The Advanced Color Toner for the Fine Image Quality

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Abstract

The full color printer has been rapidly spread in the office and the demand on the full color printer has been also increasing. Especially high-speed printing, oil-less fusing and fine image quality are strongly requested.

Recently, several chemical toners are launched. Because they have the small and narrow particle size distribution, they have the advantage in the fine image quality. However the resin of chemical toner is usually styrene-acrylic which is not suitable for the high-speed printing. Moreover, styrene-acrylic has to be high molecular weight to make toner have a sufficient durability. Thus the chemical toner has also a disadvantage in the glossy image for pictorial printing. On the other hand the polyester usually used in the pulverized color toner has better property for the high-speed printing than styrene-acrylic. And because polyester has the good durability even if it has the low molecular weight to provide the glossy image. Thus the pulverized toner using polyester has several advantages over chemical toner, but it has been difficult to make pulverized toner having small and narrow particle size distribution.

In this report the design of the pulverized color toner having small and narrow particle size distribution was investigated. This advanced color toner can provide high-speed printing, oil-less fusing and also fine image quality. Furthermore, this toner has the high reliability because of less free silica.

Introduction

In recent years, as color printers have become to be widely used, the requirements of the improvements for color printers have been also increasing, for instance, low cost, high image quality, high speed, and so on. To achieve these requirements, various functions are required for the toner.

To meet the demands, several chemical toners were developed and launched. It is said that the chemical toner is much better than the pulverized toner in various points of the performance.[1,2]

1. Small and Narrow Size Distribution

To obtain high image quality, the toner having small and narrow size distribution is necessary. Chemical toner has an advantage in the small and narrow size distribution, because the chemical toner is directly polymerized.

2. Capability of Structure Control

It is said that spherical toner is proper to achieve high transfer efficiency because such toner comes in contact with photoconductor by a point area and it is easy to remove from that. The chemical toner is generally spherical, and it is possible to control the shape on the grounds of producing methods.

3. Oil-Less Fusing

Generally, the resin of color toner has low and narrow molecular weight distribution, and such resin cannot give the wide non-offset range in fusing. Therefore, the attempt to make color toner include the plenty of wax had been done. But in the conventional pulverizing method, toner tends to split at the surface between wax and binder resin. Thus such large amount of wax makes a durability of toner worse because of the existence of large domains of wax on the toner surface. On the other hand chemical toner can include plenty of wax without problems, because the toner can include wax inside and the wax does not exist on the toner surface.

As mentioned above, chemical toner has some merit, however the resin of chemical toner is usually styrene-acrylic which is not suitable for the high-speed printing. If the molecular weight is low to improve the fusing ability, the durability of toner become worse. So styrene-acrylic has to be high molecular weight to make toner have a sufficient durability. But such high molecular weight cannot provide the glossy image for pictorial printing. On the other hand the polyester usually used in the pulverized color toner has better property for the high-speed printing than styrene-acrylic. And because polyester has the good durability even if it has the low molecular weight to provide the glossy image.

Therefore the pulverized toner using the polyester resin has also many merits in comparison with the chemical toner. Moreover the color gamut of the pulverized polyester toner is also larger than the chemical toner because the dispersion of the pigment is better. Fig.1 shows the comparison of the color gamut of the pulverized toner and the typical chemical toner.

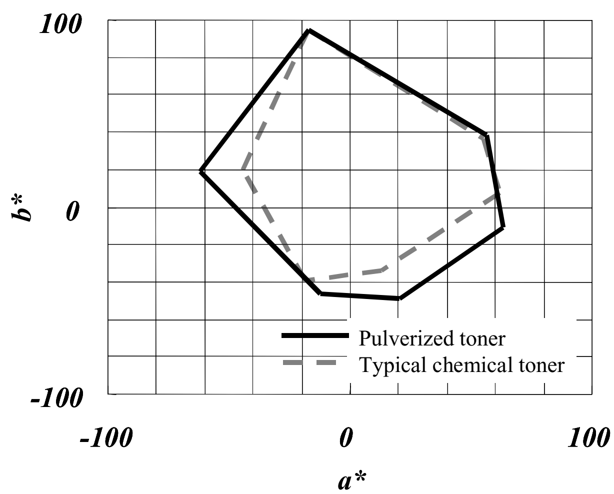


Figure 1. The comparison of the color gamut of the pulverized toner and the chemical toner

In addition, the study to enhance the performance of pulverized toner has been advanced steadily to overtake above merits of chemical toner. With regard to the oil-less fusing, it was reported that it was possible to make the pulverized toner have both of the good offset ability and the durability.[3] To achieve the oil-less fusing, it is necessary to add a plenty of low melt wax to the toner. But it is difficult to disperse such amount of wax for twin-extruder that is conventionally and usually used in kneading process and the dispersed size of wax of the toner becomes very large. And such poor dispersion of wax causes the poor durability of the toner. In that study, it was reported the open-roll type kneader (Fig. 3) is suitable for the fine dispersion of wax because of the low temperature in the kneading process (Fig. 2).

