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(54) **Title**: FLEXIBLE ABRASIVE ARTICLE AND METHOD OF USING THE SAME

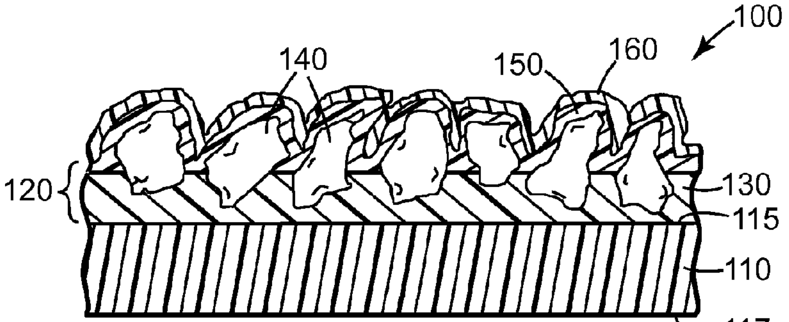

FIG. 1

(57) **Abstract**: A flexible abrasive article includes a unitary backing having first and second opposed major surfaces and comprising a polyurethane. In some embodiments, the backing has an average thickness of from 4 to 6 mils (102 to 152 microns), a tensile strength of 500 to 3200 psi (3.45 to 22.1 MPa), and an ultimate elongation of 230 to 530 percent. In some embodiments, the flexible abrasive article has a tensile strength of 400 to 2400 psi (2.8 to 16.5 MPa), and a ultimate elongation of 180 to 380 percent. An abrasive layer is disposed on and secured to the unitary backing.

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FLEXIBLE ABRASIVE ARTICLE AND METHOD OF USING THE SAME

BACKGROUND

Sandpaper is widely sold in home improvement and hardware stores for household sanding applications. Common household substrates to be sanded include, for example, moldings, raised panels, carvings, and flutings. It is common practice for users to fold and/or wrap the sandpaper around their finger tip for greater control and ability to get into tight spots. However, such practices may be less than ideal due to stiffness of typical paper-backed sandpaper; indeed, the sandpaper may crack thereby causing reduced product life.

SUMMARY

The present inventors have overcome the above-mentioned deficiencies by making a flexible abrasive article that includes a flexible and durable backing comprising polyurethane.

Advantageously, the flexible abrasive products may outlast commercial sandpaper sold into the home improvement market by up to 1600 percent. Further, the flexible abrasive articles are sufficiently flexible that they are well-suited for sanding intricate details in wooden architectural element such as moldings, raised panels, carvings, flutings, etc., and can be easily and comfortably be rolled, folded, or wrapped around the user's fingertip for superior control and ability to get into tight spots.

In one aspect, the present disclosure provides a flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the backing has an average thickness of from 4 to 6 mils (102 to 152 microns), a tensile strength of 500 to 3200 pounds per square inch (psi) (3.45 to 22.1 MPa), and a ultimate elongation of 230 to 530 percent; and

an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article.

In another aspect, the present disclosure provides a flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the unitary backing has an average thickness of from 4 to 6 mils (102 to 152 microns); and an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article,

wherein the flexible abrasive article has a tensile strength of 400 to 2400 psi (2.8 to 16.5 MPa), and a ultimate elongation of 180 to 380 percent.

In another aspect, the present disclosure provides a method of abrading a workpiece, the method comprising:

providing a flexible abrasive article according to the present disclosure;

frictionally contacting at least a portion of the abrasive layer with a surface of a workpiece; and

moving at least one of the abrasive layer or the surface of the workpiece to abrade the surface of the workpiece.

As used herein:

the prefix "(meth)acryl" refers to acryl, methacryl, or both;

the term "polyepoxide" refers to a compound having at least two epoxy groups;

the term "polyfunctional poly(meth)acrylate" refers to a compound having at least two (meth)acrylate groups; and.

the term "tensile strength" refers to tensile strength at break, unless otherwise specified.

In this application, elongation at break and tensile strength are to be determined according to ASTM International Test Method D882-12"Standard Test Method for Tensile Properties of Thin Plastic Sheeting", published September 2012 by ASTM International, West Conshohocken, Pennsylvania, using an extension rate of ten percent of the gauge length per minute.

Features and advantages of the present disclosure will be further understood upon consideration of the detailed description as well as the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side view of a flexible abrasive article 100 according to the present disclosure.

It should be understood that numerous other modifications and embodiments can be devised by those skilled in the art, which fall within the scope and spirit of the principles of the disclosure. The figure may not be drawn to scale.

DETAILED DESCRIPTION

Referring now to FIG. 1, flexible abrasive article 100 comprises unitary polyurethane backing 110 having first and second opposed major surfaces 115, 117. Abrasive layer 120 is disposed on and secured to first major surface 115 of unitary polyurethane backing 110. Abrasive layer 120 comprises make layer 130, abrasive particles 140, and size layer 150 which is disposed on make layer 130 and abrasive particles 140. Optional supersize layer 160 is disposed on size layer 150.

The backing may have a number of physical properties that collectively impart flexibility and durability to the flexible abrasive articles.

In a first embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the backing may have a tensile strength in the range of from 500 to 3200 psi (3.4 to 22.1 MPa), preferably 1000 to 2500 psi (6.9 to 17.2 MPa), more preferably 1600 to 2100 psi (11.0 to 14.5 MPa), and an ultimate elongation (i.e., elongation at break) of 230 to 530 percent, preferably300 to 460 percent, and more preferably 350 to 410 percent.

In a second embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the backing may have an average tensile strength in the range of from 500 to 3200 pounds per square inch (psi) (3.4 to 22.1 MPa), preferably 1000 to 2500 psi (6.9 to 17.2 MPa), more preferably 1600 to 2100 psi (11.0 to 14.5 MPa), and an average ultimate elongation (i.e., elongation at break) of 230 to 530 percent, preferably300 to 460 percent, and more preferably 350 to 410 percent.

In a third embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the backing may have a maximum, and optionally minimum, tensile strength in the range of from 500 to 3200 pounds per square inch (psi) (3.4 to 22.1 MPa), preferably 1000 to 2500 psi (6.9 to 17.2 MPa), more preferably 1600 to 2100 psi (11.0 to 14.5 MPa), and a maximum, and optionally minimum, ultimate elongation (i.e., elongation at break) of 230 to 530 percent, preferably300 to 460 percent, and more preferably 350 to 410 percent.

In a fourth embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the flexible abrasive article may have a tensile strength of from at least 400 psi (2.8 MPa), at least 500 psi (3.4 MPa), at least 600 psi (4.1MPa), at least 700 psi (4.8 MPa), at least 800 psi (5.5 MPa), at least 900 psi (6.2 MPa), at least 1000 psi (6.9 MPa), at least 1100 psi (7.6 MPa), at least 1200 psi (8.3 MPa), or even at least 1300 psi (9.0 MPa) up to 1500 psi (10.3 MPa), 1600 psi (11.0 MPa), 1700 psi (11.7 MPa), 1800 psi (12.4 MPa), 1900 psi (13.1 MPa), 2000 psi (13.8 MPa), 2100 psi (14.5 MPa), 2200 psi (15.1 MPa), 2300 psi (15.9 MPa), or even up to 2400 psi (16.5 MPa), or any combination thereof, and the flexible abrasive article has an ultimate elongation of from at least 180, at least 190, at least 200, at least 210, at least 220, at least 230, at least 240, at least 250, at least 260, or even at least 270 percent up to 340 percent, up to 350 percent, up to 360 percent, up to370 percent or even up to380 percent, or any combination thereof.

