composite is formed.

[0065] There are two main classes of thermosetting resins, condensation curable and addition polymerizable resins. Addition polymerizable resins are advantageous because they are readily cured by exposure to radiation energy. Addition polymerized resins can polymerize through a cationic mechanism or a free radical mechanism. Depending upon the energy source that is utilized and the binder precursor chemistry, a curing agent, initiator, or catalyst is sometimes preferred to help initiate the polymerization.

[0066] Examples of typical binders precursors include phenolic resins, urea-formaldehyde resins, aminoplast resins, urethane resins, melamine formaldehyde resins, cyanate resins, isocyanurate resins, acrylate resins (e.g., acrylated urethanes, acrylated epoxies, ethylenically unsaturated compounds, aminoplast derivatives having pendant alpha,beta-unsaturated carbonyl groups, isocyanurate derivatives having at least one pendant acrylate group, and isocyanate derivatives having at least one pendant acrylate group) vinyl ethers, epoxy resins, and mixtures and combinations thereof. The term acrylate encompasses acrylates and methacrylates.

[0067] Phenolic resins are suitable for this invention and have good thermal properties, availability, and relatively low cost and ease of handling. There are two types of phenolic resins, resole and novolac. Resole phenolic resins have a molar ratio of formaldehyde to phenol of greater than or equal to one to one, typically in a range of from 1.5:1.0 to 3.0:1.0. Novolac resins have a molar ratio of formaldehyde to phenol of less than one to one. Examples of commercially available phenolic resins include those known by the trade designations "DUREZ" and "VARCUM" from Occidental Chemicals Corp., Dallas, Tex.; "RESINOX" from Monsanto Co., Saint Louis, Mo.; and "AEROFENE" and "AROTAP" from Ashland Specialty Chemical Co., Dublin, Ohio.

[0068] Acrylated urethanes are diacrylate esters of hydroxy terminated NCO extended polyesters or polyethers. Examples of commercially available acrylated urethanes include those available under the trade designations "UVITHANE 782" from Morton Thiokol Chemical, and "CMD 6600", "CMD 8400", and "CMD 8805" from UCB Radcure, Smyrna, Ga.

[0069] Acrylated epoxies are diacrylate esters of epoxy resins, such as the diacrylate esters of bisphenol A epoxy resin. Examples of commercially available acrylated epoxies include those available under the trade designations "CMD 3500", "CMD 3600", and "CMD 3700" from UCB Radcure.

[0070] Ethylenically unsaturated resins include both monomeric and polymeric compounds that contain atoms of carbon, hydrogen, and oxygen, and optionally, nitrogen and the halogens. Oxygen or nitrogen atoms or both are generally present in ether, ester, urethane, amide, and urea groups. Ethylenically unsaturated compounds preferably have a molecular weight of less than about 4,000 g/mole and are preferably esters made from the reaction of compounds containing aliphatic monohydroxy groups or aliphatic polyhydroxy groups and unsaturated carboxylic acids, such as acrylic acid, methacrylic acid, itaconic acid, crotonic acid, isocrotonic acid, maleic acid, and the like. Representative examples of acrylate resins include methyl methacrylate, ethyl methacrylate styrene, divinylbenzene, vinyl toluene, ethylene glycol diacrylate, ethylene glycol methacrylate, hexanediol diacrylate, triethylene glycol diacrylate, trimethylolpropane triacrylate, glycerol triacrylate, pentaerythritol triacrylate, pentaerythritol methacrylate, pentaerythritol tetraacrylate and pentaerythritol tetraacrylate. Other ethylenically unsaturated resins include monoallyl, polyallyl, and polymethallyl esters and amides of carboxylic acids, such as diallyl phthalate, diallyl adipate, and N,N-diallyl adipamide. Still other nitrogen containing compounds include tris(2-acryloyl-oxyethyl) isocyanurate, 1,3,5-tri(2-methacryloxyethyl)-s-triazine, acrylamide, N-methylacrylamide, N,N-dimethylacrylamide, N-vinylpyrrolidone, and N-vinylpyrrolidone.

[0071] The aminoplast resins have at least one pendant alpha,beta-unsaturated carbonyl group per molecule or oligomer. These unsaturated carbonyl groups can be acrylate, methacrylate, or acrylamide type groups. Examples of such materials include N-(hydroxymethyl)acrylamide, N,N'-oxydimethylenebisacrylamide, ortho and para acrylamidomethylated phenol, acrylamidomethylated phenolic novolac, and combinations thereof. These materials are further described in U.S. Pat. Nos. 4,903,440 and 5,236,472 (both to Kirk et al.).

[0072] Isocyanurate derivatives having at least one pendant acrylate group and isocyanate derivatives having at least one pendant acrylate group are further described in U.S. Pat. No. 4,652,274 (Boettcher et al.). An example of one isocyanurate material is the triacrylate of tris(hydroxyethyl) isocyanurate.