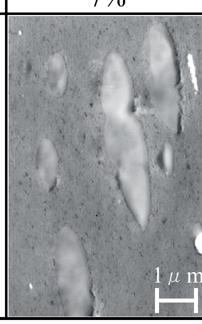
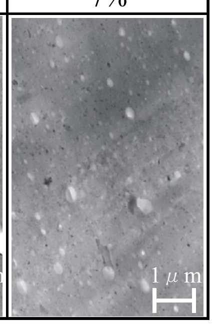
Kneader	Twin Extruder	Open-roll Type
Wax (MP=80℃)	7%	7%
The wax dispersion in the toner (TEM investigation)		

Figure 2. The comparison of the wax dispersion in the toner

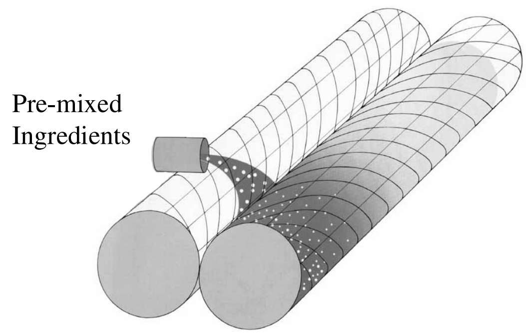


Figure 3. Open-roll Type Kneader

Furthermore, it is possible to get high transfer efficiency by using the spherically shaped pulverizing toner. Recently many technologies of that were unveiled.

With regard to small and narrow particle size distribution, it was reported that it was possible to generate small toner particles at high yields by investigating better rotor and new nozzle design.4) But in case of the oil-less toner containing a plenty of wax, it is still difficult to pulverize the toner to small size. Because the existence of a plenty of wax makes the fluidity of the toner extremely poor in the pulverizer. And the toner particles adhere each other, thus the pulverizing efficiency becomes very bad.

In this report, an actual product design of the oil-less toner having small and narrow particle size distribution is investigated. This product design can provide not only small size pulverized toner but also the toner having good durability.

Experimental

Preparation of Polyester Resin

Bisphenol A propylene oxide adducts, ethylene oxide adducts, Terephthalic acid, C12-Succinic anhydride, and Trimellitic anhydride were allowed to react for condensation polymerization at 230°C with the small amount of catalyst in a glass flask, which was equipped with a thermometer, a stainless steel stirring rod, a reflux condenser and nitrogen inlet tube.

Table 1. Properties of the Experimental Polyester Resin

Resin	Acid Value[1)] (mg KOH/g)	T1/2[2)] (°C)	Tg[3)] (°C)
Polyester	20	115	63

1. The acid value was measured according to ASTM D-1980-67.
2. The softening point (T1/2) was measured according to ASTM E-28-67.
3. The glass transition temperature (Tg) was measured by a differential scanning calorimeter "DSC Model 200" manufactured by Seiko Instruments Inc., at a heating rate of 10/min.

Preparation of Toner Samples

Toner samples were comprised of this resin, the wax, the charge control agent and the colorant. The colorant was Quinacridone (Pigment Red 122) and the melting point of the wax was 80°C. The content of the colorant was 6.5wt% and the wax was 2.0wt%.

The materials were premixed in a batch mixer; then they were kneaded by open-roll type kneader. And before pulverizing, this toner chip was mixed with 1.0wt% of the hydrophobic silica. We call this process "pre-condition". And then, it was pulverized and classified. The target size was 5 μm (Toner A). On the other hand, toner chip without "pre-condition" was also pulverized and classified (Toner B). In the same way, we prepared the toner sample whose wax content was 6.0%, Toner C (with pre-condition) and Toner D (without pre-condition). The target size was also 5 μm. And the silica was added to the Toner B and Toner D to make them have the same contents of silica with Toner A and Toner C by mixer, usually used in the adding process.

