



## A STRUCTURED ABRASIVE ARTICLE

### Background of the Invention

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#### 1. Field of the Invention

This invention relates to an abrasive article comprising a backing having a composite abrasive bonded thereto.

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#### 2. Discussion of the Art

Two major concerns associated with abrasive articles, particularly in fine grade articles, are loading and product consistency. Loading is a problem caused by the filling of the spaces between abrasive grains with swarf (i.e., material removed from the workpiece being abraded) and the subsequent build-up of that material. For example, in wood sanding, particles of sawdust lodge between abrasive grains, thereby reducing the cutting ability of the abrasive grains, and possibly resulting in burning of the surface of the wood workpiece.

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U.S. Patent No. 2,252,683 (Albertson) discloses an abrasive comprising a backing and a plurality of abrasive grains bonded to the backing by a resinous adhesive. During the manufacturing, before the resinous adhesive is cured, the abrasive article is placed in a heated mold which has a pattern. The inverse of the pattern transfers to the backing.

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U.S. Patent No. 2,292,261 (Albertson) discloses an abrasive article comprising a fibrous backing having an abrasive coating thereon. The abrasive coating contains abrasive particles embedded in a binder. When the binder is uncured, the abrasive coating is subjected to a pressure die containing a plurality of ridges. This

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results in the abrasive coating being embossed into rectangular grooves in the vertical and horizontal directions.

U.S. Patent No. 3,246,430 (Hurst) discloses an abrasive article having a fibrous backing saturated with a thermoplastic adhesive. After the backing is preformed into a continuous ridge pattern, the bond system and abrasive grains are applied. This results in an abrasive article having high and low ridges of abrasive grains.

U.S. Patent No. 4,539,017 (Augustin) discloses an abrasive article having a backing, a supporting layer of an elastomeric material over the backing, and an abrasive coating bonded to the supporting layer. The abrasive coating consists of abrasive grains distributed throughout a binder. Additionally the abrasive coating can be in the form of a pattern.

U.S. Patent No. 4,773,920 (Chasman et al.) discloses an abrasive lapping article having an abrasive composite formed of abrasive grains distributed throughout a free radical curable binder. The patent also discloses that the abrasive composite can be shaped into a pattern via a rotogravure roll.

Although some of the abrasive articles made according to the aforementioned patents are loading resistant and inexpensive to manufacture, they lack a high degree of consistency. If the abrasive article is made via a conventional process, the adhesive or binder system can flow before or during curing, thereby adversely affecting product consistency.

It would be desirable to provide a loading resistant, inexpensive abrasive article having a high degree of consistency.

#### Summary of the Invention

The present invention provides a structured abrasive article and a method of preparing such an article.

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In one aspect, this invention involves a coated abrasive article comprising a backing bearing on at least one major surface thereof abrasive composites comprising a plurality of abrasive grains dispersed in a binder. The binder serves as a medium for dispersing abrasive grains, and it may also bond the abrasive composites to the backing. The abrasive composites have a predetermined shape, e.g., pyramidal. Before use, it is preferred that the individual abrasive grains do not project beyond the plane of the predetermined shape. The dimensions of a given shape can be made substantially uniform. Furthermore, the composites are disposed in a predetermined array. The predetermined array can exhibit some degree of repetitiveness. The repeating pattern of a predetermined array can be in linear form or in the form of a matrix.

In another aspect, this invention involves a coated abrasive article comprising a backing bearing on at least one major surface thereof abrasive composites comprising a plurality of abrasive grains dispersed in a radiation-curable binder. The abrasive composites have a predetermined shape disposed in a predetermined array.

The precise nature of the abrasive composites provide an abrasive article that has a high level of consistency. This consistency further results in excellent performance.

In still another aspect, the invention involves a method of making a coated abrasive article comprising the steps of:

- (1) introducing a slurry containing a mixture of a binder and a plurality of abrasive grains onto a production tool;
- (2) introducing a backing to the outer surface of the production tool such that the slurry wets one major surface of the backing to form an intermediate article;
- (3) at least partially curing or gelling the



binder before the intermediate article departs from the outer surface of the production tool to form a coated abrasive article; and

(4) removing said coated abrasive article from the production tool.

5 It is preferred that the four steps are carried out in a continuous manner, thereby providing an efficient method of making a coated abrasive article. In either procedural embodiment, after the slurry is introduced to the  
10 production tool, the slurry does not exhibit appreciable flow prior to curing or gelling.

In a further aspect, the invention involves a method of making a coated abrasive article comprising the steps of:

15 (1) introducing a slurry containing a mixture of a binder and plurality of abrasive grains on to a backing such that the slurry wets the front side of the backing to form an intermediate article;

(2) introducing the intermediate article to a production tool having an outer surface;

20 (3) at least partially curing or gelling the binder before the intermediate article departs from the outer surface of the production tool to form a coated abrasive article; and

25 (4) removing the coated abrasive article from the production tool.

It is preferred that the four steps are carried out in a continuous manner, thereby providing an efficient method of making a coated abrasive article. In either procedural embodiment, after the slurry is introduced to the  
30 production tool, the slurry does not exhibit appreciable flow prior to curing or gelling.

#### Brief Description of the Drawings

35 FIG. 1 is a side view in cross section of an abrasive article of the present invention.

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FIG. 2 is a schematic view of apparatus for making an abrasive article of the invention.

FIG. 3 is a perspective view of an abrasive article of the present invention.

5 FIG. 4 is Scanning Electron Microscope photomicrograph taken at 30 times magnification of a top view of an abrasive article having an array of linear grooves.

10 FIG. 5 is Scanning Electron Microscope photomicrograph taken at 100 times the magnification of a side view of an abrasive article having an array of linear grooves.

15 FIG. 6 is Scanning Electron Microscope photomicrograph taken at 20 times magnification of a top view of an abrasive article having an array of pyramidal shapes.

20 FIG. 7 is Scanning Electron Microscope photomicrograph taken at 100 times magnification of a side view of an abrasive article having an array of pyramidal shapes.

