ACRYLATE COLOR-STABILIZED PHENOLIC BOUND ABRASIVE PRODUCTS AND METHODS FOR MAKING SAME

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Abstract
Described is a color-stable abrasive article that includes a phenolic resin binder; a color stabilizer, a colorant, and abrasive grains. The color stabilizer includes at least one acrylate. The color-stable abrasive article is formed by a method including the steps of blending a resole and a color stabilizer to form a resole composition; contacting a plurality of abrasive particles with the resole composition; and curing the resole composition to produce the color-stable abrasive article. Thus provided are color stabilized phenolic bound abrasives and a method for making such abrasives that resist color change over time and upon exposure to high temperature and maintain the mechanical strength of a phenolic resin.
ACRYLATE COLOR-STABILIZED PHENOLIC BOUND ABRASIVE PRODUCTS AND METHODS FOR MAKING SAME

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 61/199,471, filed on Nov. 17, 2008. The entire teachings of the above application are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The term “phenolic resin” describes a wide variety of resin products that result from the reaction product of phenols and aldehydes. Phenols react with formaldehydes under both acidic and basic conditions. If a base-catalyzed mixture of a phenol and a formaldehyde contains one or more moles of formaldehyde per mole of phenol, it will produce a thermosetting (one-step) resin, or “resole.” Common base compounds employed as catalysts for resole resins include the hydroxides of alkali metals, such as sodium, potassium, or lithium. While alkali metal hydroxide-catalyzed phenolic resins are commercially useful, they have an undesirable tendency to darken as they age, are heated or otherwise cured. The extent of darkening is known to be dependent on the curing or use temperature of the resin and the time of exposure to such temperature.

[0003] Alkali metal hydroxide-catalyzed phenolic resins are commonly used as a component of the bond system of abrasive products, such as coated, bonded, and three-dimensional, low density abrasive products. The resin darkening problem is particularly pronounced in coated abrasive and three-dimensional, low density abrasive products because of the more visible presence of the bond system. Also, since the darkening increases with temperature and exposure time, any variation in the temperature profile of the product results in color variation within the product itself. Color variation is particularly noticeable for light-colored products, causing such products to be unacceptable for aesthetic or other reasons.

[0004] Furthermore, abrasive bond systems may comprise colorants to identify the manufacturer, type of product, application, etc. The darkening of the resin can interfere with the desired coloration, causing the final product to have a different color from the colorant added. For example, a resin that normally turns yellow after curing will yield a green colored product when combined with a blue dye or pigment. On the other hand, if the same yellow resin is combined with a green dye or pigment, the resin will typically result in simply another shade of green.

[0005] One known method for imparting color stability in phenolic resoles includes adding melamine formaldehyde resin into the formulation. While this achieves color stability, it also imparts brittleness, takes longer to cure, and results in mechanical weakness and therefore reduced grinding performance in the finished product.

[0006] Another proposed method includes the addition of an ammonium based salt to the phenolic resole. However, this method is not sufficiently effective in stabilizing the color of phenolic resin products having certain colorants, such as light blue and orange pigments or dyes.

[0007] What is needed is an effective phenolic resin color-stabilizer that reduces the aforementioned problems without imparting undesirable properties in the finished product.

SUMMARY OF THE INVENTION

[0008] In one aspect, the present invention is directed to a color-stable abrasive article that includes a phenolic resin binder; a color stabilizer, a colorant, and abrasive grains. The color stabilizer includes at least one acrylate.

[0009] In another aspect, the present invention is directed to a method of making a color-stable abrasive article including the steps of blending a resole and a color stabilizer to form a resole composition; contacting a plurality of abrasive particles with the resole composition; and curing the resole composition to produce the color-stable abrasive article. The color stabilizer comprises at least one acrylate.

[0010] In yet another aspect, the present invention is directed to a method for abrading a work surface including applying color-stable abrasive article to a work surface in an abrading motion to remove a portion of the work surface. The abrasive product includes a binder having a phenolic resin, a color-stabilizer that includes at least one acrylate, and abrasive grains.

[0011] Thus provided are color stabilized phenolic bound abrasives and a method for making such abrasives that resist color change over time and upon exposure to high temperature and maintain the mechanical strength of a phenolic resin.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments of the present invention.

[0013] FIG. 1 is a schematic representation of a cross-sectional view of one embodiment of coated abrasive tools of the invention.

