Chemically Produced Toner Containing a Binary Polyester Binder

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Abstract

The fuser roller is commonly used in electrophotograhic machines such as copiers, laser printers and multifunctional printers to fix toner image on paper. For improving printing speeds, image gloss and energy consumptions, an increasing number of printers are designed to adopt polyester toner. Polyester toner, with its low fusing temperatures, is aimed to accommodate fuser rollers operated at low temperatures to reduce energy consumption. Although polyester toner has the above advantages, low fusing temperatures on the other hand can cause hot-offset defects on the fuser roller. This paper reports the study of chemically produced toner (CPT) consisting of a binary polyester binder. The toner was prepared by phase-separation/aggregation (PSA) method. It was found a balance of low-temperature fixing and anti-offset characteristics can be achieved by incorporating a binary polymer mixture of low- and high-molecular weight polyesters. The addition of wax was also used to provide an option to tune the fixing and anti-offset characteristics. Wax content, however, was found to exhibit some threshold value, above which wax tends to separate from the toner and the resultant wax leaks can contaminate associated printer parts to cause streaking defects.

Introduction

The development process of electrophotography is shown schematically in Figure 1. Typical electrophotographic process based on photoreceptors goes through seven steps in reproducing a toned image on paper: charging, exposure, development, transfer, fusing, cleaning and discharge. In the charging step, the photoreceptor is covered with static charge by PCR. In the exposure step, an optical system will write down the latent image on the photoreceptor. In the development step, toner of the appropriate polarity is typically brought into contact with this latent image. In the transfer step, a piece of paper is brought into contact with the photoreceptor to attract the toner onto paper by electrostatic force. In the fusing step, the toner is melted onto the paper surface. In the cleaning step, the residual toner on the photoreceptor after transfer step is removed by wiper blade. In the discharge step, the photoreceptor charge is erased by exposing it to a lamp or AC bias. The entire process is then repeated as the photoreceptor drum or belt returns to its starting point [1].

Typical electrophotographic machines such as copiers, laser printers and multifunction printers use the fuser roller to fix the toner image on paper. For improving printing speeds, image gloss levels and energy consumptions, many printers are gradually using polyester toner. Polyester toner is characterized with low fusing temperatures, allowing the possibility of improving energy consumptions, image gloss levels and printing speeds[2]. With all the expectations of the above advantages, low fusing temperature undesirably tends to cause hot-offset defects on fuser roller. To solve hot-offset defects, commonly used method is to add release agents such as wax. Although the presence of wax can suppress hot-offset defects, poor compatibility of wax and resin materials can result in separated wax causing sticking defects on the print.

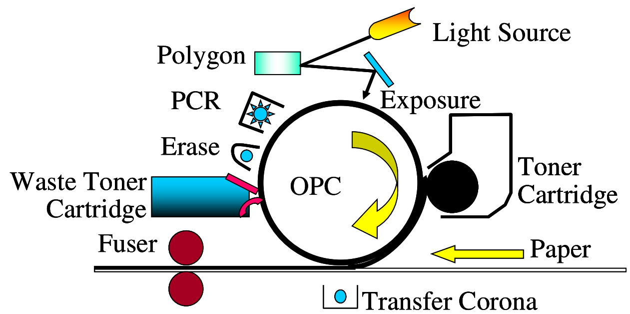

***Figure 1** : Electrophotographic Process*

Conventional toner production methods such as mechanical grinding and jet milling require certain levels of “brittleness” for the constituent resin materials. Polyesters and polyamides, owing to their tough properties, are not suitable for conventional toner production. In conventional milling methods, resin materials are mixed and kneaded with other constituents under high temperatures above resin’s transition points. Disadvantages related to high energy consumption and inefficient mixing and dispersion can not be neglected even in the advanced equipments using mechanical grinding or jetting processes. Although toner shape can be made spherical by advanced grinding or extra heat treatment, the limitation of broad size distribution still poses as a disadvantage and enormous amounts of electric energy and process time are required to classify the toner size. It is easily understood as toner sizes miniaturize the production costs of mechanical toner processes increase excessively.

Small particle sizes are desirable in regard to enhanced image resolution and thin coverage of toner layers. Sharpened particle size distribution leads to improved uniformity of tribocharges on individual toner particles, which is imperative to high-quality toner image formation. Furthermore, spherical or pseudo-spherical particle shape is beneficial to toner flow, leading to better toner transfer efficiency from image-bearing photoreceptors to printing media. Spheroidization and narrow particle size distribution represent two major technical obstacles that need to be overcome in conventional mechanical grinding or jet milling processes[3].

For the improvements of toner properties and performance, wet processes employing chemical dispersions or solutions have been used to prepare chemically produced toners[4-5]. Due to the chemical synthetic characteristics in which particles are obtained through gradual growth from respective constituents, particle sizes and particle shape are relatively easy to control within the desirable specifications. As a result, chemical toners become popularly adopted in new color laser printers and color copiers to enhance the print quality.