25 FIG. 8 is Scanning Electron Microscope photomicrograph (top view) taken at 30 times magnification of an abrasive article having an array of sawtooth shapes.

FIG. 9 is Scanning Electron Microscope photomicrograph (side view) taken at 30 times magnification of an abrasive article having an array of sawtooth shapes.

FIG. 10 is a graph from the Surface Profile Test of an abrasive article of the invention.

30 FIG. 11 is a graph from the Surface Profile Test of an abrasive article made according to the prior art.

FIG. 12 is a front schematic view for an array of linear grooves.

35 FIG. 13 is a front schematic view for an array of linear grooves.

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FIG. 14 is a front schematic view for an array of linear grooves.

FIG. 15 is a top view of a Scanning Electron Microscope photomicrograph taken at 20 times magnification of an abrasive article of the prior art.

5 FIG. 16 is a top view of a Scanning Electron Microscope photomicrograph taken at 100 times magnification of an abrasive article of the prior art.

FIG. 17 is a front schematic view for an array of a specified pattern.

10 FIG. 18 is a front schematic view for an array of a specified pattern.

FIG. 19 is a front schematic view for an array of a specified pattern.

15 Detailed Description

The present invention provides a structured abrasive article and a method of making such an article. As used herein, the phrase "structured abrasive article" means an abrasive article wherein composites comprising  
20 abrasive grains distributed in a binder have a predetermined shape and are disposed in a predetermined array.

Referring to FIG. 1, coated abrasive article 10 comprises a backing 12 bearing on one major surface  
25 thereof abrasive composites 14. The abrasive composites comprise a plurality of abrasive grains 16 dispersed in a binder 18. In this particular embodiment, the binder bonds abrasive composites 14 to backing 12. The abrasive composite has a discernible shape. It is preferred that  
30 the abrasive grains not protrude beyond the planes of the shape before the coated abrasive article is used. As the coated abrasive article is being used to abrade a surface, the composite breaks down revealing unused abrasive  
35 grains.

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Materials suitable for the backing of the present invention include polymeric film, paper, cloth, metallic film, vulcanized fiber, nonwoven substrates, combinations of the foregoing, and treated versions of the foregoing. It is preferred that the backing be a  
5 polymeric film, such as polyester film. In some cases, it is desired that the backing be transparent to ultraviolet radiation. It is also preferred that the film be primed with a material, such as polyethylene acrylic acid, to  
10 promote adhesion of the abrasive composites to the backing.

The backing can be laminated to another substrate after the coated abrasive article is formed. For example, the backing can be laminated to a stiffer, more rigid substrate, such as a metal plate, to produce a  
15 coated abrasive article having precise abrasive composites supported on a rigid substrate.

The surface of the backing not containing abrasive composites may also contain a pressure-sensitive adhesive or a hook and loop type attachment system so that  
20 the abrasive article can be secured to a back-up pad. Examples of pressure-sensitive adhesives suitable for this purpose include rubber-based adhesives, acrylate-based adhesives, and silicone-based adhesives.

The abrasive composites can be formed from a  
25 slurry comprising a plurality of abrasive grains dispersed in an uncured or ungelled binder. Upon curing or gelling, the abrasive composites are set, i.e., fixed, in the predetermined shape and predetermined array.

The size of the abrasive grains can range from  
30 about 0.5 to about 1000 micrometers, preferably from about 1 to about 100 micrometers. A narrow distribution of particle size can often provide an abrasive article capable of producing a finer finish on the workpiece being abraded. Examples of abrasive grains suitable for this  
35 invention include fused aluminum oxide, heat treated



aluminum oxide, ceramic aluminum oxide, silicon carbide, alumina zirconia, garnet, diamond, cubic boron nitride, and mixtures thereof.

The binder must be capable of providing a medium in which the abrasive grains can be distributed. The binder is preferably capable of being cured or gelled relatively quickly so that the abrasive article can be quickly fabricated. Some binders gel relatively quickly, but require a longer time to fully cure. Gelling preserves the shape of the composite until curing commences. Fast curing or fast gelling binders result in coated abrasive articles having abrasive composites of high consistency. Examples of binders suitable for this invention include phenolic resins, aminoplast resins, urethane resins, epoxy resins, acrylate resins, acrylated isocyanurate resins, urea-formaldehyde resins, isocyanurate resins, acrylated urethane resins, acrylated epoxy resins, glue, and mixtures thereof. The binder could also be a thermoplastic resin.

Depending upon the binder employed, the curing or gelling can be carried out by an energy source such as heat, infrared irradiation, electron beam, ultraviolet radiation, or visible radiation.

As stated previously, the binder can be radiation curable. A radiation-curable binder is any binder that can be at least partially cured or at least partially polymerized by radiation energy. Typically, these binders polymerize via a free radical mechanism. They are preferably selected from the group consisting of acrylated urethanes, acrylated epoxies, aminoplast derivatives having pendant  $\alpha,\beta$ -unsaturated carbonyl groups, ethylenically unsaturated compounds, isocyanurate derivatives having at least one pendant acrylate group, isocyanates having at least one pendant acrylate group, and mixtures thereof.

The acrylated urethanes are diacrylate esters of hydroxy terminated isocyanate (NCO) extended polyesters or polyethers. Representative examples of commercially



available acrylated urethanes include UVITHANE 782, from Morton Thiokol, and CMD 6600, CMD 8400 and CMD 8805, from Radcure Specialties. The acrylated epoxies are diacrylate esters such as the diacrylate esters of bisphenol A epoxy resin. Examples of commercially available acrylated epoxies include CMD 3500, CMD 3600 and CMD 3700, from Radcure Specialties. The aminoplast derivatives have at least 1.1 pendant  $\alpha,\beta$ -unsaturated carbonyl groups and are further described in U.S. Patent No. 4,903,440, incorporated herein by reference. Ethylenically unsaturated compounds include monomeric or polymeric compounds that contain atoms of carbon, hydrogen, and oxygen, and optionally, nitrogen and the halogens. Oxygen and nitrogen atoms are generally present in ether, ester, urethane, amide, and urea groups. Examples of such materials are further described in U.S. Patent No. 4,903,440, previously incorporated herein by reference. Isocyanate derivatives having at least one pendant acrylate group and isocyanurate derivatives having at least one pendant acrylate group are described in U.S. Patent No. 4,652,274, incorporated herein by reference. The above-mentioned adhesives cure via a free radical polymerization mechanism.