[0014] FIG. 2 is a schematic representation of a cross-sectional view of another embodiment of coated abrasive tools of the invention.

DETAILED DESCRIPTION OF THE INVENTION


[0016] The present invention relates to abrasive articles which include a phenolic resin binder that is color-stabilized by acrylates. The color-stabilized abrasive article further includes a colorant and abrasive grains. As used herein, an abrasive article or resin is considered to be “color-stable” if it has essentially the same color after about 8 hours of curing at about 235°F as it does after about 2 hours of curing at about 235°F.

[0017] The term “phenolic resin” refers to any resinous reaction product of a phenol, such as phenol, resorcinol, alkyl-substituted phenol such as cresol, xylenol, p-tert-butyphenol, and p-phenylphenol and the like, with an aldehyde,
such as formaldehyde, acetaldehyde and furfuraldehyde, and the like. "Color-stabilized alkali metal hydroxide catalyzed phenolic resin" refers to a cured alkali metal hydroxide phenolic resin which is color-stabilized by a color stabilizing agent.

[0018] The abrasive products are characterized by having a phenolic resin binder, one or more acrylate color-stabilizers, one or more optional colorants, abrasive grains, a support member or backing, and can further include curing agents, non-reactive thermoplastic resins, fillers, grinding aids, and other additives.

Structure and Methods of Making the Abrasive Article

[0019] In one embodiment, the color-stabilized abrasive article includes a phenolic resin binder, a color stabilizer, and an abrasive material. The color-stabilized abrasive article can be either a bonded, structured, or coated abrasive.

[0020] Coated abrasive tools of the invention can include a substrate, an abrasive material and at least one phenolic resin binder to hold the abrasive material to the substrate. As used herein, the term "coated abrasive tool" encompasses a non-woven abrasive tool. The abrasive material, such as abrasive grains, particles or agglomerate thereof, can be present in one layer (e.g., resin-abrasive layer) or in two layers (e.g., make coat and size coat) of the coated abrasive tools. Examples of such coated abrasive tools that can be made by the methods of the invention are shown in FIGS. 1 and 2. Referring to FIG. 1, in coated abrasive tool 10, substrate 12 is treated with optional backsize coat 16 and optional presize coat 18. Overlaying the optional presize coat 18 is make coat 20 to which abrasive material 14, such as abrasive grains or particles, are applied. Size coat 22 is optionally applied over make coat 20 and abrasive material 14. Overlaying size coat 22 is optional supersize coat 24. Depending upon their specific applications, coated abrasive tool 10 may or may not include backsize coat 16 and/or presize coat 18. Also, depending on their specific applications, coated abrasive tool 10 may or may not include size coat 22 and/or supersize coat 24. Shown in FIG. 2 is an example of coated abrasive tools that can be formed by the methods of the invention, where coated abrasive tool 30 includes a single binder/abrasive layer 32 of an abrasive material and adhesive(s) and optional backsize coat 16. Optionally, presize coat 18, size coat 22 and supersize coat 24, as shown in FIG. 1, can be included in coated abrasive tool 30. The coated abrasive article can include a color stable phenolic resin binder in at least one layer selected from the group consisting of a binder/abrasive layer, a backsize coat, a presize coat, a make coat, a size coat, and a supersize coat.

[0021] In embodiments including size coats and supersize coats, such as that shown in FIG. 1, abrasive materials can be applied separately by gravity, electrostatic deposition, air stream, or as a slurry together with the polyurethane adhesive compositions. The make coat 20 adheres the abrasive material to the surface of the substrate, and can be formed by impregnating the support substrate with the phenolic resin binder without abrasive grains.

[0022] In the embodiment of FIG. 2, the support substrate may be impregnated with a resin/abrasive slurry that includes an abrasive material and a resin composition including a phenolic resin binder and a color-stabilizer, to form a binder/abrasive layer 32.

[0023] In one embodiment, a method of making a color-stable abrasive article includes: blending a resole and a color-stabilizer comprising at least one acrylate to form a resole composition; contacting a plurality of abrasive particles with the resole composition; and curing the resole composition to produce the color-stable abrasive product. In addition to the coated abrasives described above, color-stable abrasive articles formed by this method include, for example, structured abrasives and bonded abrasives.

