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(54) Abstract Title
Electrophotographic member with controlled roughness

(57) An electrophotographic member such as a fixing roller has an outermost layer containing an elastomer such as an organopolysiloxane and an aluminium oxide filler. The filler is of controlled particle size such that not more than 1 weight percent of the total weight of the particles are greater than 45 microns and the mean size is less than 20 microns. The filler has a thermal conductivity of above 5 BTU.

ELECTROPHOTOGRAPHIC MEMBER WITH CONTROLLED ROUGHNESS

This invention relates to electrophotographic members, particularly fuser members, useful for heat and pressure fixing heat-softenable toner to a receiver in an electrophotographic process.

In modern electrophotographic processes, a latent image of information to be reproduced or printed is formed on a dielectric member to alter the charge in an image-wise pattern. The latent image charge pattern is then developed with pigmented marking particles, or toner, and the image transferred by various means to a receiver sheet. The toned image on the receiver sheet must then be fixed permanently or fused to the receiver sheet for the final desired image.

When heat-softenable toners are employed, for example thermoplastic polymers, the usual method for fixing toner to the receiver involves applying heat and pressure to soften the toner and ensure good contact with the receiver. This is usually accomplished with at least one heated member in contact and under pressure with another member. One such well known fusing method comprises passing the toned receiver between the nip formed by a pair of opposing rolls, one or both of which may contain an elastic cushion, where the roll in contact with the toned surface is heated (usually referred to as the fusing roll). The opposing roll, or pressure roll serves to press the receiver sheet into contact with the fuser roll. Fusing rolls employed in this manner may be heated internally or externally and are often comprised of an elastomer that contains inorganic filler to improve material properties such as compression set, swell resistance (when used in conjunction with release fluids), thermal stability, or increase the thermal conductivity.

Fillers usually contain a distribution of particle sizes and often contain large particles that add texture to the roller. The fused image surface will tend to reproduce this roller surface texture. In another configuration a member may be used after a fixing process to imprint a uniform surface finish or gloss to the toned image surface. In this configuration the member contacts the toned image while the toner is still in a warm or softened state and imparts a desired surface texture to the toned image.

Once the desired fixed image has been prepared on a receiver, which may be one of several or of hundreds of such receivers, the sheets may be processed further by operations including, for example, sorting, binding, inserting other media, character recognition, and booklet making. In addition single sheets may be subjected to folding, mailing, or re-printing (either same side of back side of the receiver). Any of these or similar operations can cause the toned image to contact other surfaces and leave an objectionable mark caused by the transfer of toner from the original receiver. This transfer of toner or marking can appear on a variety of locations, for example the backside of another sheet, another portion of the same sheet (when folded), or some other surface which would be visible to the intended recipient of the material.

It is known that toner marking can be reduced by a number of methods including wax additives to the toner, increasing the toner toughness, adding release lubricants to the toner surface, and reducing the force of contact causing the toner marking. A few of these approaches have been described in patent disclosures listed below.

U.S. Patent Nos. 4,167,602 and 4,165,308 disclose toner materials that impart improved toner adhesion and reduced toner smear.

U.S. Patent No 4,859,550 discloses an additive comprised of an aliphatic hydrocarbon or polymeric alcohol which reduces image smearing in magnetic ink reader/sorter devices.

U.S. Patent No 5,209,464 discloses a scuff feeder device which minimize high pressure points that contribute to toner marking.

While these approaches may reduce the severity, complete elimination of toner marking may require a smooth topology of the toned image--a smooth surface is less susceptible to toner marking. However, in heated roller fusing, fillers are often employed to impart material properties (including thermal conductivity) and these fillers often produce a rough, abraded surface after extended use. Such fillers are described in U.S. Patent Nos. 5,480,724 and 5,480,725 (SnO); 5,336,539 (NiO); 5,292,562 and 5,753,361 (Cr2O3); 5,269,740

(CuO); 4,763,158 (BN); and 4,623,35 (SiC). Such a rough surface imparts a rough toned image topology that is more susceptible to toner marking problems. It would therefore be desirable to have electrophotographic members that contain fillers, (such as thermally conductive fuser rollers with metal fillers), maintain a smooth surface over time despite surface wear. Such electrophotographic members would minimize toner marking problems.