[0073] Epoxy resins have one or more epoxide groups that may be polymerized by ring opening of the epoxide group(s). Such epoxide resins include monomeric epoxy resins and oligomeric epoxy resins. Examples of useful epoxy resins include 2,2-bis[4-(2,3-epoxypropoxy)-phenyl propane] (diglycidyl ether of bisphenol) and materials available under the trade designations "EPON 828", "EPON 1004", and "EPON 1001F" from Shell Chemical Co., Houston, Tex.; and "DER-331", "DER-332", and "DER-334" from Dow Chemical Co., Midland, Mich. Other suitable epoxy resins include glycidyl ethers of phenol formaldehyde novolac commercially available under the trade designations "DEN-431" and "DEN-428" from Dow Chemical Co.

[0074] The epoxy resins of the invention can polymerize via a cationic mechanism with the addition of an appropriate

cationic curing agent. Cationic curing agents generate an acid source to initiate the polymerization of an epoxy resin. These cationic curing agents can include a salt having an onium cation and a halogen containing a complex anion of a metal or metalloid.

[0075] Other cationic curing agents include a salt having an organometallic complex cation and a halogen containing complex anion of a metal or metalloid which are further described in U.S. Pat. No. 4,751,138 (Tumey et al.). Another example is an organometallic salt and an onium salt is described in U.S. Pat. No. 4,985,340 (Palazzotto et al.); U.S. Pat. No. 5,086,086 (Brown-Wensley et al.); and U.S. Pat. No. 5,376,428 (Palazzotto et al.). Still other cationic curing agents include an ionic salt of an organometallic complex in which the metal is selected from the elements of Periodic Group IVB, VB, VIB, VIIB and VIIIB which is described in U.S. Pat. No. 5,385,954 (Palazzotto et al.).

[0076] Regarding free radical curable resins, in some instances it is preferred that the abrasive slurry further comprise a free radical curing agent. However, in the case of an electron beam energy source, the curing agent is not always required because the electron beam itself generates free radicals.

[0077] Examples of free radical thermal initiators include peroxides, e.g., benzoyl peroxide and azo compounds. Compounds that generate a free radical source if exposed to actinic electromagnetic radiation are generally termed photoinitiators. Examples of photoinitiators that, if exposed to ultraviolet light generate a free radical source, include but are not limited to those selected from the group consisting of organic peroxides, azo compounds, quinones, benzophenones, nitroso compounds, acryl halides, hydrazones, mercapto compounds, pyrylium compounds, triacrylimidazoles, bisimidazoles, chloroalkytriazines, benzoin ethers, benzil ketals, thioxanthones, and acetophenone derivatives, and mixtures thereof. Examples of photoinitiators that, if exposed to visible radiation, generate a free radical source, can be found in U.S. Pat. No. 4,735,632 (Oxman et al.). One suitable photoinitiator for use with visible light is available under the trade designation "IRGACURE 369" from Ciba Specialty Chemicals, Tarrytown, N.Y.

[0078] To promote an association bridge between the abovementioned binder and the abrasive particles, a silane coupling agent may be included in the slurry of abrasive particles and binder precursor, typically in an amount of from about 0.01 to 5 percent by weight, more typically in an amount of from about 0.01 to 3 percent by weight, more typically in an amount of from about 0.01 to 1 percent by weight, although other amounts may also be used, for example depending on the size of the abrasive particles. Suitable silane coupling agents include, for example, methacryloxypropylsilane, vinyltriethoxysilane, vinyltri(2-methoxyethoxy)silane, 3,4-epoxycyclohexylmethyltri-methoxysilane, gamma-glycidoxypolytrimethoxysilane, and gamma-mercaptopropyltrimethoxysilane (e.g., as available under the respective trade designations "A-174", "A-151", "A-172", "A-186", "A-187", and "A-189" from Witco Corp., Greenwich, Conn.), allyltriethoxysilane, diallyldichlorosilane, divinylidethoxysilane, and m,p-styrylthiyltrimethoxysilane (e.g., as commercially available under the respective trade designations "A0564", "D4050", "D6205", and "S 1588" from United Chemical Industries, Bristol, Pa.),

dimethyldiethoxysilane, dihydroxydiphenylsilane, triethoxysilane, trimethoxysilane, triethoxysilanol, 3-(2-aminoethylamino)propyltrimethoxysilane, methyltrimethoxysilane, vinyltriacetoxysilane, methyltriethoxysilane, tetraethyl orthosilicate, tetramethyl orthosilicate, ethyltriethoxysilane, amyltriethoxysilane, ethyltrichlorosilane, amyltrichlorosilane, phenyltrichlorosilane, phenyltriethoxysilane, methyltrichlorosilane, methyldichlorosilane, dimethyldichlorosilane, dimethyldiethoxysilane, and mixtures thereof.