Another binder suitable for the abrasive article of the present invention comprises the radiation-curable epoxy resin described in U.S. Patent No. 4,318,766, incorporated herein by reference. This type of resin is preferably cured by ultraviolet radiation. This epoxy resin cures via a cationic polymerization mechanism initiated by an iodonium photoinitiator.

A mixture of an epoxy resin and an acrylate resin can also be used. Examples of such resin mixtures are described in U.S. Patent No. 4,751,138, incorporated herein by reference.

If the binder is cured by ultraviolet radiation, a photoinitiator is required to initiate free radical polymerization. Examples of photoinitiators suitable for



this purpose include organic peroxides, azo compounds, quinones, benzophenones, nitroso compounds, acryl halides, hydrazones, mercapto compounds, pyrylium compounds, triacrylimidazoles, bisimidazoles, chloralkyltriazines, benzoin ethers, benzil ketals, thioxanthenes, and  
5 acetophenone derivatives. The preferred photoinitiator is 2,2-dimethoxy-1,2-diphenyl-1-ethanone.

If the binder is cured by visible radiation, a photoinitiator is required to initiate free radical polymerization. Examples of photoinitiators suitable for  
10 this purpose are described in U.S. Patent No. 4,735,632, col. 3, line 25 through col. 4, line 10, col. 5, lines 1-7, col. 6, lines 1-35, incorporated herein by reference.

The ratio, based on weight, of abrasive grain to binder generally ranges from about 4 to 1 parts abrasive  
15 grains to 1 part binder, preferably from about 3 to 2 parts abrasive grains to 1 part binder. This ratio varies depending upon the size of the abrasive grains and the type of binder employed.

The coated abrasive article may contain an  
20 optional coating disposed between the backing and the abrasive composites. This coating serves to bond the abrasive composites to the backing. The coating can be prepared from the group of binder materials suitable for preparing the composites themselves.

The abrasive composite can contain other  
25 materials in addition to the abrasive grains and the binder. The materials, referred to as additives, include coupling agents, wetting agents, dyes, pigments, plasticizers, fillers, release agents, grinding aids, and  
30 mixtures thereof. It is preferred that the composite contains a coupling agent. The addition of the coupling agent significantly reduces the coating viscosity of the slurry used to form abrasive composites. Examples of such coupling agents suitable for this invention include organo  
35 silanes, zircoaluminates, and titanates. The weight of the coupling agent will generally be less than 5%,



preferably less than 1%, of the binder, based on weight.

The abrasive composites have at least one predetermined shape and are disposed in a predetermined array. In general, the predetermined shape will repeat with a certain periodicity. This repeating shape can be in one direction or, preferably, in two directions. The surface profile is a measure of the reproducibility and consistency of the repeating shape. A surface profile can be determined by the following test.

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Surface Profile Test

The abrasive article to be tested is placed on a flat surface and a probe (radius of five micrometers) from a profilometer (SURFCOM profilometer, commercially available from Tokyo Seimitsu Co., LTD., Japan) traverses the abrasive composite. The probe traverses at an angle perpendicular to the array of shapes and parallel to the plane of the backing of the abrasive article. Of course, the probe contacts the abrasive shapes. The traversal speed of the probe is 0.3 millimeter/second. The data analyzer is a SURFLYZER Surface Texture Analyzing System from Tokyo Seimitsu Co., LTD., Japan. The data analyzer graphs the profile of the shapes of the abrasive composites as the probe traverses and contacts the composites of the abrasive article. In the case of this invention, the graph will display a certain periodicity characteristic of a repeating shape. When the graph of one region of the article is compared to a graph of another region of the article, the amplitude and frequency of the output will essentially be the same, meaning that there is no random pattern, i.e., a very clear and definite repeating pattern is present.

The shapes of the abrasive composites repeat themselves at a certain periodicity. Typically, abrasive composites have a high peak (i.e., region) and a low peak (i.e., region). The high peak values from the data

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analyzer are within 10% of each other and the low peak values from the data analyzer are within 10% of each other.

5 An example of an ordered profile is illustrated in FIG. 3. The periodicity of the pattern is the distance marked "a'". The high peak value distance is marked "b'" and the low peak value distance is marked "c'".

10 The following procedure can be used as an alternative to the Surface Profile Test. A cross-sectional sample of the abrasive article is taken, e.g., as shown in FIG. 1. The sample is then embedded in a holder, so that the sample can be viewed under a microscope. Two microscopes that can be used for viewing the samples are a scanning electron microscope and an optical microscope. Next, the surface of the sample in  
15 the holder is polished by any conventional means so that the surface appears clean when the sample is viewed under the microscope. The sample is viewed under a microscope and a photomicrograph of the sample is taken. The photomicrograph is then digitized. During this step, x  
20 and y coordinates are assigned to map the predetermined shapes of the abrasive composites and the predetermined arrays.

25 A second sample of the abrasive article is prepared in the same manner as the first sample. The second sample should be taken along the same plane as the first sample to ensure that the shapes and arrays of the second sample are of the same type as those of the first sample. When the second sample is digitized, if the x and y coordinates of the two samples do not vary by more than  
30 10%, it can be concluded that the shapes and array were predetermined. If the coordinates vary by more than 15%, it can be concluded that the shapes and array are random and not predetermined.

35 For abrasive composites that are characterized by distinct peaks or shapes, as in FIGS. 1, 6, 7, and 18, the digitized profile will vary throughout the array. In



other words, peaks will differ from valleys in appearance. Thus, when the second sample is prepared, care must be taken so that the cross-section of the second sample corresponds exactly to the cross-section of the first sample, i.e., peaks correspond to peaks and valleys correspond to valleys. Each region of peaks or shapes will, however, have essentially the same geometry as another region of peaks or shapes. Thus, for a given digitized profile in one region of peaks or shapes, another digitized profile can be found in another region of peaks or shapes that is essentially the same as that of the first region.