The present invention provides an electrophotographic member, such as a fuser roller, useful in heat-fixing an electrophotographic toner. The member comprises an elastomer and fillers of a controlled particle size whereby the member maintains a low surface roughness while providing high thermal conductivity. The present invention imparts improved surface roughness control to the toner image and reduces toner marking despite surface wear and abrasion.

More particularly, the present invention provides an electrophotographic member comprising an outermost layer containing an elastomer and a filler,

wherein the filler is of controlled particle size such that no more than 1 weight percent of the total weight of the particles are greater than 45 microns and the mean size is less than 20 microns; and

wherein the filler has a thermal conductivity of above 5 BTU/(hr*ft*F).

The electrophotographic member of the present invention comprises an outermost layer of an elastomeric material which may be a single layer or one of many layers on a metal core. One elastomeric material widely employed to form a resilient base cushion layer is crosslinked poly(dimethylsiloxane), hereafter "PDMS". PDMS is widely available as addition cure in the case of vinyl functional PDMS with hydride functional PDMS materials, or as condensation cure using PDMS containing hydroxy groups or a hydroxy forming group. Addition cure silicones are usually employed as two part LIM (liquid injection moldable) materials, room temperature vulcanized (RTV), and low temperature vulcanized (LTV) silicones. A variety of addition cure materials are available as vinyl and hydride containing silicone polymers from United Chemical of Bristol, PA. Condensation cure silicones can be high temperature vulcanized (HTVs) or RTVs and are typically one part with an added catalyst. Condensation cure silicones are available from a variety of manufacturers, for example DC0133 from Dow Corning is a hydroxy terminated PDMS. Addition cure materials often achieve superior compression set properties and toughness compared to condensation cure materials, however condensation cure materials often perform better as a release surface for the toner. Other organo-polysiloxanes are used to achieve improved resistance to swell by release fluids or thermal stability. Examples of swell resistant organo-silicones include fluorosilicone (U.S. Patent No. 5,563,202) and phenylsilicone (U.S. Patent No. 5,474,852).

Fillers are typically used in the silicone elastomer to provide reinforcement and thermal conductivity. Silica is widely used to reinforce silicone elastomers and has been described in U.S. Patent Nos. 4,357,388 and 4,360,566. Typical reinforcing silica is amorphous and does not have the thermal conductivity of crystalline quartz. Fumed silica may fail to provide the necessary thermal conductivity required for a particular application and fillers with substantially higher thermal conductivities are often required. Such fillers are described in U.S. Patent Nos. 5,480,724 and 5,480,725 (SnO); 5,336,539 (NiO); 5,925,62 and 5,753,361 (Cr2O3); 5,269,740 (CuO); 4,763,158 (BN); and 4,562,335 (SiC). Higher thermal conductivity fillers usually fall in the range of 3 BTU/(ft*hr*F) and higher, more preferably 5 BTU/(ft*hr*F) and higher. Carbides, silicides, and oxides are preferred for their high thermal conductivity, low reactivity and hard reinforcing nature. More preferably, aluminum oxide is used for its wide availability and good toner releasing properties when dispersed in a silicone elastomer. Aluminum oxide is available as tabular or calcined alumina in a variety of shapes and sizes. Filler levels may be varied to achieve the desired thermal conductivity, and in one embodiment, the fillers occupy from 15 to 45% by volume. More preferably, the fillers occupy 20 to 40% by volume. At filler levels significantly above 45% the elastomer loses processibility and the mechanical properties degrade. At low filler levels in silicone elastomers the wear mechanism changes to a chunking wear in which the surface layer is worn away in chunks. This action will produce a rough surface despite control of the particle size distribution. Silicone elastomers are typically used in conjunction with heat stabilizing agents including iron oxide, chromium oxide, etc. Stabilizers are typically added at 1 to 10 pph and do not constitute the majority of the filler.