This paper reports the preparation of polyester toner consisting a binary resin mixture of low- and high-molecular weight polyester resins by using phase-separation/aggregation

(PSA) method[6]. Balanced characteristics of low-temperature fusing and anti-offset are achieved by adjusting the composition of low- and high-molecular weight polyesters, and incorporating wax in the toner.

Experimental

To a flask the resin including polyester of high molecular weight (HMW, Mw = 156K) and low molecular weight (LMW, Mw = 58K), additives and organic solvent were added and the mixture was heated and stirred until complete dissolution of the polymer resin. The solution, after being cooled, was transferred to a jar containing a color pigment and glass beads of 0.8~1.0 mm in diameter. The jar was then subject to milling by a paint shaker for 48 hrs. After filtering to remove glass beads, an organic phase solution was obtained.

Adequate amounts of poly(vinyl alcohol) were mixed with water in a flask and the mixture was heated until complete dissolution of the polymer. After being cooled to room temperature, an aqueous non-solvent phase solution was obtained.

One part of the organic phase solution was placed in a reaction flask under stirring, then the non-solvent phase solution was added at a constant rate. As the addition of non-solvent phase continued, the organic phase and the non-solvent phase became phase separated and finally a dispersion of gel colloids of the organic phase in the aqueous phase was obtained. In total, two parts of the aqueous non-solvent phase solution were used. After forming the gel colloids, stirring was continued for 10 min to facilitate aggregation and coalescence of the gel colloids. Plenty of water was then added to the mixture to solidify the gel particles. During the mixing of the organic and aqueous phases, solidification occurs spontaneously due to partial solubility of the organic solvent in water. After repeated washing with water and filtering, solid particles were obtained and then dried in vacuum to afford dry particles. Figure 2 shows the schematic diagram of the phase-separation/aggregation process and detailed constituent compositions of the experiments are listed in Table 1.

The toner is prepared by taking one hundred parts of the dry particles and one part of fumed silica to blend in a Henschel mixer. The fusing temperature, $T_{1/2}$, is determined by Shimadzu Flowtester CFT-500D.

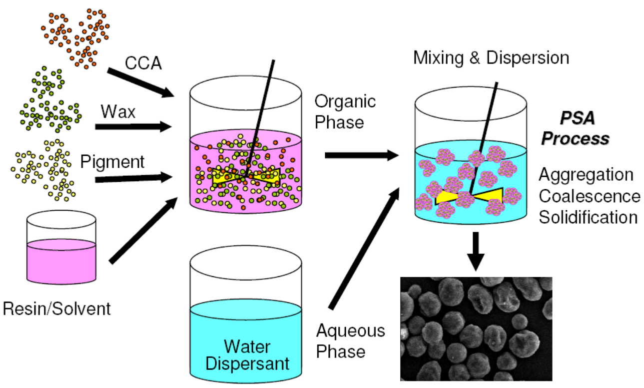

Figure 2 : *PSA Process.*

Table 1: Toner Compositions Prepared by PSA Process

Organic and Aqueous Phase(weight%)									
Toner	Solid Content	HMW Polyester	LMW Polyester	Wax Tm = 85℃	CCA	Pigment	$T_{1/2}$ (℃)	Solvent MEK : EAc	PVA
1	50%	45.5%	0.0%	1.5%	0.5% SZr[1]	2.5% PR146	138	1 : 2	15%
2	50%	30.3%	15.2%	1.5%	0.5% SZr	2.5% PR146	131	1 : 2	15%
3	50%	22.7%	22.8%	1.5%	0.5% SZr	2.5% PR146	128	1 : 2	15%
4	50%	0.0%	45.5%	1.5%	0.5% SZr	2.5% PR146	122	1 : 2	15%
5	50%	45.5%	0.0%	5.0%	0.5% SZr	2.5% PR146	128	1 : 2	15%
6	50%	45.5%	0.0%	7.5%	0.5% SZr	2.5% PR146	124	1 : 2	15%

[1]SZr: Zirconium Salicylate

Results and Discussion

The polyester of LMW is suitable for use in low-temperature fixing. Toner particles containing LMW polyester exhibit high-gloss image quality and good fixing property, but hot-offset defects tend to occur in the toner fusing process. On the contrary, the polyester of HMW exhibit good toner releasing property from fuser roller. Toner particles made with HMW polyester are capable to avoid hot-offset defects despite its poor fixing property. To solve hot-offset defects and poor fixing simultaneously, toner release agents such as wax are commonly used. Although the addition of wax can suppress hot-offset defects and improve fixing, poor compatibility between wax and resins can give rise to separated wax, creating sticking defects on the print. To achieve a balanced performance of low-temperature fusing and anti-offset, a binary polymer mixture of HMW- and LMW-polyester resins is investigated and the dependence of fusing temperatures on binary compositions is studied.

