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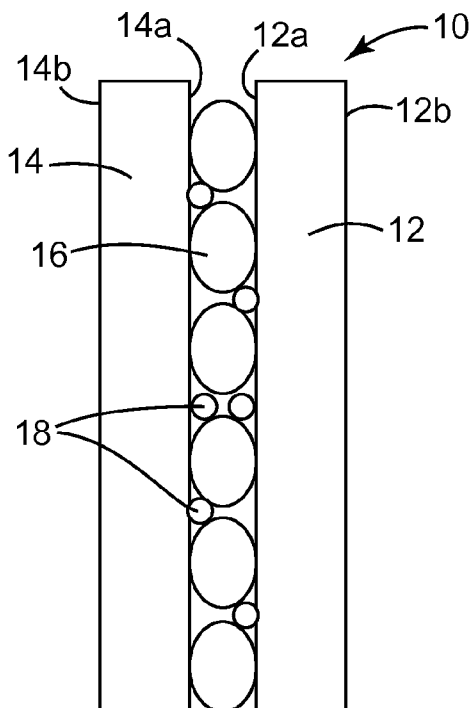
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(54) Title: FUNCTIONAL PARTICLE TRANSFER LINER



*Fig. 1*

(57) Abstract: A functional particle transfer liner is provided that includes a release liner that has a release coating and a layer of functional particles disposed upon the release coating. The functional particles are free of abrasive particles and metal particles. The functional particle transfer particles are selected from wear-resistant particles, optical particles, biologically-active particles, photocatalytic particles, dielectric particles, fluorescent particles, and combinations thereof. Also provided is a method of making a modified substrate using the provided functional particle transfer liner.

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**FUNCTIONAL PARTICLE TRANSFER LINER**

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**Background**

There are numerous ways to apply particulate-coated liners to a substrate. For example, U. S. Pat. No. 2,332,505 (Crompton) discloses a method of making an abrasive disk having a layer of diamond abrasives on one or both sides of the disk using a system having a hydraulic press. The method recites a first step of molding under light pressure a disk from metal powders. Thereafter, diamond  
10 abrasive grains were sprinkled onto one side of the disk. An electromagnetic force of about 10,000 volts was applied to the system such that the diamond grains acquire an electric charge thereby orienting their longest dimension.

U.S. Pat. No. 5,368,618 (Masmar et al.) discloses a method of making a coated abrasive liner where the presence of multiple layers of abrasive grains is minimized. One method involves the steps of  
15 providing a backing, applying a make coat precursor to the backing, partially curing the make coat precursor, applying, preferably by projecting, a plurality of abrasive grains into the partially cured make coat precursor, and completely curing the partially cured make coat precursor. In one variation, a size coat precursor is applied over the abrasive grains and cured make coat and the size coat is completely cured. In another variation, the size coat precursor is applied over the abrasive grains and the partially  
20 cured make coat precursor, and the make coat precursor and size coat precursor are completely cured.

U. S. Pat. No. 5,620,775 (LaPerre) discloses a transfer liner that can be used to make a bead coated liner that may have retroreflective images and non-retroreflective images. The transfer liner includes (a) a transfer carrier having a support layer and a thermoplastic glass bead release layer bonded to the support layer; (b) a layer of a mixture of transparent glass beads and irregularly shaped glass liners  
25 partially embedded in the thermoplastic release layer; and (c) a layer of a first adhesive formed on the surfaces of the glass beads and the irregularly shaped glass liners not embedded in the thermoplastic release layer. A method of making a transfer liner is also disclosed. The transfer coating method uses a transfer carrier, which in its simplest form, includes a support layer and a thermoplastic release layer bonded thereto. The thermoplastic release layer of the transfer carrier temporarily partially embeds a  
30 layer of glass beads.

Additionally, liner transfer liners are known that include a first liner having opposing first and second surfaces, the first surface having a release value of less than about 700 gram per inch per ASTM D3330/D3330M-04 and a powder comprising abrasive or metal liners disposed on the first surface of the first liner. The liner can have a release coating selected from the group consisting of a fluorine containing  
35 material, a silicon containing material, a fluoropolymer, a silicone polymer or a poly (meth)acrylate ester derived from a monomer comprising an alkyl (meth)acrylate having an alkyl group having 12 to 30 carbon atoms. The term (meth)acrylate includes acrylate and methacrylate.

### Summary

There is a desire to produce liners for packaging, protection and storage of functional particles in a film format and for eventual delivery of a monolayer of these functional particles onto a substrate, which may be rigid, for example, a precisely planar rigid lapping surface, or flexible, to create liner-modified substrates. The present disclosure provides a streamlined and economically efficient solution to create functional particle transfer liners and functional particle modified substrates or plates. The provided functional particle transfer liners enable the coating, packaging, storage, and delivery of functional particles in a film format. The functional particles are unperturbed by resinous coatings or binders that can compromise their functional value. Lacking a continuous constricting binder, precise placement of the particles can be achieved. Typically, the functional particles substantially form a monolayer on a release liner and are held onto the release liner by electrostatic forces.

As used herein, the term “functional particle transfer liner” generally refers to release liners that provide particles that, in turn provide functionality such as wear resistance, friction, lubricity, electrochemical activity, chemical activity, biological activity, or catalytic activity. “Functional particle transfer liners” do not include abrasive particle transfer liners. Abrasive particle transfer liners are used to fabricate abrasive articles that can be used to polish, abrade, or finish a liner or workpiece.

The term “cured” encompasses partially cure or fully cured condition of the binder. The term “partially cured” means a condition of the resinous binder in which the resin has begun to polymerize and has experienced an increase in molecular weight, but in which the resin continues to be at least partially soluble in an appropriate solvent. The term “fully cured” means a condition of the resinous binder in which the resin is polymerized and is in a solid state and in which the resin is not soluble in a solvent. The term “particles”, “microspheres” and “beads” are used interchangeably.

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

### Brief Description of the Drawings

The invention will be further described with reference to the following drawings, wherein:

Fig. 1 is a schematic cross-sectional view of a functional particle transfer liner according to one aspect of the present disclosure;

Fig. 2 is a schematic cross-sectional view of an exemplary method of using a functional particle transfer liner according to one aspect of the present disclosure; and

Fig. 3 is a perspective view of a roll of functional particle transfer liner according to one aspect of the present disclosure.

These figures are illustrative, are not drawn to scale, and are intended merely for illustrative purposes.