[0079] Structured abrasive articles suitable for embossing may be prepared by forming a slurry of abrasive grains and a solidifiable or polymerizable precursor of the abovementioned binder resin (i.e., a binder precursor), contacting the slurry with a backing (or if present, optional adhesive layer) and at least partially curing the binder precursor (e.g., by exposure to an energy source) in a manner such that the resulting structured abrasive article has a plurality of shaped abrasive composites affixed to the backing. Examples of energy sources include thermal energy and radiant energy (including electron beam, ultraviolet light, and visible light).

[0080] In one embodiment, a slurry of abrasive particles in a binder precursor may be coated directly onto a production tool having precisely shaped cavities therein and brought into contact with the backing (or if present, optional adhesive layer), or coated on the backing and brought to contact with the production tool.

[0081] In this embodiment, the slurry is typically then solidified (e.g., at least partially cured) while it is present in the cavities of the production tool.

[0082] The production tool can be a belt, a sheet, a continuous sheet or web, a coating roll such as a rotogravure roll, a sleeve mounted on a coating roll, or die. The production tool can be composed of metal, (e.g., nickel), metal alloys, or plastic. The metal production tool can be fabricated by any conventional technique such as, for example, engraving, bobbing, electroforming, or diamond turning.

[0083] A thermoplastic tool can be replicated off a metal master tool. The master tool will have the inverse pattern desired for the production tool. The master tool can be made in the same manner as the production tool. The master tool is preferably made out of metal, e.g., nickel and is diamond turned. The thermoplastic sheet material can be heated and optionally along with the master tool such that the thermoplastic material is embossed with the master tool pattern by pressing the two together. The thermoplastic can also be extruded or cast onto the master tool and then pressed. The thermoplastic material is cooled to solidify and produce the production tool. Examples of preferred thermoplastic production tool materials include polyester, polycarbonates, polyvinyl chloride, polypropylene, polyethylene and combinations thereof. If a thermoplastic production tool is utilized, then care must be taken not to generate excessive heat that may distort the thermoplastic production tool.

[0084] The production tool may also contain a release coating to permit easier release of the abrasive article from the production tool. Examples of such release coatings for metals include hard carbide, nitrides or borides coatings. Examples of release coatings for thermoplastics include silicones and fluorochemicals.

[0085] Additional details concerning methods of manufacturing structured abrasive articles having precisely

shaped abrasive composites may be found, for example, in U.S. Pat. No. 5,152,917 (Pieper et al.); U.S. Pat. No. 5,435,816 (Spurgeon et al.); U.S. Pat. No. 5,672,097 (Hoopman); U.S. Pat. No. 5,681,217 (Hoopman et al.); U.S. Pat. No. 5,454,844 (Hibbard et al.); U.S. Pat. No. 5,851,247 (Stoetzel et al.); and U.S. Pat. No. 6,139,594 (Kincaid et al.); the disclosures of which are incorporated herein by reference.

[0086] Precisely shaped abrasive composites may be of any three-dimensional shape that results in at least one of a raised feature or recess on the exposed surface of the abrasive layer. Useful shapes include, for example, cubic, prismatic, pyramidal (e.g., square pyramidal or hexagonal pyramidal), truncated pyramidal, conical, frustoconical. Combinations of differently shaped and/or sized abrasive composites may also be used.

[0087] In another embodiment, a slurry comprising a binder precursor and abrasive particles may be deposited on a backing in a patterned manner (e.g., by screen or gravure printing) and partially polymerized to render at least the surface of the coated slurry plastic but non-flowing. Then, a pattern is embossed upon the partially polymerized slurry formulation, which is subsequently further cured (e.g., by exposure to an energy source) to form a plurality of shaped abrasive composites affixed to the backing. Further details concerning this method and related methods are described, for example, in U.S. Pat. No. 5,833,724 (Wei et al.); U.S. Pat. No. 5,863,306 (Wei et al.); U.S. Pat. No. 5,908,476 (Nishio et al.); U.S. Pat. No. 6,048,375 (Yang et al.); U.S. Pat. No. 6,293,980 (Wei et al.); and U.S. Pat. Appl. Pub. No. 2001/0041511 (Lack et al.); the disclosures of which are incorporated herein by reference.

[0088] For fine finishing applications, the height of the shaped abrasive composites is generally greater than or equal to 1 micrometer and less than or equal to 20 mils (510 micrometers); for example, less than 15 mils (380 micrometers), 10 mils (200 micrometers), 5 mils (200 micrometers), 2 mils (5 micrometers), or even less than 1 mil, although greater and lesser heights may also be used.

[0089] For fine finishing applications, the areal density of shaped abrasive composites in the abrasive layer is typically in a range of from at least 1,000, 10,000, or even at least 20,000 shaped abrasive composites per square inch (e.g., at least 150, 1,500, or even 7,800 shaped abrasive composites per square centimeter) up to and including 50,000, 70,000, or even as many as 100,000 shaped abrasive composites per square inch (7,800, 11,000, or even as many as 15,000 shaped abrasive composites per square centimeter), although greater or lesser densities of shaped abrasive composites may also be used.