In a fifth embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the flexible abrasive article may have an average tensile strength of from at least 400 psi (2.8 MPa), at least 500 psi (3.4 MPa), at least 600 psi (4.1MPa), at least 700 psi (4.8 MPa), at least 800 psi (5.5 MPa), at least 900 psi (6.2 MPa), at least 1000 psi (6.9 MPa), at least 1100 psi (7.6 MPa), at least 1200 psi (8.3 MPa), or even at least 1300 psi (9.0 MPa) up to 1500 psi (10.3 MPa), 1600 psi (11.0 MPa), 1700 psi (11.7 MPa), 1800 psi (12.4 MPa), 1900 psi (13.1 MPa), 2000 psi (13.8 MPa), 2100 psi (14.5 MPa), 2200 psi (15.1 MPa), 2300 psi (15.9 MPa), or even up to 2400 psi (16.5 MPa), or any combination thereof, and the flexible abrasive article has an ultimate elongation of from at least 180, at least 190, at least 200, at least 210, at least 220, at least 230, at least 240, at least 250, at least 260, or even at least 270 percent up to 340 percent, up to 350 percent, up to 360 percent, up to370 percent or even up to380 percent, or any combination thereof.

In a sixth embodiment, the backing may have an average thickness of 4 to 6 mils (102 to 152 microns), preferably 4.5 to 6.5 mils (114 to 165 microns), and more preferably 4.8 to 6.2 mils (122 to 157 microns). In this embodiment, the flexible abrasive article may have an average maximum and/or minimum tensile strength of from at least 400 psi (2.8 MPa), at least 500 psi (3.4 MPa), at least 600 psi (4.1MPa), at least 700 psi (4.8 MPa), at least 800 psi (5.5 MPa), at least 900 psi (6.2 MPa), at least 1000 psi (6.9 MPa), at least 1100 psi (7.6 MPa), at least 1200 psi (8.3 MPa), or even at least 1300 psi (9.0 MPa) up to 1500 psi (10.3 MPa), 1600 psi (11.0 MPa), 1700 psi (11.7 MPa), 1800 psi (12.4 MPa), 1900 psi (13.1 MPa), 2000 psi (13.8 MPa), 2100 psi (14.5 MPa), 2200 psi (15.1 MPa), 2300 psi (15.9 MPa), or even up to 2400 psi (16.5 MPa), or any combination thereof, and the flexible abrasive article has an ultimate elongation of from at least 180, at least 190, at least 200, at least 210, at least 220, at least 230, at least 240, at least 250, at least 260, or even at least 270 percent up to 340 percent, up to 350 percent, up to 360 percent, up to370 percent or even up to380 percent, or any combination thereof.

The backing may be unitary; that is, it may consist of a single layer, although in certain embodiments it may be a composite backing, if desired. Typically, the backing is at least substantially homogeneous, although this is not a requirement. The backing may be perforated; however, if perforated, the average thickness is not determined using areas of the perforations where the thickness would, of course, be zero as no backing is present there. Preferably, the backing is impermeable to liquid water and substantially free of void space, although minor amounts of porosity may be acceptable. For example, the backing may have less than 10 percent, less than 2 percent, less than 1 percent, or even less than 0.01 percent of intrinsic voids (i.e., voids that are not deliberately added, but are an intrinsic property of the material making up the backing), based on the total volume of the backing.

The backing may comprise one or more polyurethanes. Preferably, the polyurethane comprises, or at least consists essentially of, at least one thermoplastic polyurethane (TPU). The term "consisting essentially of" as used in this context means that additive compounds (e.g., fragrances, colorants, antioxidants, UV light stabilizers, and/or fillers) may be present in the backing as long as tensile strength and ultimate elongation remains substantially unaffected by their presence. For example, the additives may have less than a 5 percent, preferably less than 1 percent, effect on tensile strength and ultimate elongation.

In some embodiments, the backing may comprise a single thermoplastic polyurethane or a combination of thermoplastic polyurethanes. One preferred class of polyurethanes is aromatic polyether – based polyurethanes, preferably thermoplastic polyether-based polyurethanes. In some embodiments, the thermoplastic polyether-bases polyurethanes are derived from 4,4'-methylenedicyclohexyl diisocyanate (MDI), a polyether polyol, and butanediol.

Thermoplastic polyurethanes are well known and can be made according to many known techniques, or they may be obtained for commercial suppliers. For example, Lubrizol Corp., Cleveland, Ohio, is one commercial supplier of various thermoplastic polyurethanes such as , for example: polyester-based aromatic TPUs available under the trade designation "ESTANE GP TPU (B series)" (e.g., grades 52 DB, 55 DB, 60 DB, 72 DB, 80 AB, 85 AB, and 95 AB); and polyester and polyether based TPU s available under the trade designation "ESTANE 58000 TPU series" (e.g., grades 58070, 58091, 58123, 58130, 58133, 58134, 58137, 58142, 58144, 58201, 58202, 58206, 58211, 58212, 58213, 58215, 58219, 58226, 58237, 58238, 58244, 58245, 58246, 58248, 58252, 58271, 58277, 58280, 58284, 58300, 58309, 58311, 58315, 58325, 58370, 58437, 58610, 58630, 58810, 58863, 58881, and 58887).

The backing may be cast (e.g., from solvent or water) or extruded. It may contain one or more additives such as fillers, melt processing aids, antioxidants, flame retardants, colorants, or ultraviolet light stabilizers.

The make and size layers can be prepared by curing a respective make or size layer precursor. The make and size layer precursors may have the same or different compositions, and may be applied at the same or different coat weights.

The make and size layer comprise at least one polyepoxide and at least one polyfunctional (meth)acrylate, a curative (e.g., polyamine, polythiol, acid catalyst, or photocatalyst) for the polyepoxide and a free-radical initiator (photoinitiator and/or thermal initiator). Monofunctional epoxides and polyols (e.g., diols used as chain extenders) may also be used in combination with the polyepoxide(s).

Useful polyepoxides may be aromatic or aliphatic polyepoxide(s), or a combination thereof. Useful polyepoxides may be liquid or solid, but are typically liquid for ease of handling. Whether liquid or solid, the polyepoxide(s) should generally be selected such that it can be dissolved in the precursor composition (e.g., make or size layer precursor composition). In some instances, heating may be useful to facilitate dissolution of the polyepoxide.