The more consistent an abrasive article of this invention, the more consistent will be the finish imparted by the abrasive article to the workpiece. An abrasive article having an ordered profile has a high level of consistency, since the height of the peaks of the abrasive composites will normally not vary by more than 10%.

The coated abrasive article of this invention displays several advantages over coated abrasive articles of the prior art. In some cases, the abrasive articles have a longer life than abrasive articles not having abrasive composites positioned according to a predetermined array. The spaces between the composites provide means for escape of the swarf from the abrasive article, thereby reducing loading and the amount of heat built up during use. Additionally, the coated abrasive article of this invention can exhibit uniform wear and uniform grinding forces over its surface. As the abrasive article is used, abrasive grains are sloughed off and new abrasive grains are exposed, resulting in an abrasive product having a long life, high sustained cut rate, and consistent surface finish over the life of the product.

Abrasive composites disposed in a predetermined array can range through a wide variety of shapes and periods. FIGS. 4 and 5 show linear curved grooves. FIGS. 6 and 7 show pyramidal shapes. FIGS. 8 and 9 show linear



grooves. FIG. 1 shows projections 14 of like size and shape and illustrates a structured surface made up of trihedral prism elements. FIG. 3 shows a series of steps 31 and lands 32.

5 Each composite has a boundary, which is defined by one or more planar surfaces. For example, in FIG. 1 the planar boundary is designated by reference numeral 15; in FIG. 3 the planar boundary is designated by reference numeral 33. The abrasive grains preferably do not project  
10 above the planar boundary. It is believed that such a construction allows an abrasive article to decrease the amount of loading resulting from grinding swarf. By controlling the planar boundary, the abrasive composites can be reproduced more consistently.

15 The optimum shape of a composite depends upon the particular abrading application. When the areal density of the composites, i.e., number of composites per unit area, is varied, different properties can be achieved. For example, a higher areal density tends to produce a lower unit pressure per composite during  
20 grinding, thereby allowing a finer surface finish. An array of continuous peaks can be disposed so as to result in a flexible product. For medium unit pressures, such as off hand grinding applications, it is preferred that the aspect ratio of the abrasive composites range from about  
25 0.3 to about 1. An advantage of this invention is that the maximum distance between corresponding points on adjacent shapes can be less than one millimeter, and even less than 0.5 millimeter.

30 Coated abrasive articles of this invention can be prepared according to the following procedure. First, a slurry containing abrasive grains and binder is introduced to a production tool. Second, a backing having a front side and a back side is introduced to the outer surface of a production tool. The slurry wets the front  
35 side of the backing to form an intermediate article. Third, the binder is at least partially cured or gelled



before the intermediate article is removed from the outer surface of the production tool. Fourth, the coated abrasive article is removed from the production tool. The four steps are preferably carried out in a continuous manner.

5 Referring to FIG. 2, which is a schematic diagram of the process of this invention, a slurry 100 flows out of a feeding trough 102 by pressure or gravity and onto a production tool 104, filling in cavities (not shown) therein. If slurry 100 does not fully fill the  
10 cavities, the resulting coated abrasive article will have voids or small imperfections on the surface of the abrasive composites and/or in the interior of the abrasive composites. Other ways of introducing the slurry to the production tool include die coating and vacuum drop die  
15 coating.

It is preferred that slurry 100 be heated prior to entering production tool 104, typically at a temperature in the range of 40°C to 90°C. When slurry 100 is heated, it flows more readily into the cavities of  
20 production tool 104, thereby minimizing imperfections. The viscosity of the abrasive slurry is preferably closely controlled for several reasons. For example, if the viscosity is too high, it will be difficult to apply the abrasive slurry to the production tool.

25 Production tool 104 can be a belt, a sheet, a coating roll, a sleeve mounted on a coating roll, or a die. It is preferred that production tool 104 be a coating roll. Typically, a coating roll has a diameter between 25 and 45 cm and is constructed of a rigid  
30 material, such as metal. Production tool 104, once mounted onto a coating machine, can be powered by a power-driven motor.

Production tool 104 has a predetermined array of at least one specified shape on the surface thereof, which  
35 is the inverse of the predetermined array and specified shapes of the abrasive composite of the article of this

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invention. Production tools for the process can be prepared from metal, e.g., nickel, although plastic tools can also be used. A production tool made of metal can be fabricated by engraving, hobbing, assembling as a bundle a plurality of metal parts machined in the desired configuration, or other mechanical means, or by electroforming. The preferred method is diamond turning. These techniques are further described in the Encyclopedia of Polymer Science and Technology, Vol. 8, John Wiley & Sons, Inc. (1968), p. 651-665, and U.S. Patent No. 3,689,346, column 7, lines 30 to 55, all incorporated herein by reference.

In some instances, a plastic production tool can be replicated from an original tool. The advantage of plastic tools as compared with metal tools is cost. A thermoplastic resin, such as polypropylene, can be embossed onto the metal tool at its melting temperature and then quenched to give a thermoplastic replica of the metal tool. This plastic replica can then be utilized as the production tool.

For radiation-curable binders, it is preferred that the production tool be heated, typically in the range of 30° to 140°C, to provide for easier processing and release of the abrasive article.

A backing 106 departs from an unwind station 108, then passes over an idler roll 110 and a nip roll 112 to gain the appropriate tension. Nip roll 112 also forces backing 106 against slurry 100, thereby causing the slurry to wet out backing 106 to form an intermediate article.

The binder is cured or gelled before the intermediate article departs from production tool 104. As used herein, "curing" means polymerizing into a solid state. "Gelling" means becoming very viscous, almost solid like. After curing or gelling, the specified shapes of the abrasive composites do not change after the coated abrasive article departs from production tool 104. In some cases, the binder can be gelled first, and then the

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intermediate article can be removed from production tool 104. The binder is then cured at a later time. Because the dimensional features do not change, the resulting coated abrasive article will have a very precise pattern. Thus, the coated abrasive article is an inverse replica of  
5 production tool 104.

