Properties and Printer Performance of Wax-containing Polyester Toners Prepared by Chemical Milling

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Abstract

Recently oiless color laser printing and wax-containing color toner are gaining popularity in the market for reasons of a simpler fuser design and a small number of consumables. We developed polyester color toner containing a wax inside the toner particles using proprietary Chemical Milling Process.

The CM toner® particles were substantially spherical in shape, their mean diameters in the range of 3-15 µm and the size distribution was uniform with the 80% span in the range of 0.5-1.0. A wax-content in the particles as high as 15 wt.% was achieved. The wax-incorporation significantly broadened the fusing latitude of CM toner® in comparison with the toner with no wax component, especially by increasing the hot offset temperature up to 190°C in a high speed (24ppm) oiless fusing unit.

The DPI-proprietary CM toner® process utilizes the surface chemical interaction between a partially-polar polyester resin and a non-polar dispersion medium as well as mechanical agitation to produce toner particles with a small diameter. However, to achieve the wax incorporation in the toner particles, we modified the process to be conducted in a highly polar dispersion medium so that non-polar wax is encapsulated in the particles. In the presentation, we will describe the details of the physical properties and printer performance of the wax-containing CM toner®.

Introduction

Recently the dramatic increase in digital information has made the needs for high quality print image and high performance color laser printer in office as well as personal applications. The trend in the market has influenced the hardware manufacturer to design a new printer system with the simple configuration, a small box size, and the low energy consumption.

One main development in the market is a new printer with a simple design that eliminated the oil feeder unit from the fuser by adopting wax-containing toners. In this case the toner particles are modified to have good release property, which enables the offset-free fusing during the oiless printing process. Currently the wax incorporation is a generally accepted method of improving the release property of toner.

The wax-containing toners have been developed by the technologies based on aqueous polymerization processes, for example, the suspension polymerization and the emulsion aggregation.[1-4] Therefore the processes mentioned above are solely useful for the production of toner particles based on the specific binder resin, which can be polymerized in aqueous medium.

Recently we introduced a proprietary technology, Chemical Milling (CM), for making high resolution toner particles without any chemical reaction limiting the type of binder resin.[5] Here we present a modified chemical milling method for producing the wax-containing toners. In addition, the properties and performance of the chemically milled wax-containing toner are reported.

Experimental

Particle Formation by Chemical Milling

A cationically dyeable polyester was prepared as in the previous work.[5] The particle formation by chemical milling process is briefly described as follows.

The polyester binder resin, a wax and a plasticizer were mixed and molten in a vessel equipped with an agitator at about 70 degree C. Then the dyeing process was conducted for 2 hours at the same temperature by adding the dyestuff into the vessel containing the mixture above. The mixture of the water, a thickening agent, and a surfactant was prepared as the dispersion medium in a vessel equipped with an impeller type agitator and a condenser at 70 degree C.

The chemical milling was carried out by charging the dyed resin mixture in the aqueous dispersion medium under a shearing condition. After a sufficient agitation, the reactor temperature was increased to 85°C to eliminate the plasticizer. The resulting slurry containing dyed resin particles was allowed to cool down to the ambient temperature and the toner particles were recovered through a washing and filtration, and a subsequent drying process.

We found that the wax component could be incorporated up to 15wt% of toner by the chemical milling described above. We prepared the CM toner® sample containing 10wt% of wax for the analysis in this study.

Characterization and Measurements

Particle size and distribution was determined with a TAII Coulter device (Coulter Electronics, Inc). The size distribution of the toner particle was represented by the 80% span value, defined as $(d_{90}-d_{10})/d_{50}$, calculated by using the cumulative volumetric diameter distribution diagram.

Electron microscopic analysis was performed using a JEOL 840A scanning electron microscope.

The specific charge of toner particles was measured with a Vertex Tribo-tester T-150 (New Jersey) using blow-off method. The blow-off pressure was 5 psi and the applied time was 15 sec. The environmental charge stability data were collected under H/H (30°C / 80% RH) and L/L (5°C / 30% RH) condition.

Melt viscosities of toners were recorded with a RMS 800 (Rheometric Scientific) rheometer at 10% strain and a frequency of 10 rad/sec.

The fusing latitude was determined using a roller-type oiless fusing unit at a fusing speed of 24ppm. Both the upper and the lower rolls were heated during the fusing process.

