Effects of Toner Surface Treatment Powder Blending Parameters on Developer Triboelectric Properties

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Abstract

Silica and metal oxides are used to modify the physical and triboelectric properties of electrophotographic toners resulting in improvements in key attributes such as image quality and triboelectric charging characteristics. The mixing energy intensity of the powder blending process for toner surface treatment effects the degree of dispersion and embedment of these materials on the toner particle surface. Quantitative surface elemental analysis was used to characterize the toner particle surface composition after surface treatment. Surface treated toner properties such as powder cohesiveness, triboelectric charge level, charging rate, and the charging rate of replenishment toner were evaluated for surface treated toners that had been powder blended over a range of energy intensities. The following effects were observed:

For surface treatments that are added to improve powder flow properties, embedment of surface treatment particles increase toner cohesiveness.

Embedment of silica particles that are used to increase developer charging rate diminishes this effect.

The triboelectric charge level time dependent response of a developer shows that charge level can either increase or decrease as surface treatment particles are embedded in the toner particle during developer agitation. The response was dependent on the relative charge level of the surface treatment particle and the toner particle.

Introduction

The addition of silica to toners has been shown to improve image quality by reducing the level of character voids, but it can also degrade image quality by increasing background levels.[1,2] These effects are dependent on the concentration level of the surface treatment. The triboelectric charge level can be modified with inorganic oxides, particularly with silicas that have been chemically modified. Powder mixing variables in a toner surface treatment process where investigated to determine if the conditions that were used for powder blending had effects on toner and developer properties. The surface treatment process can be conceptually described as fragmenting agglomerates of inorganic oxides, dispersing the aggregates over the surface of the toner particle, and with high intensity blending conditions embedding the particles into the amorphous toner surface. For both the image quality and triboelectric effects the response was found to depend on the intensity of mixing and the atomic surface concentration of the inorganic oxide.

Materials and Surface Treatment Process

The toners used in this study were negative charging, black toners made from styrene acrylic binder polymer, carbon black pigment, and a negative charging organo metalic charge control agent. Carriers were hard magnetic ferrites coated with a silicone resin for charge stability. Surface treatment materials were commercially available silica (Wacker HDK1303) and titania (DeGussa T805). Aggregate particle size for the surface treatment materials was ~0.1µ. Bulk toner was surface treated by powder blending toner with silica and titania in a Henschel mixer. The mixer configuration was 10 liter in volume, with a 4 ele-ment impeller. Mixing speed and time were variable. ESCA was used to measure the atomic percentage of elemental carbon, oxygen, silicon, and titanium on the toner particle surface. The percentage of silica or titania on the surface was expressed as a percentage of elemental silica or titanium.

Surface Composition and Blending

It was found that for a given weight concentration of silica or titania in a surface toner that there could be relatively large variations of the oxide on the toner surface depending on the intensity of mixing. Table 1 illustrates that by either extending the blending time or increasing the mixing impeller speed the surface concentration of silica was reduced. The same effect was measured for titania, but the magnitude of variation was less.

A larger sample set of surface treated toners that was used for statistical analysis to quantify the surface treatment process effects is shown in Tables 2 and 3. As an example to illustrate the magnitude of blending effects, Sample 1 was made with 0.15 wt% silica, blended at the least energy intensive conditions, and had a surface silicon concentration of 3.35 atomic%, compared to Sample 7 which was formulated with 0.25 wt% silica, blended at the most energy intensive conditions, and actually had a lower surface silicon concentration of 1.53%. Mean response levels, Table 3, showed that mixing speed and time were as important as the weight percentage of silica or titania in determining the surface composition.