### Detailed Description

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

10 Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein. The use of numerical ranges by endpoints includes all numbers within that range (e.g. 1 to 5 includes 1, 1.5, 2, 15 2.75, 3, 3.80, 4, and 5) and any range within that range.

Now turning to the figures, Fig. 1 shows a schematic cross-sectional view of an exemplary functional particle transfer liner 10 having a first release liner 12, a second liner 14, and functional particle 16 disposed or sandwiched between the two liners. Each of the first and second liner has a first surface 12a and 14a respectively and an opposing second surface 12b and 14b respectively. A release coating (not shown) is disposed on the first surface 12a of the first liner and optionally on the first surface of 14a of the second liner. Optionally, a particulate binder 18, which can function as a second binder (as further described below), can be disposed between the first and second liners. The particulate binder 18 can be a thermoplastic or a thermosetting resin. While Fig. 1 shows the thermoplastic resin as smaller than the functional particles, the thermoplastic resin can be of the same or larger size than the functional particles. As used herein, a “powder” can include the functional particle, the particulate binder, and combinations thereof.

Fig. 2 shows a schematic cross-sectional view of a portion of an exemplary transfer method that can be used to make a modified substrate of the present disclosure. Prior to a functional particle liner transfer step, a substrate 20, having opposing first and second surfaces 20a and 20b respectively, has a first binder 22 coated on the substrate’s first surface. The second liner 14 of functional particle transfer liner 40 of Fig. 2 has been removed to expose the functional particles 16 and any particulate binder 18, if used, which remains on the first liner 12. The first liner is disposed on the substrate such that the functional particles 16 are in direct contact with the first binder 22. Fig. 2 shows that pressure is manually applied, using a lamination device 30, to the second surface 12b of the first liner 12 to promote

the transfer of the functional particles **16** and any particulate binder **18** from the first liner to the first binder. Other lamination techniques known to those skilled in the art can also be used. The largest functional particles typically penetrate the resinous binder **22** to come in direct contact with the first surface **20a** of the rigid substrate. Thereafter the first liner is removed.

5           During the process of contacting the functional particles **16** and any particulate binder material **18**, if used, to the first binder **22**, the resinous binder material should be in a tacky state. That is, the first binder should have sufficient tack to enable at least 20%, more typically at least 50% and most typically at least 70% of the functional particles **16** and any particulate binder material **18**, to be transferred to the first binder. Depending on the type of first binder used, this tacky state can be achieved in a variety of  
10 ways.

          When the first binder is formed from a solvent-based mixture containing a polymer, oligomer, monomer or combinations thereof, a tacky state may be inherent in the mixture. If not, it may be achieved by removing at least some of the solvent and, if required, at least partially curing the polymer, oligomer or monomer.

15           When the first binder is formed from a substantially solvent-free mixture containing a liquid polymer, oligomer, monomer or combinations thereof, the tacky state may be inherent in the mixture as well. If not, a tacky state may be achieved by heating or cooling the mixture or may be achieved by at least partially curing the polymer, oligomer, monomer or combinations thereof.

          When the first binder is a particulate binder material, a tacky state may be achieved by heating the  
20 particulate binder material to a temperature near, at or above its glass transition ( $T_g$ ) temperature and/or melting point to enable sufficient tack to develop. Advantageously, in this case, a uniform coating of the first binder on a rigid substrate (such as substrate **20** in Fig. **2**) can be facilitated by heating the particulate binder material to a temperature above its  $T_g$  temperature and/or melting point causing a phase transition from the solid to liquid state. The heating can be done, for example, by placing the substrate containing  
25 the particulate binder into an oven or other heating devices. Once in the liquid state, a uniform coating of the particulate binder material can be formed by techniques known to those skilled in the art, such as, for example, by manually spreading the now liquid material. Thus, in this particular case, the particulate binder material used as a first binder **22** may be the same or different from particulate binder material **18**.

          In one embodiment, after functional particle transfer liners **16** and any particulate binder material  
30 **18**, if used, are transferred to the first binder **22**, the binder may be at least partially cured and/or partially solidified, forming a solid or substantially solid first binder. With a solid first binder, the functional particles are rigidly held therein, being substantially fixed in place, forming a modified substrate comprising functional particles. When the first binder is thermoplastic resin, it can be solidified by cooling below its melting point and/or  $T_g$  temperature. When the first binder is a solvent-based mixture  
35 containing a polymer, oligomer, monomer or combinations thereof, it can be transformed to the solid state by removal of a majority of the solvent and/or by various methods of curing known to those skilled in the

art. When the first binder is a substantially solvent-free mixture containing liquid polymer, oligomer, monomer or combinations thereof, it can be transformed to the solid state by various methods of curing known to those skilled in the art.

In another embodiment, after functional particles **16** and any particulate binder material **18**, if used, are transferred to the first binder **22**, it remains in a liquid state forming a non-fixed, functional particle, modified substrate. The viscosity of the first binder in the liquid state may be adjusted to the desired level by a variety of methods including, for example, heating, cooling, partially curing, and removing solvent (if present). In these embodiments, the functional particles are substantially free to move within the first binder.

In still another embodiment, optional second binder and optional third binder may be applied to the first binder and the functional particle modified substrate. The first binder can be in the solid state or liquid state during the coating process step. Preferably, the first binder is in the solid state. The optional second binder and optional third binder can be applied by known coating techniques. Compositions of the functional particle transfer liners, optional second binder and optional third binder are discussed in below in detail.

Fig. 3 shows a perspective view of a roll of provided functional particle transfer liner **50**. The roll of functional particle transfer liner may be subsequently converted into sheets and discs or may be in the form of a sheet or disc. The transfer liners of the present disclosure may be used to modify a substrate, both rigid and flexible with unique surface distribution of functional particles.

The roll of transfer liner includes a single release liner **52** having opposing first surface and second surface **52b**, with a release coating (not shown) disposed on the first surface. Functional particles **56** and optional particulate binder material (not shown) are disposed on the first surface. Optionally, a second release coating (not shown) is also disposed on the second surface **52b** of the release liner, the second release coating having a lower release value than the first release coating thereby promoting the unwinding of the roll and minimizing if not eliminating the possibility of the functional particles (and any particulate binder material if used) remaining with the second surface **52b** of the liner.