The binder can be cured or gelled by an energy source 114 which provides energy such as heat, infrared radiation, or other radiation energy, such as electron beam radiation, ultraviolet radiation, or visible  
10 radiation. The energy source employed will depend upon the particular adhesive and backing used. Condensation curable resins can be cured or gelled by heat, radio frequency, microwave, or infrared radiation.

Addition polymerizable resins can be cured by  
15 heat, infrared, or preferably, electron beam radiation, ultraviolet radiation, or visible radiation. Electron beam radiation preferably has a dosage level of 0.1 to 10 Mrad, more preferably 1 to 6 Mrad. Ultraviolet radiation is non-particulate radiation having a wavelength within  
20 the range of 200 to 700 nanometers, more preferably between 250 to 400 nanometers. Visible radiation is non-particulate radiation having a wavelength within the range of 400 to 800 nanometers, more preferably between 400 to 550 nanometers. Ultraviolet radiation is preferred. The  
25 rate of curing at a given level of radiation varies according to the thickness of the binder as well as the density, temperature, and nature of the composition.

The coated abrasive article 116 departs from production tool 104 and traverses over idler rolls 118 to  
30 a winder stand 120. The abrasive composites must adhere well to the backing, otherwise the composites will remain on production tool 104. It is preferred that production tool 104 contain or be coated with a release agent, such as a silicone material, to enhance the release of coated  
35 abrasive article 116.

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In some instances, it is preferable to flex the abrasive article prior to use, depending upon the particular pattern employed and the abrading application for which the abrasive article is designed.

5 The abrasive article can also be made according to the following method. First, a slurry containing a mixture of a binder and plurality of abrasive grains is introduced to a backing having a front side and a back side. The slurry wets the front side of the backing to form an intermediate article. Second, the intermediate  
10 article is introduced to a production tool. Third, the binder is at least partially cured or gelled before the intermediate article departs from the outer surface of the production tool to form the abrasive article. Fourth, the abrasive article is removed from the production tool. The  
15 four steps are preferably conducted in a continuous manner, thereby providing an efficient method for preparing a coated abrasive article.

The second method is nearly identical to the first method, except that in the second method the  
20 abrasive slurry is initially applied to the backing rather than to the production tool. For example, the slurry can be applied to the backing between unwind station 108 and idler roll 110. The remaining steps and conditions for the second method are identical to those of the first  
25 method. Depending upon the particular configuration of the surface of the production tool, it may be preferable to use the second method instead of the first method.

In the second method, the slurry can be applied to the front side of the backing by such means as die  
30 coating, roll coating, or vacuum die coating. The weight of the slurry can be controlled by the backing tension and nip pressure and the flow rate of the slurry.

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The following non-limiting examples will further illustrate the invention. All weights in the examples are given in g/m<sup>2</sup>. All ratios in the following examples were based upon weight. The fused alumina used in the examples was a white fused alumina.

5           The following abbreviations are used throughout the examples:

|    |         |                                                                                                                                                                    |
|----|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10 | TMDIMA2 | dimethacryloxy ester of<br>2,2,4-trimethylhexamethylenediisocyanate                                                                                                |
|    | IBA     | isobornylacrylate                                                                                                                                                  |
| 15 | BAM     | an aminoplast resin having pendant acrylate<br>functional groups, prepared in a manner<br>similar to that described in U.S. Patent<br>No. 4,903,440, Preparation 2 |
| 20 | TATHEIC | triacylate of tris(hydroxy<br>ethyl)isocyanurate                                                                                                                   |
| 25 | AMP     | an aminoplast resin having pendant acrylate<br>functional groups, prepared in a manner<br>similar to that described in U.S. Patent<br>No. 4,903,440, Preparation 4 |
| 30 | PH1     | 2,2-dimethoxy-1-2-diphenyl-1-ethanone,<br>commercially available from Ciba Geigy<br>Company under the trade designation<br>IRGACURE 651                            |
|    | LP1     | an array of curved shapes illustrated in<br>FIG. 12                                                                                                                |
| 35 | LP2     | an array of curved shapes illustrated in<br>FIG. 14                                                                                                                |

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- LP3 an array of linear shapes at a specified angle illustrated in FIG. 13
- LP4 an array of shapes illustrated in FIG. 19
- 5 LP5 an array of linear shapes illustrated in FIG. 17
- LP6 an array of linear grooves in which there are 40 lines/cm
- 10 CC an array of pyramidal shapes illustrated in FIG. 18

Dry Push Pull Test

- 15 The abrasive article was converted to a 2.54 cm diameter disc. Double-coated transfer tape was laminated to the back side of the backing. The coated abrasive article was then pressed against a 2.54 cm diameter FINESSE-IT brand back up pad, commercially available from
- 20 Minnesota Mining and Manufacturing Company, St. Paul, Minnesota. The workpiece was a 45 cm by 77 cm metal plate having a urethane primer. This type of primer is commonly used in the automotive paint industry. The coated abrasive article was used to abrade, by hand,
- 25 approximately thirty (30) 2.54 cm by 22 cm sites on a sheet. The movement of the operator's hand in a back and forth manner constituted a stroke. The cut, i.e., the amount in micrometers of primer removed, was measured after 100 strokes. The paint thickness was measured with
- 30 an ELCOMETER measurement tool, available from Elcometer Instruments Limited, Manchester, England. The finish, i.e., the surface finish of the metal primed plate, was measured after 10 to 100 strokes. The finish (Ra) was measured using a SURTRONIC 3 profilometer, available from
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Rauk Taylor Hobson Limited, from Leicester, England. Ra was the arithmetic average of the scratch size in microinches.

Wet Push Pull Test

- 5           The wet push pull test was identical to the dry push pull test, except that the primed metal plate surface was flooded with water.