The toner samples are listed in Table 2. And we compare the particle size distribution of each toner and the productivity.

Measurement of the Particle Size Distribution

The particle size distribution was measured Coulter Multisizer II with the 100 μm size aperture.

Table 2. Toner Samples 1

Toner No.	Wax	Pre-condition
Toner A	2.0%	Silica=1.0wt%
Toner B	2.0%	None
Toner C	6.0%	Silica=1.0wt%
Toner D	6.0%	None

Measurement of the Image Quality

The toner was developed by a non-magnetic single component printer. The resolution was 1200dpi. The dot image on the paper before fusing was observed.

Results and Discussion

The Particle Size Distribution of Toner A and Toner B with 2.0% of Wax (The Effect of the Pre-Condition)

Figure 4 shows the particle size distribution of each toner. The toner A (with pre-condition) has small and very narrow particle size distribution similar to the chemical toner. Toner B (without pre-condition) has also small particle size distribution, but it includes the more extra-size particles. So, the particle distribution is broader than Toner A. This tendency is conspicuous when the content of the wax is large.

Figure 5 shows the particle size distribution of Toner C and Toner D. The toner C (with pre-condition) has also small and very narrow particle size distribution similar to the chemical toner. On the other hand, Toner D (without pre-condition) could not be pulverized to the small size, and it contains many amounts of extra-size particles. In addition, the yield rate of Toner B was extremely poor. This effect of the precondition is interpreted below. As described at introduction, the large amount of wax makes the cohesive force between the toner particles increased. Thus the fluidity of the toner with a large amount of wax becomes worse. And this tendency is enhanced when the toner particle size becomes smaller. But the existence of silica decreases the cohesive force between each toner particles (Fig. 6). Thus the dispersibility of the toner particles in the pulverizer becomes good, the efficiency of pulverizing and classifying also becomes good. By using this technology, the pulverized toner having such a small and narrow distribution can be provided in the mass product scale without regard to the quantity of the wax.

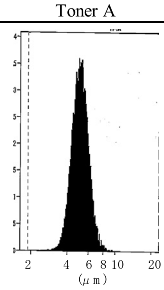
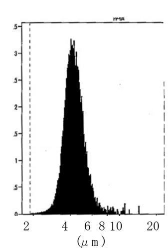
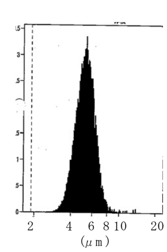
	Toner A	Toner B	Typical Chemical Toner
Particle size distribution (vol)			
D50(μm)	5.1	4.9	5.2
3μm>(%)	0.3	2.3	0.2
8μm<(%)	0.4	1.8	1.2
10μm<(%)	0.0	0.7	0.4
CV	18	24	21

Figure 4. The comparison of the particle size distribution of Toner A and Toner B

The Particle Size Distribution of Toner C and Toner D with 6.0% of Wax (The effect of the pre-condition)

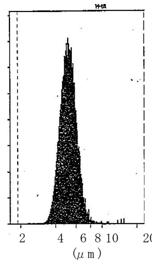
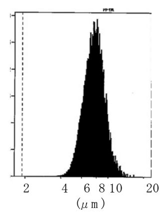
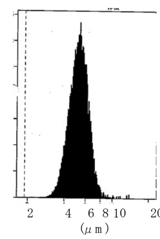
	Toner C	Toner D	Typical Chemical Toner
Particle size distribution (vol)			
D50(μ m)	5.2	7.6	5.2
3 μ m>(%)	0.2	0.3	0.2
8 μ m<(%)	1.0	40.5	1.2
10 μ m<(%)	0.3	8.4	0.4
CV	19	23	21