[0024] With respect to structured abrasives, the article is formed by any of those techniques known in the art in which abrasive structures are shaped prior to curing. Such techniques include, for example, embossing techniques. In one embodiment, for instance, a mixture of phenolic resin binder, acrylate color-stabilizer, optional colorants, and abrasive grains, can be contacted with a backing and a production tool wherein the mixture adheres to one surface of the backing. Abrasive structures are thus formed that have the shape of an inside surface of the production tool.

[0025] A bonded abrasive article can be formed by preparing an agglomerate that includes the phenolic resin binder, acrylate color-stabilizer, optional colorants, and abrasive grains. The agglomerate is then shaped using any of the techniques known in the art for preparing a bonded abrasive. Suitable techniques for preparing bonded abrasives are further described in, for example, U.S. Pat. Nos. 5,738,696 of Wu; 5,738,697 of Wu, et al.; and 6,679,758 of Bright, et al.; and U.S. Patent Publication No. 2003/0192258 A1 of Simon, the entire contents of each of which are incorporated herein by reference.

[0026] A work surface is abraded by applying the color-stable abrasive article to a work surface in an abrading motion to remove a portion of the work surface.

Phenolic Resin Binder

[0027] Typical phenolic resins employed in the present invention are resoles, which result from the alkali metal hydroxide catalyzed reaction of phenol and formaldehyde in a mole ratio of phenol/formaldehyde of about 1:1 to about 1:3 moles and a mole ratio of phenol/alkali metal hydroxide of about 1:1 to about 100:1. The color of such resole, or base-catalyzed phenolic resin is stabilized by the addition of one or more acrylates. Durez Vacurn Resin No. 94908, manufactured by Durez Corporation is one example of a water-based, single-staged liquid phenolic resin that can be used as the binder. Other examples are provided in Table 1 below.

<table>
<thead>
<tr>
<th>Phenolic Resin Binders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin Code</td>
</tr>
<tr>
<td>HJR15881</td>
</tr>
<tr>
<td>HJR15997</td>
</tr>
<tr>
<td>HJR16051</td>
</tr>
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<td>94-908</td>
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<td>13537</td>
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<td>80-5080A</td>
</tr>
<tr>
<td>80-5078</td>
</tr>
<tr>
<td>80-5046A</td>
</tr>
</tbody>
</table>
Color-Stabilizer

[0028] The color-stabilizers employed in the present invention include acrylates. Examples of acrylates include ethyl acrylate, epoxy acrylate, pentacrylate, and trimethylol propane triacrylate (TMPTA). Depending on the presence of other components in the formulation, the optimal amount of acrylate present in the binder formulation can vary. In certain embodiments, the percentage of the acrylate resin can be between about 2% and about 60% by weight of the phenolic resin, between about 5% and about 60% by weight of the phenolic resin, between about 10% and about 60% by weight of the phenolic resin, or between about 7% and about 15% by weight of the phenolic resin.

[0029] For example, in embodiments where the phenolic resin formulation includes peroxide or an ultraviolet photo-initiator, as described further below, the acrylate is preferably present in a larger percentage, such as between about 10% and about 60% by weight. In embodiments where the acrylate resin can react with the phenolic resin, the percentage of acrylate can be between about 5% and about 60% by weight.

[0030] In one embodiment, the color-stabilizer is one or more acrylate resins having high functionality of acrylic groups, such as pentacrylate and trimethylolpropane triacrylate (TMPTA). Other suitable resins include methyl lactate, ethyl lactate, n-propyl lactate, butyl lactate, epoxy acrylate, and 2-ethylhexyl lactate.

[0031] In another embodiment, the one or more acrylate resin is a water soluble resin, such as ethoxylated TMPTA. As described herein, the term “water soluble" means completely miscible in water. In yet another embodiment, the one or more acrylate resin is not water soluble. The insoluble acrylate resin can be present in an amount between about 2% and about 15% by weight. In some embodiments, the composition further includes a co-solvent, such as glycol. Optionally, vitamins E and C can be added between 1% and 20% by weight of resin.

[0032] It is believed that acrylates impart color stability to phenolic resins by reacting with phenoxy radicals that would otherwise oxidize and form darkly colored quinone structures. Reactions 1 and 2 represent an example of the mechanism that is believed to occur when an acrylate is not present in the phenolic resin, while reaction 3 represents an alternative to reaction 2 that occurs when an acrylate is present.

[0033] In reaction 1, the phenol ionizes in basic media, forming a phenolate ion and a corresponding resonant phenoxy radical structure.

[0034] In Reaction 2, the phenoxy radical undergoes rapid oxidation in base to form a darkly colored quinone structure.