Examples of aromatic polyepoxides include: polyglycidyl ethers of polyhydric phenols such as such as bisphenol A diglycidyl ether (commonly referred to in the art as DGEBA) and commercially available bisphenol A-derived and bisphenol F-derived epoxy resins having the trade designation "EPON" (for example, EPON RESIN 825, EPON RESIN 828, EPON RESIN 1001F, EPON RESIN 1002F, EPON RESIN 1004F, EPON RESIN 1007F, and EPON RESIN 1009F), marketed by Hexion Specialty Chemicals, Columbus, Ohio, and bisphenol A-derived epoxy resins having the trade designation "DER" (for example, DER 332, DER 337, DER 362, and DER 364), marketed by Dow Chemical Company, Midland, Michigan; epoxy cresol-novolac resins; epoxy phenol-novolac resins; and glycidyl esters of aromatic carboxylic acids (e.g., phthalic acid diglycidyl ester, isophthalic acid diglycidyl ester, trimellitic acid triglycidyl ester, and pyromellitic acid tetraglycidyl ester), and combinations thereof.

Examples of useful aliphatic polyepoxides include epoxycyclohexanecarboxylates (e.g., 3,4-epoxycyclohexylmethyl 3,4-epoxycyclohexanecarboxylate (e.g., as available as ERL-4221 from Dow Chemical Co.); 3,4-epoxy-2-methylcyclohexylmethyl 3,4-epoxy-2-methylcyclohexanecarboxylate; bis(3,4-epoxy-6-methylcyclohexylmethyl) adipate; 3,4-epoxy-6-methylcyclohexylmethyl 3,4-epoxy-6-methylcyclohexanecarboxylate (e.g., as available as ERL-4201 from Dow Chemical Co.); vinylcyclohexene dioxide (e.g., as available as ERL-4206 from Dow Chemical Co.); bis(2,3-epoxycyclopentyl) ether (e.g., as available as ERL-0400 from Dow Chemical Co.); bis(3,4-epoxy-6-methylcyclohexylmethyl) adipate (e.g., as available as ERL-4289 from Dow Chemical Co.); dipenteric dioxide (e.g., as available as ERL-4269 from Dow Chemical Co.); 2-(3,4-epoxycyclohexyl-5,1'-spiro-3',4'-epoxycyclohexane-1,3-dioxane; and 2,2-bis(3,4-epoxycyclohexyl)propane.

The amount of polyepoxide present in the make layer precursor typically ranges from about 40 to 70 percent by weight, preferably 50 to 60 percent by weight, based on the total weight of solids (i.e., nonvolatile components) in the make layer precursor, although amounts outside this range may also be used.

Useful polyfunctional (meth)acrylates may be liquid or solid, but are typically liquid for ease of handling. Whether liquid or solid, the polyfunctional (meth)acrylates should generally be selected such that it can be dissolved in the precursor composition. In some instances, heating may be useful to facilitate dissolution of the polyfunctional (meth)acrylate. Exemplary useful polyfunctional (meth)acrylates include (meth)acrylate monomers, (meth)acrylate oligomers, (meth)acrylated polymers, and combinations thereof.

A wide variety of polyfunctional (meth)acrylate(s) are readily commercially available; for example, from such vendors as Sartomer Co., Exton, Pennsylvania, and UCB Chemicals Corp., Smyrna, Georgia.

Exemplary polyfunctional (meth)acrylate(s) include ethylene glycol di(meth)acrylate, hexanediol di(meth)acrylate, triethylene glycol di(meth)acrylate and methacrylate, trimethylolpropane tri(meth)acrylate, glycerol tri(meth)acrylate, pentaerythritol tri(meth)acrylate and methacrylate, ethoxylated trimethylolpropane tri(meth)acrylate and trimethacrylate, neopentyl glycol di(meth)acrylate and dimethacrylate, pentaerythritol tetra(meth)acrylate and tetramethacrylate, dipentaerythritol penta(meth)acrylate, sorbitol tri(meth)acrylate, sorbitol hexa(meth)acrylate, Bisphenol A di(meth)acrylate, ethoxylated Bisphenol A di(meth)acrylate, and mixtures thereof.

Example of useful polyfunctional (meth)acrylate monomers include trimethylolpropane triacrylate, available, for example, from Sartomer Co. as SR 351; ethoxylated trimethylolpropane triacrylate, available, for example, from Sartomer Co. as SR 454; pentaerythritol tetraacrylate, available, for example, from Sartomer Co. as SR 295; and neopentyl glycol diacrylate, available, for example, from Sartomer Co. as SR 247.

The polyfunctional acrylate may comprise at least one (meth)acrylate oligomer. Exemplary (meth)acrylate oligomers include (meth)acrylated epoxy oligomers (e.g., Bisphenol-A based epoxy (meth)acrylate oligomers), aliphatic urethane (meth)acrylate oligomers, and aromatic urethane (meth)acrylate oligomers. Additional useful polyfunctional (meth)acrylate oligomers include polyether oligomers such as a polyethylene glycol 200 diacrylate, available, for example, from Sartomer Co. as SR 259 and a polyethylene glycol 400 diacrylate available from Sartomer Co. as SR 344; and acrylated epoxies including those available as EBECRYL 3500, EBECRYL 3600, and EBECRYL 3700, from UCB Chemicals Corp.

In some preferred embodiments, the, polyfunctional (meth)acrylate, whether present as a blend of polymerizable (meth)acrylates or as a single component, has an average (meth)acryloxy group functionality of at least 2.2., at least 2.5, or even at least 3.

The amount of polyfunctional (meth)acrylate(s) present in the make layer precursor typically ranges from about 5 to about 20 percent by weight, preferably from about 5 to about 15 percent by weight, and even more desirably from about 8 to about 12 percent by weight, based on the total weight of solids (i.e., nonvolatile components) in the make layer precursor, although amounts outside this range may also be used.

The make and size layer precursors may further comprise an optional bireactive polymerizable component, for example, a compound having at least one free-radically polymerizable group, and at least one cationically polymerizable group. Bireactive compounds can be made, for example, by introducing at least one ethylenically-unsaturated group into a compound that already contains one or more epoxy groups, or, conversely, by introducing at least one epoxy group into a compound that already contains one or more ethylenically-unsaturated group.

Exemplary bireactive polymerizable compounds include those contained in the reaction products of 0.4 to 0.6 weight equivalent of an acrylic acid and one mole of diglycidyl ether of Bisphenol A, polyglycidyl ether of phenol-formaldehyde novolac, polyglycidyl ether of cresol-formaldehyde novolac, diglycidyl terephthalate, triglycidyl ester of trimellitic acid, dicyclopentadiene dioxide, vinylcyclohexene dioxide, bis(2,3-epoxycyclopentyl)ether, 3,4-epoxycyclohexylmethyl 3,4-epoxycyclohexanecarboxylate, and bis(3,4-epoxy-6-methylcyclohexyl)methyl adipate.

If used, optional bireactive materials are desirably selected such that they do not significantly inhibit the cure of cationically polymerizable resin. Exemplary groups that may interfere with such cure include primary, secondary and tertiary amines, amides, and imides.

The make and size layer precursor typically contain an effective amount of curative for the polyepoxide curative (e.g., a polyamine or a Lewis acid catalyst) and free-radical polymerization initiator (preferably a free-radical photoinitiator) for the polyfunctional (meth)acrylate; however, depending on curing conditions this is not a requirement.

