Control of the Rheological Properties of Toners for the Simultaneous Fusing System

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Abstract

Fusing properties of a black toner and a color toner, made from the same binder resin, have been investigated with the simultaneous fusing printer. It is found that the rheological properties correlate well to the fusing properties. The rheological properties of the black toner is influenced by carbon black added to the black toner.

On the other hand, the rheological and fusing properties of the color toner are found to be adjustable those of the black toner by utilizing a hydrophobic silica, which does not influence on the electric properties and the hue of the color. Thus the color toner with added hydrophobic silica provides wide non-offset window for the simultaneous fusing.

Introduction

In recent years, concern has been raised about the color printing system. The request for color printing has been increasing, and several kinds of color printing technologies have been developed. It is very common that the black toner and the color toner for most of color printers are made from the same binder resin.[1]

The reason why each toners use the same binder resin is that the thermal, electrostatic and environment properties should be optimized to the system of the color printer, and that these properties are determined by the toner binder resin.[2] But actually, as shown in Table 3, the fusing properties of the color toner is different from that of the black toner even if the same resin is used for the binder. This difference has forced a severe restrictions on the design of the fusing system, which has been overcome by a lot of efforts of printer manufacturers. If the difference would have been improved from material side, it might give more flexibility in the design of the fusing system of the printer. It is reasonable to assume that the apparent inconsistency in the fusing behavior is attributable to the difference of the coloring agent in toner, since the black toner and the color toner are manufactured through the same process.

We investigate the cause of the difference of black toner and the color toner in fusing properties and to develop color toner having the same thermal properties as the black toner and having wide non-offset window for the simultaneous fusing system.

Experiment

A Typical Black Toner and Color Toner for Simultaneous Fusing System

Sample. The formulation given in Table 1 represents a typical black toner and color toner for simultaneous fusing system. The binder used to the black and the color toner are KAO polyester resin, cross-linked type. The polyester resin of average molecular weight 66,000, glass transition temperature 67ºC, softening point 132ºC, and gel content 20%. Additives of the black toner are composed of carbon black, charge control agent (CCA), and wax. Additives of the color toner are composed of pigment, CCA and wax. The binder and the wax for the black and the color toner were used the same materials respectively.

These toners were manufactured through the same process. The materials were premixed in a batch mixer; then they were kneaded in twin screw extruder and were pulverized in the jet mill. Finally Black toner 1 and Color toner 1 having an average size of 11 μm were obtained.

Results and Discussion

Fusing Properties. The fusing properties of the black and the color toner are measured by a printer. Table 2 shows the details of the printer. This printer speed is 40ppm as process speed and is able to fuse the black toner and the color toner simultaneously. Table 3 shows the non-offset window and the fusing goodness for each toner. The fusing goodness is measured by a tape test. There is no significant

Table 1. Formulations of the Black and Color Toner

	Black toner 1		Color toner 1	
	Material	parts	Material	parts
Toner resin	Polyester	100	Polyester	100
Coloring agent	Organic salt	9	Red pigment	5
Charge control agent	Carbon black	1.5	Organic salt	2
Wax	Polypropylene	3	Polypropylene	3
Softening point (°C)	127		121	

difference in the fusing goodness between two toners, but hot-offset starting temperature of the black toner is higher than that of the color toner in Table 3.

Table 2. Specifications of Simultaneous Fusing Printer

Speed	400ppm (Monocolor) 20ppm (Twincolor)
Photoconductor	Organic photoconductor
Developer	Two-component developer (-) toner and magnetic carrier
Paper Type	Plain paper, Cut sheet, Card

Softening Point. Softening point. (Tsp) is measured using Flow tester (SIMADZU Flow Tester, model CFT-500). Results of the softening point are listed in Table 1, Tsp of the color toner is lower than that of black toner, in spite of the same toner binder resin.

Table 3. Fusing Properties of Black and Color Toner made from the Same Resin Goodness

	Non offset temperature range	Goodness of fusing at 165
Black toner	160 - 195	55.8 (%)
Color toner	150 - 165	81.2 (%)

Rheological Properties. Rheological properties of the color toner, the black toner, and the binder resin itself are measured using rheometer (Rheometrics Dynamic Analyzer II). Setup conditions for the rheometer are listed in Table 4, and the measurement condition is as follows; amount of sample: 1gr. (toner powder); temperature: from 220ºC down to 60ºC. The rheological properties are represented by two parameters; Storage modulus (G') and Loss modulus (G"), and the temperature dependence of G' and G" at frequency 0.628rad/s were shown in Figure 1.

