Study on the effects of wax in the polyester color toner

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Abstract

To achieve the oil-less fusing of the color toner, the large amount of the wax is included in the color toner. It is true the wax is useful to improve the fusing ability, however the large amount of the wax makes the durability of the toner worse. So, it is difficult to apply the large amount of the wax to the color toner.

In this paper the investigations to apply the various kinds of waxes to the polyester color toner used in the non-magnetic single component development system are reported. As a result, it was found 1) the wax having the low melting point gives the good fusing ability. 2) The fusing ability is effected not only the melting point of the wax but also the dispersed size of the wax in the toner. 3) The more the wax is contained in the toner, the better the fusing ability is. 4) The bigger the dispersed size of the wax is, the worse the durability of the toner becomes. Consequently, on the non magnetic single component development system, to obtain the good fusing ability and the enough durability, it is necessary to disperse the wax having the low melting point to the proper size.

Introduction

In recent years, as color printers have become to be widely used, the requirements of the improvements for the color printer have been also increasing. One of these requirements is the oil-less fusing. Generally, the binder resin having the low and narrow molecular weight distribution is used to achieve the good transparency. However such binder resin cannot give the wide non-offset range in fusing because the elasticity of the toner melted by heat roller is low. Therefore, on many color printers the silicone oil is applied to the heat roller to prevent the offset[1]. However there are many problems, for example, the oil contamination on the paper, and so on. Then, many attempts have been done to achieve the oilless fusing of the color toner[2]. One of these attempts is adding the large amount of the wax to the color toner.

On the other hand, a non-magnetic single component development system is widely used in the desktop color laser printer. Because this apparatus is compact, low cost and easy maintenance. In this system, the toners are charged by rubbing between the doctor blade and the developing roller. Therefore, the toners must have enough durability.

In this paper, the effects of wax contained in the color toner for the non-magnetic single component development system were investigated.

Experimental

Preparation of Polyester Resin

Bisphenol A propylene oxide adduct, ethylene oxide adduct, Terephthalic acid, C_{12}-Succinic anhydride, and Trimellitic anhydride were allowed to react for condensation polymerization at 230℃ with small amount of catalyst in a glass flask, which 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)] (℃)	Tg[3)] (℃)
Polyester	23	118	59

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 is Carmine 6B (Pigment Red 57:1). And the following 5 types of wax were used (Table 2). Wax A was polypropylene and wax B was also polypropylene having the lower melting point than wax A. Wax C was polyethylene and wax D was polyethylene denatured by the aromatic compound so as to improve the compatibility with the polyester resin. Wax E was the ester wax having the low melting point.

Table 2 wax used for this experiment

Wax	Type	Melting point (℃)	Mw
A	Polypropylene	142	10000
B	Polypropylene	123	7100
C	Polyethylene	109	1100
D	Denatured polyethylene	104	1500
E	Ester	82	630

Toner samples were prepared through the same process. The materials were premixed in a batch mixer; then they were kneaded, pulverized and classified. And then, samples having average size of 9.0μm were obtained. Each toner was blended with fumed silica to get efficient flow ability and charging ability for the test operation.

The toner samples are listed in table 3.

Table 3 Toner samples

Amount of Wax / Type of wax	1%	3%	5%
A	-	Toner A-3	-
B	Toner B-1	Toner B-3	Toner B-5
C	-	Toner C-3	-
D	-	Toner D-3	-
E	Toner E-1	Toner E-3	Toner E-5

And as the reference, the toner containing no wax named 'Toner ref.' was prepared.

Measurement of the dispersed size of wax

The dispersed size of the wax was observed by TEM. For convenience of evaluation, the TEM photograph was taken over the toner before pulverizing.

Measurement of the fusing ability

The fusing ability was tested by using the off-line fuser. (Heat roller: silicone / Pressure roller: silicone) The silicone oil was removed completely. The diameter of the heat roller was 60mm and the width of the nip was 4mm.

At first, each toner sample was developed and transferred on the paper (LX paper ; Xerox corporation) so that the mass per area was 0.6mg/cm^2. Then the paper was passed through the fuser. The line speed was 50mm/sec.

The upper limit of the fusing temperature was defined as the upper limit temperature that the hot-offset was not observed.