Suitable curative(s) include those that are photosensitive and/or thermally-sensitive, and desirably comprise at least one free-radical polymerization initiator and at least one cationic polymerization catalyst, which may be the same or different. In order to minimize heating during cure while preserving pot-life of the make and/or size layer precursors, the precursors are preferably photocurable and comprise a photoinitiator and/or a photocatalyst.

"Photocatalysts" as defined herein are materials that form active species that, if exposed to actinic radiation, are capable of at least partially polymerizing polyepoxides employed in practice of the present disclosure. Optionally, the binder precursor may comprise at least one photocatalyst (e.g., an onium salt and/or cationic organometallic salt).

Desirably, onium salt photocatalysts comprise iodonium complex salts and/or sulfonium complex salts. Useful aromatic onium complex salts are further described, for example, in U.S. Pat. No. 4,256,828 (Smith). Exemplary aromatic iodonium complex salts include diaryliodonium hexafluorophosphate or a diaryliodonium hexafluoroantimonate. Exemplary aromatic sulfonium complex salts include as triphenylsulfonium hexafluoroantimonate and p-phenyl(thiophenyl)diphenylsulfonium hexafluoroantimonate.

Aromatic onium salts, useful in practice of the present disclosure, are typically photosensitive only in the ultraviolet region of the spectrum; however, they can be sensitized to the near ultraviolet and the visible range of the spectrum by sensitizers for known photolyzable organic halogen compounds. Exemplary sensitizers include aromatic amines and colored aromatic polycyclic hydrocarbons, as described, for example, in U.S. Pat. No. 4,250,053 (Smith).

Suitable photoactivatable organometallic complex salts useful in the present disclosure include those described, for example, in U.S. Pat. Nos. 5,059,701 (Keipert); 4,751,138 (Tumey); 4,985,340 (Palazzotto); 5,191,101 (Palazzotto et al.); and 5,252,694 (Willett et al.).

Exemplary organometallic complex cations useful as photoactivatable catalysts include:

(η6-benzene)(η5-cyclopentadienyl) Fe^+ SbF_6^-,

(η6-toluene)(η5 -cyclopentadienyl)Fe^+ SbF_6^-,

(η6-xylene)(η5 -cyclopentadienyl) Fe^+ SbF_6^-,

(η6-cumene)(η5 -cyclopentadienyl) Fe^+ PF_6^-,

(η6-xylenes (mixed isomers))(η5 -cyclopentadienyl)Fe^+ SbF_6^-,

(η6-xylenes (mixed isomers))(η5 -cyclopentadienyl)Fe^+ PF_6^-,

(η6-o-xylene)(η5 -cyclopentadienyl)Fe^+ $CF_3SO_3^-$,

(η^6-m-xylene)(η^5 -cyclopentadienyl)Fe^+ BF_4^-,

(η^6-mesitylene)(η^5 -cyclopentadienyl)Fe^+ SbF_6^-,

(η^6-hexamethylbenzene)(η^5 -cyclopentadienyl)Fe^+ SbF_5OH^-, and

η^6-fluorene)(η^5 -cyclopentadienyl)Fe^+ SbF_6^-.

Optionally, organometallic salt initiators can be accompanied by an accelerator such as an oxalate ester of a tertiary alcohol. If present, the accelerator desirably comprises from about 0.1 to about 4 percent by weight of the total binder precursor, more desirably about 60 percent of the weight of the organometallic salt initiator.

Useful commercially available photocatalysts include an aromatic sulfonium complex salt available as UVI-6974 from Dow Chemical Co.

Useful free-radical photoinitiators include, for example, those known as useful for photocuring free-radically polyfunctional acrylates. Exemplary photoinitiators include benzoin and its derivatives such as α-methylbenzoin; α-phenylbenzoin; α-allylbenzoin; α-benzylbenzoin; benzoin ethers such as benzil dimethyl ketal; benzoin methyl ether; benzoin ethyl ether; benzoin n-butyl ether; acetophenone and its derivatives such as 2-hydroxy-2-methyl-1-phenyl-1-propanone and 1-hydroxycyclohexyl phenyl ketone; 2-methyl-1-[4-(methylthio)phenyl]-2-(4-morpholinyl)-1-propanone; 2-benzyl-2-(dimethlamino)-1-[4-(4-morpholinyl)phenyl]-1-butanone; pivaloin ethyl ether; anisoin ethyl ether; anthraquinones such as anthraquinone, e.g., 2-ethylanthraquinone; 1-chloroanthraquinone; 1,4-dimethylanthraquinone; 1-methoxyanthraquinone; benzanthraquinonehalomethyltriazines; benzophenone and its derivatives; diaryliodonium salts and triarylsulfonium salts; titanium complexes such as bis(η^5-2,4-cyclopentadien-1-yl)bis[2,6-difluoro-3-(1H-pyrrol-1-yl)phenyl]titanium, halomethylnitrobenzenes; mono- and bis-acylphosphines; and combinations thereof.

Photoinitiators and photocatalysts useful in the present disclosure can be present in an affect amount, generally in the range of 0.01 to 10 weight percent, more typically 0.01 to 5, or even 0.1 to 2 weight percent, based on the total solids of the make and size/layer precursors amount of photocurable (i.e., crosslinkable by electromagnetic radiation) components of the binder precursor, although amounts outside of these ranges may also be useful.

Optionally, thermal curative may be included in the binder precursor. Desirably, such thermal curative is thermally stable at temperatures at which mixing of the components takes place. Exemplary thermal curatives for epoxy resins and acrylates are well known in the art, and are described, for example, in U.S. Pat. No. 6,258,138 (DeVoe et al.). Thermal curative may be present in the make and/or size layer precursors in any effective amount. Such amounts are typically in the range of about 0.01 parts to 5 parts, desirably in the range from about 0.025 to 2 parts by weight, based on the total solids of the make and size/layer precursors, although amounts outside of these ranges may also be useful.

The make, size, and optional supersize layer precursors used to make flexible abrasive articles according to the present disclosure may optionally contain additional curable components such as, for example, phenolic resins (novolac or resole), aminoplasts, cyanate resins, isocyanate resins, and/or alkyd resins.

In addition to other components, the make, size, and optional supersize layers, of flexible abrasive articles according to the present disclosure may contain optional additives, for example, to modify performance and/or appearance. Exemplary optional additives include grinding aids, fillers, plasticizers, wetting agents, surfactants, pigments, coupling agents, fibers, lubricants, thixotropic materials, antistatic agents, suspending agents, pigments, and dyes.

Exemplary grinding aids, which may be organic or inorganic, include waxes, halogenated organic compounds such as chlorinated waxes like tetrachloronaphthalene, pentachloronaphthalene, and polyvinyl chloride; halide salts such as sodium chloride, potassium cryolite, sodium cryolite, ammonium cryolite, potassium tetrafluoroborate, sodium tetrafluoroborate, silicon fluorides, potassium chloride, magnesium chloride; and metals and their alloys such as tin, lead, bismuth, cobalt, antimony, cadmium, iron, and titanium; and the like. Examples of other grinding aids include sulfur, organic sulfur compounds, graphite, and metallic sulfides. A combination of different grinding aids can be used such as that described, for example, in U.S. Pat. No. 5,552,225 (Ho).

