



- (51) International Patent Classification:
G03G 15/02 (2006.01)
- (21) International Application Number:
PCT/US2014/049186
- (22) International Filing Date:
31 July 2014 (31.07.2014)
- (25) Filing Language: English
- (26) Publication Language: English
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

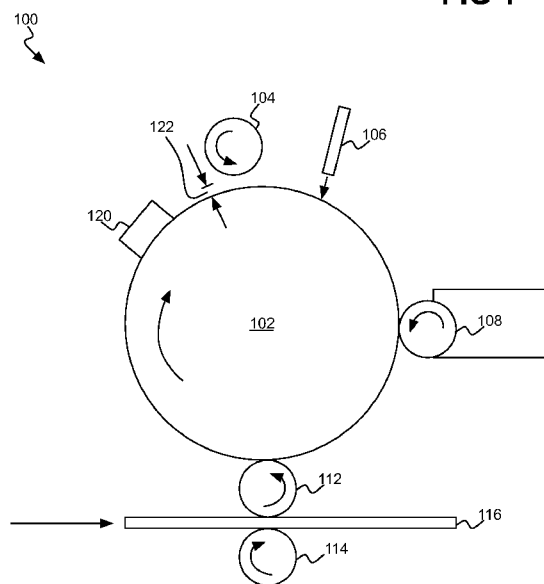
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

- with international search report (Art. 21(3))

(54) Title: INNER RESISTIVE FILM WITH DUCTILE PARTICLES AND OUTER RESISTIVE FILM

FIG 1



(57) Abstract: An inner resistive film is applied to a conductive substrate. Ductile particles are disposed substantially uniformly throughout the inner resistive film. An outer resistive film is applied to the inner resistive film.

INNER RESISTIVE FILM WITH DUCTILE PARTICLES AND OUTER RESISTIVE FILM

BACKGROUND

[0001] Electrophotographic printing devices, such as laser printing devices, form images on media like paper. In general, a photoconductive cylinder is charged over its entire surface, and then selectively discharged in accordance with the image to be formed. Charged colorant such as toner adheres to locations on the cylinder that have been discharged, and the toner is then directly or indirectly transferred from the cylinder to the media.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] FIG. 1 is a diagram of an example electrophotographic printing device.

[0003] FIG. 2 is a diagram of an example charge roller for an electrophotographic printing device.

[0004] FIG. 3 is a flowchart of an example method for applying a resistive film having at least two layers to a substrate like a charge roller for an electrophotographic printing device.

[0005] FIG. 4 is a diagram of an example thermally sprayed resistive film on a substrate.

DETAILED DESCRIPTION

[0006] As noted in the background section, in electrophotographic printing devices, a photoconductive surface is charged prior to being selectively

discharged with an image to be formed on media. Printing devices employ either a charge roller or a corona wire to charge the photoconductive cylinder. The charge roller has a cylindrical conductive substrate to transfer a charge to the entire surface of the photoconductive cylinder.

5 **[0007]** In some electrophotographic printing devices, the charge roller is in direct physical contact with the photoconductive cylinder while charging, and has an outermost material made of a compliant, conductive rubber so as not to physically damage the photoconductive cylinder. In other electrophotographic printing devices, the outermost material of the charge roller is a hard ceramic. As
10 such the charge roller is usually positioned with a physical air gap between the photoconductive cylinder and the charge roller to minimize potential damage to the photoconductive cylinder.

[0008] There are at least two issues involved with the charge roller's functionality of charging the photoconductive cylinder in such a way that ensures
15 optimal print quality of the formed images on media. First, during charging of the photoconductive surface by the charge roller, high intensity discharges, which are referred to as streamers, can occur. Such high intensity discharge events can negatively affect print quality, because the photoconductive surface may not be uniformly charged.

20 **[0009]** Second, there is an optimal window of the physical gap between the charge roller and the photoconductive cylinder. If the roller-cylinder gap is less than the minimum gap specified by the window, the charge roller may contact the photoconductive cylinder if the machining tolerances of printing

device components that affect the gap exceed the minimum gap. If the gap is greater than the maximum gap specified by the window, print quality is impaired.

[0010] As to the former issue, it has been found that the intensity of the streamers can be decreased by coating the metal charge roller core with a

5 resistive film. As such, high intensity discharge events are reduced. Specifically, the intensity of the streamers is a function of the thickness of the film applied to the conductive surface, as well as electrical properties of the film.

[0011] As to the latter issue, it has been found that coating the metal charge roller core with a resistive material likewise increases the size of the

10 optimal window of the physical roller-cylinder gap in which print quality remains high. Specifically, the maximum gap of the window is increased as the thickness of the resistive coating is increased. This is advantageous, because manufacturing tolerances and other challenges can make it difficult to precisely position the charge roller vis-à-vis the photoconductive cylinder within the

15 confines of a small gap window.

[0012] For many types of electrophotographic printing devices, charge rollers are disposable components built into toner cartridges that are periodically replaced, or are otherwise considered periodically replaced consumable items.

These types of charge rollers generally have a rubber coating as their resistive
20 film. The rubber coating degrades relatively quickly over time, but the charge roller is regularly replaced when the toner of the toner cartridge of which the charge roller is a part is depleted and a new toner cartridge inserted into the

printing device, or when separate replacement is performed to maintain print quality.