And the lower limit of the fusing temperature was also defined as the lower limit temperature that the cold-offset was not observed.

The range from lower limit of the fusing temperature to upper limit was defined as the fusing latitude of the each toner sample.

Measurement of the durability

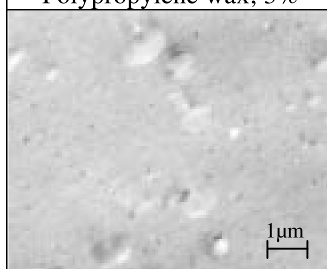
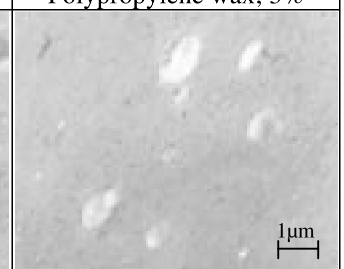
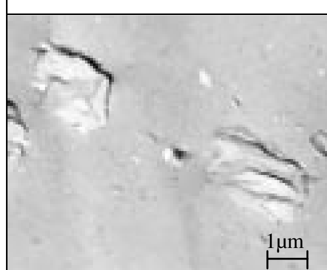
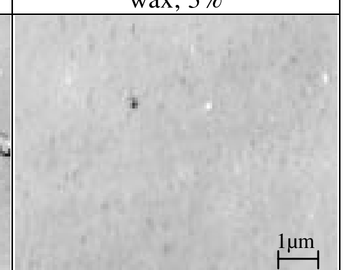
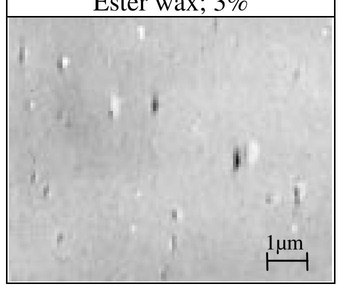
The durability was tested by using the toner cartridge of the color laser printer "Phaser 560 (Tektronix). Put the toner into the cartridge and rotated the developer roll at 60r/min without developing the toner to OPC. The durability was defined as the time when the filming of the toner to the doctor blade occurred and the streak appeared at the toner layer on the developer roller.

Result and Discussion

The dispersed size of each wax in the toner

The TEM photographs of each toner are shown in the table 4. These TEM photographs indicate that the kind of the wax influences the dispersed size of the wax in the toner.

Table 4 The dispersed size of each wax in the toner

Toner A-3 Polypropylene wax; 3%	Toner B-3 Polypropylene wax; 3%
	
Toner C-3 Polyethylene wax; 3%	Toner D-3 Denatured polyethylene wax; 3%
	
Toner E-3 Ester wax; 3%	
	

As shown in Table 4, the dispersed size of the polyethylene wax was larger than others (about 2μm). On the other hand, the dispersed size of the denatured polyethylene wax was very small (< 0.2μm). The dispersed size of the ester wax was under 0.5μm and that of the polypropylene wax was about 1μm. These results indicates that the dispersion sizes of the wax are affected by the compatibility of the each wax to the polyester resin. However the influence of the melting point of the wax seems to be small.

The dependency of the fusing ability of the toner on the melting point of the wax

The fusing latitude of the Toner ref., the Toner A-3, the Toner B-3, and the Toner C-3 are shown in Figure 1. This figure indicates that the toner using the wax having low melting point shows the wide non-offset range. This result means that the lower the melting point of wax is, the more immediately the wax bleed out to the toner surface when the toner passes through the heat roller, and helps the toner releases from the heat roller.

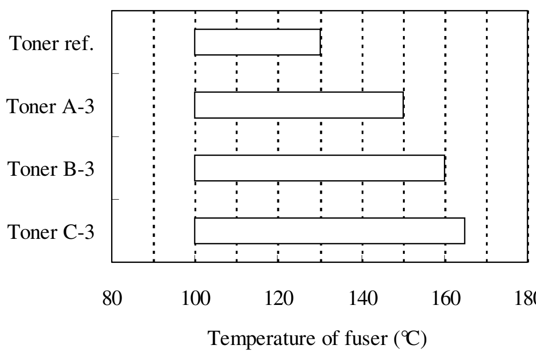


Figure 1. The dependency of the fusing latitude on the melting point of the wax

The influence of the dispersed size of the wax on the fusing ability of the toner