[0035] In Reaction 3, trimethylolpropanetriacrylate reacts with the phenoxy radical, precluding the formation of the darkly colored quinone moiety, resulting in a color stable resin. Incorporation of the acrylate repeat unit into the phenolic resin network has also shown to impart toughness to the polymer.

Colorant

[0036] The abrasive product can include a colorant, for example, dyes or pigments. Generally, a portion of the colorant can be visible through the cured resin. In some embodiments, a portion of the colorant is included in the cured resin, in an optional support substrate, and/or in a coating between the optional support substrate and the cured resin. In particular embodiments, the colorant can include organic polycyclic dyes, organic monoazo dyes, organic diazo dyes, organo-metal complexes, inorganic pigments such as metal oxides or complexes. Dyes can be perinone, anthraquinone, azo dye complexes and thiindigoid.

[0037] A fluorescent colorant is a dye or pigment containing a fluorescent organic molecule. Detailed descriptions of fluorescent colorants can be found in Zellinger, H., “Color Chemistry: Synthesis, Properties, and Applications of Organic Dyes and Pigments”, 2nd Ed., VCH, New York, 1991, the entire teachings of which are incorporated herein by ref-
ference. As used herein, a fluorescent colorant can be, for example, a xanthene, thioxanthene, fluorene (e.g., fluoresceins, rhodamines, eosines, phloxines, uranines, succineins, saccharine, roseamine, and rhodols), naphthylamine, naphthylamide, naphtholactam, azalactone, methine, oxazine, thiazine, benzopyran, coumarin, aminoacetone, anthraquinone, isoviolanthrone, anthrapyridone, pyranine, pyrazoline, benzothiazene, perylene, or thiindigoid. More preferably, a fluorescent colorant is selected from the group consisting of xanthenes, thioxanthenes, benzopyrans, coumarins, aminoacetones, anthraquinones, isoviolanthrones, anthrapyridones, pyranines, pyrazolines, benzothiazenes, thiindigoids and fluorenes. Most preferably, the fluorescent colorant is a thioxanthene or thioxanthene.

[0038] One skilled in the art understands that, for many, commercially available colorants, the specific chemical structure of individual derivatives within a class, e.g., thioxanthene derivatives, may not be publicly available. Thus, specific fluorescent colorants are typically referred to by Colour Index (C.I.) name, as defined in "Colour Index International", 4th Ed. American Association of Textile Chemists and Colorists, Research Triangle Park, N.C., 2002. The Colour Index is also available online at www.colour-index.org. The entire teachings of the Colour Index are incorporated herein by reference.

[0039] Examples of preferred fluorescent colorants include C.I. Solvent Orange 63 (Hostosol Red GG, Hoechst AG, Frankfurt, Germany), C.I. Solvent Yellow 86 (Hostosol Yellow 3G, Hoechst AG, Frankfurt, Germany), and C.I. Solvent Orange 118 (FL Orange SFR, Keystone Aniline Corporation, Chicago, Ill.).

[0040] The amount of colorant that can be employed depends on the particulars of the intended use, the characteristics of the colorant, the other components in the composition, and the like. One skilled in the art will know how to judge these details to determine the amount of colorant for a particular use. Typically, the amount of colorant will be a weight fraction of the total composition of about 0.01 and about 2%, more preferably between about 0.05 and about 0.5%, and most preferably, about 0.2%.

[0041] In specific embodiments, the colorant is a red, orange, yellow, green, blue, indigo, or violet colorant. In specific embodiments, the colorant is fluorescent, for example, a fluorescent red, fluorescent orange (blaze orange), fluorescent yellow, fluorescent green, or the like.

[0042] The colorant can be employed to identify the abrasive product, e.g., for commercial branding, for usage indication such as wet, dry, wood, metal, or the like, or for identification of grit size, or the like.

Abrasive Grains

[0043] Abrasive grains can include of any one or a combination of grains, including, but not limited to, silica, alumina (fused or sintered), zirconia, zirconia/alumina oxides, silicon carbide, garnet, diamond, cubic boron nitride (CBN), silicon nitride, ceria, titanium dioxide, titanium diboride, boron carbide, tin oxide, tungsten carbide, titanium carbide, iron oxide, chromia, flint, and emery. For example, the abrasive grains may be selected from a group consisting of silica, alumina, zirconia, silicon carbide, silicon nitride, boron nitride, garnet, diamond, coarsened alumina zirconia, ceria, titanium diboride, boron carbide, flint, emery, alumina nitride, and a blend thereof. In some instances, dense abrasive grains comprised principally of alpha-alumina and/or gamma alumina can be used.