[0013] However, for commercial production environments, charge rollers are not built into toner cartridges, and further are not considered disposable

5 components that are to be frequently replaced. This is at least because in many such production environments, the electrophotographic printing devices are treated as digital printing presses and run nearly constantly, such that downtime is undesirable. Therefore, it is desirable for the charge rollers to be considered nearly permanent components that are not normally replaced, or at most are
10 infrequently replaced, within the printing devices.

[0014] In such electrophotographic printing devices, rubber-coated charge rollers are disadvantageous due to the impermanence of their rubber coatings. A more permanent resistive film is desirably employed, such as ceramic materials like various metal oxides, nitrides, and carbides. A noted shortcoming of such
15 so-called permanent resistive ceramic films is that they are difficult to apply with great thickness. Above about 500 microns, the brittle ceramic films tend to crack during application to the charge roller's metal core and further may delaminate from the substrate.

[0015] A resistive coating of 500 microns or less in thickness does not
20 result in optimal print quality, unfortunately, because high intensity discharge events are not minimized as much as desired. Furthermore, a charge roller having a resistive film 500 microns or less results in a relatively small roller-cylinder gap window in which print quality remains high. This small window can

be difficult to achieve in electrophotographic printing devices without undue expense and redesign of the printing devices.

[0016] In the patent application entitled “resistive film with ductile particles,” filed on _____, and assigned application number _____, techniques are

5 presented to alleviate these shortcomings associated with permanent charge rollers. A charge roller for an electrophotographic printing device includes a cylindrical conductive substrate and a resistive film applied thereto to reduce high intensity discharge events. Ductile particles are disposed substantially uniformly throughout the resistive film to reduce the film’s brittleness, thus reducing the
10 likelihood of cracking and delamination, even for films greater than 500 microns in thickness. Extending film thickness beyond 500 microns increases the roller-cylinder gap window in which print quality remains high and improves print quality at operating conditions relative to a thinner film by a further reduction in high intensity discharge events.

15 **[0017]** However, it has been found that in implementations in which the ductile particles are conductive, such as metal, the ductile particles at the surface of the resistive film may in some situations themselves cause high intensity discharge events. Particularly, when the charge roller is subjected to high voltage, free electrons resident in the conductive particles may respond to an air
20 Paschen discharge, enhancing the resulting electric field, and further accelerating Paschen discharge. This cycle between air discharge and field enhancement proceeds through a positive feedback cycle, and eventually can potentially cause high intensity discharge events that can affect print quality.

[0018] Disclosed herein are techniques to alleviate high intensity discharge events resulting from the inclusion of conductive ductile particles within a resistive film-coated charge roller. A charge roller for an electrophotographic printing device includes a cylindrical conductive substrate and two resistive films.

5 An inner resistive film is applied to the substrate to reduce high intensity discharge events, primarily by recessing highly conductive substrate from the discharge region, and includes conductive ductile particles disposed substantially uniformly therein to reduce brittleness. An outer resistive film applied to the inner resistive film does not have conductive particles therein, to further reduce high
10 intensity discharge events, primarily those resulting from the conductive ductile particles at or near the surface of the inner resistive film.

[0019] The outer resistive film thus buries the reservoirs of electrons within the conductive ductile particles at the surface of the inner resistive film, minimizing the effect that such electrons can have during charging. The resulting
15 electric field is also reduced, for at least three reasons. First, the distance between the conductive substrate of the charge roller and the photoconductive cylinder is increased due to the additional thickness of the outer resistive film. Second, the distance between the reservoirs of electrons within the conductive particles in the inner resistive film and the photoconductive cylinder is increased.
20 Third, thin, high curvature metal features that may be present in the conductive ductile particles are further distanced from the photoconductive cylinder.

[0020] FIG. 1 shows an example electrophotographic printing device 100. Cylindrical components, such as rollers, of the device 100 rotate in the directions

indicated by their arrows. A photoconductive cylinder 102, which may also be referred to as a drum, rotates to receive a charge transferred by a rotating charge roller 104 across its photoconductive surface. The photoconductive cylinder 102 and the charge roller 104 are separated by a gap 122 that is within an optimal gap window in which print quality remains high.

[0021] An optical discharge mechanism 106, such as a laser, selectively discharges the photoconductive cylinder 102 in accordance with an image to be formed onto media 116, such as paper, as the cylinder 102 continues to rotate. At least one rotating dispensing roller 108 transfers toner to the photoconductive cylinder 102 as the cylinder 102 continues to rotate. The toner is deposited onto the photoconductive cylinder 102 typically just where the cylinder 102 has been discharged, and thus in accordance with the image to be formed.

[0022] As the photoconductive cylinder 102 continues to rotate with the selectively transferred toner thereon, a rotating transfer roller 112 transfers the toner from the cylinder 102 onto the media 116 that is advancing from left to right between the transfer roller 112 and a rotating impression roller 114. The photoconductive cylinder 102 rotates past a cleaning mechanism 120 to completely discharge its photoconductive surface and remove any remaining toner still thereon before repeating the described process via being charged by the charge roller 104.

[0023] FIG. 2 shows an example of the charge roller 104 in more detail. The charge roller 104 has a cylindrical conductive substrate 202, which may be steel. The conductive substrate 202 receives a charge to transfer to the

photoconductive surface of the photoconductive cylinder 102 of the electrophotographic printing device 100. The charge roller 104 further includes a resistive film 204 or coating, such as a ceramic film or coating, applied thereto to reduce high intensity discharge events while the photoconductive surface of the printing device 100 is being charged.