Results

Wax Incorporation

A modified chemical milling method conducted in aqueous medium can make the wax-containing toners available. Figure 1 shows a schematic diagram of chemical milling process for producing the wax-containing toner particles. The polymer droplets containing the wax component forms the dispersed phase in aqueous medium by the appropriate combination of chemical (surface) and mechanical (shearing) forces. The capability of wax incorporation owes to the difference in polarity between the medium and the dispersed phases. The non-polar wax component is able to be buried stably in the inner region of dispersed phase having relatively weak polarity. On the other hand the aqueous phase cannot stabilize the wax due to the high polarity of medium water.

It was confirmed by microscopic study (not shown) that the domain size of wax phase inside the toner particles was in the range of 2~4 microns and the wax component was distributed homogeneously in each toner particle.

Control of Particle Size

There are several factors affecting the particle size of the wax-containing CM toner®. However, we found the shearing rate by impeller agitation was the primary factor controlling the toner particle size.

The particle size distributions produced at different shearing rates are illustrated in Figure 2. The fine control of particle size was possible with altering the shearing rate by adjustment of the agitation speed. It was observed that the volumetric mean particle size and the span value were controllable in the range of 3~15 microns and 0.5~1.0 respectively by varying the shearing rate.

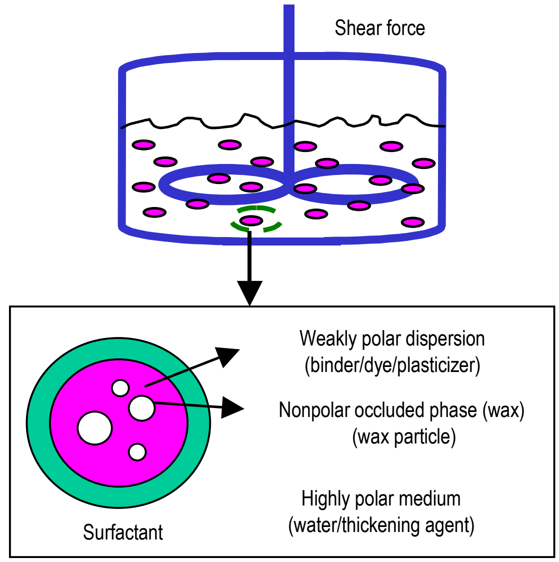

Figure 1. Schematic diagram of chemical milling process producing the wax-containing toner

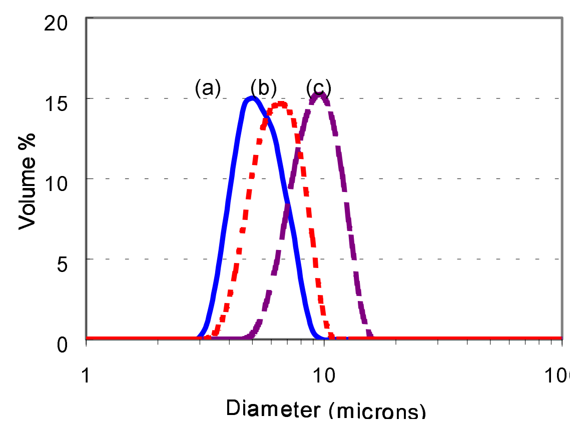

Figure 2. Particle size distributions of wax-containing toners produced by chemical milling at different shearing rates. (a) 5.7microns (b) 6.7microns (c) 9.8microns

Particle Shape and Surface Morphology

The uniform and spherical particle shape of the wax-containing CM toner® provides improved flowability compared to the conventional pulverized toner with irregular particle shape.

Furthermore, as shown in the SEM micrograph, the surface morphology of wax-containing toner particle is observed as the slightly rough texture. The surface roughness of toner particle highly affects the triboelectric charging property of the toner as reported previously.[5]

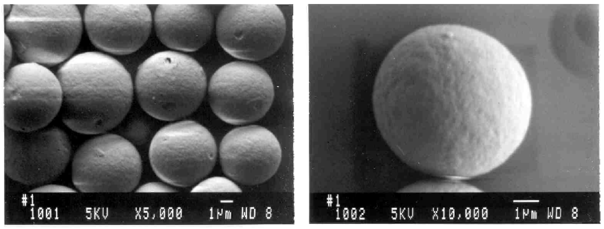

Figure 3. SEM micrographs of the wax-containing toner produced by chemical milling. (a) X 5000 (b) X 10000

Charging Property

We had found that the charging speed of toner could be significantly enhanced with the increase in surface roughness of toner particle. It was thought that the fast charging behavior might be due to the fast electrical charge accumulation on the sharp edge of rough surface.