[0044] The abrasive grains can also include abrasive agglomerate grains, also known as agglomerated abrasive grains. Abrasive agglomerate grains include abrasive particles adhered together by a particle binder material. The abrasive particles present in abrasive agglomerate grains can include one or more of the abrasives known for use in abrasive tools such as, for example, silica, alumina (fused or sintered), zirconia, zirconia/alumina oxides, silicon carbide, garnet, diamond, cubic boron nitride (CBN), silicon nitride, ceria, titanium dioxide, titanium diboride, boron carbide, tin oxide, tungsten carbide, titanium carbide, iron oxide, chromia, flint, emery, and combinations thereof. The abrasive particles can be of any size or shape. The abrasive agglomerate grains can be adhered together by a particle binder material such as, for example, a metallic, organic, or vitreous material, or a combination of such materials. Abrasive agglomerate grains suitable for use in the present invention are further described in U.S. Pat. No. 6,797,023, to Knapp, et al., the entire contents of which are incorporated herein by reference.

[0045] The abrasive grains can have one or more particular shapes. Example of such particular shapes include rods, triangles, pyramids, cones, solid spheres, hollow spheres and the like. Alternatively, the abrasive grains can be randomly shaped.

[0046] Typically, the abrasive grains have an average grain size not greater than 2000 microns such as, for example, not greater than about 1500 microns. In another example, the abrasive grain size is not greater than about 750 microns, such as not greater than about 350 microns. In some embodiments, the abrasive grain size may be at least 0.1 microns, such as from about 0.1 microns to about 1500 microns, and, more typically, from about 0.1 microns to about 200 microns or from about 1 micron to about 100 microns. The grain size of the abrasive grains is typically specified to be the longest dimension of the abrasive grain. Generally, there is a range distribution of grain sizes. In some instances, the grain size distribution is tightly controlled.

Support Member/Backing

[0047] The abrasive articles can include a support member, or backing. The backing can be flexible or rigid. The backing can be made of any number of various materials including those conventionally used as backings in the manufacture of coated abrasives. Suitable backings can include polymeric films (for example, a primed film), such as polyolefin films (e.g., polypropylene including biaxially oriented polypropylene), polyester films (e.g., polyethylene terephthalate), polyamide films, or cellulose ester films; metal foils; meshes; foams (e.g., natural sponge material or polyurethane foam); cloth (e.g., woven, non-woven, felted, stitch bonded, or quilted, or cloth made from fibers or yarns comprising polyester, nylon, silk, cotton, poly-cotton or rayon); paper; vulcanized paper; vulcanized rubber; vulcanized fiber; nonwoven materials; a treated backing thereof, or any combination thereof.

[0048] The backing can have at least one of a saturant, a presize layer or a backsize layer. The purpose of these layers typically is to seal the backing or to protect yarn or fibers in the backing. If the backing is a cloth material, at least one of these layers typically is used. The addition of the presize layer or backsize layer may additionally result in a “smoother”
surface on either the front or the back side of the backing. Other optional layers known in the art can also be used (for example, a tie layer; see U.S. Pat. No. 5,700,302 of Stoetzel, et al., the entire contents of which are incorporated herein by reference).

[0049] In some embodiments, the abrasive articles are intended for use as fine grinding materials and hence a very smooth surface can be preferred. Examples of such smooth surfaced backings include finely calendared papers, plastic films or fabrics with smooth surface coatings.

[0050] The backing can have antistatic properties. The addition of an antistatic material can reduce the tendency of the abrasive article to accumulate static electricity when sanding wood or wood-like materials. Additional details regarding antistatic backings and backing treatments can be found in, for example, U.S. Pat. Nos. 5,108,463 of Buchanan, et al.; 5,137,542 of Buchanan, et al.; 5,328,716 of Buchanan; and 5,560,753 of Buchanan, et al., the entire contents of which are incorporated herein by reference.