Another embodiment includes multiple layers of release liner and functional particles. For example, a transfer liner may comprise a first liner having a first and second surface. A first layer of functional particles is disposed on the first surface of the first liner. A second liner, having a first and second surface, is disposed on the layer of functional particles such that the first surface of the second liner is in contact with the functional particles. Thus, the functional particles are sandwiched between the first and second liners. A second layer of functional particles is disposed on the second surface of the second liner. Optionally a third liner, having a first and second surface, is in contact with the second layer of functional particles. The number of layers of liners and the number of layers of functional particles can be selected based on the desired end use. The first, second, third and any additional liners

may be the same or may be different. Similarly, the first, second and any additional layers of functional particles may be the same or may be different.

### **Materials for the First and Optional Second Liner**

5           The type of release liner suitable for use in the present disclosure is not limited, so long as the liner can cause an electrostatic attraction to or electrostatic adhesion between it and the functional particles thereby allowing the functional particles to remain or cling to the liner. As discussed with reference to the drawings above, the liner has a release coating disposed on its first surface.

10           In one embodiment, the liner is a flexible backing. Exemplary flexible backings include densified Kraft paper (such as those commercially available from Loparex North America, Willowbrook, IL), poly-coated paper, and polymeric film. Suitable polymeric film includes polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene.

15           In one embodiment, the release coating of the liner has a release value of less than about 700 gram per inch. Various test method can be used to measure this release value, such as for example ASTM D3330/D3330M-04. In another embodiment, the release coating of the liner is fluorine-containing material, a silicon-containing material, a fluoropolymer, a silicone polymer, or a poly (meth)acrylate ester derived from a monomer comprising an alkyl (meth)acrylate having an alkyl group 12 to 30 carbon atoms. In one embodiment, the alkyl group can be branched. Illustrative examples of useful fluoropolymers and silicone polymers can be found in U.S. Pat. Nos. 4,472,480; 4,567,073; and  
20           4,614,667. Illustrative example of a useful poly (meth)acrylate ester can be found in U.S. Patent Publ. No. 2005/118352.

25           In one embodiment, a first surface of the liner on which the functional particles are to be disposed may be textured so that at least one plane of the first surface of the liner is higher than another plane. The textured surface may be patterned or random. The highest plane or planes of the textured surface may be designated as the “delivery plane” because the highest plane or planes will deliver the functional particles to the substrate. The lower plane or planes may be designated as “recessed planes.”

### **Functional Particle Transfer Liners**

30           Functional particle transfer liners, as used herein, do not include abrasive particles. In this disclosure, abrasive particles are particles that can be used to polish, abrade, or finish a workpiece. Such excluded particles include fused aluminum oxide, heat treated aluminum oxide, white fused aluminum oxide, black silicon carbide, green silicon carbide, titanium diboride, boron carbide, tungsten carbide, titanium carbide, diamond (both natural and synthetic), silica, iron oxide, chromia, ceria, zirconia, titania, silicates, tin oxide, cubic boron nitride, garnet, fused alumina zirconia, sol gel abrasive liners and the like.  
35           Examples of sol gel abrasive particles can be found in U.S. Pat. Nos. 4,314,827 (Leitheiser et al.);



4,623,364 (Cottringer et al); 4,744,802 (Schwabel); 4,770,671 (Monroe et al.); and 4,881,951 (Wood et al.).

Functional particle transfer liners, as used herein, do not include metal particles. Metal particles include tin, copper, indium, zinc, bismuth, lead, antimony, and silver, and alloys thereof, as well as combinations thereof. Metal particles include tin/bismuth metal beads. Provided functional particles include particles that have functions other than use as an abrasive. For example, functional particles can include wear-resistant particles, optical particles, biologically-active particles, photocatalytic particles, dielectric particles, fluorescent particles, and combinations thereof. Wear-resistant particles include polyurethane beads, poly(methyl methacrylate) beads, and polystyrene beads. Optical particles include particles that can have optical properties such as those that function as lenses or have retroreflective properties. These particles can be useful in optical microlens arrays such as those disclosed, for example in U. S. Pat. Publ. Nos. 2006/018739 (Yamanaka et al.), 2008/0278663 (Krishnan et al.), or 2010/0002468 (Liu). In other embodiments that particles can be useful as LED light extractors as, for example, in U. S. Pat. No. 7,423,297 (Leatherdale et al.), or as photoconductors as in U. S. Pat. No. 3,446,616 (Clark). Also included are pharmaceutical particles that can be biologically-active. Such particles include spray dried pharmaceuticals (see *Pharmaceutical Research*, **25**(5), p. 999 (May 2008)), bioapplications of sol gel particles as disclosed, for example, in Livage et al., *J. Mater. Chem*, **16**, 1013-1030, or the use of spray drying for chitosan materials as disclosed, for example, in Rege et al., *International Journal of Pharmaceuticals*, **252**, 41-51 (2003). Provided particles also include photocatalytic liners such as those that use perfluorinated silica gel for catalytic reactions without perfluorinated solvents. These catalytic support particles are disclosed, for example, in Tzchucke et al., *Angew. Chem. Int. Ed.*, **41**, 4500 (2002).

The provided functional particles include particles that are viscoelastic providing mechanical functionality such as friction, lubricity, or dampening. Other functional particles include ionic conductors or other electrochemically active particles useful as materials in, for example, anodes, cathodes, or separators in electrochemical cells such as, for example, lithium-ion electrochemical cells. Functional particles can be chemically, biologically, or catalytically active. Functional particles can be porous and capable of adsorbing or entrapping materials such as in filtering, or in ion exchange or chromatography. Provided functional particles also include those that are capable of changing energy from one form to another such as radiant energy into electrical, mechanical, or audible energy. Functional particles can be plastic, polymeric, glassy, crystalline, organic, inorganic, hollow or solid, light-reflecting, light-transmitting, or light manipulating particles. The choice of functional particles depends upon the intended application.

The provided functional particle transfer liners can include a substantially monolayer coating of shaped particles that are electrostatically attached to a flexible static insulating release liner. The provided functional particle transfer liners can be covered with a protective liner and/or rolled upon

themselves. The release liner can be a film backing that includes a hydrophobic, static-insulating material or coating. The protective liner can be static-insulating or static-dissipative. The advantage of the provided functional particle transfer liners is that they can provide a method of applying functional particles onto a surface with a high degree of control of the volume, bearing area, and thickness of the resulting layer, thereby allowing greater control of the desired properties that can be achieved through the particle functionality.