[0090] Once the structured abrasive layer is affixed to the backing, the resultant structured abrasive articles, whether in sheet or disc form at this point, have features embossed therein such that both the backing and the structured abrasive layer have superposed embossed features. Embossing may be accomplished by any suitable means including, for example, application of heat and/or pressure to an embossing die (i.e., by embossing) having the desired pattern (or its inverse) depending on the embossing conditions used. The embossing die may comprise, for example, a plate or a roll. Typically, the dimensions of the embossed features will be at least an order of magnitude larger in cross section (e.g., at

least 10, 100 or even at least 1000 times larger) than the average size of the shaped abrasive composites. The embossed features may have any shape or combination of shapes, and may be arranged according to a pseudo-random or regular pattern. For example, they may comprise dimples, posts, bumps, letters, geometric shapes, graphic designs, and combinations thereof. Embossed features may be abrupt or of a gradual nature. In some embodiments, the density of embossed features may be at least 1, 2, 5, 10, or more per square centimeter.

[0091] In general, from 5 to 95 percent of the structured abrasive layer is included within the embossed features of the backing, based on the total area of the backing or optional adhesive layer that contacts the structured abrasive layer, although higher and lower percentages may also be used. Typically, it is desirable to adjust the included percentages to achieve a high value of abrasive cut while maintaining low stiction.

[0092] Embossed structured abrasive articles according to the present invention may be secured to a support structure such, for example, a backup pad secured to a tool such as, for example, a random orbital sander. The optional attachment interface layer may be an adhesive (e.g., a pressure sensitive adhesive) layer or a double-sided adhesive tape. The optional attachment interface layer may be adapted to work with one or more complementary elements affixed to the support pad or back up pad in order to function properly. For example, the optional attachment interface layer may comprise a loop fabric for a hook and loop attachment (e.g., for use with a backup or support pad having a hooked structure affixed thereto), a hooked structure for a hook and loop attachment (e.g., for use with a back up or support pad having a looped fabric affixed thereto), or an intermeshing attachment interface layer (e.g., mushroom type interlocking fasteners designed to mesh with a like mushroom type interlocking fastener on a back up or support pad). Further details concerning such attachment interface layers may be found, for example, in U.S. Pat. No. 4,609,581 (Ott); U.S. Pat. No. 5,152,917 (Pieper et al.); U.S. Pat. No. 5,254,194 (Ott); U.S. Pat. No. 5,454,844 (Hibbard et al.); U.S. Pat. No. 5,672,097 (Hooper); U.S. Pat. No. 5,681,217 (Hooper et al.); and U.S. Pat. Appl. Pub. Nos. 2003/0143938 (Braunschweig et al.) and 2003/0022604 (Annen et al.).

[0093] Likewise, the second major surface of the backing may have a plurality of integrally formed hooks protruding therefrom, for example, as described in U.S. Pat. No. 5,672,186 (Chesley et al.). These hooks will then provide the engagement between the structured abrasive article and a back up pad that has a loop fabric affixed thereto.

[0094] Embossed structured abrasive articles according to the present invention may be provided in any form (for example, as a sheet, belt, or disc), and be of any overall dimensions. Embossed structured abrasive discs may have any diameter, but typically have a diameter in a range of from 0.5 centimeter to 15.2 centimeters.

[0095] The embossed structured abrasive article may have slots or slits therein and may be otherwise provided with perforations.

[0096] Embossed structured abrasive articles according to the present invention are generally useful for abrading a workpiece, and especially those workpieces having a hardened polymeric layer thereon.

[0097] The workpiece may comprise any material and may have any form. Examples of materials include metal, metal alloys, exotic metal alloys, ceramics, painted surfaces, plastics, polymeric coatings, stone, polycrystalline silicon, wood, marble, and combinations thereof. Examples of workpieces include molded and/or shaped articles (e.g., optical lenses, automotive body panels, boat hulls, counters, and sinks), wafers, sheets, and blocks.

[0098] Embossed structured abrasive articles according to the present invention are typically useful for repair and/or polishing of polymeric coatings such as motor vehicle paints and clearcoats (e.g., automotive clearcoats), examples of which include: polyacrylic-polyol-polyisocyanate compositions (e.g., as described in U.S. Pat. No. 5,286,782 (Lamb, et al.); hydroxyl functional acrylic-polyol-polyisocyanate compositions (e.g., as described in U.S. Pat. No. 5,354,797 (Anderson, et al.); polyisocyanate-carbonate-melamine compositions (e.g., as described in U.S. Pat. No. 6,544,593 (Nagata et al.); and high solids polysiloxane compositions (e.g., as described in U.S. Pat. No. 6,428,898 (Barsotti et al.)).

[0099] Protective, glossy finishes such as on automobiles are typically the result of a layer of clearcoat that is sprayed over the colored basecoat. Invariably, this sprayed clearcoat finish contains texture, commonly referred to as "orange peel". In the process of abrasively removing defects (e.g., dust nibs) in the clearcoat, the orange peel in the abraded area is generally also modified. Depending on the particular circumstance and texture of the orange peel in the surrounding area, it may be desirable to remove (flatten) most or all of the orange peel texture. In other instances, it may be desirable to leave as much orange peel texture as possible, also known as "riding" the orange peel.