The fusing latitude of the Toner ref., the Toner C-3, and the Toner D-3 is shown in Figure 2. This indicates that the Toner D-3 shows the poor fusing ability in comparison with the Toner C-3 although the melting point of the wax D is close to the wax C. The dispersed size of the wax D is very small (under 0.2μm) in comparison with the dispersed size of the wax C (about 2μm) as shown in table 4. This result means if the dispersed size of the wax is too small, it become to be difficult that the sufficient amounts of the wax melts and bleeds out to the toner surface from inside at the fusing process.

On the other hand, in Figure 1, the difference of the dispersed size of wax between 1μm(the Toner A-3, B-3) and 2μm(the Toner C-3) seems not to influence the fusing ability so much. This result indicates that if the dispersed size of the wax is larger than the certain extent, the enough releasing efficiency is obtained. And if the dispersed size of the wax is larger than that size, the better releasing efficiency will not be obtained.

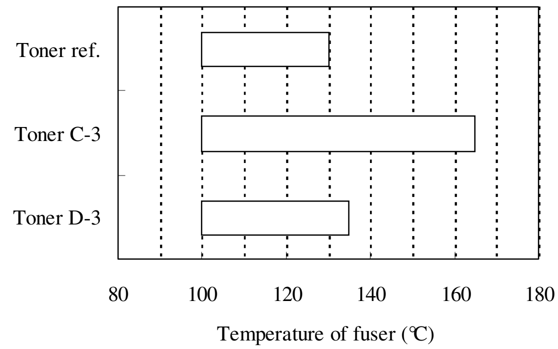


Figure 2. The influence of the dispersion size of the wax on the fusing ability

The dependency of the fusing ability of the toner on the amount of the wax E

The dependency of the upper limit temperature of the fusing latitude on the amount of the wax E is shown in Figure 3. This result indicates the more the amount of wax is contained in the toner, the higher the upper limit of the fusing range becomes.

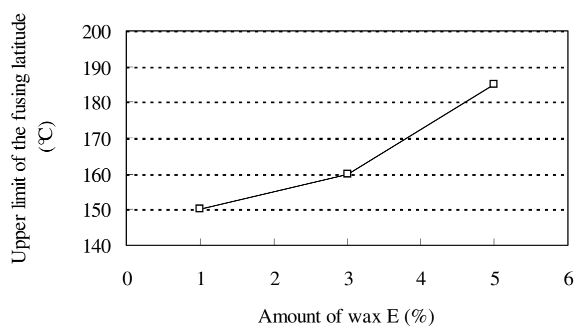


Figure 3. The dependency of the upper limits of fusing range on the amount of wax B and E

Furthermore, the improvement of the fusing ability from 3% to 5% is larger than the improvement from 1% to 3%. The difference is caused by the dispersed size of the wax E. As shown in table 5, the dispersed size of the wax in the Toner E-1 and E-3 is small (under 0.5μm). And this dispersed size is too small to be obtained the enough fusing ability. On the other hand, the dispersed size in the Toner E-5 is larger (about 1.0μm), and then the enough fusing ability was obtained. This results indicate to obtain the sufficient releasing effect of wax, the dispersion size of wax should be controlled over 1μm.

Table 5 The dispersion of wax E in the Toner E-1, the Toner E-3 and the Toner E-5