### Binders

Materials that are useful as the first binder 22 are also useful as the second binder. Examples of suitable first and or second binders include thermosetting resins, such as phenolic resins, aminoplast resins having pendant  $\alpha,\beta$ -unsaturated carbonyl groups, urethane resins, acrylated urethane resins, epoxy resins, acrylated epoxy resins, ethylenically-unsaturated resins, acrylated isocyanurate resins, urea-formaldehyde resins, isocyanurate resins, bismaleimide resins, fluorene modified epoxy resins, and mixtures thereof.

Suitable epoxy resins have an oxirane ring and are polymerized by the ring opening. Such epoxide resins include monomeric epoxy resins and polymeric epoxy resins. These resins can vary greatly in the nature of their backbones and substituent groups. For example, the backbone may be of any type normally associated with epoxy resins and substituent groups thereon can be any group free of an active hydrogen atom that is reactive with an oxirane ring at room temperature. Representative examples of acceptable substituent groups include halogens, ester groups, ether groups, sulfonate groups, siloxane groups, nitro groups and phosphate groups. Examples of some preferred epoxy resins include 2,2-bis[4-(2,3-epoxy-propoxy)phenyl]propane (diglycidyl ether of bisphenol) and resins which are commercially available from Shell Chemical Co., Houston, TX, under the trade designations EPON 828, EPON 1004, and EPON 1001F; and from Dow Chemical Co., Midland, MI, under the trade designations DER 331, DER 332, and DER 334. Other suitable epoxy resins include glycidyl ethers of phenol formaldehyde novolac (from Dow Chemical Co.) under the trade designations DEN 431 and DEN 438.

Phenolic resins may be used as binder 22 because of their thermal properties, availability, cost and ease of handling. There are two suitable types of phenolic resins, resole and novolac. Resole phenolic resins have a molar ratio of formaldehyde to phenol, of greater than or equal to 1:1, typically between 1.5:1.0 to 3.0:1.0. Novolac resins have a molar ratio of formaldehyde to phenol of less than one to one. Suitable examples of phenolic resins include those commercially available from Occidental Chemical Corp., Tonawanda, NY, under the trade designations DUREZ and VARCUM; from Monsanto Co., St. Louis, MO, under the trade designation RESINOX; and from Ashland Chemical Inc., Columbus, OH, under the trade designations AROFENE and AROTAP. The aminoplast resins which can be used as resinous binders have at least one pendant  $\alpha,\beta$ -unsaturated carbonyl group per molecule or oligomer.

These materials are further described in U.S. Pat. Nos. 4,903,440 (Larson et al.) and 5,236,472 (Kirk et al.).

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

Acrylated urethanes are diacrylate esters of hydroxy terminated isocyanate extended polyesters or polyethers. Examples of acrylated urethanes which can be used as binders include those commercially available from Radcure Specialties, Inc., Atlanta, GA, under the trade designations, UVITHANE 782, CMD 6600, CMD 8400, and CMD 8805. Acrylated epoxies which can be used are diacrylate esters of epoxy resins, such as the diacrylate esters of bisphenol A epoxy resin. Examples of acrylated epoxies include those available from Radcure Specialties, under the trade designations, CMD 3500, CMD 3600, and CMD 3700. Bismaleimide resins which also can be used as resinous binder are further described in U.S. Pat. No. 5,314,513 (Miller et al.).

At least one of first and second binder can be system that contains a ternary photoinitiator system allowing for photocuring as disclosed in U.S. Pat. No. 4,735,632 (Oxman et al.). Other suitable first and second binders are disclosed in U.S. Pat. Nos. 5,580,647 (Larson et al.) and 6,372,336 B1 (Clausen). At least one of the first and second binder can also contain optional additives, such as, for example, fillers, fibers, lubricants, wetting agents, thixotropic materials, surfactants, pigments, dyes, antistatic agents, coupling agents, plasticizers, and suspending agents. The amounts of these materials are selected to provide the properties desired.

### Particulate Binders

The first binder 22, second binder and optional third binder can be a particulate binder material that is a solid at room temperature (23°C). The particulate binder can become a solid either (i) through the curing (such as visible light cure or ultraviolet light cure) of a thermosetting liquid composition or (ii) by the cooling of a thermoplastic material, which can be semi-crystalline or non-crystalline. In some aspects, the particulate binder material may be mixed with functional particles. The particulate binder material typically comprises organic polymer particles. The particulate polymers typically are capable of softening on heating to provide a liquid capable of flowing sufficiently so as to be able to wet either a functional particle surface or the surface of an substrate.

Suitable particulate binder material is capable of providing satisfactory functional particle bonding to the rigid substrate by being activated or rendered tacky at a temperature which avoids causing heat damage or disfiguration to the rigid substrate to which it is adhered. The particulate binder materials meeting these criteria can be selected from among certain thermosetting materials, thermoplastic materials and mixtures of thermosetting and thermoplastic materials, as described herein.

The thermosetting particulate systems involve particles made of a temperature-activated thermosetting resin. Such particles are used in a solid granular or powder form. The initial effect of a temperature rise above the  $T_g$  temperature is a softening of the material into a flowable fluid-like state. This change in physical state allows the resin particles to mutually wet or contact the substrate and/or functional particles. Prolonged exposure to a sufficiently high temperature triggers a chemical reaction which forms a cross-linked three-dimensional molecular network. The solidified (cured) resin particles bond the functional particles to the substrate. Useful particulate binder materials are selected from the group consisting of phenolic resins, phenoxy resins, polyester resins, copolyester resins, polyurethane resins, polyamide resins and mixtures thereof. Useful temperature-activated thermosetting systems include formaldehyde-containing resins, such as phenol formaldehyde, novolac phenolics and especially those with added crosslinking agent (e.g., hexamethylenetetramine), phenoplasts, and aminoplasts; unsaturated polyester resins; vinyl ester resins; alkyd resins, allyl resins; furan resins; epoxies; polyurethanes; cyanate esters; and polyimides. Useful thermosetting resins include the thermosetting powders disclosed, for example, in U.S. Pat. Nos. 5,872,192 (Kaplan et al.) and 5,786,430 (Kaplan et al.). In the use of heat-activated thermosetting fusible powders, the particulate binder material is heated to at least its cure temperature to optimize the substrate and particulate bonding.