In the present invention the filler particle size and distribution is controlled as the size distribution affects the surface roughness. Fillers are typically available in a wide range of sizes typically described by the average or mean particle size. While this provides some information about the filler particles, it gives little information about the distribution of the sizes. Commercial fillers often have broad size distributions or the distribution may be multi-modal so that the reported average particle size does not indicate the presence of significantly larger than average particles in the distribution. In some applications, including reinforcement, the breadth of the size distribution is of less importance as a broad distribution includes both large particles (that may be less reinforcing) and smaller particles (that should be more reinforcing) thus compensating for any size effects. In the present invention, large particle sizes are excluded to produce a wearing surface that maintains a low surface roughness despite surface abrasion.

While the mechanism is not entirely understood, it is thought that the elastomer surface is abraded by the receiver material until the filler particles are exposed and removed from the surface. As a filler particle is exposed, it remains higher than the elastomer surface due to its hard, low-wear properties. In this manner, the exposed filler may impinge on the toner at a much higher force than the surrounding matrix leaving an indent in the toner surface. As the elastomer continues to wear, the particle is removed before the particle is completely exposed. The filler particle then leaves behind a hole in the elastomer matrix. In this case, the toner may fill the hole as the surrounding matrix presses against the toner, thus creating an impression of the hole. This impression appears as a peak in the toner surface. This pattern of peaks and indents creates a rough surface that is susceptible to toner marking.

The toner itself has a specific size and toned image may have multiple layers of toner to produce a greater thickness than a single toner particle. The toner particle size is typically 8-12 microns, but may range from 2 to 30 microns. The roughness of a fixed toned image cannot exceed the toned image thickness by much more than 50 percent unless the toner is over heated. An over heated toner will flow more easily and if it adheres to the fusing surface it may draw out tall peaks from the surface. The toner particle size and laydown puts some limit on the maximum filler particle size and the surface roughness it may produce. While this is not well understood, it is thought that there should not be particles larger than 1.5 to 2 times the toner particle size, preferably having the largest particle size less than this, with a mean size equal or less than the toner size. The described mean is based on the frequency of the number of particles. This size limit is about 50 microns in many toners for the largest toner sizes. This should achieve a surface roughness of below 1.5 times this particle size, or about 70-75 microns by contact profilometry with a sharp tip. For smaller toners and demanding surface requirements, this surface roughness may be preferably 15-20 microns. To achieve this maximum, the filler should contain few particles greater than 45 microns. Few particles mean less than 1 percent of the total number of particles. In a preferred embodiment, the mean filler particle size is 13 microns or less with few particles greater than 26 microns. Few particles mean less than 5 percent of the total number of particles and in the preferred embodiment less than 1 percent of the total number of particles. In a more preferred embodiment, the mean filler particle size is 5 microns or less with few particles greater than 10 microns. Few particles mean less than 5 percent and in the preferred embodiment less than 1 percent. In yet another more preferred embodiment, the mean filler particle size is 3 microns or less with few particles larger than 5 microns. Mean particle sizes less than one micron become increasingly reinforcing and high filler levels for thermal conductivity are difficult to achieve. For broad or bi-modal distributions, the number of particles may not be representative of the impact of large particles due to the diluting effect of the large number of small particles given their mass. In all of the preferred embodiments described herein, the weight percent should be used when it provides a more stringent size requirement.

Particle size distributions may be indicated by size percentiles, including the percent of the distribution within a specific size range, or the percent of the distribution that is below a given particle size. Size distributions are typically reported in units of weight fraction, volume fraction, or number fraction at various sizes. However, given the size, density, and one of the distributions the other two distributions can be analytically determined. In the present invention, both the mean particle size and the size range limitation requirements should be met to produce the desired roughness control and low wear surface.

The present invention may be used in various fusing configurations including coated on a cylindrical core as a single layer or as an outer layer to one or more layers. The core of the fuser member is usually cylindrical in shape and may be comprised of any rigid metal, ceramic, or plastic with the necessary strength and heat stability. Suitable core materials include aluminum, steel, various alloys, and thermoset resins with fiber reinforcement. For applications where internal heat is necessary, a metal core is usually preferred.