[0100] For embossed structured abrasive articles according to the present invention that include fine grade abrasives (e.g. P500 and finer), the ability to flatten or ride orange peel can be controlled by selecting an appropriate backing. On one hand, a relatively hard and incompressible backing such as, for example, polyester film or paper will typically result in an abrasive article that tends to level orange peel. On the other hand, a relatively soft backing (e.g., a resilient foam) will tend to ride orange peel, thereby leaving much more texture after abrading. If removing dust nibs in fresh clearcoat applied to a car, it is usually desirable to substantially remove the nib while leaving as much orange peel texture as possible. Typically, there is a continuum of properties in between these two extremes, such that one can find a suitable backing that provides an aesthetically acceptable balance between the two. For example, for denibbing fresh automotive clearcoat, a backing having a hardness (for example, a Shore A, B, C, or D hardness) between that of a polyester film and an open-cell, 6 lb/ft³ (100 kg/m³) polyurethane foam is typically suitable. Backing thickness also typically influences that ability of the embossed structured abrasive article to level orange peel. For example, as the backing gets thicker, there is less ability for the abrasive to locally conform to the orange peel.

[0101] Depending upon the application, the force at the abrading interface can range from about 0.1 kg to over 1000 kg. Generally, this range is between 1 kg to 500 kg of force at the abrading interface. Also, depending upon the application there may be a liquid present during abrading. This

liquid can be water and/or an organic compound. Examples of typical organic compounds include lubricants, oils, emulsified organic compounds, cutting fluids, surfactants (e.g., soaps, organosulfates, sulfonates, organophosphonates, organophosphates), and combinations thereof. These liquids may also contain other additives such as defoamers, degreasers, corrosion inhibitors, and combinations thereof.

[0102] Embossed structured abrasive articles according to the present invention may be used, for example, with a rotary tool that rotates about a central axis generally perpendicular to the structured abrasive layer, or with a tool having a random orbit (e.g., a random orbital sander), and may oscillate at the abrading interface during use. In some instances, this oscillation may result in a finer surface on the workpiece being abraded.

[0103] Objects and advantages of this invention are further illustrated by the following non-limiting 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

[0104] Unless otherwise noted, all parts, percentages, ratios, etc. in the examples and the rest of the specification are by weight, and all reagents used in the examples were obtained, or are available, from general chemical suppliers such as, for example, Sigma-Aldrich Company, Saint Louis, Mo., or may be synthesized by conventional methods.

[0105] The following abbreviations are used throughout the Examples:

[0106] MN1: a grade JIS 1000 silicon carbide abrasive mineral, commercially available under the trade designation "GC1000" from Fujimi Corp., Elmhurst, Ill.

[0107] MN2: grade JIS 2000 silicon carbide abrasive mineral, commercially available under the trade designation "GC2000" from Fujimi Corp., Elmhurst, Ill.

[0108] PM1: 2-phenoxyethyl acrylate monomer available under the trade designation "SR 339" from Sartomer Company, Exton, Pa.

[0109] PM2: trimethylolpropane triacrylate available under the trade designation "SR 351" from Sartomer Company.

[0110] PM3: a polymeric dispersant available under the trade designation "SOLPLUS D520" from Noveon, Inc., Cleveland, Ohio.

[0111] PM4: gamma-methacryloxypropyltrimethoxysilane resin modifier available under the trade designation "SILQUEST A174" from Witco Corporation, Greenwich, Conn.

[0112] PM5: ethyl 2,4,6-trimethylbenzoylphenylphosphinate photoinitiator available under the trade designation "LUCIRIN TPO-L" from BASF Corp., Charlotte, N.C.

[0113] PM6: silicon dioxide available under the trade designation “AEROSIL OX-50” from Degussa Corp., Dusseldorf, Germany.

Preparation of Abrasive Slurry 1 (AS 1)

[0114] PM1 (146.5 grams), 146.5 grams of PM2, 41.85 grams of PM3, 31.41 grams of PM4 and 31.41 grams of PM5 were combined and mixed for 10 minutes at 20° C. PM6 (52.29 grams) was added to the mixture with continued mixing until the mixture appeared homogeneous resulting in a resin pre-mix. MN1 (596 grams) was added to 450 grams of the resin pre-mix, and then combination was mixed for 5 minutes on a high-speed shear mixer until homogeneous to give abrasive slurry AS 1. The temperature during the high speed mixing step was kept below 100° F. (37.8° C.).