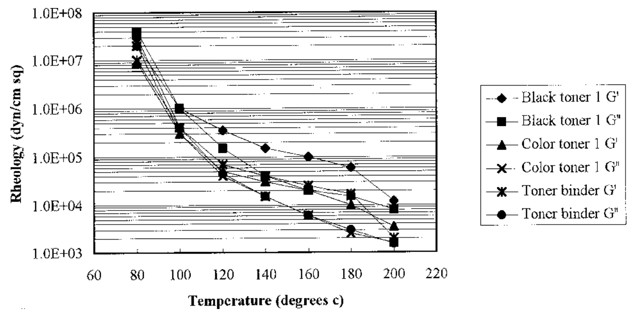

Figure 1. Temperature dependence of rheological properties of toner binder, black and color toner (Freq. 0.628 rad/s)

Figure 1 shows that the G' of the black toner is higher than that of the color toner and the rheological properties of the toner binder is equaled to that of the color toner. Thus the value of G' seems to correlate well to the hot off-set starting temperature. If the G' of the color toner could increased to the same level of the black toner, the non-off-set window of the color toner would be equalized to the black toner level. Since the toner binder resin and the color toner shows almost the same rheological properties, it is supposed that the G' of the black is determined by the carbon black and CCA in the black toner.

Comparison of Additives in the Black Toner

Sample. Influence of the carbon black and the charge control agent to the rheological properties of the toner are investigated by trying the following combination in the formulation (Table 5).

Table 4. Sweep Conditions for Rheometer

Plate	Parallel plate (radius: 12.5 mm)	
Test mode	Kinematic viscoelastic property analysis	
Sweep type	Frequency/Temperature-Sweep	
Strain		2%
Measured Temperature	220	80
Frequency	0.628 rad/s 291.48 rad/s	
Step size		10
Soak time	30 seconds	
Point/Decade		3
Tension	Auto	

Table 5. Formulations of the Black Toners

	Material	Black toner 1 parts	Black toner 2 parts	Black toner 3 parts	Black toner 4 parts
Toner resin	Polyester	100	100	100	100
Coloring agent	Carbon black	9	0	0	9
Charge control agent	Organic salt	2	0	2	0
Wax	Polypropylene	3	3	3	3

The process used preparing these black toners is the same previously (refer to Experiment Sample).

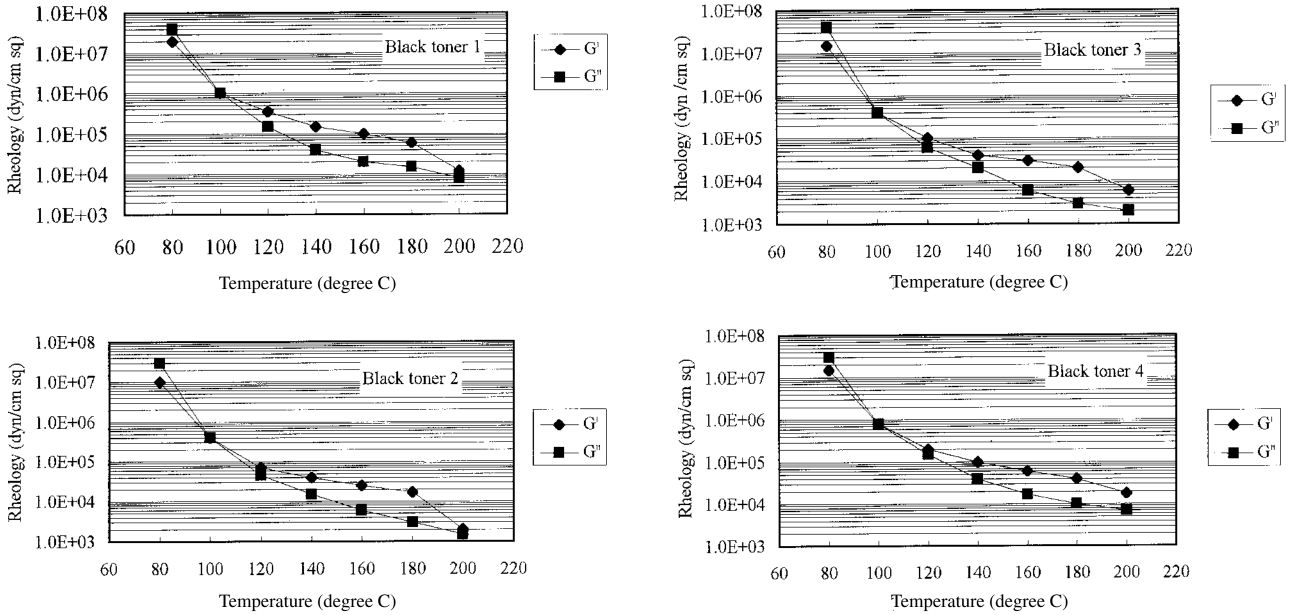

Figure 2. The temperature of G′ and G″ with these toners t frequency 0.628 rad/s.
1. Black toner 1: standard
2. Blact toner 2: without carbon black and CCA
3. Black toner 3: without carbon black
4. Black toner 4: without CCA

The process used to prepare these black toners is the same previously (refer to chapter 1-1).