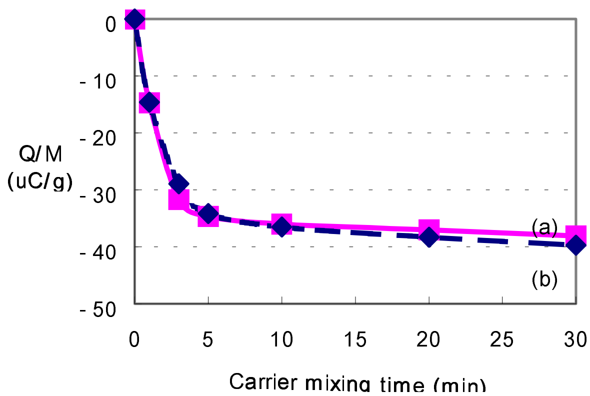

Figure 4. Charging behavior of the wax-containing toner at different environmental conditions. (a) H/H (30 μ/80%RH) (b) L/L (5μ/30%RH)

The wax-containing toner with slightly rough surface texture also showed the rapid charging characteristics as represented in Figure 4. The fast charging speed and the highly negative saturated charge value were retained at different environmental conditions, denoted as H/H (high temperature / high humidity) and L/L (low temperature / low humidity) condition. It reflects that the wax-containing toner would be able to display the good and stable electro-photographic performance at various circumstances in field application.

Control of Colorant Concentration

The CM toner® can adopt a dyestuff as a colorant on the basis of specifically designed molecular structure of the binder resin. The binder polyester is dyeable by the molecular binding with dye molecules through the ionic interaction. More specifically, the functional group of polyester, the sodium-sulfonate group can interact with a cationic dye through ion-ion interaction.

The use of dyestuff as a colorant provides an obvious advantage for producing small size toners useful for high resolution electrophotography, since the concentration of dye in the toner particle can be easily adjusted to achieve the high level of optical density.

In general a chemically produced toner with small particle size delivers the high quality print image based on its better dot addressability than the conventional toner. In addition, the smaller particle size lowers the toner pile height and the transferred toner mass on the image area. It subsequently affects the print yield per toner mass and print cost per page. In other words, the people can have more prints with the same mass of toner or the same number of prints with the lower toner consumption, if the smaller size toner is available.

It is however that the discussion above might be meaningless unless the small size toner reproduces the same level of image density. To retain the same image density using the smaller size toner (or with the toner pile of thinner thickness), the optical density of toner per micron has to be increased by the additional incorporation of colorant.

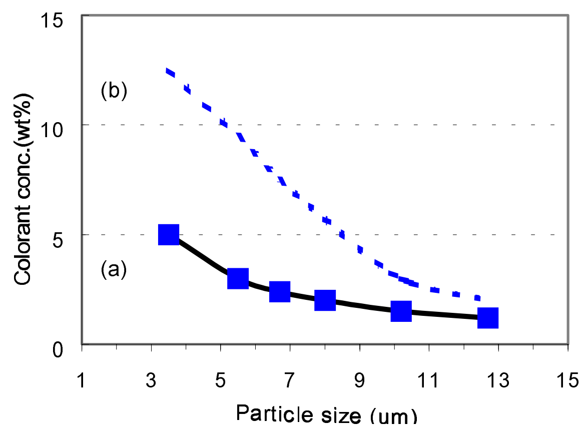

Figure 5. Optimum colorant concentration with toner particle size (a) Dyed toner (b) Pigmented toner

It is known that the optimum pigment concentration of pigmented toner increases markedly with decreasing toner particle size.[3,4] As shown in Figure 6, the dyed toner requires less colorant than the pigmented toner for producing the same level of image density (1.4 for solid image on plain paper) for all the range of toner particle size. The dyed CM toner® has substantially high absorptivity due to the molecular level of dye incorporation in toner particle. On the contrary the pigment is usually dispersed physically in the binder resin with a sub-micron order of domain. Thus the pigment absorbs less light compared with the dyestuff at the same colorant concentration.

From the manufacturing point of view, the issue of pigment dispersion becomes more and more critical as the toner particle size decreases and the pigment concentration increases for preparing the high resolution toner particles.

Moreover, the dyed toner is superior to pigmented toner in terms of toner cost due to the less amount of incorporation and the chief price of dyestuff in comparison with the pigment. Therefore it is believed that the dyed CM toner® will be a good alternative for application emphasizing the high quality of print image.