[0051] The backing can include a fibrous reinforced thermoplastic such as, for example, in U.S. Pat. No. 5,417,726 of Stot et al., or an endless spliceless belt, as described, for example, in U.S. Pat. No. 5,573,619 of Benedit, et al., the entire contents of which are incorporated herein by reference. Likewise, the backing can include a polymeric substrate having hooking stems projecting therefrom as that described, for example, in U.S. Pat. No. 5,505,747 of Chelsey, et al., the entire contents of which are incorporated herein by reference. Similarly, the backing can include a fabric such as that described, for example, in U.S. Pat. No. 5,565,011 of Follett, et al., the entire contents of which are incorporated herein by reference.

Other Components

[0052] The abrasive articles of the present invention can also include various other components, such as curing additives, non-reactive thermoplastic resins, fillers, grinding aids; and other additives.

[0053] In some embodiments, the abrasive article includes a curing additive, such as a photoinitiator, which generates free radicals when exposed to radiation, e.g., UV radiation. Free-radical generators can include organic peroxides, azo compounds, quinones, benzophenones, nitroso compounds, acryl halides, hydrozones, mercapto compounds, pyrylium compounds, triacylimidazoles, bisimidazoles, chloroalkyl triazines, benzox ethers, benzil ketals, thioureas, and acetophenones, including derivatives of such compounds.

Among these the most commonly employed photoinitiators are the benzil ketals such as 2,2-dimethoxy-2-phenyl acetophenone (available from Ciba Specialty Chemicals under the trademark IRGACURE® 651) and acetophenone derivatives such as 2,2-diethoxycetophenone ("DEAP", which is commercially available from First Chemical Corporation), 2-hydroxy-2-methyl-1-phenyl-propan-1-one ("HMPP", which is commercially available from Ciba Specialty Chemicals under the trademark DAROCUR® 1173), 2-benzyl-2-N,N-dimethylamino-1-(4-morpholinophenyl)-1-butanol, (which is commercially available from Ciba Specialty Chemicals under the trademark IRGACURE® 369); and 2-methyl-1-(4-(methylthio)phenyl)-2-morpholinopropan-1-one, (available from Ciba Specialty Chemicals under the trademark IRGACURE® 907).

[0054] The abrasive articles can include a non-reactive thermoplastic resin such as, for example, polypropylene glycol, polyethylene glycol, and polyoxypropylene-polyoxyethene block copolymer.

[0055] Fillers include organic fillers, inorganic fillers, and nano-fillers. Examples of suitable fillers include, but are not limited to, metal carbonates such as calcium carbonate and sodium carbonate; silicas such as quartz, glass beads, glass bubbles; silicates such as talc, clays, calcium metasilicate; metal sulfates such as barium sulfate, calcium sulfate, aluminum sulfate; metal oxides such as calcium oxide, aluminum oxide; aluminum trihydrate, and combinations thereof.

[0056] The abrasive articles can include a grinding aid to increase the grinding efficiency and cut rate. Useful grinding aids can be inorganic, such as halide salts, e.g., sodium chloro- and potassium tetrafluoroborate; or organic based, such as chlorinated waxes, e.g., polyvinyl chloride. In one particular embodiment, the abrasive article includes chloro- and potassium tetrafluoroborate with particle size ranging from about 1 micron to about 80 microns, most typically from about 5 microns to about 30 microns. The concentration of grinding aid in a make coat is generally not greater than about 50 wt%, for example, the concentration of grinding aid is about 0.1 wt% to 50 wt% and most typically about 10 wt% to 30 wt% (all wt% based on make coat weight including abrasive grains).

[0057] Examples of additional additives include coupling agents, such as silane coupling agents, e.g., A-174 and A-1100 available from Osi Specialties, Inc., titanate, and zirconiumtitanates; anti-static agents, such as graphite, carbon black, and the like; suspending agent, such as fumed silica, e.g., Cab-O-Sil M5, Aerosil 200; anti-loading agents such as zinc stearate and calcium stearate; lubricants such as wax, PTFE powder, polyethylene glycol, polypropylene glycol, and polysiloxanes; wetting agents; pigments; dispersants; and defoamers.

EXEMPLIFICATION

[0058] The invention will now be further and specifically described by the following examples which are not intended to be limiting.