Comparative Example A

[0115] AS1 was applied via knife coating to a polypropylene production tool having a uniform pattern, as disclosed in col. 14, line 22-41 and FIGS. 13-15 of U.S. Pat. No. 6,923,840 (Schutz et al.). The slurry coated polypropylene production tool was brought into contact with the adhesive side of a 7 mils (178 micrometers) thickness adhesive coated polyethylene film, commercially available under the trade designation “3M 481 PRESERVATION TAPE”, from 3M Company. The production tool was then irradiated with an ultraviolet (UV) lamp, type “D” bulb, obtained from Fusion Systems Inc., Gaithersburg, Md., operated at 600 Watts per inch (236 Watts per cm) while moving the web at a speed of 30 feet per minute (9.14 meters/minute), and using a nip pressure of 60 pounds per square inch (410 kilopascals (kPa)) for a 10-inch (25.4-cm) wide web. The production tool was removed from the resulting substantially cured shaped abrasive coating.

Comparative Example B

[0116] Dimples were thermally embossed into “3M 481 PRESERVATION TAPE” by conveying the tape through a set of chrome steel nip rolls at a speed of 3 feet/minute (91.4 cm/minute) and using a nip pressure of 275 pounds force per linear inch of web width (48.2 kN/m of web width). One of the nip rolls was a smooth roll at (20° C.), the other roll was patterned with a series of 1.0 mm (diameter) protrusions 2.3 mm high, evenly distributed over the roll surface and accounting for 20% of its area, heated to 200° F. (93.3° C.). AS1 was then applied to the adhesive side of the dimpled polyethylene backing according to the method described in Comparative Example A.

Comparative Example C

[0117] A structured abrasive article was prepared according to the method described in Comparative Example B, except that the dimpled nip roll was replaced with a roll patterned containing a with of a series of 3.25 mm (diameter) holes evenly distributed over the roll surface such that the holes account for 47% of the roll surface; the nip pressure was 250 pounds force per linear inch of web width (43.8 kN/m of web width).

Example 1

[0118] An embossed structured abrasive article was prepared according to the method described in Comparative

Example B, except that the polyethylene backing was embossed after applying and curing the abrasive slurry.

Example 2

[0119] An embossed structured abrasive article was prepared according to the method described in Comparative Example C, except that the polyethylene backing was embossed after applying and curing the abrasive slurry.

[0120] The structured abrasive discs of Comparative Examples A-C and Examples 1 and 2 were laminated to the adhesive coated planar surface of a polypropylene mechanical fastener laminate having hooking stems on the opposite surface as described in U.S. Pat. No. 6,923,840 (Schutz et al.) in col. 15 line 62 through col. 16, line 7. Six-inch (15.2 cm) discs were then die cut from the sheet material from Comparative Examples A-C and Examples 1 and 2.

Testing

[0121] The cut and finish performance of abrasive discs was tested on automotive clearcoat. Additionally, a qualitative assessment was made on the damp-handling stiction of each abrasive during abrading, and whether the abrasive created any “wild scratches” during the abrading process. The workpieces were 18-inch by 24-inch (45.7-cm by 61-cm) clear coated black painted cold roll steel test panels, obtained under the trade designation “APR45077”, from ACT Laboratories, Inc., Hillsdale, Mich. The panels were then scuffed to ensure mechanical paint adhesion using “TRIZACT HOOKIT II BLENDING DISC, 443SA, GRADE P1000” commercially available from 3M Company, attached to a random orbit sander, model number “59025” obtained from Dynabrade, Inc., Clarence, N.Y., operating at a line pressure of 40 pounds per square inch (276 kilopascals (kPa)). The panels were scuffed by abrading around the edges of the panel first, then abrading the entire panel with an up/down motion and then side-to-side motion. The panels had a matte finish when this step was complete. The panels were wiped down with dry paper toweling to remove the wet swarf.

[0122] A clearcoat solution was prepared by mixing together 3 parts of resin, available under the trade designation “CHROMA CLEAR G2 4500S”, 1 part activator, available under the trade designation “62-4508S”, and 1 part reducer, available under the trade designation “12375S”, all commercially available from E. I. du Pont de Nemours & Co., Wilmington, Del. The clearcoat was applied to the panel using a spray gun, model “RP” from SATA Farbspritztechnik GmbH, Kornwestheim, Germany with 1.3-mm spray nozzle was used at 40 pounds per square inch (276 kPa). The clearcoat solution was sprayed onto each panel at a nominal thickness of 2 mils (51 micrometers). The panels were allowed to dry at room temperature in air for 3 days before use, and are referred to hereinafter as workpiece WP 1.