Figure 5. The comparison of the particle size distribution

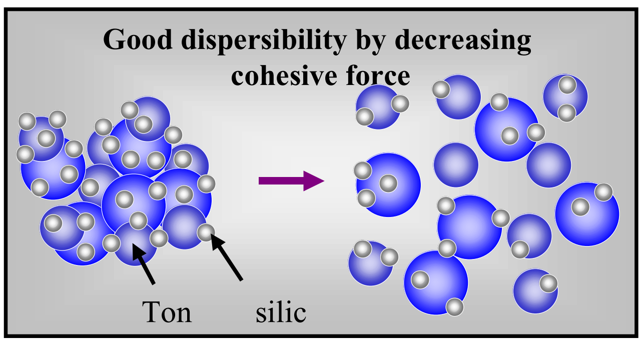


Figure 6. The effect of the pre-condition silica

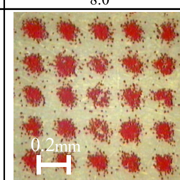
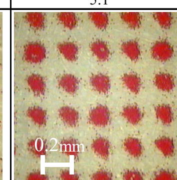
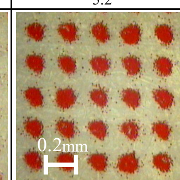
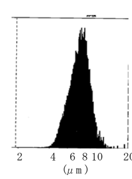
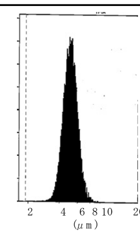
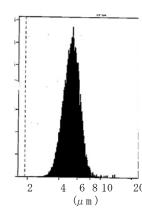
	conventional pulverized toner	Toner C	Typical chemical toner
D50(μ m)	8.0	5.1	5.2
dot image			
Particle size distribution (vol)			

Figure 7. The comparison of the image quality of each toner. For reference, the conventional pulverized toner (8 μm size) is also listed.

The Image Quality of the Toner C

Figure 7 shows the image quality of toner C. In this table, the conventional pulverized toner (8 μ m size) and typical chemical toner are also listed for reference. This table shows Toner C (the pulverized toner having small and narrow particle size distribution with a plenty of wax for oil-less fusing) provide the good image quality similar to the chemical toner.

The Effect of the Silica Added by the Pre-Condition Method

The dispersion state of silica added by the precondition method was investigated compared to silica added to the toner by conventional mixer. The dispersibility of the silica of Toner A and Toner B was measured by the SEM investigation method and the Particle Analyzer (Horiba). The result is listed in Fig. 8.

The SEM photograph indicates the silica added by precondition is treated rigidly to the toner surface. On the other hand, on the surface of Toner B, the agglomeration of silica is observed. The result of the Particle Analyzer also shows the silica dispersion of Toner A is better and the quantity of free silica is less than Toner B. In general, free silica causes the trouble such as the blade filming, OPC filming and so on. Thus the pre-condition method is effective for not only the productivity of the small size toner but also the dispersion of the silica on the toner surface.

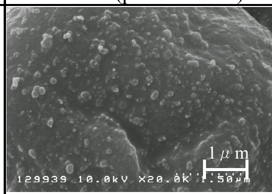
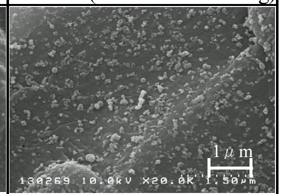
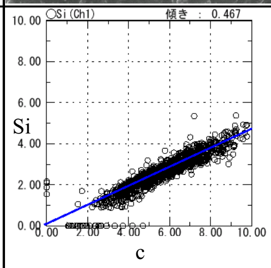
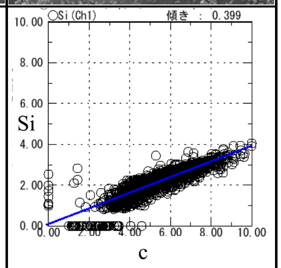
	Toner A (pre-condition)	Toner B (conventional adding)
SEM of the toner surface		
Si dispersion		
SD of the Si dispersion	0.061	0.092
free Si rate	0.39%	1.02%

Figure 8. The dispersion state of silica added by pre-condition method and the conventional mixer method.

Conclusion

The design of the pulverized polyester toner having the small and narrow particle size distribution can be summarized as follows.

(1) The pre-condition method is suitable for the production of the small particle size toner because of the decreasing the adhesion force between the toner particles in the pulvelizer.

(2) The pulverized toner having small and narrow particle size distribution can provide the good image quality similar to the chemical toner having small and narrow size distribution.

(3) The silica added by the pre-condition method is treated to the toner surface rigidly, thus toner contain little free silica which cause some life troubles.

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Biography

Akihiro Eida received his master degree in physics from Hokkaido University in 1996. Since 1996 he has been working for Kao Corporation in the Performance Chemicals Research Laboratories in Wakayama, Japan. His work has primarily focused on the development of toner and toner binding with polyester resin, including the design of color toner regarding wax, colorant, CCA and surface treatment agent. E-mail: eida.akihiro@kao.co.jp