Results and Discussion

Rheological Properties. Figure 2 shows the temperature dependence of G' and G" with these toners at frequency 0.628 rad/s. This result demonstrates that the rheological properties of the black toner are dominated by adding the carbon black.

Generally, the carbon black for the black toner have the character in coloring, charging and control of resistivity.[3] On the other hand, the carbon black is often used to enhance the elasticity of rubber as is common in tires for automobiles. This effect is known as BOUND RUBBER EFFECT.[4] If the carbon black could be added in the color toner, the color toner having the same rheological properties would be obtained as the black toner by this kind of bound rubber effect, but the hue of the color toner would be completely changed. We have to find out a white filler with a bound rubber effect. Candidates of the filler are silicon dioxide, titanium dioxide, alumina, zirconium dioxide and so on. Generally, the bound rubber effect is exhibited by small size particle and high degree of dispersion of the filler.[5] As a results, a hydrophobic silica which has small size, high dispersion and white color is selected as a filler, and the color toner employing the hydrophobic silica are prepared.

Hydrophobic Silica

Sample

Table 6 shows the details of the hydrophobic silica. This hydrophobic silica is very popular as a surface treatment agent for toner. The hydrophobic silica is added in the color toner as an additive with the same toner process. Added amount of hydrophobic silica in the color toner is varied from 0 to 10 parts by weight in Table 7.

Results and Discussion

Rheological Properties. Figure 3 shows the temperature dependence of G' and G" with the color toners which have different amount of the hydrophobic silica at frequency 0.628 rad/s. The graphs show that the G' are increased with an increasing the amount of the hydrophobic silica. Specially, the G' is proportional to the hydrophobic silica amount until 5 part by weight, however over 5 parts by weight, the effect is saturated.

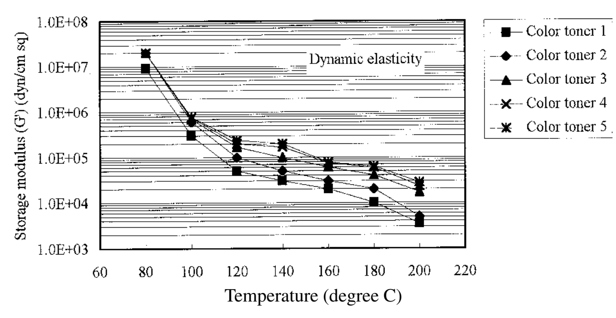

Figure 3. Temperature dependence of G' and G" with color toners with added hydrophobic silica at frequency 0.628 rad/s.

Electric Charge Properties. Normally, the hydrophobic silica for surface treatment increases flowability of a toner, so the charging rate and charging level of the toner is increased with increasing the hydrophobic silica amount.

But when the hydrophobic silica is kneaded into the toner, the flow ability of the toner does not vary, so it is expected that the electric charge property of this toner does not vary so mach as for the hydrophobic silica amount.

Figure 4 shows the activation time dependence of the electric charge property with the color toners added the hydrophobic silica in Table 7. The color toners are blended with a silicon coated magnetite carrier of 110 µm diameter in proportions of 97.5 to 2.5 by weight. The charge per unit mass, q/m, of the toner/carrier mixture is measured by using the blow off method which employed a Faraday cage based instrument built in-house.

As a result, the charging level of these toners is decreased with increasing the hydrophobic silica amount, although the change is little until 5 parts by weight. These results conflict with our expectation. These discrepancies are interpreted as following:

1. The hydrophobic silica which crops out on the surface of the toner increase with increasing additional amount.
2. PH value of the hydrophobic silica influences on the electric charge property of the toner.
3. Until 5 parts by weight, degree of outcrop of the hydrophobic silica is little, so change in the charging level of these toners is little.

Dielectric Properties. It is known that the degree of dispersion of internal additives of toner is predicted by the resistivity or the dissipation factor. Table 8 shows the dielectric properties of Color toner 1 (standard: without silica) and Color toner 3 (silica 5 parts by weight). The experimental conditions for the dielectric properties are as follows; sample: toner cookie (pressed the toner powder at 0.4t/cm2 into press mold), sample thickness: 1.5~2.0mm, diameter: 58mm,; experimental apparatus: LCR meter (Hewlett packard model 4284A impedance analyzer), electrode: parallel plate, measurement frequency: 1 kHz. Capacitance and conductance are measured and dielectric constant, resistivity and dissipation factor are calculated.