[0024] A portion 206 of the resistive film 204 of the charge roller 104 is shown in magnified fashion in FIG. 2. Specifically, the resistive film 204 is made up of an inner resistive film 210 and an outer resistive film 212. One or more of the resistive films 210 and 212 may be a ceramic material, such as alumina-titania ($\text{Al}_2\text{O}_3\text{-TiO}_2$). That is, the resistive films 210 and 212 may be the same or different material. The inner resistive film 210 includes conductive ductile particles 208 disposed substantially uniformly therethrough. By comparison, the outer resistive film 212 does not include any conductive particles.

[0025] The conductive ductile particles 208 disposed substantially uniformly throughout the inner resistive film 210 to reduce brittleness of the overall resistive film 204, reduce potential for delamination of the film 204 from the conductive substrate 202 during application, and permit the thickness of the film 204 to be increased without cracking of the film 204. The dispersal of the ductile particles 208 throughout the inner resistive film 210 further increases the maximum operating gap 122 between the photoconductive cylinder 102 and the charge roller 104 while maintaining or ensuring print quality.

[0026] In one implementation, the conductive ductile particles 208 are a metal or metal alloy, such as a nickel aluminum (NiAl) alloy. Testing has shown

that when such ductile particles 208 are dispersed within a resistive film 210 of Al₂O₃-TiO₂ at five percent by weight, which is 2.5% by volume, brittleness of the overall film 204 is greatly reduced. Specifically, brittleness of the resistive film 210 is reduced sufficiently to avoid cracking and delamination during application
5 on the conductive substrate 202 at thicknesses up to two millimeters. This represents an increase of more than 300% as compared to an Al₂O₃-TiO₂ resistive film 210 that does not have such NiAl ductile particles 208 dispersed substantially uniformly therein.

[0027] More generally, the conductive ductile particles 208 can be of a
10 particular resistivity, size, and/or density that permits the thickness of the resistive film 204 to be increased to achieve the advantages and benefits associated with such increased thickness. Metals may have a resistivity in the range 5×10^{-6} to 100×10^{-6} Ohm-centimeters. Furthermore, metal silicides and amorphous metal-based alloys, which are in the class of metals, can have higher
15 resistivity than crystalline metals, but with resistivity generally less than 1×10^{-3} Ohm-centimeters; such metal inclusions may affect print quality. Examples of metal silicides include molybdenum silicide (MoSi₂), tungsten silicide (WSi₂), titanium silicide (TiSi₂), magnesium silicide (Mg₂Si), chromium silicide (Cr₃Si), and NiSi. Examples of amorphous metal-based alloys include cobalt zirconium
20 (CoZr), cobalt zirconium boron (CoZrB), molybdenum tungsten silicon (MoWSi), molybdenum tantalum boron (MoTaB), and cobalt hafnium silicon (CoHfSi).

[0028] The diameter of metal particles in the resistive film is desirably less than about ten microns, such as about two microns. Particle geometry depends

on the method of film deposition, such as thermal spraying, as is described in detail later in the detailed description. The sizes mentioned herein are for disk diameters of thermally sprayed materials, and sphere diameters may be somewhat lower.

5 **[0029]** The volume density of ductile particles within the high resistivity coating is desirably below the percolation threshold for creating a continuous string of ductile particles across the thickness of the film, which is a function of particle geometry and orientation within the film. For spherical inclusions, the percolation threshold is usually about 25%, and for randomly oriented oblate
10 ellipsoids with an aspect ratio of ten, the percolation threshold drops to generally 10%. Ductile metal particle concentration in thermally sprayed resistive coatings is desirably between 2% and 10% by volume.

[0030] The outer resistive film 212 is applied to and makes contact with the inner resistive film 210 that is applied to and makes contact with the
15 conductive substrate 202. The outer resistive film 212 ensures that there are no conductive particles on the exterior surface of the resistive film 204 as a whole. Any conductive ductile particles 208 that are at the outer surface of the inner resistive film 210 are covered, or buried, with application of the outer resistive film 212.

20 **[0031]** The outer resistive film 212 serves to reduce high intensity discharge events in two ways during charging. First, along with the inner resistive film 210, the outer resistive film 212 increases a thickness of the resistive film 204 as a whole. Because high intensity discharge event reduction

is a function of increasing thickness, adding the outer resistive film 212 to the inner resistive film 210 makes for a thicker overall resistive film 204. In this way, too, the outer resistive film 212 provides for an increase in the maximum operating roller-photoconductive cylinder gap, which is also a function of increasing thickness of the resistive film 204 as a whole. Second, because the presence of the outer resistive film 212 ensures that there are no conductive ductile particles 208 at or near the outer surface of the overall resistive film 204, high intensity discharge events that would otherwise result from such exposed particles 208, or particles 208 proximate to the surface, are reduced.

[0032] The outer resistive film 212 provides an additional benefit in that it decouples film surface topography, internal film morphology, and film surface chemistry from the inclusion of ductile conductive particles. Surface topography of a resistive ceramic charge roller coating may be affected by inclusion of the conductive ductile particles 208. For example, the addition of the conductive ductile particles 208 into the inner resistive film 210 may increase the surface roughness thereof by disparate morphologies of ceramic versus metal portions or by the creation of more voids within the film. Rougher films are more likely to damage the photoconductive cylinder by incidental contact; the addition of the outer resistive film 212 ensures a uniform composition at the coating surface, thus mitigating any roughening associated with a mixture of ceramic and metal.