Commonly used methods for preparing CPT include suspension polymerization and emulsion/aggregation method. However, these two methods may have difficulties to afford a binary resin binder. We have reported a process consisting of phase separation and aggregation (PSA) steps to prepare polymer particles for electrophotographic toner. In this paper, we use PSA process to prepare CPT incorporating a binary resin binder to solve the issues related to low-temperature fixing and hot-offset defects. As shown in Table 1, toner1 sample consists of 45.5wt% HMW polyester binder. Toner2 sample is similar to toner1 except the binder material is made of a hybrid mixture containing 30.3wt% HMW polyester and 15.2wt% LMW polyester. Toner3 sample contains an increased amount of LMW polyester, 22.7wt%. Toner4 sample is made of LMW polyester only. The fusing temperatures of these toner samples are determined by Shimadzu

Flowtester CFT-500D and the data are also shown in Table 1. Print tests were done by using the commercially available HP color LeaserJet 4650 printer. This printer is equipped with a fuser unit operated at about 165±10℃ and the toner exhibits a $T_{1/2}$ temperature of about 124℃.

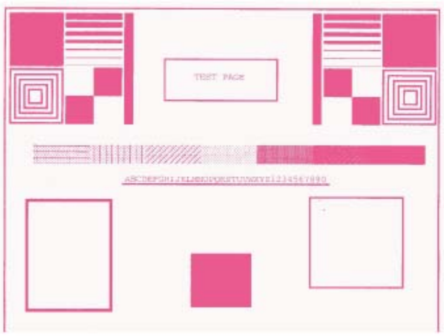

Figure 3a: *Printed image of toner1 sample.*

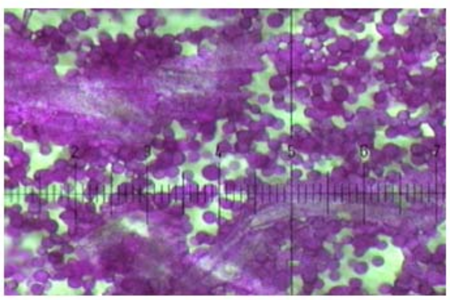

Figure 3b: *Magnified image of toner1 printout.*

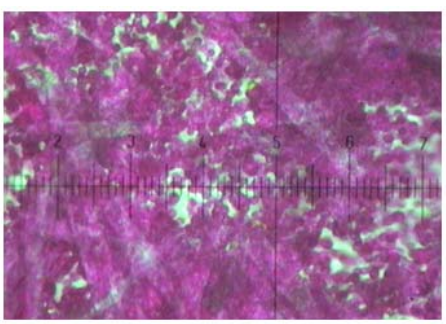

Figure 4: *Magnified image of toner2 printout.*

Comparisons of the fusing temperature data shown in Table 1 show toner1 sample has the highest $T_{1/2}$ of 138℃, which is higher than the machine-set toner fusing temperature of 124℃. By using toner1 sample, print test was performed on the printer and the print is shown in Figure 3a. The print of HMW toner1 does not show any hot-offset defects, but the close-up image under a microscope shows that the toner is not fused properly as shown in figure 3b. In toner2 sample, the HMW polyester content is decreased the LMW portion is increased. As a result, $T_{1/2}$ of toner2 is decreased to 131℃. A similar trend on the decreasing $T_{1/2}$ temperatures with increasing LMW contents can also be observed in toner3 sample. The printing result of toner2 and toner3 is like the printout result of toner1. The microscope images of printouts are shown in Figure 4 and Figure 5. It is found that the image fixing of toner3 sample is better than that of toner2 sample. Furthermore, both toner2 and toner3 samples show better fixing characteristics than toner1 sample. It is evident that toner fixing can be improved by adding LMW binder materials because of the decreased fusing temperatures. Neither toner3 nor toner4 sample exhibits hot-offset defects on the print. An interesting observation is noted in toner4 sample which exhibits a $T_{1/2}$ temperature of 122℃ (Table 1). Although the fixing property is very good, hot-offset defects occur as shown in the printed image in Figure 6. Hot-offset defects occur as a result of poor release property of the LMW binder as compared to the HMW binder.