Examples 1 - 5

- 10           The coated abrasive articles for Examples 1 through 5 illustrate various shapes and arrays of the abrasive article of this invention. These articles were made by means of a batch process. Example 1 illustrates a LP1 array; Example 2 illustrates a LP2 array; Example 3  
15 illustrates a LP3 array; Example 4 illustrates a LP4 array; and Example 5 illustrates a CC array.

- The production tool was a 16 cm by 16 cm square nickel plate containing the inverse of the array. The production tool was made by means of a conventional  
20 electroforming process. The backing was a polyester film (0.5 mm thick) that had been treated with CF<sub>4</sub> corona to prime the film. The binder consisted of 90% TMDIMA2/10% IBA/10% PH1 adhesive. The abrasive grain was fused  
25 alumina (40 micrometer average particle size) and the weight ratio of abrasive grains to the binder in the slurry was 1 to 1. The slurry was applied to the production tool. Then the polyester film was placed over the slurry, and a rubber roll was applied over the polyester film so that the slurry wetted the surface of  
30 the film. Next, the production tool containing the slurry and the backing was exposed to ultraviolet light to cure the adhesive. The article of each sample was passed three times under an AETEK ultraviolet lamp operating at 400 Watts/inch at a speed of 40 feet/minute. Then the article  
35 of each example was removed from the production tool. The abrasive articles of Examples 1 through 5 were tested

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under the Dry Push Pull Test and the Wet Push Pull Test. The results of the Dry Push Pull Test are set forth in Table 1 and the results of the Wet Push Pull Test are set forth in Table 2. FIG. 10 illustrates the output of a Surface Profile Test for the coated abrasive article of Example 1.

Table 1

| Example no. | Cut ( $\mu\text{m}$ ) | Surface finish (Ra) |            |
|-------------|-----------------------|---------------------|------------|
|             |                       | 10 cycles           | 100 cycles |
| 1           | 5.6                   | 16.6                | 11.3       |
| 2           | 3.1                   | 13.5                | 14.5       |
| 3           | 7.6                   | 13.7                | 10.0       |
| 4           | 3.4                   | 15.0                | 9.0        |

Table 2

| Example no. | Cut ( $\mu\text{m}$ ) | Surface finish (Ra) |            |
|-------------|-----------------------|---------------------|------------|
|             |                       | 10 cycles           | 100 cycles |
| 1           | 18.5                  | 17.5                | 12.0       |
| 2           | 11.7                  | 20.0                | 8.0        |
| 3           | 39.9                  | 15.0                | 12.0       |
| 4           | 30.0                  | 17.5                | 9.5        |
| 5           | 53.3                  | 24.0                | 18.5       |

Example 6

The coated abrasive article of Example 6 was made in a manner identical to that used to prepare the articles of Examples 1 through 5, except that the array was LP5. The results of the Wet Push Pull Test are set forth in Table 3.

Comparative Example A was a grade 600 WETORDRY TRI-M-ITE paper coated abrasive, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

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Comparative Example B was a grade 320 WETORDRY TRI-M-ITE paper coated abrasive, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

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Table 3

|    | <u>Example no.</u> | <u>Cut (<math>\mu</math>m)</u> |
|----|--------------------|--------------------------------|
|    | 3                  | 12.7                           |
|    | 5                  | 18.0                           |
| 10 | 6                  | 18.0                           |
|    | Comparative A      | 7.7                            |
|    | Comparative B      | 30.9                           |

15 From the foregoing data, it can be seen that those shapes with sharp features, i.e. those having either points or ridges, were the most effective and those shapes with flat features were less effective in removal of primer. In addition, the array LP3 displayed limited flexibility while the CC array was quiet flexible.

20 The article of Example 6 (the LP5 array) had a directionality in its pattern. The article of Example 6 was tested on a modified Dry Push Pull Test in which one stroke equaled one movement in one direction, reverse or forward. The results are set forth in Table 4.

25

Table 4

|    | <u>Direction</u> | <u>Cut (<math>\mu</math>m)</u> |
|----|------------------|--------------------------------|
|    | reverse          | 2.54                           |
| 30 | forward          | 7.62                           |

Examples 7 ~ 11

35 The coated abrasive articles of Examples 7 through 11 were made in the same manner as were those of Examples 1 through 5, except that fused alumina grain having 12 micrometer average particle size was used.

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Example 7 illustrates a LP2 array; Example 8 illustrates a LP1 array; Example 9 illustrates a CC array; Example 10 illustrates a LP5 array; and Example 11 illustrates a LP3 array. The abrasive articles of these examples were tested under the Wet Push Pull Test and the results of the test are set forth in Table 5.

Comparative Example A was a grade 600 WETORDRY TRI-M-ITE a weight paper, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

Table 5

| Example no.   | Cut ( $\mu$ m) | Surface finish (Ra) |            |
|---------------|----------------|---------------------|------------|
|               |                | 10 cycles           | 100 cycles |
| 7             | 23.0           | 11                  | 5          |
| 8             | 30.5           | 12                  | 5          |
| 9             | 30.5           | 12                  | 5          |
| 10            | 30.5           | 13                  | 6          |
| 11            | 38.1           | 8                   | 6          |
| Comparative A | 23.0           | 11                  | 5          |

Examples 12 - 14

The abrasive articles of Examples 12 through 14 were made in the same manner as were those of Examples 1 through 5, except that fused alumina grain having 90 micrometer average particle size was used. Example 12 illustrates a LP3 array; Example 13 illustrates a LP5 array; Example 14 illustrates a CC array. The abrasive articles of these examples were tested under the Dry Push Pull Test and the results are set forth in Table 6.

Comparative Example B was a grade 320 WETORDRY TRI-M-ITE A weight paper coated abrasive, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

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Table 6

|   | Example no.   | Cut ( $\mu\text{m}$ ) | Surface finish (Ra) |            |
|---|---------------|-----------------------|---------------------|------------|
|   |               |                       | 10 cycles           | 100 cycles |
| 5 | 12            | 36.3                  | 40                  | 34         |
|   | 13            | 48.3                  | 60                  | 45         |
|   | 14            | 50.8                  | 55                  | 49         |
|   | Comparative B | 30.5                  | 62                  | 33         |

Table 7 compares performance differences of an abrasive article containing an abrasive grain having 40 micrometer average particle size (Example 3) and an abrasive article containing an abrasive grain having 12 micrometer average particle size (Example 11) under the Dry Push Pull Test.