Useful thermoplastic particulate binder materials include polyolefin resins such as polyethylene and polypropylene; polyester and copolyester resins; vinyl resins such as poly(vinyl chloride) and vinyl chloride-vinyl acetate copolymers; polyvinyl butyral; cellulose acetate; acrylic resins including polyacrylic and acrylic copolymers such as acrylonitrile-styrene copolymers; and polyamides (e.g., hexamethylene adipamide, polycaprolactum), and copolyamides.

In the case of semi-crystalline thermoplastic binder particles (e.g., polyolefins, polyesters, polyamides, polycaprolactum), it is typical to heat the binder particles to at least their melting point where upon the particles become molten to form a flowable fluid. Where noncrystallizing thermoplastics are used as the particulate binders (e.g., vinyl resins, acrylic resins), the particles preferably are heated above  
5 the  $T_g$  temperature and rubbery region until the fluid flow region is achieved.

Mixtures of the above thermosetting and thermoplastic particle materials may also be used in the invention. Furthermore, the size of the particulate binder material is not particularly limited. In general, the average diameter of the particle is less than 1000  $\mu\text{m}$  (0.039 in), typically less than 500  $\mu\text{m}$  (0.020 in), or less than 100  $\mu\text{m}$  (0.0039 in). Generally, the smaller the diameter particles, the more efficient they  
10 may be rendered flowable because the surface area of the particles will increase as the materials are more finely divided.

The amount of particulate binder material used in the particulate binder-functional particle mixture generally will be in the range from 5 to 99 wt % particulate binder material, with the remainder 1 to 95 wt % comprising functional particles and optional fillers. Typical proportions of the components in  
15 the mixture are 10 to 90 wt % functional particles and 90 to 10 wt % particulate binder material, and more preferably 50 to 85 wt % functional particles and 50 to 15 wt % particulate binder material.

The particulate binder material may include one or more optional additives selected from the group consisting of fillers, wetting agents, surfactants, pigments, coupling agents, dyes, initiators, curing agents, energy receptors, and mixtures thereof.  
20

### **Substrate**

The substrate may be rigid or flexible. The term "rigid" describes a substrate that is at least self-supporting, i.e., it does not substantially deform under its own weight. By rigid, it is not meant that the substrate is absolutely inflexible. Rigid substrates may be deformed or bent under an applied load but  
25 offer very low compressibility. In one embodiment, the rigid substrates comprise materials having a modulus of rigidity of  $1 \times 10^6$  pound per square inch (psi) ( $7 \times 10^4 \text{ kg/cm}^2$ ) or greater. In another embodiment, the rigid substrates comprise material having a modulus of rigidity of  $10 \times 10^6$  psi ( $7 \times 10^5 \text{ kg/cm}^2$ ) or greater.

Suitable materials that can function as the rigid substrate include metals, metal alloys, metal-  
30 matrix composites, metalized plastics, inorganic glasses and vitrified organic resins, formed ceramics, and polymer matrix reinforced composites. Suitable materials that can function as a flexible substrate include polyester, polyimide, polyurethane, or other polymeric materials that can form a flexible web.

In one embodiment, the substrate is substantially flat such that the height difference between its opposing first and second surfaces is less than 10  $\mu\text{m}$  at any two points thereon. In another embodiment,  
35 the rigid substrate has a precise, non-flat geometry. Yet another embodiment includes a modified substrate comprising a substrate having a first and a second surface, a first binder on the first surface of

the substrate, and a layer of functional particles disposed in the first binder, wherein the layer comprises at least two concentric regions on the first binder. The term "concentric" refers to a sharing of the same center, axis or origin, i.e., the center of the substrate. Suitable shapes for concentric regions include, but are not limited to, circles, squares and stars. Each concentric region varies in some way from another concentric region so that each concentric region comprises functional particle liners having a feature which differs from a feature of functional particle liners of any other concentric region. For example, a concentric region may vary from another concentric region by the areal density (bearing area) or the functional particles, the wear resistance, the type, the size, the shape and or the placement (random or uniformly spaced) of the functional particles. In addition, within a region, the placement or location of functional particles may be such that the functional particles are uniformly spaced or randomly spaced. Also, the type and or shape of functional particles may be varied within a region and yet still be different from another region.

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

### Examples

#### Example 1

A functional particle transfer liner was made as follows. A first release liner, a 25 inch (63.5 cm) square sheet of 3M NON-SILICONE RELEASE LINER 4935 (available from 3M Company, St. Paul, MN), has a first side containing a release coating thereon and an opposing second side. The liner was taped to a 25 inch (63.5 cm) square 2.0 mm thick aluminum plate, with the first, release side exposed. The aluminum plate with liner was placed on a substantially horizontal work surface. About 2 g of Art Pearl C-70T urethane beads (available from Negami Chemical Ltd., Nomi-city, Japan), having an average diameter of about 60 micrometer ( $\mu\text{m}$ ), were placed in a line across one edge of the liner. The edge of the aluminum plate having the urethane beads was lifted up at an angle from the horizontal work surface and the back side of the aluminum plate was tapped, causing the beads to roll down and coat the liner. Additional urethane beads were added to substantially cover the entire exposed surface area of the first release side of the first liner. Thereafter, the aluminum sheet with the attached and now urethane bead coated liner was held nearly vertically and tapped to remove excess beads. The aluminum plate was replaced on the horizontal work surface.

A second release liner, 3M NON-SILICONE RELEASE LINER 4935 liner, has a first side containing a release coating thereon and an opposing second side. The second liner was applied to the urethane beads of the first liner such that the first release side of the second liner was in contact with the urethane beads. Pressure was then manually applied to the beads by rolling the second surface of the

second liner using, e.g., a hand roller. It is believed that this manual rolling process aligns the largest diameter urethane particles into a substantially uniform layer, perhaps even a monolayer, of particles disposed in between the first and second liner, forming a functional particle transfer liner. The coating weight of urethane beads was about  $3.4 \times 10^{-3} \text{ g/cm}^2$ .