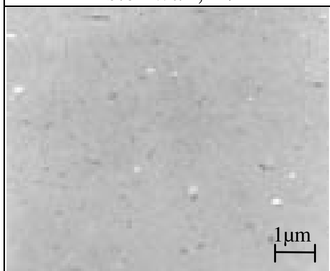
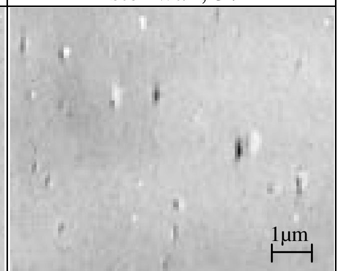
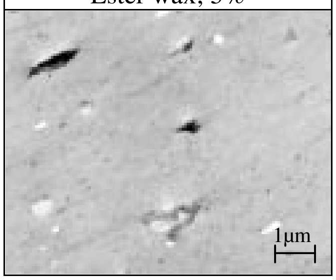
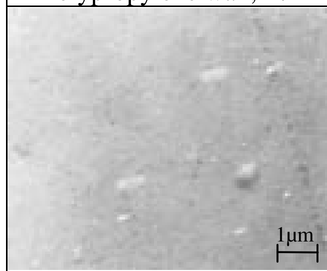
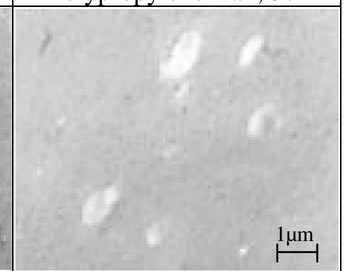
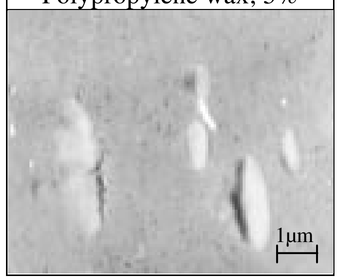
Toner E-1 Ester wax; 1%	Toner E-3 Ester wax; 3%
	
Toner E-5 Ester wax; 5%	
	

Table 6 The dispersion of wax B in the Toner B-1, the Toner B-3 and the Toner B-5

Toner B-1 Polypropylene wax; 1%	Toner B-3 Polypropylene wax; 3%
	
Toner B-5 Polypropylene wax; 5%	
	

The relation between the durability of the toner and the dispersed size of wax

The dependency of the durability of the toner on the amount of the wax B and wax E is shown in Figure 4. This shows the more the amount of wax is contained in the toner, the worse the durability of toner becomes.

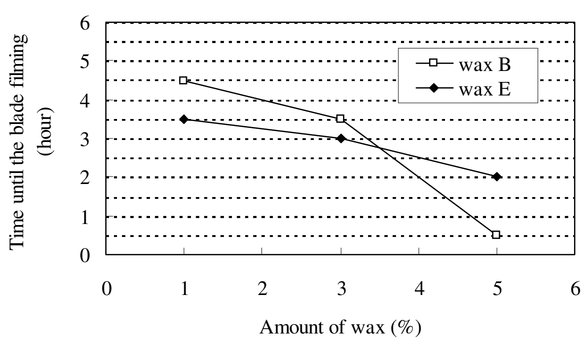


Figure 4. The dependency of the durability on the amount of wax B and E

Figure 4 indicates the deterioration of the durability of the toner using the wax B is drastic at the amount of 5%. On the other hand, the deterioration of the durability of the toner using the wax E is not so drastic even if the amount is 5%. To investigate this reason, the dispersion of wax B in the each toner was observed. (Table 6)

As shown in Table 6, when the amount of wax increase, not only the numbers of the domain of the wax increases, but also the dispersed size of wax becomes to be larger. Especially, when the amount is 5%, the dispersion size becomes to be >2μm. This is the reason of the drastic deterioration of the durability. On the other hand, as shown in table 5, in the case of the wax E, the dispersion size of wax is only 1μm even if the amount is 5%. Therefore to obtain the toner having the good durability, it is necessary to control the dispersion size under 2μm.

Conclusion

The influences of the wax in the polyester color toner used in non-magnetic single component development system can be summarized as follows:

(1) The wax having the low melting point gives the good fusing ability to the toner.
(2) When the dispersed size of the wax is too small, the enough releasing efficiency cannot be obtained.
(3) To obtain the sufficient releasing efficiency of wax, the dispersion size of wax should be controlled over 1μm.
(4) The bigger the dispersion size of the wax is, the worse the durability of the toner becomes. And to obtain the good durability, the dispersed size of the wax should be controlled under 2μm.

References

1. H. Kawaji, K. Aoki and K. Kawabe *IS&T's 11th International Congress on Advance in NIP Technologies*, 87 (1996).
2. H. Kawaji, J. Shimizu and S. Omatsu IS&T's NIP 13 International Conference on Digital Printing Technologies, 109 (1997)

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 full color toner regarding CCA, wax, colorant, and surface treatment agent. E-mail: 308837@kastanet.kao.co.jp