[0123] Each test panel was divided into four 18" (45.7 cm) long lanes, each lane being 6 inches (15.2 cm) wide. Each abrasive disc was tested by damp-abrading (with water) for 30 seconds in a single lane. The test panel was weighed before and after abrading of each lane. The difference in mass is the measured cut, reported as grams per 30 seconds. After abrading, the average surface finish (R_z) in micrometers (μm) of each lane was measured using a profilometer available under the trade designation “SURTRONIC 3+

PROFILOMETER" from Taylor Hobson, Inc., Leicester, England. R_z is the average of 5 individual measurements of the vertical distance between the highest point and the lowest point over the sample length of an individual profilometer measurement. Five finish measurements were made per lane. Four abrasive discs were tested per Lot and the results are reported as average of all four abrasive discs, such that the reported cut is the average of four measurements and the reported finish is the average of 20 measurements. "Stiction", that is, the tendency for the abrasive coating to stick to the workpiece surface, with unwanted results, was also noted. It is generally desired to minimize stiction in fine finishing applications. After finish measurements were made on each panel, it was visually inspected for the existence of "wild scratches". "Wild Scratches" are a line of spiral-shaped or hook-shaped deep scratches in the direction that the DA sander was moved across the abrading substrate. To test for "wild scratches", the panel was buffed using a Dewalt Buffer model no. 849, commercially available from Dewalt Industrial Tool, Hampstead, Md., operating at 1400 rotations per minute (rpm). The buffing process used a machine glaze, available under the trade designation "PERFECT-IT III TRIZACT MACHINE GLAZE", Part No. 05930, a backup pad available under the trade designation "HOOK-IT BACKUP PAD", Part No. 05718, and a polishing pad available under the trade designation "PERFECT-IT FOAM POLISHING PAD", Part No. 05995", all commercially available from 3M Company. The buffing process in this case is intended to remove most of the scratches. The panel was then visually inspected for the presence of "wild scratches". It is generally desirable to eliminate the creation of "wild scratches". Results are reported in Table 1 (below).

TABLE 1

	Average Cut, grams	Standard Deviation	Average R_z , micrometers	Stiction	Wild Scratches
Comparative Example A	0.21	0.03	0.8	Yes	No
Comparative Example B	0.25	0.02	0.9	Slight	Yes
Comparative Example C	0.33	0.04	1.0	Slight	Yes
Example 1	0.35	0.05	1.0	No	No
Example 2	0.37	0.01	1.1	No	No

Preparation of Abrasive Slurry 2 (AS2)

[0124] The resin pre-mix used for AS 1 was also used to prepare AS2. MN2 (596 grams) was added to 450 grams of the resin premix, and the combination was mixed for 5 minutes on a high-speed shear mixer until homogeneous to give abrasive slurry AS2. The temperature during the high speed mixing step was kept below 100° F. (37.8° C.).

Example 3

[0125] A structured abrasive film was prepared according to the method described in Comparative Example A, except that AS2 was substituted for AS1. Subsequently, the resulting structured abrasive film was embossed using the pattern and conditions set forth in Comparative Example B.

Example 4

[0126] A structured abrasive film was prepared according to the method described in Example 3, except that "3M 481

PRESERVATION TAPE" was replaced by a 3.71 mil (94.2 micrometer) polyester film sold as "MA370M" film, from 3M Company.

Example 5

[0127] A structured abrasive film was prepared according to the method described in Example 4, except the polyester film was replaced by a 16-mil (400-micrometer) thickness elastomeric tape, available as "4921" tape from 3M Company.

Example 6

[0128] A structured abrasive film was prepared according to the method described in Example 4, except the polyester film was replaced by a 2-mil (50-micrometer) polypropylene tape, available as "375" tape, commercially available from 3M Company.

[0129] The embossed, structured abrasive sheets of Examples 3-6 were each laminated to double-sided adhesive film, sold as "442 KW" tape, from 3M Company. Discs (1.5" diameter (3.8 cm)) were die cut from the sheet material and evaluated.

[0130] The effect of abrasive backing on orange peel texture modification was tested using WP1 workpieces.

[0131] A 1.5" disc (3.8 cm) from each of Examples 3-6 was used to abrade two dust nibs on a panel. Testing of all specimens was done on a single WP 1 panel for facile, relative comparison of texture modification. Each structured abrasive disc was attached to a random orbit sander, model number "57502" obtained from Dynabrade Inc., Clarence, N.Y., using backup pad part number 02345 commercially available from 3M company, operating at a line pressure of 40 lbs per square inch (280 kilopascals (kPa)). Each dust nib was dry-abraded for five seconds. The abraded areas were then buffed using a Dewalt model no. 849 buffer, commercially available from Dewalt Industrial Tool, operating at 1400 rotations per minute (rpm). The buffing process used a machine glaze, available under the trade designation "PERFECT-IT III TRIZACT MACHINE GLAZE", Part No. 05930, a backup pad available under the trade designation "HOOK-IT BACKUP PAD", Part No. 05718, and a polishing pad available under the trade designation "PERFECT-IT FOAM POLISHING PAD", Part No. 05995", all commercially available from 3M Company. The abraded and buffed WP1 panel was then visually inspected to qualitatively assess the degree of both nib removal and orange peel texture modification.

Orange Peel Rating Scale:

[0132] 1=no change in orange peel appearance

[0133] 2=slight change in orange peel texture

[0134] 3=orange peel texture is reduced, but blends in with remaining orange peel texture

[0135] 4=orange peel texture is noticeably reduced upon close inspection

[0136] 5=significant, noticeable flattening of orange peel texture

Nib Removal Rating Scale:

- [0137] 1=no change in nib appearance or size
- [0138] 2=nib appears to be rounded off
- [0139] 3=significant reduction in nib size, but blends in with remaining orange peel
- [0140] 4=nib is essentially gone
- [0141] 5=complete leveling of nib
- [0142] Results are reported in Table 2 (below).