The basis weight of the make layer (i.e., after curing) may depend, for example, on the intended use(s), type(s) of abrasive particles, and nature of the coated abrasive article being prepared, but generally will be in the range of from about 1 to about 30 grams per square meter (i.e., gsm), preferably from about 10 to about 25 gsm, and more desirably from about 10 to about 20 gsm.

The make layer can be formed by coating the make layer precursor on a major surface of the backing The make layer precursor may be applied, for example, by any known coating method for applying a make layer to a backing including, for example, roll coating, extrusion die coating, curtain coating, knife coating, gravure coating, and spray coating.

After the make layer precursor is applied to the backing, but before the size layer precursor is applied, the abrasive particles can be applied to make layer precursor and then the make layer precursor can be optionally partially cured (e.g., to an a-stage or b-stage).

Abrasive particles suitable for use in abrasive layers utilized in practice of the present disclosure include any abrasive particles known in the abrasive art. Exemplary useful abrasive particles include fused aluminum oxide based materials such as aluminum oxide, ceramic aluminum oxide (which may include one or more metal oxide modifiers and/or seeding or nucleating agents), and heat-treated aluminum oxide, silicon carbide, co-fused alumina-zirconia, diamond, ceria, titanium diboride, cubic boron nitride, boron carbide, garnet, flint, emery, sol-gel derived abrasive particles, and blends thereof. Desirably, the abrasive particles comprise fused aluminum oxide, heat-treated aluminum oxide, ceramic aluminum oxide, silicon carbide, alumina zirconia, garnet, diamond, cubic boron nitride, sol-gel derived abrasive particles, or mixtures thereof. Examples of sol-gel abrasive particles include those described U.S. Pat. Nos. 4,314,827 (Leitheiser et al.); 4,518,397 (Leitheiser et al.); 4,623,364 (Cottringer et al.); 4,744,802 (Schwabel); 4,770,671 (Monroe et al.); 4,881,951 (Wood et al.); 5,011,508 (Wald et al.); 5,090,968 (Pellow); 5,139,978 (Wood); 5,201,916 (Berg et al.); 5,227,104 (Bauer); 5,366,523 (Rowenhorst et al.); 5,429,647 (Laramie); 5,498,269 (Larmie); and 5,551,963 (Larmie).

The abrasive particles may be in the form of, for example, individual particles, agglomerates, abrasive composite particles, alpha alumina abrasive shards, and mixtures thereof. Exemplary agglomerates are described, for example, in U.S. Pat. Nos. 4,652,275 (Bloecher et al.) and 4,799,939 (Bloecher et al.). It is also within the scope of the present disclosure to use diluent erodible agglomerate grains as described, for example, in U.S. Pat. No. 5,078,753 (Broberg et al.). Abrasive composite particles comprise abrasive grains in a binder. Exemplary abrasive composite particles are described, for example, in U.S. Pat. No. 5,549,962 (Holmes et al.). Alpha alumina abrasive shards are described in U.S. Pat. Appln. Publ. 2011/0314746 A1 (Erickson et al.).

The abrasive particles typically have an average diameter of from about 0.1 to about 2000 micrometers, more desirably from about 1 to about 1300 micrometers. Abrasive particles are generally graded to a given particle size distribution before use. Such distributions typically have a range of particle sizes, from coarse particles to fine particles. In the abrasive art this range is sometimes referred to as a "coarse", "control", and "fine" fractions.

Abrasive particles graded according to abrasive industry accepted grading standards specify the particle size distribution for each nominal grade within numerical limits. Such industry accepted grading standards (i.e., abrasive industry specified nominal grade) include those known as the American National Standards Institute, Inc. (ANSI) standards, Federation of European Producers of Abrasive Products (FEPA) standards, and Japanese Industrial Standard (JIS) standards.

ANSI grade designations (i.e., specified nominal grades) include: ANSI 4, ANSI 6, ANSI 8, ANSI 16, ANSI 24, ANSI 36, ANSI 40, ANSI 50, ANSI 60, ANSI 80, ANSI 100, ANSI 120, ANSI 150, ANSI 180, ANSI 220, ANSI 240, ANSI 280, ANSI 320, ANSI 360, ANSI 400, and ANSI 600. FEPA grade designations include P8, P12, P16, P24, P36, P40, P50, P60, P80, P100, P120, P150, P180, P220, P320, P400, P500, P600, P800, P1000, and P1200. JIS grade designations include JIS8, JIS12, JIS16, JIS24, JIS36, JIS46, JIS54, JIS60, JIS80, JIS100, JIS150, JIS180, JIS220, JIS240, JIS280, JIS320, JIS360, JIS400, JIS600, JIS800, JIS1000, JIS1500, JIS2500, JIS4000, JIS6000, JIS8000, and JIS10,000. For use in hand sanding applications such as wood trim and moldings (painted or unpainted) with shaped three-dimensional surfaces, the abrasive particles have a size distribution falling within the range of ANSI grades P100 to P320, inclusive.

Alternatively, the abrasive particles can graded to a nominal screened grade using U.S.A. Standard Test Sieves conforming to ASTM E-11 "Standard Specification for Wire Cloth and Sieves for Testing Purposes". ASTM E-11 proscribes the requirements for the design and construction of testing sieves using a medium of woven wire cloth mounted in a frame for the classification of materials according to a designated particle size. A typical designation may be represented as -18+20 meaning that abrasive particles pass through a test sieve meeting ASTM E-11 specifications for the number 18 sieve and are retained on a test sieve meeting ASTM E-11 specifications for the number 20 sieve. In certain embodiments, the abrasive particles have a particle size such that most of the abrasive particle pass through an 18 mesh test sieve and can be retained on a 20, 25, 30, 35, 40, 45, or 50 mesh test sieve. In various embodiments of the present disclosure, the abrasive particles can have a nominal screened grade comprising: -18+20, -20+25, -25+30, -30+35, -35+40, -40+45, -45+50, -50+60, -60+70, -70+80, -80+100, -100+120, -120+140, -140+170, -170+200, -200+230, -230+270, -270+325, -325+400, -400+450, -450+500, or -500+635.

Coating weights for the abrasive particles may depend, for example, on the binder precursor used, the process for applying the abrasive particles, and the size of the abrasive particles, but typically range from about 5 to about 250 grams per square meter (gsm), preferably from 20 to 100 gsm, more preferably 30 to 80 gsm, and more preferably 45 to 65 gsm; although other amounts may also be used.

Next, the size layer precursor can be applied over the make layer precursor and abrasive particles and the make and size layer precursors sufficiently cured to form a useable coated abrasive article. Curing may be accomplished using thermal and/or photochemical methods.

As with the make layer, the size layer can be likewise formed from a precursor composition (i.e., size layer precursor). The size layer can be include any of the components listed hereinabove for use in the make layer precursor.

The amount of polyepoxide present in the size layer precursor typically ranges from about 40 to 80 percent by weight, preferably 50 to 70 percent by weight, and more preferably 55 to 65 percent by weight, based on the total weight of solids (i.e., nonvolatile components) in the make layer precursor, although amounts outside this range may also be used.