Table 1. Dependence of toner surface composition on blending conditions

Mixing Speed, RPM	Mixing Time, min	Surface Concentration, Atomic %
Toners surface treated with 0.15 wt% silica		
2000	2	2.98
2000	10	1.58
4900	2	2.07
4900	10	1.12
Toners surface treated with 0.35 wt% titania		
2000	2	1.44
2000	10	0.88
4900	2	1.23
4900	10	0.69

Triboelectric Charge Level

The toner triboelectric charge measured on a two component developer for samples that were surface treated under conditions that represent "low" energy intensity, 2000 RPM for 2 minutes, and "high" energy intensity, 4900 RPM for 10 minutes, are plotted in Figures 1 and 2 as a function of developer exercise time. These samples had equivalent weight percentage of the surface treatment materials, but varied in the surface compositions. For toner samples surface treated with silica only the charge level expressed as a charge to mass ratio, Q/m rose the fastest and reached the highest level for the toner that was blended under the least intensive conditions and had the highest surface concentration of silica. The titania surface treat-ment, which in this toner had the effect of lowering the Q/m as the weight percentage of titania was added, showed the opposite response. Low intensity powder blending con-ditions resulted in higher surface concentrations of titania, lower initial Q/m levels and slower charge rises.

Analysis of a toner stripped from a replenished developer showed that the surface Si level had increased form 3.17% in the replenishment toner to 3.85% in the developer, for a titania surface treatment the surface Ti decreased from 1.26% in the replenishment toner to 0.92% in the developer. These effects could result from continued dispersion and embedment of the surface treatments as the developer is agitated in a toning station.

Measurement of toner charge to mass levels in replenished developers showed that the Q/m level could be correlated with the surface concentration of silica and titania, Table 2.

The residence time of toner in a high speed, digital printer is on the order of 15 to 60 minutes, the same time scale over which these measurements were made. The process conditions for surface treating the replenishment toner would be expected to effect the Q/m transient response of an operating printer developer system.

Image Quality and Toner Cohesiveness

The image quality of prints made from a samples set of toners that varied the surface treatment weight percentage, type (silica and or titania), and blending conditions (mixing time and speed) were evaluated quantitatively for character voids, or hollow character, and satellites. Hollow character was measured as the –log(%void area) for letter characters. Satellites, high background immediately adjacent to a character, was measured by the background RMSGS metric for a screened area immediately surrounding the printed letter (3).

Table 2. Surface Treatment Process Taguchi L8 Matrix

Sample	Silica	Titania	Surface Treatment		Surface Analysis		Q/m	Predicted Q/m
	Wt %	Wt %	Speed, RPM	Time, min	Atomic % Si	Atomic % Ti	μC/gm	μC/gm
Reference	none	none0						
#1	0.15	0.35	2000	2	3.35	1.38	-19.3	-19.7
#2	0.15	0.55	2000	10	3.23	2.19	-17.4	-17.4
#3	0.15	0.35	4900	10	1.24	0.69	-19.6	-20.5
#4	0.15	0.55	4900	2	2.36	1.68	-19.2	-18.4
#5	0.25	0.35	2000	2	4.29	1.42	-20.7	-20.1
#6	0.25	0.55	2000	10	4.31	2.18	-17.0	-18.0
#7	0.25	0.35	4900	10	1.53	0.65	-21.2	-20.8
#8	0.25	0.55	4900	2	3.09	1.71	-19.1	-18.7

Table 3. Mean Response Level of Surface Compositon to Blending Parameters

Variable	Level	Mean Response	
		Surface Atomic Si%	Surface Atomic Ti%
Silica wt %	Low	2.54	
	High	3.30	
Titania, wt%	Low		1.03
	High		1.94
Mixing Speed	Low	3.80	1.79
	High	2.06	1.18
Mixing Time	Low	3.27	1.54
	High	2.58	1.42

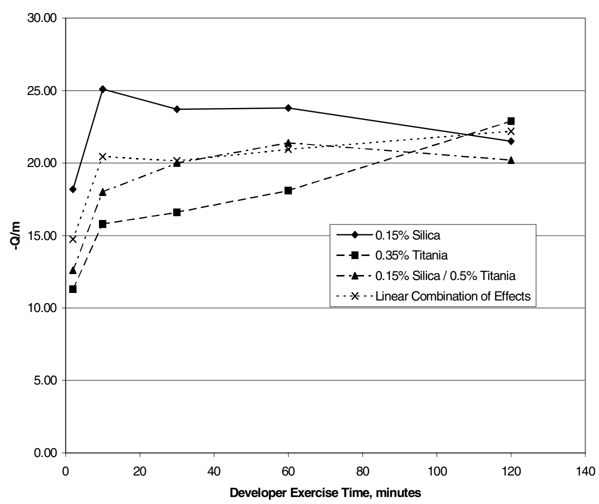

Figure 1. Toner charge / mass for toner surface treated at "low intensity" blending conditions