Table 7

|    | Example no. | Cut ( $\mu\text{m}$ ) | Surface finish (Ra) |           |
|----|-------------|-----------------------|---------------------|-----------|
|    |             |                       | 10 cycles           | 90 cycles |
| 15 | 3           | 40.6                  | 16.5                | 11.0      |
|    | 11          | 38.1                  | 8.0                 | 4.8       |

With the LP3 array, the cut was more dependent upon the array and shape of the composite than upon the particular size of the abrasive grain. It had been conventionally thought that the size of the abrasive grain employed had a significant influence on the cut. This phenomenon was surprising and was contrary to what is generally believed in the art.

Examples 15 - 16 and  
Comparative Examples C and D

These examples compared the performance of coated abrasive articles of the prior art with coated abrasive articles of the present invention. The coated abrasive articles of these examples were made by means of a continuous process and were tested under the Dry Push Pull Test, except that the cut was the amount of primer removed, in grams. Additionally, the surface finish was

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taken at the end of the test, and both Ra and RTM were measured in microinches. RTM was a weighted average measurement of the deepest scratches. The results are set forth in Table 8.

5 The coated abrasive articles for these examples  
were prepared with an apparatus that was substantially  
identical to that shown in FIG. 2. A slurry 100  
containing abrasive grains was fed from a feeding trough  
102 onto a production tool 104. Then a backing was  
introduced to production tool 104 in such a way that  
10 slurry 100 wetted the surface of the backing to form an  
intermediate article. The backing was forced into slurry  
100 by means of a pressure roll 112. The binder in slurry  
100 was cured to form a coated abrasive article. Then the  
coated abrasive article was removed from production tool  
15 104. The slurry and the backing were made of the same  
materials as were used in Example 1. The temperature of  
the binder was 30°C and the temperature of the production  
tool was 70°C.

20

#### Examples 15 - 16

For Examples 15 and 16, the ultraviolet lamps  
were positioned so as to cure the slurry on the production  
tool. For Example 15, the production tool was a gravure  
roll having a LP6 array. For Example 16, the production  
25 tool was a gravure roll having a CC array.

#### Comparative Examples C and D

For Comparative Examples C and D, the  
ultraviolet lamps were positioned so as to cure the slurry  
after it had been removed from the production tool. Thus,  
30 there was a delay between the time when the intermediate  
article left the production tool and the time when the  
adhesive was cured or gelled. This delay allowed the  
adhesive to flow and alter the array and shape of the  
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composite. For Comparative Example C, the production tool had a CC array; for Comparative Example D the production tool had a LP6 array.

The improvement in the coated abrasive articles of the present invention as compared to the coated abrasive articles of the prior art resulted from the curing or gelling on the production tool. This improvement is readily seen in the photomicrographs of FIGS. 6, 7, 15, and 16. FIGS. 15 and 16 pertain to Comparative Example C, while FIGS. 6 and 7 pertain to Example 16. FIG. 11 illustrates the output of a Surface Profile Test for the coated abrasive article of Comparative Example D.

Table 8

| Example no.   | Cut (g) | Surface Finish |     |
|---------------|---------|----------------|-----|
|               |         | Ra             | RTM |
| 15            | 0.190   | 25             | 135 |
| 16            | 0.240   | 25             | 125 |
| 20            | 0.200   | 15             | 55  |
| Comparative C | 0.375   | 30             | 175 |
| Comparative D | 0.090   | 20             | 110 |

The most preferred coated abrasive product is one that has a high cut with low surface finish values. The abrasive articles of the present invention satisfy these criteria.

Examples 17 - 20

The abrasive articles of these examples illustrate the effect of various adhesives. The abrasive articles were made and tested in the same manner as was that of Example 1, except that a different adhesives were employed. The weight ratios for the materials in the slurry were the same as was that of Example 1. The adhesive for Example 17 was TMDIMA2, the adhesive for Example 18 was BAM, the adhesive for Example 19 was AMP,

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and the adhesive for Example 20 was TATHEIC. The test results are set forth in Table 9. Comparative Example A was a grade 600 WETORDRY TRI-M-ITE A weight paper, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

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Table 9

|             |                | Initial<br>surface finish (Ra) |    |
|-------------|----------------|--------------------------------|----|
|             |                | 10 cycles                      |    |
| Example no. | Cut ( $\mu$ m) |                                |    |
| 10          | 17             | 9.14                           | 12 |
|             | 18             | 2.54                           | 10 |
|             | 19             | 7.61                           | 8  |
|             | 20             | 16.00                          | 5  |
|             | Comparative A  | 1.52                           | 10 |

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Examples 21 - 24

The coated abrasive articles for Examples 21 through 24 were made in the same manner as was that of Example 16, except that different slurries were used. For Example 21, the abrasive slurry consisted of 40 micrometer average particle size fused alumina grain (100 parts)/TMDIMA2 (90 parts)/IBA (10 parts)/PH1 (2 parts), for Example 22 the abrasive slurry consisted of 40 micrometer average particle size fused alumina grain (200 parts)/TMDIMA2 (90 parts)/IBA (10 parts)/PH1 (2 parts), for Example 23 the abrasive slurry consisted of 40 micrometer average particle size fused alumina grain (200 parts)/AMP (90 parts)/IBA (10 parts)/PH1 (2 parts), and for Example 24 the abrasive slurry consisted of 40 micrometer average particle size fused alumina grain (200 parts)/TATHEIC (90 parts)/IBA (10 parts)/PH1 (2 parts). Comparative Example E was a grade 400 WETORDRY TRI-M-ITE A weight paper coated abrasive, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

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Lap Test

The abrasive articles were converted into 35.6 cm diameter discs and tested on a RH STRASBAUGH 6AX lapping machine. The workpiece were three 1.2 cm diameter 1018 steel rods arranged in 7.5 cm diameter circle and set in a holder. The lapping was conducted in the absence of water, and the normal (perpendicular) load on the workpiece was one kilogram. The workpiece drive spindle was offset 7.6 cm. From the center of the lap to the workpiece drive spindles rotation was 63.5 rpm. The lap rotated at 65 rpm. The coated abrasive disc was attached to the abrasive holder by double-coated tape. The test was stopped at 5, 15, 30, and 60 minute intervals to measure cumulative cut. The test results are set forth in Table 10.