The amount of polyfunctional (meth)acrylate(s) present in the size layer precursor typically ranges from about 5 to about 50 percent by weight, preferably from about 15 to about 40 percent by weight, and even more desirably from about 25 to about 35 percent by weight, based on the total weight of solids (i.e., nonvolatile components) in the make layer precursor, although amounts outside this range may also be used.

The basis weight of the size layer (i.e., after curing) will also necessarily vary depending on the intended use(s), type(s) of abrasive particles, and nature of the coated abrasive article being prepared, but generally will be in the range of from 10 to 150 gsm, preferably from 20 to 80 gsm, and more preferably from 35 to 55 gsm. The size layer may be applied, for example, by any known coating method for applying a size layer to a backing, including, for example, roll coating, extrusion die coating, curtain coating, and spray coating.

Next, the size layer precursor and any uncured make layer precursor are sufficiently cured to provide a usable coated abrasive article. In general, this curing step involves thermal and/or radiation energy (e.g., ultraviolet and/or visible actinic radiation or electron beam radiation), but this is not a requirement. Useful forms of thermal energy include, for example, heat and infrared radiation. Exemplary sources of thermal energy include ovens (for example, festoon ovens), heated rolls, hot air blowers. Exemplary sources of radiation energy include, for example, electron beam, ultraviolet light (e.g., from a medium pressure mercury bulb, a xenon flashlamp, or a type H or type D microwave-driven bulb), and visible light. Other sources of radiation energy include infrared and microwave. Electron beam radiation, which is also known as ionizing radiation, can be used at a dosage of about 0.1 to about 10 megarads (Mrad0, preferably at a dosage of about 1 to about 10 Mrad. Ultraviolet radiation refers to non-particulate radiation having a wavelength within the range of about 200 to about 400 nanometers (nm), preferably within the range of about 250 to 400 nm. In certain embodiments, the ultraviolet radiation can be provided by ultraviolet lights at a dosage of 100 to 300 Watts/cm. Visible radiation refers to non-particulate radiation having a wavelength within the range of about 400 to about 800 nm, and in certain embodiments, within the range of about 400 to about 550 nm.

Optionally a supersize layer may be applied to at least a portion of the size layer. If present, the supersize typically includes grinding aids and/or anti-loading materials. The optional supersize layer may serve to prevent or reduce the accumulation of swarf (the material abraded from a workpiece) between abrasive particles, which can dramatically reduce the cutting ability of the coated abrasive article. Useful supersize layers typically include a grinding aid (for example, potassium tetrafluoroborate), metal salts of fatty acids (for example, zinc stearate or calcium stearate), salts of phosphate esters (for example, potassium behenyl phosphate), phosphate esters, urea-formaldehyde resins, mineral oils, crosslinked silanes, crosslinked silicones, and/or fluorochemicals. Useful supersize materials are further described, for example, in U.S. Pat. No. 5,556,437 (Lee et al.).

The basis weight of the supersize layer, if present, can be from 1 to 50 gsm, more preferably 5 to 30 gsm, more preferably from about 10 to about 20 gsm. The supersize may contain a binder such as for example, those used to prepare the size or make layer, but it need not contain any binder resin. The supersize layer is generally dried and/or cured to provide a flexible abrasive article, which may be in sheet of web form, for example. Converting into particular shapes (e.g., rectangular sheets or discs) can be accomplished using conventional methods such as, for example die cutting, knife cutting, and laser cutting.

The resulting flexible abrasive article may be subjected to further conventional treatments such as, for example, printing, laser marking, trimming, perforating, flexing, post-curing, or a combination thereof.

In certain embodiments, for example, those in which the flexible abrasive article is at least translucent, indicia or other markings can be disposed (e.g., printed) on the first major surface of the backing prior to coating the make layer precursor, although it can be placed on the second major surface of the backing as well.

In some preferred embodiments, the various components are selected such that the flexible abrasive article is sufficiently translucent or transparent that a user can visually perceive the workpiece while abrading without removing the flexible abrasive article from the surface of the workpiece. This offers an advantage as compared with paper-backed abrasive products.

Flexible abrasive articles according to the present disclosure are typically well-suited for use in hand sanding applications to painted or unpainted wood or metal workpieces (e.g., furniture and architectural trim such as moldings, handrails, or cabinetry), especially involving curved and/or complex surface shapes. Advantages of flexible abrasive products according to the present disclosure for this use may include one or more of excellent hand feel, hand grip, see-through translucency, and flexibility and conformability to workpiece surfaces comprises architectural trim having three-dimensional detail.

SELECT EMBODIMENTS OF THE PRESENT DISCLOSURE

In a first embodiment, the present disclosure provides a flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the backing has an average thickness of from 4 to 6 mils (102 to 152 microns), a tensile strength of 500 to 3200 psi (3.45 to 22.1 MPa), and a ultimate elongation of 230 to 530 percent; and

an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article.

In a second embodiment, the present disclosure provides a flexible abrasive article according to the first embodiment, the present disclosure provides a flexible abrasive article according to the first or second embodiment, wherein the abrasive particles have a nominal size grade of less than or equal to an ANSI grade P80 and greater than or equal to ANSI grade P320.

In a third embodiment, the present disclosure provides a flexible abrasive article according to the first embodiment, wherein the abrasive particles have a nominal size grade of less than or equal to an ANSI grade P180 and greater than or equal to ANSI grade P320.

In a fourth embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to third embodiments, wherein the average thickness of the backing is from 4.5 to 5.5 mils.

In a fifth embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to fourth embodiments, wherein the backing comprises a thermoplastic polyurethane.

In a sixth embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to fifth embodiments, wherein the flexible abrasive article is translucent.

In a seventh embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to sixth embodiments, further comprising a supersize layer disposed on at least a portion of the size layer.

In an eighth embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to seventh embodiments, wherein the backing has a maximum tensile strength of 1000 to 2500 psi and a maximum ultimate elongation of 300 to 460 percent.

In a ninth embodiment, the present disclosure provides a flexible abrasive article according to any one of the first to seventh embodiments, wherein the backing has a maximum tensile strength of 1600 to 2100 psi and a maximum ultimate elongation of 350 to 410 percent.

In a tenth embodiment, the present disclosure provides a flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the unitary backing has an average thickness of from 4 to 6 mils (102 to 152 microns); and

an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer precursor comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article,

wherein the flexible abrasive article has a tensile strength of 400 to 2400 psi (2.8 to 16.5 MPa), and a ultimate elongation of 180 to 380 percent.

In an eleventh embodiment, the present disclosure provides a method of abrading a workpiece, the method comprising:

providing a flexible abrasive article according to any one of the first to tenth embodiments;

frictionally contacting at least a portion of the abrasive layer with a surface of a workpiece; and moving at least one of the abrasive layer or the surface of the workpiece to abrade the surface of the workpiece.

In a twelfth embodiment, the present disclosure provides a method according to the tenth embodiment, wherein the workpiece comprises painted or unpainted wood or metal.

In a thirteenth embodiment, the present disclosure provides a method according to the eleventh or twelfth embodiment, wherein the workpiece comprises architectural trim having three-dimensional detail.