The material may be injection molded, compression molded or extruded onto the core as a single layer, or coated onto an existing base cushion layer. The application of multiple layers can be achieved by a number of application methods including molding; solvent dip, spray, or transfer coating; curtain or knife coating; and crosshead extrusion. In this configuration, the base cushion may be optimized separately from the outer most release layer. Base cushion layers are chosen to provide resilience to the fuser and from a fusing nip. The thickness is chosen with consideration to the requirements of the particular intended application. Except in those applications where the base cushion is not necessary, the outer layers are typically thinner than the base cushion. Base cushion may range from .02 to .7 inches thick and outer layers from .0005 to .05 inches.

Suitable base cushion materials can be obtained commercially for a variety of applications. For a thermally conductive base cushion material, the condensation cured PDMS marketed as EC4952 by Emerson Cumings or GE4044 marketed by General Electric of Waterford, N,Y may be used. An example of an addition cured silicone rubber is Silastic™-J RTV marketed by Dow Corning.

A silane primer is usually applied to the core to increase the core-base cushion strength; one example is DC-1200 also marketed by Dow Corning. Attachment of the outer layer to the base cushion is generally accomplished by applying surface treatment such as a flame or corona discharge treatment to the surface of the base cushion prior to application of the outer layer.

After application the outermost layer may be ground, buffed, or lapped to achieve a certain profile or surface finish. In molded or solvent coated overcoats this may be used to remove surface imperfections or achieve a uniform finish on the fuser surface.

In addition to multiple elastomeric layers, other materials may be used as adhesion layers or oil barrier layers and be present beneath the elastomeric release layer. Oil barrier layers may include fluoroelastomer layers or organosilicone elastomer layers where the silicone contains groups that resist swell by release fluids. Release fluids are widely used to obtain superior release of the toner from the fuser surface thus extending the life of the member. Exemplary of such fluids are silicone fluids of various viscosity. Such fluids are usually inert, dimethyl-silicones end-capped by trimethylsiloxane groups. Other fluids include reactive functional fluids such as amine, thiol etc. which are used in enhance the interaction of the fluid with the fuser surface materials. These fluids have been described (U.S. Patent Nos. 4,101,686 and 4,264,181) and may be end-terminated with the desired functionality or they may be pendant along the chain as side groups.

In another embodiment of the present invention the member may be used after the initial fixing of the toner to the receiver has taken place. In this embodiment, the controlled surface roughness of the member is used to apply a desired surface texture to the fixed image. Typically, this would be done immediately after the initial fixing operation while the toner is still in a molten state. Some instances, however, intermediate operations may take place including returning the receiver to the electrophotographic process in order to apply backside imaging. In this embodiment, the member may not require additional heating, either internal or external.

The electrophotographic member of the invention is mainly exemplified herein as a fuser member in which the fuser member is a fuser roll having a core, a base cushion layer overlaying the core, and an outer layer superimposed on the base cushion. The invention is not, however, limited to a fuser or a fuser roll, nor is the invention limited to a fusing member having a core bearing two layers: the base cushion and the outer layer. The electrophotographic member of the invention can have a variety of outer configurations and layer arrangements known to those skilled in the art. For example, it could be a single layer on a hard core or platen, coated on a cushion containing an oil barrier layer, or be an endless belt with one or more layers overcoated by the present invention as an outer layer.