Table 10

|               |    | Cut (g) |         |         |         |
|---------------|----|---------|---------|---------|---------|
|               |    | 5 min.  | 15 min. | 30 min. | 60 min. |
| 20            | 21 | 15.4    | 50.6    | 107.0   | 193.9   |
|               | 22 | 32.9    | 69.4    | 159.6   | 225.7   |
|               | 23 | 126.5   | 292.9   | 425.7   | 553.8   |
|               | 24 | 117.0   | 279.8   | 444.7   | 634.5   |
| Comparative E |    | 141.9   | 237.7   | 293.8   | 335.5   |

By the proper selection of the appropriate array and shape of composite, cut rate can be maximized, depth of the scratch can be minimized, and uniformity of the scratch pattern can be maximized.

The coated abrasive article of this invention did not load as much as did the coated abrasive article of Comparative Example E. The uniform array and shape of composites of the coated abrasive article of this invention contributed to its enhanced performance.

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In order to furnish guidance in the area of manufacturing production tools for preparing the coated abrasive articles of this invention, FIGS. 12-14, inclusive, and 17-19, inclusive, have been provided to set forth proposed dimensions for coated abrasive articles. The dimensions, i.e., inches or degrees of arc, are set forth in Table 11.

Table 11

| FIG. no. | Reference letter | Dimensions |
|----------|------------------|------------|
| 12       | a                | 12°        |
|          | b                | 0.0020 in. |
|          | c                | 0.0200 in. |
|          | d                | 0.0055 in. |
| 13       | e                | 90°        |
|          | f                | 0.0140 in. |
|          | g                | 0.0070 in. |
| 14       | h                | 16°        |
|          | j                | 0.0035 in. |
|          | k                | 0.0120 in. |
|          | L                | 0.0040 in. |
| 17       | m                | 0.052 in.  |
|          | n                | 0.014 in.  |
| 18       | o                | 0.018 in.  |
|          | p                | 0.018 in.  |
|          | r                | 0.023 in.  |
|          | s                | 0.017 in.  |
| 19       | t                | 0.004 in.  |
|          | v                | 0.009 in.  |
|          | w                | 53°        |

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Various modifications and alterations of this invention  
will become apparent to those skilled in the art without  
departing from the scope and spirit of this invention, and  
it should be understood that this invention is not to be  
5 unduly limited to the illustrative embodiments set forth  
herein.

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WHAT IS CLAIMED IS:

1. A coated abrasive article comprising a backing bearing on at least one major surface thereof abrasive composites comprising a plurality of abrasive grains dispersed in a binder, said composites having at least one predetermined shape, said composites being disposed in a predetermined array.
2. The article of Claim 1, wherein said binder bonds said composites to said backing.
3. The article of Claim 1, wherein said binder is curable by radiation energy.
4. The article of Claim 1, wherein said at least one predetermined shape is a pyramid.
5. The article of Claim 1, wherein said at least one predetermined shape is a prism.
6. The article of Claim 1, wherein said at least one predetermined shape is curvilinear.
7. The article of Claim 1, wherein said grains are selected from the group consisting of fused aluminum oxide, heat treated aluminum oxide, ceramic aluminum oxide, silicon carbide, alumina zirconia, garnet, diamond, cubic boron nitride, and mixtures thereof.
8. The article of Claim 1, wherein said binder is selected from the group consisting of phenolic resins, aminoplast resins, urethane resins, epoxy resins, acrylate resins, acrylated isocyanurate resins, urea-formaldehyde resins, isocyanurate resins, acrylated urethane resins, acrylated epoxy resins, glue, and mixtures thereof.

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9. The article of Claim 1, wherein substantially the entire surface of said backing is covered by said composites.

5 10. The article of Claim 1, wherein at least a portion of the surface of said backing is free of said composites.

10 11. The article of Claim 1, wherein said predetermined shapes have bases defined by intersecting grooves.

12. A method of making a coated abrasive article comprising the steps of:

15 (1) introducing a slurry containing a mixture of a binder and a plurality of abrasive grains onto a production tool;

(2) introducing a backing to the outer surface of the production tool such that the slurry wets one side of the backing to form an intermediate article;

20 (3) at least partially curing or gelling the binder before the intermediate article departs from the outer surface of the production tool to form a coated abrasive article; and

25 (4) removing the coated abrasive article from the production tool.

30 13. The method of Claim 12, wherein said binder is cured by radiation energy.

14. The method of Claim 12, wherein said production tool is cylindrical in shape.

35 15. The method of Claim 12, wherein said production tool is a belt.

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16. The method of Claim 12, wherein said binder is cured by thermal energy.

17. The method of Claim 12, further including the step of fully curing the coated abrasive article after  
5 removal from the production tool.

18. A method of making a coated abrasive article comprising the steps of:

10 (1) introducing a slurry containing a mixture of a binder and plurality of abrasive grains on to a backing such that the slurry wets the front side of the backing to form an intermediate article;

15 (2) introducing the intermediate article to a production tool having an outer surface, the outer surface of the production tool containing a specified pattern;

20 (3) at least partially curing or gelling the binder before the intermediate article departs from the outer surface of the production tool to form a coated abrasive article; and

(4) removing from the coated abrasive article from the production tool.

25 19. The method of Claim 18, wherein said binder is cured by radiation energy.

30 20. The method of Claim 18, wherein said production tool is cylindrical in shape.

21. The method of Claim 18, wherein said production tool is a belt.

35 22. The method of Claim 18, wherein said binder is cured by thermal energy.



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23. The method of Claim 18, further including the step of fully curing the coated abrasive article after removal from the production tool.

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