In a fourteenth embodiment, the present disclosure provides a flexible abrasive article according to any one of the eleventh to thirteenth embodiments, wherein the flexible abrasive article is hand held.

Objects and advantages of this disclosure 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 disclosure.

EXAMPLES

Unless otherwise noted, all parts, percentages, ratios, etc. in the Examples and the rest of the specification are by weight. Materials listed without sources may be obtained from general commercial suppliers such as, for example, Aldrich Chemical Company, Milwaukee, Wisconsin, or synthesized according to known methods.

MATERIAL ABBREVIATIONSUSED IN THE EXAMPLES

"ACR" refers to trimethylolpropane triacrylate.

"ABR" refers to a P320 semi-friable blend of mineral abrasive particles consisting of 96% by weight of aluminum oxide, 3 percent by weight of titanium dioxide, and less than 1% by weight total of other oxides (silicon, magnesium, calcium, iron) available as ARTIRUNDUM SFB from Art Abrasives Limited, Suzhou, China.

"AMOX" refers to di-t-amyl oxalate, which can be made by esterification of oxalic acid with t-amyl alcohol as described in Example 11 of U.S. Pat. No. 4,904,814 (Frei et al.).

"CHDM" refers to 1,4-cyclohexanedimethanol.

"EP1" refers to a Bisphenol-A epichlorohydrin based epoxy resin having an epoxy equivalent weight of 525-550 g/eq, an average epoxy functionality of 2, available as EPON 1001F from Momentum Specialty Chemicals, Inc., Columbus, Ohio.

"EP2" refers to a Bisphenol-A epoxy resin having an epoxy equivalent weight of 185-192 g/eq. and an average epoxy functionality of 2, available as EPON 828 from Momentum Specialty Chemicals, Inc.

"EP3" refers to (3',4'-epoxycyclohexylmethyl) 3',4'-epoxycyclohexanecarboxylate.

"PC1" refers to a mixture of 4-thiophenylphenyl diphenyl sulfonium hexafluoroantimonate and bis[4-(diphenylsulfonio)phenyl]sulfide bis(hexafluoroantimonate) in propylene carbonate, obtained under the trade designation CPI 6976 from Aceto Corporation, Port Washington, New York.

"PC2" refers to 2,2-dimethoxy-2-phenylacetophenone, obtained under trade designation IRGACURE 651 from BASF, Wyandotte, Michigan.

"PC3" refers to η^6-[xylene(mixed-isomers)]η^5-cyclopentadienyliron(1+) hexafluoro antimonate(1-).

"PC4" refers to 2,4,6-trimethylbenzoylphenylphosphinic acid ethyl ester, obtained under the trade designation IRGACURE TPO-L from BASF, Wyandotte, Michigan.

"PEP" refers to refers to a high molecular weight, hydroxyl-terminated, saturated, linear, semi-crystalline, copolyester, M_W = 35,000g/mol, available as DYNAPOL S 1227 from Evonik Industries, Parsippany, New Jersey.

"PI" refers to 2-hydroxy-2-methyl-1-phenyl-1-propanone.

"PropCarb" refers to propylene carbonate, obtained under the trade designation JEFFSOL PC from Huntsman Corp, Woodlands, Texas.

"ZNST" refers to a 39-41 percent by weight aqueous zinc stearate soap dispersion obtained under trade designation EC994C from eChem LTD, Leeds, UK..

Preparation of Flexible Film Backing

Thermoplastic polyether-based polyurethane resin (available as ESTANE 58887 NAT 021from Lubrizol Advanced Materials, Inc., Cleveland, Ohio) was extruded at an average film thickness of 5 mils. Representative tensile properties according to ASTM international test method D882-12 were: down web = 131 ± 9 kg-force/cm^2 (1860 ± 130 psi, 12.8 ± 0.9MPa) tensile strength and ultimate elongation = 391 ±17 percent; cross web = 126 ± 4 kg-force/cm^2 (1790 ± 60 psi, 12.3 ± 0.3MPa) tensile strength and ultimate elongation = 383 ±18 percent.

Preparation of Make Layer Precursor

A make resin was prepared as follows, according to the compositions listed in Table 1. AMOX, EP1, EP2, CHDM and PEP were directly metered to a twin screw extruder running at 300 rpm with temperature zones of 30, 105, 110, 100, 65 and 60°C. This mixed resin was then fed to a pin mixer running at 1750 rpm, and ACR, PC2, PC3, PC4, and PropCarb were directly metered into the pin mixer. The output from the pin mixer was fed to a heated coating die, where the flow rate from the pin mixer was controlled so as to achieve the make resin target on the abrasive backing..

TABLE 1

COMPONENT	PERCENT BY WEIGHT BASED ON TOTAL WEIGHT OF THE COMPOSITION
EP1	24.0
EP2	32.0
PEP	28.0
ACR	10.0
CHDM	2.8
PC2	0.5
PC3	0.7
PC4	0.3
propylene carbonate	1.1
AMOX	0.6

Preparation of Size Layer Precursor

Table 2 lists the components and the amounts used to formulate the size resin. Size resin was prepared by combining and mixing EP2, EP3, and ACR in a container. Prior to abrasive making, PC1 and PI were added to the premixed resin batch and stirred for 30 minutes at room temperature until homogeneous.

TABLE 2

INGREDIENT TYPE	PERCENT BY WEIGHT BASED ON TOTAL WEIGHT OF THE COMPOSITION
EP2	38
EP3	29
ACR	29
PC1	3
PI	1

EXAMPLE 1

This example was prepared generally as follows. In a continuous process, a make layer (see Table 1 formulation) precursor was coated onto the polyurethane flexible film at a nominal coating weight of 16.5 g/m^2. A polyethylene terephthalate liner was used to help convey the polyurethane film backing through the coating process and was later removed.

The coated web was then passed under a Fusion UV Systems with one set of D-bulbs and one set of V-bulbs, both operating at 600 W/in (236 W/cm). Next, ABR abrasive particles were coated onto the make layer at a nominal coating weight of 55 g/m^2, and the web was then heated under infrared heaters at a nominal web temperature setting of 100 °C for about 7 seconds. The size layer precursor (see Table 2 formulation) was then coated onto the make layer and abrasive particles at a nominal dry coat weight of 43 g/m^2 and passed under a Fusion UV Systems with one set of H-bulbs, and two sets of D-bulbs, all three operating at 600 W/in (236 W/cm). It was then processed through infrared ovens having a target exit web temperature of 125°C. ZNST at a nominal coating weight of 14 g/m^2 was then coated onto the size layer and processed through a drying oven with a target exit web temperature of 135°C. The resultant coated abrasive articles were then maintained at room temperature (i.e., 20-24 °C) and 40-60 percent relative humidity until tested.

COMPARATIVE EXAMPLE A

Aluminum oxide sandpaper (220 grit, paper-backed), available from 3M Company was used as Comparative Example A (CE-A).

Backing Wear Evaluation Test

Test specimens that measured 2.5 in x 6.0 in (6.4 cm x 15.2 cm, the "short" specimen) and 2.5 in x 9 in (9.4 cm x 22.9 cm, the "long" specimen) were cut from a coated abrasive article (i.e., sandpaper CE-A or flexible abrasive article according to Example 1) to be evaluated.