TABLE 2

Nib removal	Orange Peel Test Rating
Example 3	3
Example 4	4
Example 5	2
Example 6	3

[0143] Various modifications and alterations of this invention may be made by those skilled in the art without departing from the scope and spirit of this invention, and it should be understood that this invention is not to be unduly limited to the illustrative embodiments set forth herein.

What is claimed is:

1. An embossed structured abrasive article consisting of:
 - a backing having first and second major surfaces and comprising an inelastic dense thermoplastic film;
 - an optional adhesive layer in contact and coextensive with, and affixed to, the first major surface;
 - a structured abrasive layer in contact and coextensive with, and affixed to, either the first surface of the backing or the optional adhesive layer, wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder, and wherein both the backing and the structured abrasive layer have superposed embossed features; and
 - an optional attachment interface layer affixed to the second major surface; wherein the embossed structured abrasive article is free of porous resilient components.
2. An embossed structured abrasive article according to claim 1, wherein the optional adhesive layer is present.
3. An embossed structured abrasive article according to claim 1, wherein the optional attachment interface layer is present.
4. An embossed structured abrasive article according to claim 1, wherein from 5 to 95 percent the structured abrasive layer is included within the embossed features of the backing, based on the total area of the backing or optional adhesive layer that contacts the structured abrasive layer.
5. An embossed structured abrasive article according to claim 1, wherein the second major surface is planar.
6. An embossed structured abrasive article according to claim 1, wherein the precisely shaped abrasive composites are substantially identical.
7. An embossed structured abrasive article according to claim 1, wherein the embossed features comprise dimples.
8. An embossed structured abrasive article according to claim 1, wherein the embossed features comprise posts.
9. An embossed structured abrasive article according to claim 1, wherein the abrasive particles have an average size in a range of from at least 0.01 up to and including 1,500 micrometers.
10. An embossed structured abrasive article according to claim 1, wherein the abrasive composites have an areal density in a range of from at least 150 up to and including 15,000 shaped abrasive composites per square centimeter of the structured abrasive layer.
11. An embossed structured abrasive article according to claim 1, wherein the structured abrasive article comprises a structured abrasive disc.
12. An embossed structured abrasive article according to claim 11, wherein the disc has a diameter in a range of from 0.6 centimeter to 15.2 centimeters.
13. A method of abrading a workpiece, the method comprising:
 - a) providing an embossed structured abrasive article according to claim 1;
 - b) providing a workpiece having a hardened polymeric layer thereon;
 - c) frictionally contacting at least a portion of the structured abrasive layer with the polymeric layer; and
 - d) moving at least one of the workpiece and the structured abrasive layer relative to the other to abrade at least a portion of the polymeric layer.
14. A method according to claim 13, further comprising contacting a liquid with at least a portion of the polymeric layer and at least a portion of the structured abrasive layer during step d).
15. A method according to claim 13, wherein the polymeric layer comprises an automotive clearcoat.
16. A method of making an embossed structured abrasive article, the method comprising:
 - providing a backing having first and second major surfaces and comprising an inelastic dense thermoplastic film;
 - affixing an adhesive layer in contact and coextensive with the first major surface;
 - affixing a structured abrasive layer in contact and coextensive with the adhesive layer, wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder;
 - embossing the backing and structured abrasive layer to provide superposed embossed features in the backing and structured abrasive layer;
 - optionally affixing an attachment interface layer to the second major surface; and thereby providing an embossed structured abrasive article that is free of porous resilient components.
17. A method according to claim 16, further comprising converting the structured abrasive article to at least one structured abrasive disc.
18. A method according to claim 16, wherein from 5 to 95 percent the structured abrasive layer is included within the embossed features of the backing, based on the total area of the backing or optional adhesive layer that contacts the structured abrasive layer.

19. A method of making an embossed structured abrasive article, the method comprising:

providing an inelastic dense thermoplastic film backing having first and second major surfaces;

affixing a structured abrasive layer to the backing, wherein the structured abrasive layer contacts and is coextensive with the adhesive layer, and wherein the structured abrasive layer consists of outwardly protruding precisely shaped abrasive composites comprising abrasive particles and a binder;

embossing the backing and structured abrasive layer to provide superposed embossed features in the backing and structured abrasive layer;

optionally affixing an attachment interface layer to the second major surface; and thereby providing an embossed structured abrasive article that is free of porous resilient components.

20. A method according to claim 19, further comprising converting the structured abrasive article to at least one structured abrasive disc.

21. A method according to claim 19, wherein from 5 to 95 percent the structured abrasive layer is included within the embossed features of the backing, based on the total area of the backing or optional adhesive layer that contacts the structured abrasive layer.

* * * * *