[0033] Adding the conductive ductile particles 208 to the inner resistive film 212 results in exposed particles 208 at the surface as well. In some situations, the conductive materials of the particles 208 may be more chemically

reactive than the resistive ceramic coating of the inner resistive film 210. As such, the exposed conductive materials of the particles 208 may react with the chemistry of the printing environment, leading to increased contamination of the charge roller or photoconductive cylinder surfaces. Overcoating the inner resistive film 210 with the outer resistive film 212 prevents these potentially detrimental effects.

[0034] The thickness of the outer resistive film 212 is sufficiently thin so as not to add undue brittleness to the resistive film 204 as a whole. As such, the thickness of the outer resistive film 212 is desirably thinner than that of the inner resistive film 210. For instance, the thickness of the inner resistive film 210 may be in the range of 400 to 3,000 microns, whereas the thickness of the outer resistive film 212 may be in the range of 100 to 600, or even up to 1,000, microns.

[0035] In one example implementation, the inner resistive film 210 is an Al₂O₃-TiO₂ 23% alloy with a thickness of 1,500 microns, and the outer resistive film 212 is a Al₂O₃-TiO₂ 26% alloy with a thickness of 300 microns, which does not cause any meaningful brittleness to the overall resistive film 204. In this implementation, the conductive ductile particles 208 within the inner resistive film 210 can be NiAl, where the outer resistive film 212 does not have any conductive particles. It has been found that print quality with this implementation is improved, due to the reduction of high intensity discharge events, as compared to a comparably thick resistive film 204 that includes just the inner resistive film 210 with the conductive ductile particles 208 and not the outer resistive film 212 without any conductive particles.

[0036] FIG. 3 shows an example method 300 for forming a resistive film including an inner film having conductive ductile particles dispersed substantially uniformly therein and an outer film without any conductive particles on a substrate. The method 300 can be employed, for instance, to prepare the charge
5 roller 104 that has been described. A first material is prepared that includes a first base resistive material and conductive ductile particles dispersed substantially uniformly therein (302). The first base resistive material may be ceramic particles, such as $\text{Al}_2\text{O}_3\text{-TiO}_2$, and the conductive ductile particles may be NiAl.

[0037] Preparing the first material can include adding the conductive ductile particles to the first base resistive material particles (304), and thoroughly mixing the resulting first material to disperse the ductile particles substantially uniformly throughout the first material (306). Substantially uniformly means that the conductive ductile particles are uniformly distributed throughout the first
15 material as much as possible. Perfect uniformity is unachievable due to randomness, entropy, and so on, but thoroughly mixing the first material after the conductive ductile particles have been introduced for a sufficient length of time results in substantial uniformity.

[0038] The resulting first material is applied as an inner film to a substrate
20 at a desired thickness (308), where the conductive ductile particles reduce the brittleness of the film, permitting greater thickness than otherwise would be possible. Application can be performed by thermal spraying of the first material onto the substrate to coat the substrate with the inner film. Thermal spraying

includes flame spraying, plasma spraying, arc spraying, and high velocity oxy-fuel deposition techniques. The first material is fed in powder form, in diameters of five-to-fifty micron, into a high temperature flame that melts the particles and propels them towards the substrate, where the molten particles spread into

5 “splats” and are quickly quenched into solid form as disks. Orientation of the disks is parallel to the substrate plane, so the percolation threshold that has been described is higher than for randomly oriented disks. Extreme temperature gradients and cooling rates lead to stresses in thermally sprayed films, which increase in magnitude with film thickness. However, negative effects of such
10 stresses are reduced by the introduction of the ductile particles, as has been described.

[0039] A second material that includes a second base resistive material but without any conductive particles dispersed therein is applied as an outer film to the inner film that has been applied to the substrate (310). The second base
15 resistive material – and thus in some implementations the second material as a whole – may be ceramic particles, such as $\text{Al}_2\text{O}_3\text{-TiO}_2$. Application of the second material can be performed in the same manner as that of the first material, such as by thermal spraying of the second material onto the already applied inner film of the first material on the substrate to coat the inner film with
20 the outer film.

[0040] FIG. 4 shows an example of a thermally sprayed resistive film 204 on the conductive substrate 202 of a charge roller 104. The thermally sprayed film 204 is grown on the substrate 202 by successive deposition of particles,

those of the inner resistive film 210 and those of the outer resistive film 212. The particles of the inner resistive film 210 include the particles 402 that make up the bulk of the resistive film 210, and the conductive ductile particles 404. The particles of the outer resistive film 212 can include just the particles 406, since
5 the outer resistive film 212 has no conductive particles. The particles 406 of the outer resistive film 212 may be of the same material as the particles 402 of the inner resistive film 210.

[0041] It is noted that the film 204 as depicted in FIG. 4 is exaggerated for illustrative clarity. In actuality, the particles may be considered as being more
10 pancake-shaped and randomly stacked, with fewer voids therebetween.

Furthermore, the aspect ratio of the particles 402 and 406 that are ceramic is usually between 10:1 and 50:1, whereas the aspect ratio of the ductile particles 404 that are metal is usually between 2:1 and 10:1. It is also noted that more generally, particles can be of variously different and random shapes, in addition
15 to those described herein.