5 An annular shaped stainless steel sheet having a 100 mm OD, 7 mm ID and 1 mm thickness was then coated with an adhesion promoting layer, AlTiN. The AlTiN layer was formed on the steel sheet surface by a standard commercial sputter process, a cathodic arc process with aluminum/titanium target in the presence of nitrogen gas. A primer layer, 50/50 weight % mixture of C219 CHEMLOK 219, a mixed polymer adhesive, (available from Lord Corporation, Cary, NC) and anhydrous denatured ethanol, was  
10 spray coated onto the AlTiN layer. The primer layer was allowed to dry at ambient conditions. An adhesive layer, a 50/50 weight % mixture of CHEMLOK 213, a mixed polymer adhesive, and THINNER 248, a solvent mixture, (both available from Lord Corporation) was then applied to the primer layer. The second release liner was removed along with the attached excess urethane beads from the functional particle transfer liner. The exposed urethane bead side of the first release liner was then brought into  
15 contact with the adhesive coated stainless steel sheet. A rubber hand roller was used to apply pressure to the back side of the release liner, forcing the urethane beads into the adhesive coating. The release liner was removed, leaving the urethane beads on the steel sheet. The adhesive was subsequently cured by heating in an air flow through oven at a set point of 120°C for two hours, creating a urethane bead protective layer on the surface of the stainless steel sheet.

20

#### Example 2

A functional particle transfer liner was prepared following a similar procedure as Example 1 except that polymethylmethacrylate (PMMA) beads, 10  $\mu\text{m}$  average diameter (available from Soken Chemical and Engineering Company, Ltd., Tokyo, Japan) were used in place of the urethane beads. The  
25 coating weight of the PMMA beads was about  $8.3 \times 10^{-3} \text{ g/in}^2$  ( $1.3 \times 10^{-3} \text{ g/cm}^2$ ).

A annular shaped, anodized aluminum platen, 16 inch (40.6 cm) OD and 8 (20.3 cm) inch ID was coated with a mixture of about 1 g of SCOTCH-WELD 1838-L, a two part epoxy adhesive, (available from 3M Company) in 2 g methyl ethyl ketone. The solution was spread with a rubber hand roller across the platen, allowing some of the solvent to dry. The second release liner was removed along  
30 with the attached excess PMMA beads from the functional particle transfer liner. The exposed PMMA bead side of the first release liner was then brought into contact with the adhesive coated platen. A rubber hand roller was used to apply pressure to the back side of the release liner, forcing the PMMA beads into the adhesive coating. The liner was removed, leaving the PMMA beads on the aluminum platen. The adhesive was subsequently cured by heating in an air flow through oven at a set point of 70°C for two  
35 hours, creating a PMMA bead coated aluminum platen, which may be used as a support for an abrasive article used in lapping applications.

## Example 3

A functional particle transfer liner was prepared following a similar procedure as Example 1 except that FLUORESBRITE Plain YG, Cat#18242, monodisperse polystyrene fluorescent microspheres, 45  $\mu\text{m}$  average diameter, 2.65% by weight in water (available from Polysciences, Inc., Warrington, Pennsylvania) were used in place of the urethane beads. Prior to coating the microspheres on the first release liner, the microspheres were recovered from the solution by filtering with a piece of filter paper. The filter paper with microspheres was dried at 60  $^{\circ}\text{C}$ . The microspheres were then applied to the first release liner. In this case, only a small fraction of the release liner area was used. The second release liner was added and pressure applied, as previously described.

## Example 4

A functional particle transfer liner was prepared following a similar procedure as Example 1 except high index, reflective inorganic microspheres, 100  $\mu\text{m}$  diameter, e.g. those disclosed in US Pat. Publ. No. 2002/0006510 (Budd et al), were used in place of the urethane beads. Also, the first release liner was replaced by a 25 inch (63.5 cm) square sheet of siliconized, polycoated Kraft release paper (available from Loparex, LLC., Willowbrook, Illinois). The coating weight of the inorganic microspheres was about  $8.4 \times 10^{-3} \text{ g/cm}^2$ .

## Example 5

A functional particle transfer liner was prepared following a similar procedure as Example 1 except Silica gel 60 C8 reverse phase perfluorinated particles, 30-60  $\mu\text{m}$  diameter (available from Sigma-Aldrich, Inc., Milwaukee, WI) were used in place of the urethane beads. The coating weight of the Silica gel 60 C8 reverse phase perfluorinated particles was about  $1.3 \times 10^{-3} \text{ g/cm}^2$ .

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

Following are exemplary embodiments of a functional particle transfer liner according to aspects of the present invention.

Embodiment 1 is a functional particle transfer liner comprising: a release liner having opposing first and second surfaces, wherein the first surface comprises a release coating; and a layer of functional



particles disposed upon the release coating, wherein the functional particles are free of abrasive particles and metal particles.

Embodiment 2 is a functional particle transfer liner according to embodiment 1, wherein the first surface has a release value of less than about 700 grams per inch per ASTM D3330/D3330M-04.

5 Embodiment 3 is a functional particle transfer liner according to embodiment 1, wherein the release liner further comprises a flexible backing and a release coating disposed on at least the first surface of the release liner, the release coating comprising a fluorine containing material, a silicon containing material, a fluoropolymer, a silicone polymer, or a poly (meth)acrylate ester derived from a monomer comprising an alkyl (meth)acrylate having an alkyl group having 12 to 30 carbon atoms.

10 Embodiment 4 is a functional particle transfer liner according to embodiment 3, wherein the flexible backing is selected from the group consisting of densified kraft paper, polycoated paper, and a polymeric film.

Embodiment 5 is a functional particle transfer liner according to embodiment 4, wherein the polymeric film is selected from the group consisting of polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide, polyimide, polysilicone, and polytetrafluoroethylene.

Embodiment 6 is a functional particle transfer liner according to embodiment 5, wherein the functional particles are selected from wear-resistant particles, optical particles, biologically-active particles, photocatalytic particles, dielectric particles, fluorescent particles, and combinations thereof.

20 Embodiment 7 is a functional particle transfer liner according to embodiment 6, wherein the wear-resistant particles are selected from poly(methyl)methacrylate beads, polyurethane beads, and polystyrene beads.

Embodiment 8 is the functional particle transfer liner of embodiment 1, wherein the release liner is textured.

Embodiment 9 is a method of making a modified substrate comprising the steps of: providing a substrate having opposing first and second surfaces; coating a first binder on the first surface of the rigid substrate; providing a functional particle transfer liner comprising a release liner having opposing first and second surfaces, wherein the first surface comprises a release coating; and a layer of functional particles disposed upon the release coating; applying the functional particle transfer liner to the first surface of the substrate, wherein the functional particles are in contact with the binder; removing the release liner from the rigid substrate; and curing the binder thereby securing the functional particles to the first surface of the substrate, wherein the functional particles are free of abrasive particles and metal particles.

Embodiment 10 is a method of making a modified substrate according to embodiment 9, wherein the first surface has a release value of less than about 700 grams per inch per ASTM D3330/D3330M-04.