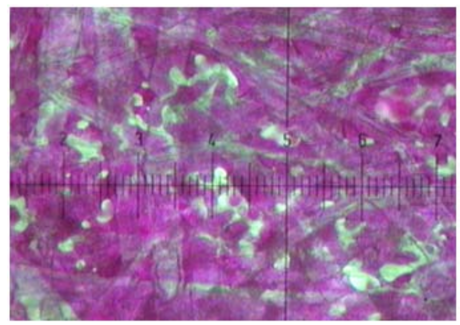

Figure 5: *Magnified image of toner3 printout.*

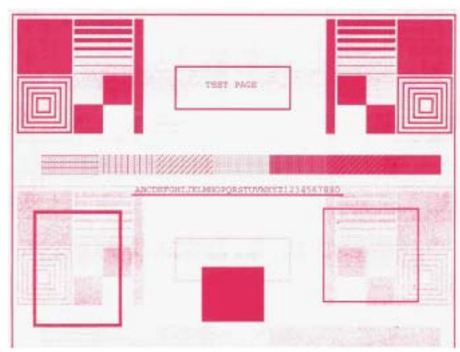

Figure 6a: *Printed image of toner4 sample.*

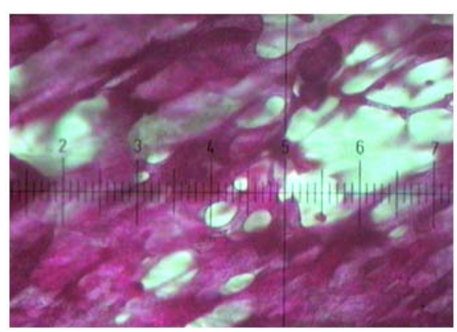

Figure 6b: *Magnified image of toner4 printout.*

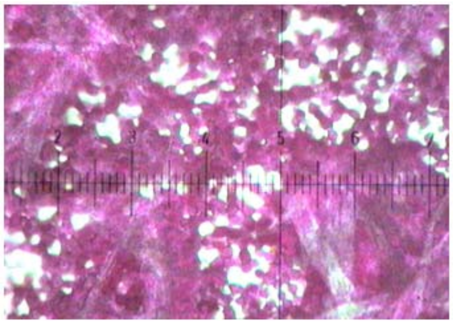

Figure 7: *Magnified image of toner5 printout.*

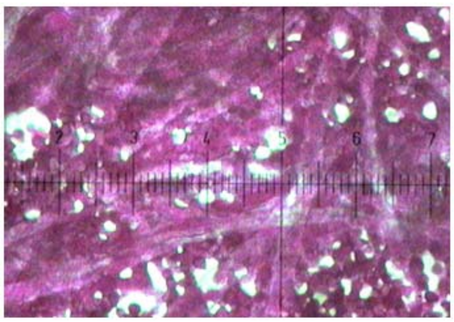

Figure 8a: *Magnified image of toner6 printout.*

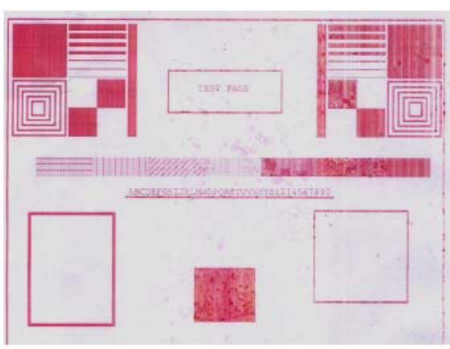

Figure 8b: *Printed image of toner6 sample.*

Toner1 sample is fixed poorly, but it can better avoid hot-offset defects. In addition to including LMW polymer resins to toner formulation, the commonly used method of including wax is also done to improve the fusibility. In Figure 7, it is shown toner5 sample exhibits improved fixing characteristics due to the increased content of wax. The fusing temperature of toner5 sample decreases upon the increased wax content (Table 1). Increasing the wax content not only strengthens fixing ability, but also provides sufficient release ability to avoid hot-offset defects. Further increase of wax content is done in toner6 sample to enhance the fixing property. The magnified image of toner6 sample under microscope is shown in Figure 8a. The fusibility is good and hot-offset defects do not occur in the printed image. But high was content can lead to wax leaks from toner particles. Free wax tends to contaminate doctor blade to cause streaking defects on the print as shown in Figure 8b. The cause of separated wax is the limited compatibility between the wax and the resin binder. In the solution state, an excessive amount of wax is prone to forming poor dispersion of wax in the solution. Poor dispersion and limited compatibility adversely affect the incorporation of wax in the resin matrix.

Conclusions

A toner formulation has been prepared by incorporating a binary resin binder which consists of low- and high-molecular weight polyester resins. The toner preparation is achieved by a solution process comprising phase separation and limited aggregation/coalescence (PSA) steps. It is shown a binary polyester resin composition can be constructed effectively by PSA method for toner formulations. Balanced characteristics of low-temperature fixing and anti-offset have been achieved by inclusion of low-molecular weight polyester and incorporation of wax materials. The addition of wax is equally effective on suppressing hot-offset defects, but constraints exist about the dispersion compatibility of wax in binder resins. Exceeding the compatibility limit, wax may separate from the resin matrix and cause streaking defects due to contamination on printer parts.

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