Fusing Property

The wax-containing CM toner® was successfully applicable to a laser printer adopting an oiless fusing system. The wax component inside the toner particle helps the release of fused toner film from the hot surface of fuser roller by lowering the surface energy during the fusing process. So there is no need to supply any additional release agent such as silicone oil to the fuser roller like in the oil-feed type fusing unit.

The fusing latitude of CM toner® was compared with other commercial toners as described in Figure 6. Both the CM toner® and the styrene-acrylic based CPT (Chemically Produced Toner) showed the acceptable fusing behavior in the range of 150~190 and 160~200 °C respectively in a high speed oiless fusing unit (24ppm), while the pulverized toner with no wax did not fuse at any temperature showing extremely narrow fusing latitude.

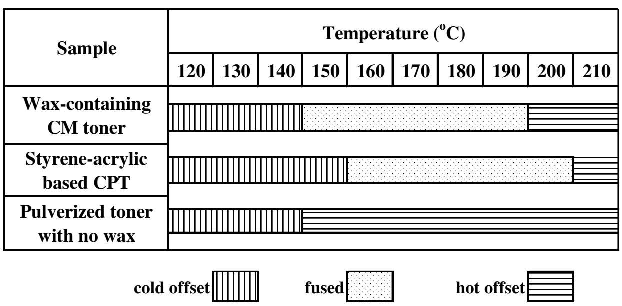

Figure 6. Fusing latitude of wax-containing CM toner® compared with other commercial toners

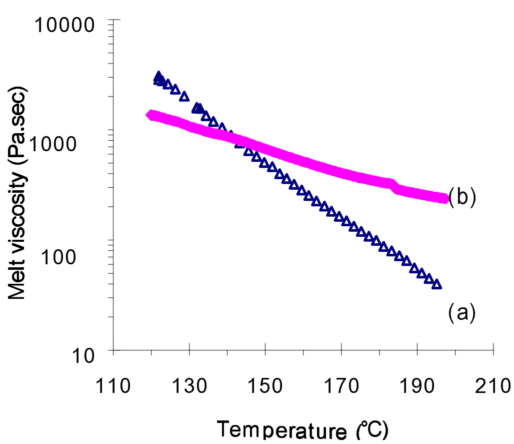

Figure 7. Melt viscosities of CM toner® and CPT based on styrene-acrylic binder. (a) CM toner (b) Styrene-acrylic based CPT

Furthermore, the figure represents that CM toner® is superior to styrene-acrylic based CPT in terms of low temperature fusing property. The fusing characteristics of toner mainly depend on the melt rheological property of binder resin. So it was thought that the superior low temperature fusing of CM toner® would result from the better melt flowability of polyester than that of styrene-acrylic binder resin.

In order to confirm this reasoning, we measured the melt viscosities of the CM toner® and the CPT. Figure 8 clearly displays the difference in melt viscosity of two toner samples. As anticipated, the CM toner® based on polyester exhibited obviously lower viscosity than the styrene-acrylic based CPT in the temperature range of 140~200 °C, which overlapped with the fusing temperature range of the two toners. Therefore we could understand the fusing latitude difference between the two toners was originated from the difference in melt viscosity. We believe that the lower fusing temperature of CM toner® would provide an important advantage for a printer manufacturer designing an improved fusing system with low energy consumption.

Conclusion

We developed a novel process for producing the wax-containing spherical polyester toners usable for an oiless printing system by the aqueous chemical milling process. The wax-containing CM toner® had the mean diameter in the range of 3~15 microns, the narrow size distribution with the span value of 0.5~1.0, and the uniform and spherical shape useful for high resolution color laser printing. The rough surface texture of the CM toner® provided the stable and rapid charging property essential for the good electrophotographic performance. The CM toner® based on polyester resin showed the superior low temperature fusing property to that of styrene-acrylic based CPT in the high speed oiless fusing characteristics.

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Biography

Dr. Eui-Jun Choi is the Team Leader of toner technology development in DPI Solutions, Inc. His team is responsible for developing novel materials and processing technologies for high-resolution color electrophotography. His research interest includes polymer processing, functional polymers and bioerodible polymers. Prior to joining DPI Solutions in 2000, he had worked in LG Chemical Tech. Center. He received Ph.D (1998) in polymer science and engineering from Korea Advanced Institute of Science and Technology.