Example 1

[0059] Four phenolic resin compositions were formulated. Each composition contained the components shown in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Resin PF Prefere 80-5000A</td>
</tr>
<tr>
<td>Pigment Eicon Orange SK</td>
</tr>
<tr>
<td>Novo 2341 Deformer</td>
</tr>
<tr>
<td>Solvad Duxad 11</td>
</tr>
<tr>
<td>Solvad Cab-o-sil</td>
</tr>
<tr>
<td>Filler Solvay Type A KBF4</td>
</tr>
<tr>
<td>TMPTA</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>100.3</td>
</tr>
</tbody>
</table>

[0060] In addition, formulations 2-4 each contained the same amounts of a different acrylate. Table 3 below indicates the amount of acrylate present in each of the formulations.
<table>
<thead>
<tr>
<th>Trial No.</th>
<th>Type of acrylate added to phenolic resin formulation</th>
<th>Amount of Color after curing acrylate present for 10 hrs @ 250°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>0% black</td>
</tr>
<tr>
<td>2</td>
<td>Epoxy Acrylate (Ebecryl 3700)</td>
<td>10% red</td>
</tr>
<tr>
<td>3</td>
<td>Pentacrylate</td>
<td>10% light brown-yellow</td>
</tr>
<tr>
<td>4</td>
<td>TMPTA</td>
<td>10% light brown-yellow</td>
</tr>
</tbody>
</table>

The table shows that the compositions containing the acrylates were resistant to darkening upon exposure to heat during curing. In particular, pentacrylate and TMPTA were found to be the most effective in stabilizing the color of the phenolic resin.

**EQUIVALENTS**

While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

What is claimed is:

1. A color-stable abrasive article, comprising:
   a) a binder comprising a phenolic resin;
   b) a color-stabilizer that includes at least one acrylate; and
   c) abrasive grains.

2. The color-stable abrasive article of claim 1, wherein the phenolic resin is a resole.

3. The color-stable abrasive article of claim 1, wherein the color-stabilizer is present in an amount between about 2% and about 60% by weight.

4. The color-stable abrasive article of claim 1, wherein the color-stabilizer is present in an amount between about 7% and about 15% by weight.

5. The color-stable abrasive article of claim 1, further comprising a support member.

6. The color-stable abrasive article of claim 1, wherein the color-stabilizer is an acrylate selected from the group consisting of ethyl acrylate, epoxy acrylate, pentacrylate, and trimethylolpropane triacrylate (TMPTA).

7. The color-stable abrasive article of claim 1, wherein the color-stabilizer includes a water soluble acrylate resin.

8. The color-stable abrasive article of claim 7, wherein the water soluble acrylate resin is ethoxylated trimethylolpropane triacrylate.

9. The color-stable abrasive article of claim 7, further comprising a co-solvent.

10. The color-stable abrasive article of claim 9, wherein the co-solvent is glycol.

11. The color-stable abrasive article of claim 1, wherein the color-stabilizer includes a water insoluble acrylate resin.

12. The color-stable abrasive article of claim 11, wherein the water insoluble acrylate resin is present in an amount between about 2% and about 15% by weight.

13. The color-stable abrasive article of claim 6, further comprising a curing additive.

14. The color-stable abrasive article of claim 13, wherein the curing additive includes one or more additives selected from the group of peroxide and a UV photo-initiator.

15. The color-stable abrasive article of claim 13, wherein the acrylate is present in an amount between about 5% and about 60% by weight.

16. The color-stable abrasive article of claim 13, wherein the acrylate is present in an amount between about 10% and about 60% by weight.

17. The color-stable abrasive article of claim 6, wherein the acrylate resin is capable of reacting with the phenolic resin.

18. The color-stable abrasive article of claim 1, having no visually perceptible color change after about 8 hours of curing at about 235°F, relative to the same article after about 2 hours of curing at about 235°F.

19. The color-stable abrasive article of claim 1, further comprising a colorant.

20. The color-stable abrasive article of claim 1, wherein the article is a bonded, structured, or coated abrasive article.

21. The color-stable abrasive article of claim 20, wherein the phenolic resin binder and color stabilizer are present in at least one layer selected from the group consisting of a binder-abrasive layer, a backsize coat, a presize coat, a make coat, a size coat, and a superset coat.

22. A method of making a color-stable abrasive article, comprising the steps of:
   a) blending a resole and a color-stabilizer comprising at least one acrylate to form a resole composition;
   b) contacting a plurality of abrasive particles with the resole composition; and
   c) curing the resole composition to produce the color-stable abrasive article.

23. A method for abrading a work surface, comprising applying color-stable abrasive article to a work surface in an abrading motion to remove a portion of the work surface, the abrasive product including:
   a) a binder comprising a phenolic resin;
   b) a color-stabilizer that includes at least one acrylate; and
   c) abrasive grains.

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