[0042] The sizes of the conductive ductile particles that have been referenced above can refer to the diameter of the disks created in the thermal spraying process. The thickness of the disks is generally on the order of one micron, independent of disk diameter. Particles having a diameter of less than
20 five micron are difficult to produce by some processing techniques like thermal spraying. Therefore, the conductive ductile particles may have a diameter of as close to five microns as possible, such as within the range of five to ten microns.

Powder source material used in thermal spray systems is typically greater than five microns in diameter.

[0043] It is noted that in the implementations that have been described above, the ductile particles within the inner resistive layer or film have been

5 stated as being conductive ductile particles, such as metal such particles.

However, the ductile particles in other implementations may be ductile particles that have higher resistivity than metal, and therefore may not be considered conductive per se. The foregoing description is applicable to such

implementations as well. The inclusion of any type of ductile particles may

10 introduce undesirable features, such as increased roughness and voids, as well as greater chemical reactivity. Therefore, having an outer resistive layer or film that encapsulates the ductile particles of the inner resistive layer or film can be beneficial even if the ductile particles are primarily resistive and not highly conductive.

15 **[0044]** Examples of resistive ductile inclusions include non-stoichiometric metal oxides having a resistivity in the range of 10^{-4} to 10^3 Ohm-centimeters.

Thus, ductile metallic materials, such as NiAl, may be replaced with a high electrical resistivity material that still has sufficient ductility to afford the

advantages associated with inclusion of the ductile particles within the inner

20 resistive film to reduce brittleness. As noted above, most metals have electrical resistivity in the range of 5×10^{-6} to 100×10^{-6} Ohm-centimeters. Electrical resistivity of stoichiometric metal oxides range from about 10^3 to 10^{13} Ohm-centimeters, but stoichiometric metal oxides are not usually ductile. However,

ductility can be improved by adding metal beyond the stoichiometric composition, although doing so reduces resistivity. Still, the resistivity of non-stoichiometric metal oxides can be many orders of magnitude higher than for metals.

[0045] The diameter of resistive ductile particles in the resistive film is

5 desirably within the range of about two to fifty microns. The sizes that have been noted are for disk diameters of thermally sprayed materials, and sphere diameters may be somewhat lower.

[0046] The volume density of resistive ductile particles within the high resistivity coating is desirably between 2% and 15% by volume.

10 **[0047]** Taking the above into account, examples of non-stoichiometric metal oxides that can be employed as the ductile particles include magnesium oxide (MgO_x), titanium oxide (TiO_x), zirconium oxide (ZrO_x), hafnium oxide (HfO_x), tantalum oxide (TaO_x), chromium oxide (CrO_x), cobalt oxide (CoO_x), iron oxide (FeO_x), copper oxide (CuO_x), aluminum oxide (AlO_x), and zinc oxide (ZnO_x). The
15 resistivity range of such ductile particles 208 is within 10^{-4} to 10^3 Ohm-centimeters.

We claim:

1. A charge roller for an electrophotographic printing device, comprising:
a cylindrical conductive substrate adapted to apply a charge to a
photoconductive surface of the electrophotographic printing device;
- 5 an inner resistive film applied to the cylindrical conductive substrate to
reduce high intensity discharge events while the photoconductive surface is
being charged, the resistive film having disposed substantially uniformly therein a
plurality of ductile particles disposed to reduce brittleness of the inner resistive
film; and
- 10 an outer resistive film applied to the inner resistive film to further reduce
the high intensity discharge events while the photoconductive surface is being
charged.
2. The charge roller of claim 1, wherein disposal of the ductile particles within
the resistive film and application of the outer resistive film to the inner resistive
- 15 film provide for a combined thickness of the inner resistive film and the outer
resistive film to be increased.
3. The charge roller of claim 1, wherein disposal of the ductile particles within
the resistive film and application of the outer resistive film to the inner resistive
film provide for an increase in a maximum operating gap between an outermost
- 20 surface of the outer resistive film and the photoconductive surface while ensuring
print quality of the electrophotographic printing device to be maintained.

4. The charge roller of claim 1, wherein one or more of:

the ductile particles are conductive ductile particles;

the ductile particles each have a particle size within the range of two-to-ten microns in diameter;

5 the ductile particles have a density within the inner resistive film of two to ten percent by volume;

the ductile particles comprise a metal having a resistivity in a range of 5×10^{-6} to 100×10^{-6} Ohm-centimeters;

the ductile particles comprise a nickel aluminum alloy; and

10 the ductile particles are substantially 2.5% by volume within the resistive film.

5. The charge roller of claim 1, wherein one or more of:

the ductile particles are resistive ductile particles;

the ductile particles comprise a material having a resistivity within a range

15 of 10^{-4} to 10^3 Ohm-centimeters;

the ductile particles comprise a non-stoichiometric metal oxide having a resistivity in a range of 10^{-4} to 10^3 Ohm-centimeters;

the ductile particles each have a particle size within the range of two-to-fifty microns in diameter;

20 the ductile particles have a density within the inner resistive film of two to fifteen percent by volume; and

the ductile particles are substantially 2.5% by volume within the resistive film

6. The charge roller of claim 1, wherein the inner resistive film and the outer resistive film comprise an identical material but for the ductile particles within the inner resistive film.
7. The charge roller of claim 1, wherein one or more of:
5 the outer resistive film comprises a ceramic material; and
the outer resistive film comprises alumina-titania.
8. The charge roller of claim 1, wherein the inner resistive film has a thickness within a range of 400 to 3,000 microns.
9. The charge roller of claim 1, wherein the outer resistive film has a
10 thickness within a range of 100 to 1,000 microns.
10. The charge roller of claim 1, wherein the outer resistive film is thinner than the inner resistive film.
11. An electrophotographic printing device comprising:
a photoconductive surface;
15 a charge roller to charge the photoconductive surface, the charge roller having an inner ceramic coating having a plurality of ductile particles dispersed substantially uniformly therethrough, and an outer ceramic coating to reduce high intensity discharge events resulting from the ductile particles within the inner ceramic coating; and

an optical discharge mechanism to selectively discharge the photoconductive surface in accordance with an image to be formed on media.