35 Embodiment 11 is a method of making a modified substrate according to embodiment 9, wherein the binder is at least partially cured prior to applying the functional particles to the substrate.

Embodiment 12 is a method of making a modified substrate according to embodiment 9, wherein the first binder is substantially solvent free.

Embodiment 13 is a method of making a modified substrate according to embodiment 9 further comprising a step of coating a second binder on the first binder of the substrate.

5 Embodiment 14 is a method of making a modified substrate according to embodiment 9, wherein the substrate is selected from the group consisting of metals, metal alloys, metal-matrix composites, metalized plastics, and polymer matrix reinforced composites.

10 Embodiment 15 is a method of making a modified substrate according to embodiment 9 further comprising a step of applying pressure to the second surface of the release liner while it is disposed on the substrate before the removing the release liner from the substrate.

Embodiment 16 is a method of making a modified substrate according to embodiment 9, wherein substrate is substantially flat such that the height difference between the opposing first and second surfaces is less than 10 micrometer from any two points on the substrate.

15 Embodiment 17 is a method of making a modified substrate according to embodiment 9, wherein the substrate has a precise, non-flat geometry.

Embodiment 18 is a method of making a modified substrate according to embodiment 9, wherein the substrate is a cylindrical disk having a circumference and where at least the binder and the liner are attached to the circumference.

20 Embodiment 19 is a method of making a modified substrate according to embodiment 9, wherein the functional particles are selected from wear-resistant particles, optical liners, biologically-active particles, photocatalytic particles, dielectric particles, fluorescent particles, and combinations thereof.

Embodiment 20 is a method of making a modified substrate according to embodiment 19, wherein the wear-resistant particles are selected from poly(methyl)methacrylate beads, polyurethane beads, and polystyrene beads.

25

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

35

What is claimed is:

1. A functional particle transfer liner comprising:  
a release liner having opposing first and second surfaces, wherein the first surface comprises a  
5 release coating; and  
a layer of functional particles disposed upon the release coating, wherein the functional particles  
are free of abrasive particles and metal particles.
2. A functional particle transfer liner according to claim 1, wherein the first surface has a release  
10 value of less than about 700 grams per inch per ASTM D3330/D3330M-04.
3. A functional particle transfer liner according to claim 1, wherein the release liner further  
comprises a flexible backing and a release coating disposed on at least the first surface of the release liner,  
the release coating comprising a fluorine containing material, a silicon containing material, a  
15 fluoropolymer, a silicone polymer, or a poly (meth)acrylate ester derived from a monomer comprising an  
alkyl (meth)acrylate having an alkyl group having 12 to 30 carbon atoms.
4. A functional particle transfer liner according to claim 3, wherein the flexible backing is selected  
from the group consisting of densified kraft paper, polycoated paper, and a polymeric film.  
20
5. A functional particle transfer liner according to claim 4, wherein the polymeric film is selected  
from the group consisting of polyester, polycarbonate, polypropylene, polyethylene, cellulose, polyamide,  
polyimide, polysilicone, and polytetrafluoroethylene.
- 25 6. A functional particle transfer liner according to claim 5, wherein the functional particles are  
selected from wear-resistant particles, optical particles, biologically-active particles, photocatalytic  
particles, dielectric particles, fluorescent particles, and combinations thereof.
7. A functional particle transfer liner according to claim 6, wherein the wear-resistant particles are  
30 selected from poly(methyl)methacrylate beads, polyurethane beads, and polystyrene beads.
8. The functional particle transfer liner of claim 1, wherein the release liner is textured.
9. A method of making a modified substrate comprising the steps of:  
35 providing a substrate having opposing first and second surfaces;  
coating a first binder on the first surface of the rigid substrate;

providing a functional particle transfer liner comprising  
a release liner having opposing first and second surfaces, wherein the first surface  
comprises a release coating; and  
a layer of functional particles disposed upon the release coating;  
5 applying the functional particle transfer liner to the first surface of the substrate, wherein the  
functional particles are in contact with the binder;  
removing the release liner from the rigid substrate; and  
curing the binder thereby securing the functional particles to the first surface of the substrate,  
wherein the functional particles are free of abrasive particles and metal particles.

10

10. A method of making a modified substrate according to claim 9, wherein the first surface has a  
release value of less than about 700 grams per inch per ASTM D3330/D3330M-04.

15

11. A method of making a modified substrate according to claim 9, wherein the binder is at least  
partially cured prior to applying the functional particles to the substrate.

12. A method of making a modified substrate according to claim 9, wherein the first binder is  
substantially solvent free.

20

13. A method of making a modified substrate according to claim 9 further comprising a step of  
coating a second binder on the first binder of the substrate.

25

14. A method of making a modified substrate according to claim 9, wherein the substrate is selected  
from the group consisting of metals, metal alloys, metal-matrix composites, metalized plastics, and  
polymer matrix reinforced composites.

30

15. A method of making a modified substrate according to claim 9 further comprising a step of  
applying pressure to the second surface of the release liner while it is disposed on the substrate before the  
removing the release liner from the substrate.

16. A method of making a modified substrate according to claim 9, wherein substrate is substantially  
flat such that the height difference between the opposing first and second surfaces is less than 10  
micrometer from any two points on the substrate.

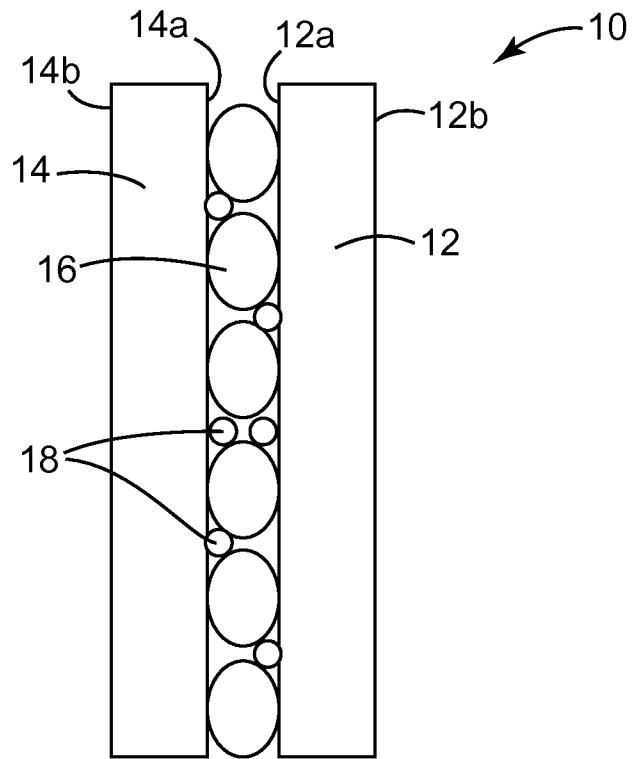
17. A method of making a modified substrate according to claim 9, wherein the substrate has a precise, non-flat geometry.