The testing apparatus consisted of a mechanically driven rubber bottomed sanding block upon which the samples were attached (bottom surface area measured 2.5 in x 6.0 in (6.4 cm x 15.2 cm)).

Adhesive transfer tape (#950 available from 3M Company) was applied to the grit side of the short specimen. The liner was removed and double-sided adhesive tape (#442KW available from 3M Company) was applied on top of the transfer tape adhesive. The liner from the double-sided tape was removed and the sample was attached to the rubber bottom of the sanding block fixture. The long specimen was then attached over the short specimen (grit side facing down), and was secured on each end of the sanding block fixture with clips.

The grit sides of the long specimen was urged with a constant load of 16 lbs (7.3 kg) against a stationary surface of a cellulose acetate butyrate substrate and passed back and forth over an 18 in (46 cm) wide (Y direction) by 24 in (61 cm) length (X direction) area of the substrate at a rate of 20 inches (51 cm) per second in the X direction and 3 inches (7.6 cm) per second in the Y direction. The backing surfaces of the short and long specimens rubbed against each other during the test. Back and forth one time was considered one pass, and there were 50 passes per cycle. This was repeated until the sample backing tore. The number of cycles it took for the sample to tear was recorded.

Backing Wear Evaluation Test Data

The flexible abrasive article of Example 1 was evaluated for backing wear by comparing it to CE-A as described in the Backing Wear Evaluation Test. Three samples CE-A were tested. The highest number of cycles the CE-A specimens survived was 44 cycles. Six samples of flexible abrasive article of Example 1 were tested. All six reached 700 cycles without tearing at which point the test was stopped.

All cited references, patents, and patent applications in the above application for letters patent are herein incorporated by reference in their entirety in a consistent manner. In the event of inconsistencies or contradictions between portions of the incorporated references and this application, the information in the preceding description shall control. The preceding description, given in order to enable one of ordinary skill in the art to practice the claimed disclosure, is not to be construed as limiting the scope of the disclosure, which is defined by the claims and all equivalents thereto.

What is claimed is:

1. A flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the backing has an average thickness of from 4 to 6 mils, a tensile strength of 500 to 3200 psi, and a ultimate elongation of 230 to 530 percent; and

an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer precursor comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article.

2. The flexible abrasive article of claim 1, wherein the abrasive particles have a nominal size grade of less than or equal to an ANSI grade P80 or greater than or equal to an ANSI grade P320.

3. The flexible abrasive article of claim 1, wherein the abrasive particles have a nominal size grade of less than or equal to an ANSI grade P180 or greater than or equal to ANSI grade P320.

4. The flexible abrasive article of any one of claims 1 to 3, wherein the average thickness of the backing is from 4.5 to 5.5 mils.

5. The flexible abrasive article of any one of claims 1 to 4, wherein the backing comprises a thermoplastic polyurethane.

6. The flexible abrasive article of any one of claims 1 to 5, wherein the flexible abrasive article is translucent.

7. The flexible abrasive article of any one of claims 1 to 6, further comprising a supersize layer disposed on at least a portion of the size layer.

8. The flexible abrasive article of any one of claims 1 to 7, wherein the backing has a maximum tensile strength of 1000 to 2500 psi and a maximum ultimate elongation of 300 to 460 percent.

9. The flexible abrasive article of any one of claims 1 to 7, wherein the backing has a maximum tensile strength of 1600 to 2100 psi and a maximum ultimate elongation of 350 to 410 percent.

10. A flexible abrasive article comprising:

a unitary backing having first and second opposed major surfaces and comprising a polyurethane, wherein the unitary backing has an average thickness of from 4 to 6 mils; and

an abrasive layer disposed on and secured to the unitary backing, wherein the abrasive layer comprises:

a make layer disposed on at least a portion of the first major surface of the unitary backing, wherein the make layer comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate;

abrasive particles secured to the make layer; and

a size layer disposed on at least a portion of the make layer and abrasive particles, wherein the size layer precursor comprises a polymerized reaction product of components comprising at least one polyepoxide and at least one polyfunctional (meth)acrylate, wherein the second major surface of the unitary backing forms an outer major surface of the flexible abrasive article,

wherein the flexible abrasive article has a tensile strength of 400 to 2400 psi (2.8 to 16.5 MPa), and a ultimate elongation of 180 to 380 percent.

11. A method of abrading a workpiece, the method comprising:

providing a flexible abrasive article according to any one of claims 1 to 10;

frictionally contacting at least a portion of the abrasive layer with a surface of a workpiece; and

moving at least one of the abrasive layer or the surface of the workpiece to abrade the surface of the workpiece.

12. The method of claim 11, wherein the workpiece comprises painted or unpainted wood or metal.

13. The method of claim 11 or 12, wherein the workpiece comprises architectural trim having three-dimensional detail.

14. The method of any one of claims 11 to 13, wherein the flexible abrasive article is hand held.

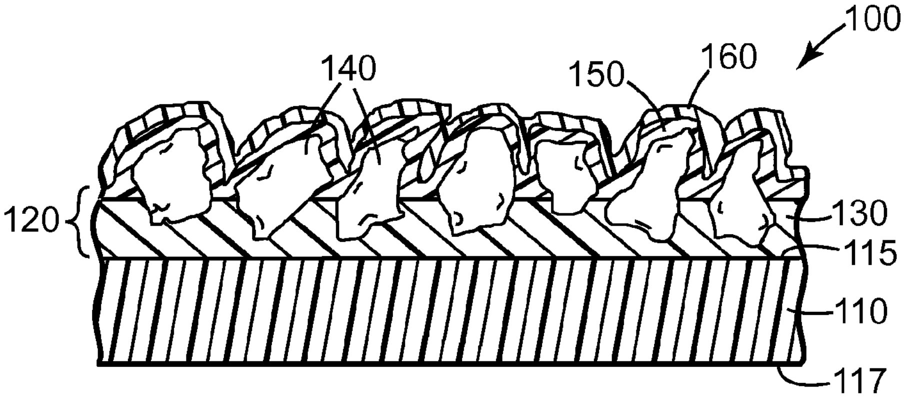

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/027189

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B24D 3/28 (2015.01)
CPC - B24D 3/28 (2015.05)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B24D 3/00, 3/28, 11/00 (2015.01)
CPC - B24D 3/28, 3/34, 11/00 (2015.05)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 51/295, 298; 428/323; 451/28 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents, Google Scholar, Google.
Search terms used: abrasive, article, flexible, make, layer, polyepoxide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/0176156 A1 (BRAUNSCHWEIG et al) 18 September 2003 (18.09.2003) entire document	1-4, 10
A	US 2006/0288647 A1 (THURBER et al) 28 December 2006 (28.12.2006) entire document	1-4, 10
A	US 2003/0148106 A1 (MA et al) 07 August 2003 (07.08.2003) entire document	1-4, 10
A	US 5,766,277 A (DEVOE et al) 16 June 1998 (16.06.1998) entire document	1-4, 10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search 26 June 2015	Date of mailing of the international search report 21 JUL 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/027189

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 5-9, 11-14
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.