12. A method comprising:

5 applying a first material including a first base resistive material and a plurality of ductile particles dispersed substantially uniformly therein as an inner film to a substrate; and

 applying a second material including a second base resistive material without any conductive particles dispersed therein as an outer film to the inner film applied to the substrate.

10 13. The method of claim 12, further comprising:

 preparing the first material by adding the ductile particles to the first base resistive material and thoroughly mixing the first material to disperse the ductile particles substantially uniformly therein.

15 14. The method of claim 12, wherein applying the first material as the inner film to the substrate comprises thermally spraying the first material onto the substrate to coat the substrate with the inner film,

 and wherein applying the second material as the outer film to the substrate comprises thermally spraying the second material onto the inner film to coat the inner film with the outer film.

15. The method of claim 12, wherein the first base resistive material and the second base resistive material are an identical material.

FIG 1

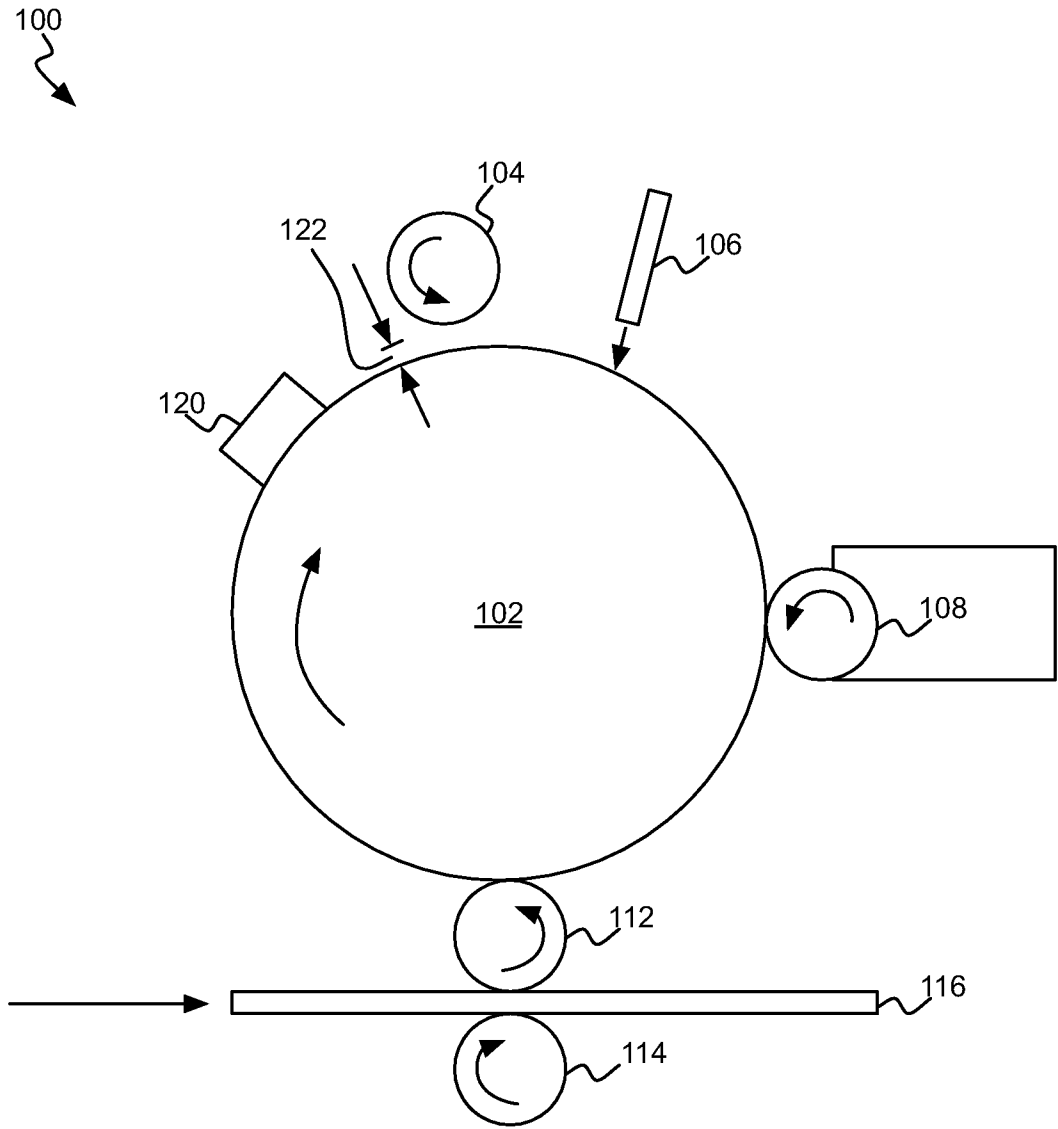
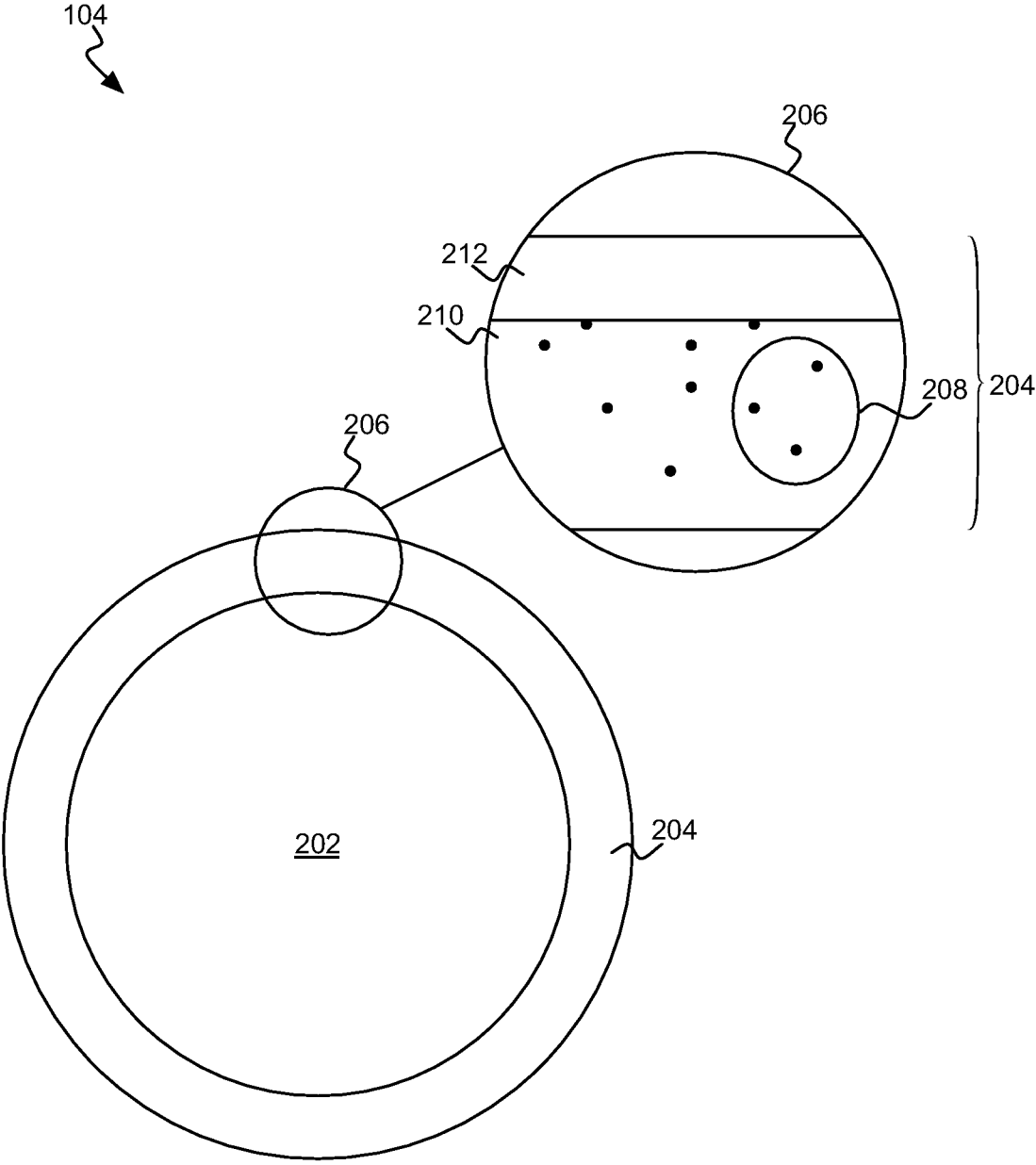