Example 1

A combination of 201 parts of AL600 (available from Atlantic Equipment Engineers of Bergenfield, NJ) per 100 parts of LS4340-103 (available from Emerson Cumings of Billerica, MA) was prepared by hand mixing and then compounded on a three roll mill into a uniform paste. The compound was combined with .25 parts of Catalyst 50 (also available from Emerson Cumings) per 100 parts of compound before compression molding under 60 tons of pressure at 125°F temperature to form a cured rubber slab. After demolding the slabs were post cured for four hours at 205°C after a two hour ramp from room temperature. A 0.59 inch wide strip was cut from the slab for surface abrasion testing. Surface abrasion was performed using a Norman abrader apparatus (Norman Tool, INC. of Evansville, IN) that uses a 0.69 inch wide strip of paper pressed in contact with the rubber sample and dragged under a load to produce abrasive wear. The sample temperature is maintained at 175°C during the test. Contact surface roughness of the sample wear track is done using a Surfanalyzer 4000 with a conical stylus under a 250mg load. Non-contact roughness is measured by enhanced phase shifting interferometry (WYKO NT2000 system) using metallized polymer replicas of the wear track surface.

Example 2

Example 2 is prepared by combining 70 parts of LS4340-103 per 100 parts of the compound in Example 1. Cat 50 was added at 0.45 parts per 100 parts of the new compound. Slabs were prepared by first degassing the mixture, then injection molding into mold cavities, and finally curing in a convection oven at 60°C for 24 hours. After demolding the slabs were post cured and sampled as described in Example 1.

Example 3

Example 3 is prepared by combining 203 parts of AL601 (also from Atlantic Equipment Engineers) per 100 parts of LS4340-103 by hand mixing and then compounding on a three roll mill into a uniform material. The compound was combined with .25 parts of Catalyst 50 per 100 parts of compound before degassing the mixture, then injection molding into mold cavities, and finally curing in a convection oven at 60°C for 24 hours. After demolding the slabs were post cured for four hours at 205°C after a two hour ramp from room temperature and sampled as described in Example 1.

Example 4

Example 4 is prepared by combining 27.6 parts of LS4340-103 per 100 parts of the compound in Example 3. Cat 50 was added at 0.36 parts per 100 parts of the new compound. Slabs and samples were prepared as in Example 2

Comparative Example 1 (CE1)

Comparative Example 1 is prepared by combining 212 parts of AL602 (also from Atlantic Equipment Engineers) per 100 parts of LS4340-103 by hand mixing and then compounding on a three roll mill into a uniform material. The compound was combined with .25 parts of Catalyst 50 per 100parts of compound before degassing the mixture, then injection molding into mold cavities, and finally curing in a convection oven at 60°C for 24 hours. After demolding the slabs were post cured and sampled as described in Example 1.

Comparative Example 2 (CE2)

Comparative example 2 was prepared by combining 78.9 parts of LS4340-103 per 100 parts of the compound in Comparative Example 1. Cat 50 was added at 0.45 parts per 100 parts of the new compound. Slabs were prepared and samples as described in CE1.

Comparative Example 3 (CE3)

Example 3 was prepared by combining 223 parts of AL604 (also from Atlantic Equipment Engineers) per 100 parts of LS4340-103 by hand mixing and then compounding on a three roll mill into a uniform material. The compound was combined with .25 parts of Catalyst 50 per 100parts of compound. Slabs were prepared and samples as described in CE1.

Comparative Example 4 (CE4)

Comparative example 4 is prepared by combining .25 parts Catalyst 50 per 100 parts of EC4952 (Emerson Cumings), then preparing slabs and sampling as described in CE1. The filler particle size is represented by T-64 (available from Whittaker, Clark, and Daniels) which is believed to be similar to the filler used in EC4952.

Table 1: Examples / Comparative Examples Slab Samples

			Particle Size (µm) Larger than			Wear Track Roughness:	
	Slab Filler Volume %	Mean Filler Size: (um)	95% of the number of particles	99% of the number of particles	95 weight percent of particles	Contact (µinch)	Non-Contact (nm)
Example 1	35	1.69	3.4	4.15	5.0	15	313
Example 3	14	1.69	3.4	4.15	5.0	22	
Example 2	35	12.5	22.8	28	36.7	64	
Example 4	22.4	12.5	22.8	28	36.7	69	
CE 1	36.2	24.7	51	73	116	114	
CE 2	14	24.7	51	73	116	121	
CE 3	37.3	81.3	152	200	300	359	
CE 4	36.2	12.9	38	53	77	114	2650

In accordance with the present invention, Table 1 demonstrates that the worn surfaces of the controlled particle size fillers maintain a low surface roughness while the distributions containing larger particle sizes produce large surface roughness which is unacceptable for toner marking. In addition, the average particle size does not indicate what is the largest particle size or the final wear roughness as Example 2 and Comparative Example 3 demonstrate.