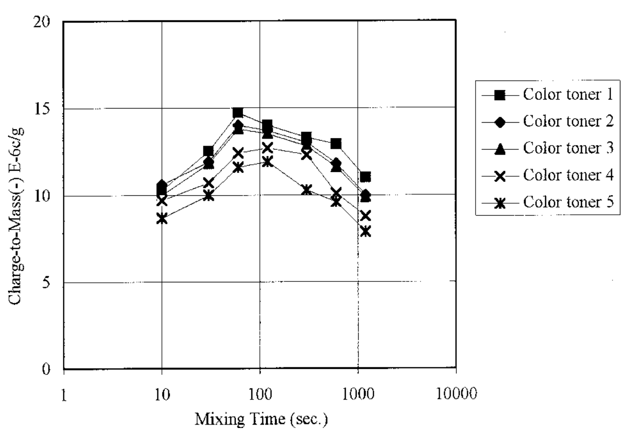

Figure 4. Charge to mass ratio values of color toner added silica.

Color toner 1 and Color toner 3 do not show significant difference in the dielectric properties. Thus the hydrophobic silica does not seem to influence on the degree of dispersion of internal additives.

Table 8. The Dielectric Properties of Color Toners.

	Color toner 1	Color toner 3
Dielectric constant	3.02	3.09
Resistivity (ohm/cm)	2.20E + 11	2.50E + 11
Dissipation factor	0.025	0.026

Hue of Color Toner. Table 9 shows the hue of Color toner 1 (without silica) and Color toner 3 (added 5 parts by weight silica). The hue of color toner is measured by the spectrodensitometer (model 938). As a result, the hue of Color toner 3 shows almost the same value as compared to Color toner 1. Thus the hydrophobic silica does not influence the hue of the color toner.

Table 9. Hue of Color Toner with Added Silica

	L	a*	b*
Color toner 1	53.68	61	36.02
Color toner 3	52.71	61.63	36.27

Fusing Properties. The fusing properties of Black toner 1 and Color toner 3 added hydrophobic silica of 5 parts by weight are measured by the printer. Table 10 shows the non-offset window and the fusing intensity for each toners. There are no significant difference in fusing properties between the two toners. Finally, it is experimentally demonstrated that the rheological properties of Color toner 3 is adjusted to be similar to Black toner 1 by adding the hydrophobic silica, as shown in Figure 5.

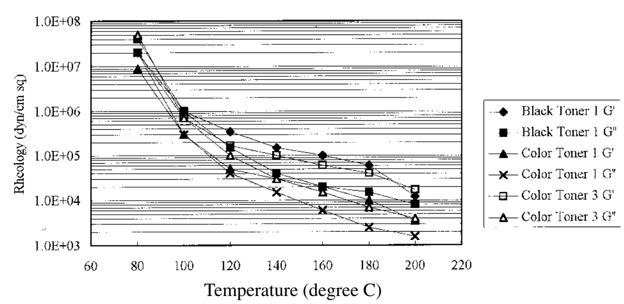

Figure 5. Temperature dependence of G′ and G″ with Black toner 1, Color toner 2 and Color toner 3 at frequency 0.628 rad/s

Conclusions

1. There is significant difference in rheological properties of the black toner and the color toner which are

Table 10. Fusing Properties of Black Toner and Color Toner added Silica 5wt%

	Non-offset window	Goodness of fusing at 180(°C)	Tsp (°C)
Black toner 1	160 - 195 (°C)	79.6 (%)	127
Color toner 3	150 - 195 (°C)	80.1 (%)	128.9

prepared with the same formulation using the same toner binder at the same kneading condition except the coloring agents. These difference is influenced by the bound rubber effect of the carbon black in the black toner.

2. To enhance the rheological properties of the color toner to that of the black toner, the hydrophobic silica introduces the bound rubber effect, and is shown to be effective as an alternative for the carbon black.
3. It is confirmed that the rheological properties are increased with increasing amount of the hydrophobic silica and this effect is saturated over 5 parts by weight. Moreover it is founded that the charge to mass ratio properties and the hue of the color are not so influenced very much.
4. It is shown that the color toner employing the hydrophobic silica has almost the same fusing properties as compared to the black toner, which expands the feasi bility for the simultaneous fusing system from material design.

Acknowledgments

The authors thank Mr. K. Inoue for making these toners. The authors also thanks Ms. E. Makino for experimental assistance. The authors acknowledge Mr. N. Hayashi, Dr. K. Maki, Mr. Y. Ueda and Mr. Kobayashi for critically reviewing the manuscript.

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