FIG 2



3/4

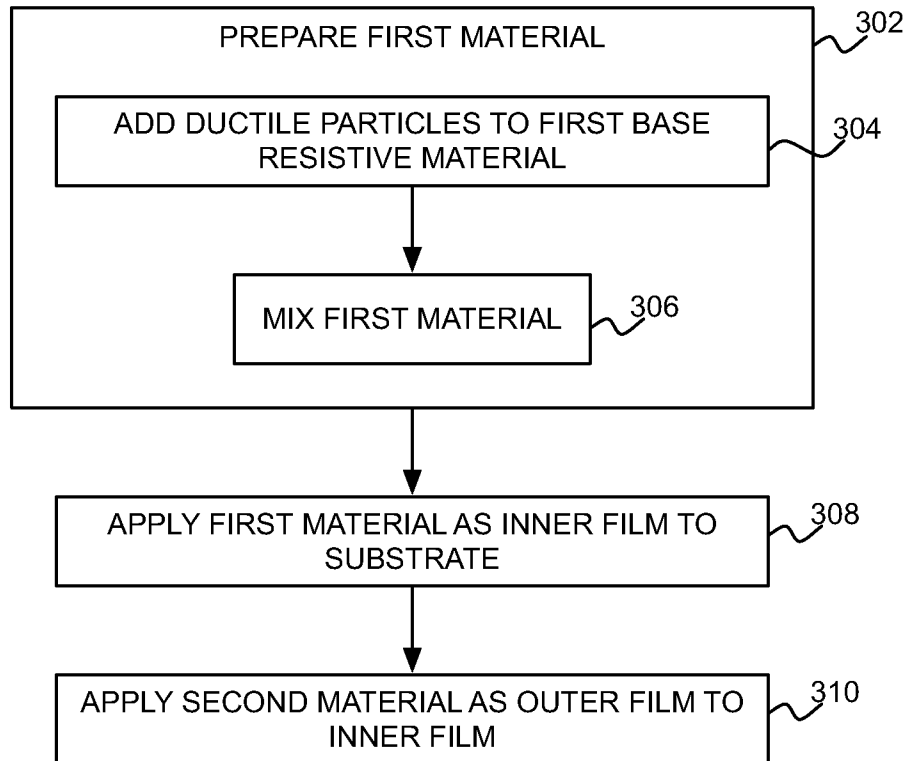
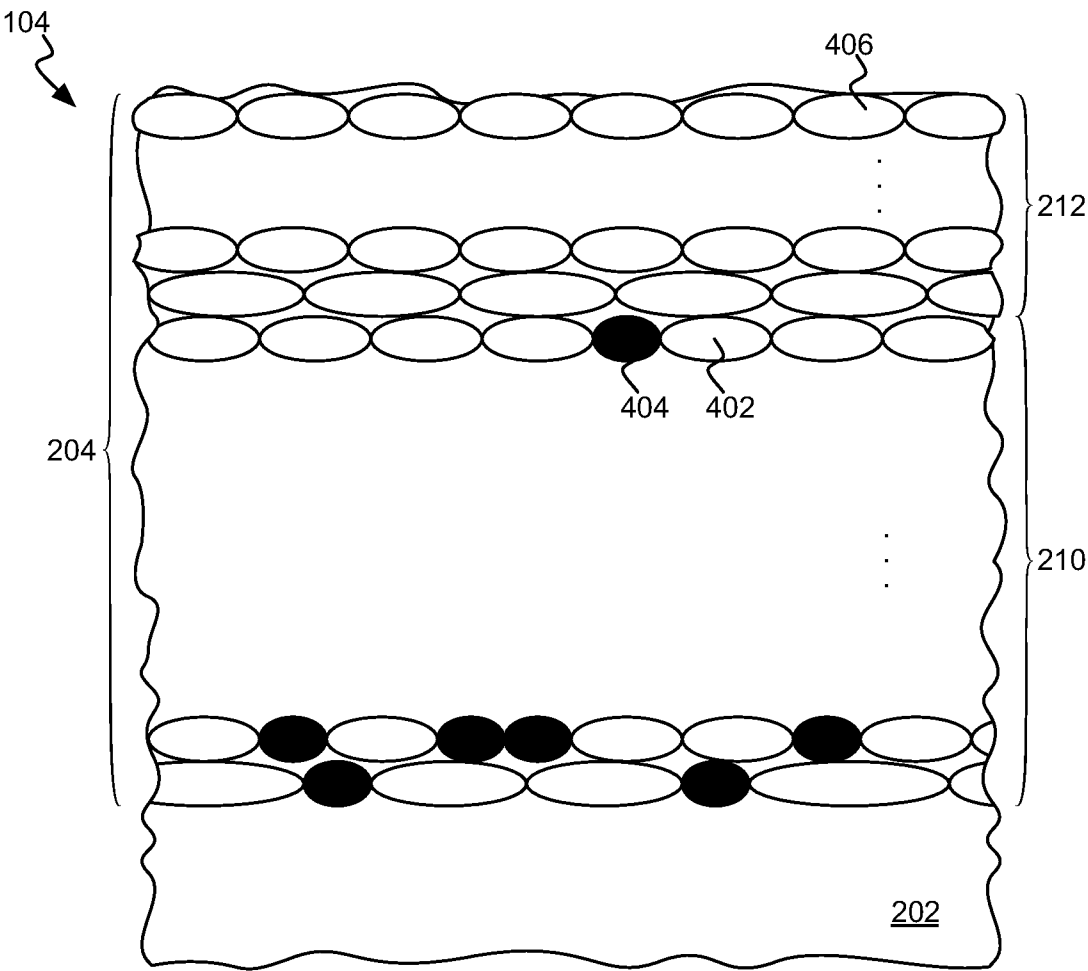
FIG 3300
↓

FIG 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/049186**A. CLASSIFICATION OF SUBJECT MATTER****G03G 15/02(2006.01)i**

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)

G03G 15/02; G03G 21/16; B05C 1/08

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: electrophotographic printing, charge roller, outer resistive film, particle, discharge

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008-0075505 A1 (YUKI NAGAMORI et al.) 27 March 2008 See paragraphs [0031]-[0064]; figure 6; and claim 1.	12-15
Y		1-11
Y	WO 2014-062153 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 24 April 2014 See page 6, line 25 - page 15, line 24; figure 1; and claims 1, 11.	1-11
A	US 2013-0149001 A1 (KOJI MIYAKE et al.) 13 June 2013 See paragraphs [0047]-[0058]; and figure 3.	1-15
A	US 2010-0247149 A1 (TAKURO HOSHIO) 30 September 2010 See paragraphs [0021]-[0041]; and figures 1-2.	1-15
A	US 2011-0201485 A1 (BRIAN P. GILMARTIN et al.) 18 August 2011 See paragraphs [0037]-[0039]; and figure 1.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

27 February 2015 (27.02.2015)

Date of mailing of the international search report

02 March 2015 (02.03.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/049186

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2011-0201485 A1	18/08/2011	None	