Example 5

A mixture of the preparation in Example 1 and 32% (wt) MEK was allowed to roll mill until dissolved. Catalyst 50 was added (as in Example 1) ten minutes prior to coating the solution onto a commercial fusing roller (consisting of an aluminum core, 183 mils of a non-conductive 60 durometer [Shore A] cushion, and a second layer of 17 mils of a thermally conductive 65 durometer silicone) and allowing to air dry. The composite was cured using a 24 bake at 218°C. The coated roller was then placed into an electrophotographic process machine and run at nominal conditions for 330,000 copies periodically taking measurements of the roller surface roughness and toner marking tendency. The roller coating surface roughness was measured at 300K to be 8 µinch Ra (contact) and 330 nm Ra (non-contact). The results show good correlation with the off-line wear roughness demonstrating a controlled roller surface roughness throughout the 300K run.

Comparative Example5:

A mixture of EC4952 and 14% by weight MEK was allowed to roll mill until dissolved. One part Catalyst 50 for every 400 parts of EC4952 was added ten minutes prior to coating the solution onto a commercial fusing roller (as in Example 5) and allowing to air dry. The composite was cured using a 24 bake at 218C. The coated roller was then placed into a electrophotographic process machine and run at nominal conditions for 300,000 copies periodically taking measurements of the roller surface roughness and toner marking tendency. The roller demonstrated reduced toner marking at the beginning of the run that degraded as the roller abraded from paper wear. The roller surface roughness was measured at 330K to be 74.6 µinch Ra (contact) and 3120 nm Ra (non-contact).

CLAIMS:

1. An electrophotographic member comprising an outermost layer containing an elastomer and a filler,
wherein the filler is of controlled particle size such that no more than 1 weight percent of the total weight of the particles is greater than 45 microns and the mean size is less than 20 microns; and
wherein the filler has a thermal conductivity of above 5 BTU/(hr*ft*F).

2. The electrophotographic member of claim 1 wherein the elastomer of the outermost layer is an organopolysiloxane.

3. The electrophotographic member of claim 1 or claim 2 wherein the filler is a metal oxide in a concentration between 10 and 45 volume % of the outermost layer.

4. The electrophotographic member of any one of claims 1 to 3 wherein no more than 1 weight percent of the filler particles is greater than 30 microns and the mean size is less than 20 microns.

5. The electrophotographic member of claim 4 wherein no more than 1 weight percent of the filler particles is greater than 26 microns and the mean size is less than 13 microns.

6. The electrophotographic member of any one of claims 1 to 5 wherein no more than 5 weight percent of the filler particles is greater than 10 microns and the mean size is less than 5 microns.

7. The electrophotographic member of claim 6 wherein no more than 1 weight percent of the filler particles is greater than 10 microns and the mean size is less than 5 microns.

8. The electrophotographic member of claim 7 wherein no more than 1 weight percent of the filler particles is greater than 5 microns and the mean size is less than 3 microns.

9. The electrophotographic member of any one of claims 1 to 8 wherein the filler is aluminum oxide.

10. The electrophotographic member of any one of claims 1 to 9 wherein the electrophotographic member is a fusing member.

11. An electrophotographic member substantially as hereinbefore described in any one of foregoing Examples 1 to 5.

Application No:	GB 0021329.8	**Examiner:**	Phil Thorpe
Claims searched:	1-11	**Date of search:**	19 December 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): B6C (BQJ) ;

Int Cl (Ed.7): G03G (15/20) ;

Other: Online : (WPI, PAJ, EPODOC) ;

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 5729813 A (Xerox)	---
A	US 5717988 A (Canon)	---
X	US 4970098 A (IBM) - see whole document.	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.