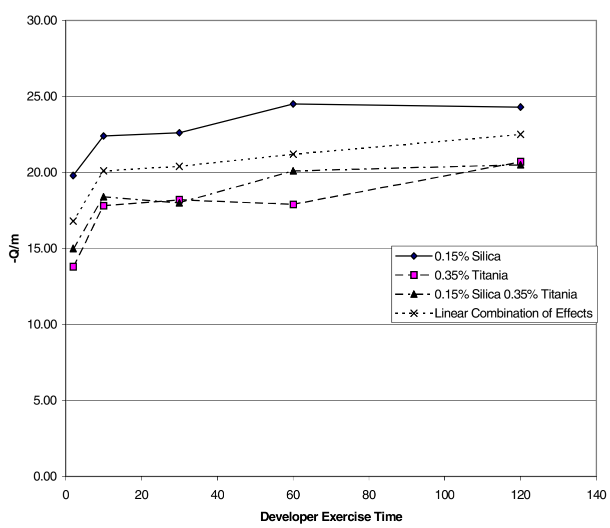

Figure 2. Toner charge / mass for toner surface treated at "high intensity" blending conditions

The physical process that causes these defects can be related to toner particle cohesiveness. Surface treat-ment particles act as "spacer" points between toner parti-cles and reduce interparticle attraction forces and toner to photoconductor adhesive forces. For the formation of satellites individual toner particles in less cohesive toners could separate when transferred from the photo-conductor to paper and the character integrity degraded. Lowering the toner to photoconductor adhesive forces and increasing the percentage of toner transferred to the paper receiver would reduce character voids.

Figure 3 illustrates that for a set of surface treated toners that there is a correlation between the level of hollow character and satellites. There is a tradeoff between these two image quality attributes. Toners with a higher surface treatment level or blended to give higher surface concentrations of silica had reduced hollow character, but higher satellite levels.

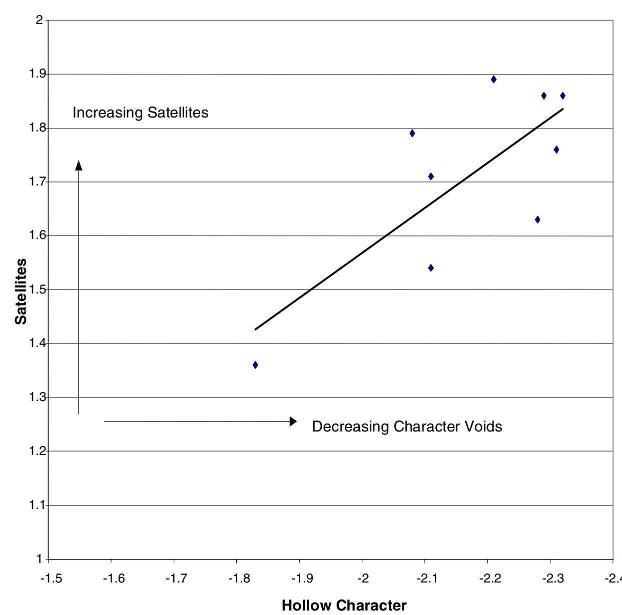

Figure 3. Image quality tradeoffs, hollow character and satellites, for surface treated toners

Conclusion

The surface concentration of silica and titania that are used to modify toner properties can be significantly changed by the energy intensity of the surface treatment process. Surface composition effects the toner transient Q/m response during developer charging, replenished developer Q/m, and image quality attributes, hollow character and satellites, that are dependant on toner powder cohesiveness.

References

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Biography

Robert D. Fields received a Ph.D. degree in Chemical Engineering from Cornell University in 1973. He is an Associate Scientist at Heidelberg Digital L.L.C. For the majority of his career he has been involved in process development and manufacturing of electrophotographic toners and developers. He is the holder of several patents in the area of toner formulations. Currently he is working on commercialization of toner materials for electrophotographic digital printers. He is a member of the IS&T.