5 18. A method of making a modified substrate according to claim 9, wherein the substrate is a cylindrical disk having a circumference and where at least the binder and the liner are attached to the circumference.

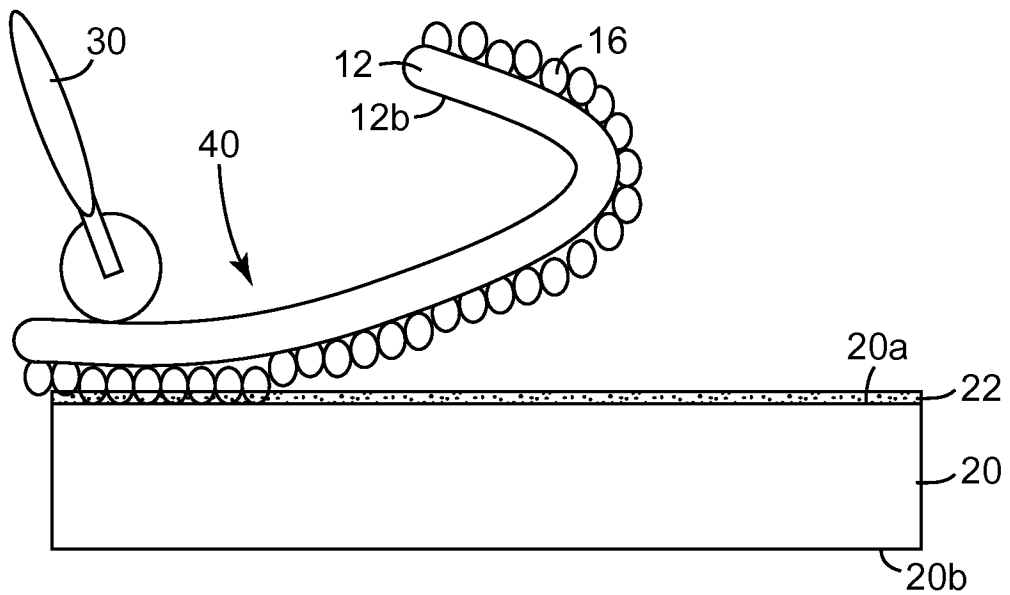
10 19. A method of making a modified substrate according to claim 9, wherein the functional particles are selected from wear-resistant particles, optical liners, biologically-active particles, photocatalytic particles, dielectric particles, fluorescent particles, and combinations thereof.

20. A method of making a modified substrate according to claim 19, wherein the wear-resistant particles are selected from poly(methyl)methacrylate beads, polyurethane beads, and polystyrene beads.

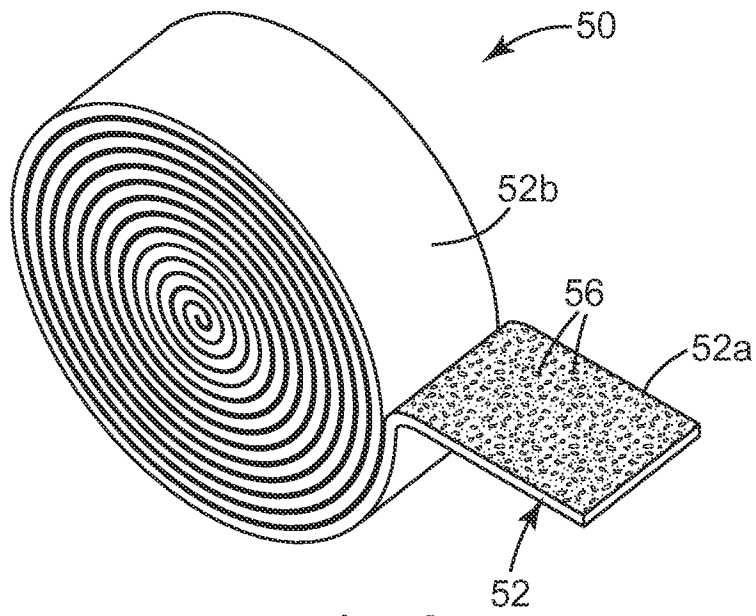
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*Fig. 1*



*Fig. 2*



*Fig. 3*

INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2011/056060

A. CLASSIFICATION OF SUBJECT MATTER  
INV. B24D18/00 B24D3/34 C09J7/02  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
C09J B24D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
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| Y         | figures 1-3<br>column 2, line 55 - line 57; examples 1,2<br>column 5, line 17 - line 26<br>claim 6                             | 1-20                  |
| X         | -----<br>WO 00/24594 A1 (KAUFMANN HARALD [DE])<br>4 May 2000 (2000-05-04)  | 1-7                   |
| Y         | figure 2<br>page 1, line 1 - page 2, line 4<br>page 8, line 24 - line 28<br>page 14, line 7 - line 11<br>examples 1,2<br>----- | 1-20                  |
|           | -/--   |                       |

Further documents are listed in the continuation of Box C.

See patent family annex.

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| Date of the actual completion of the international search<br><br>17 January 2012 | Date of mailing of the international search report<br><br>06/02/2012 |
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| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Authorized officer<br><br>Endres, Mirja |
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2011/056060

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |   |                       |
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| Y  | figures 5,6,8-11<br>column 1, line 24 - line 29<br>column 3, line 48 - line 51<br>column 5, line 12 - line 22<br>column 15, line 61 - column 16, line 7<br>column 17, line 25 - line 64<br>example 1                  | 1-20                  |
| Y  | -----<br>US 6 752 700 B2 (DUESCHER WAYNE O [US])<br>22 June 2004 (2004-06-22)<br>figures 28A,28B<br>column 9, line 57 - column 10, line 19<br>column 13, line 59 - column 14, line 10<br>column 49, line 26 - line 41 | 9-20                  |
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Information on patent family members

International application No

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