Polyester-based Chemical Toner with Low Level of Total Volatile Organic Compounds

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Abstract

As man-made material enriches our lives, indoor air pollution becomes a serious issue. Among those pollutants, the level of volatile organic compounds (VOC) in offices and homes is significantly higher than that of outdoor. Some of these compounds may have short- and long-term adverse health effects. Therefore, to protect the consumers and the environment, ecological (or environmental) labels encourage businesses to market products that meet eco-friendly criteria. Office products including toners cannot be an exception to such voluntary regulations.

We are presenting a polyester-based chemical toner with extremely low level of total VOCs. The toner is produced using ingredients dispersed in water prepared using a proprietary method. The resulting toner has narrow size distribution and controlled morphology. In addition, the total VOC level, analyzed by Landesgewerbeanstalt Bayern (LGA) is lower than 300 mg/kg. The performance of the toner was evaluated using 20/20 ppm color laser printing system and compared to those of an original equipment manufacturer (OEM) toner and aftermarket refill toners in the market.

Introduction

Electrophotographic devices become ubiquitous in our everyday lives. Thus, environmental issues related to these devices are great concerns. Among them, two major challenges are related to energy consumption and volatile organic compounds (VOCs) emissions from these devices. These are significantly getting attention because of the adverse effects on the environment and human health. As a result, ecological-(or environmental-) labels encourage businesses to develop products that meet the eco-friendly criteria to protect the environment and the consumers. These labels impose not only voluntary regulations on products but also put lots of pressure on the technology development trend. Towards this end, printing industry strives to develop electrophotographic devices with low energy consumptions and low VOC level. One of the most efficient ways to reduce the energy consumption on electrophotographic devices is lowering the temperature of the fuser. The problems regarding VOC level is mostly related to the binder resin of toner. Therefore, judicious selection of binder resin and manufacturing process control would significantly reduce the VOC level.

Various polymers have been adopted as toner binders such as vinyl polymers (styrene acrylate and styrene butadiene), cyclic olefinic copolymers and polyether polyols. Although these polymers have their own advantages and proper applications, polyester has been proven to suit better than other polymers as a resin binder for high-speed digital printing in many aspects. These include mechanical durability, low fusing temperature, high gloss, high affinity to cellulose, rapid charging, and relatively more negative charge in triboelectric series. These physical properties of polyester not only yield high quality images but also are advantageous for high-speed digital printing.

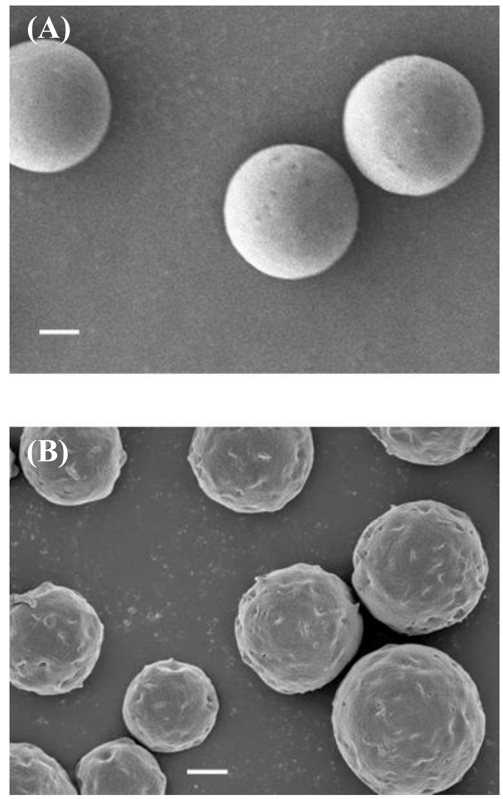

***Figure 1**. SEM images of spherically shaped the ACE Toner with controlled morphology. Scale bars on the images correspond to 2 μm. (A) shows toners with smooth surface and (B) shows toners with rough surface. Both have circularity over 0.985.*

Samsung Fine Chemicals' (SFC's) new ACE Toner is a polyester-based chemical toner with low level of total VOCs (TVOC)[7]. It offers superior quality with combined characteristics of polyester resin and chemically prepared toner (CPT). The advantages of CPTs over conventional melt pulverized toners (MPT) include small particle size, narrow size distribution, controllable shape and surface morphology, good pigment dispersion, high loading and uniform dispersion of wax, possible core-shell structure, and surface chemistry control.

Currently, depending on the binder resin choice several different processes exist to prepare CPTs. They include suspension polymerization, emulsion aggregation, encapsulation, PxP, dispersion Pzn, precipitation, solvent dispersion, and chemical milling. Because polyester cannot be synthesized by addition polymerization, CPTs using polyester as a binder resin have been manufactured using organic solvents. On the other hand, our proprietary process requires minimal use of organic solvents only during resin dispersion process. In addition, the polyester binder resin, made up of proprietary composition, does not use catalysts containing tin during the production process, which is a controlled substance because of their detrimental effects on the ecological system. Therefore, the ACE Toner, meeting the environmental standards as well as quality standards, is inherently eco-friendly.

Samsung Fine Chemicals' ACE TONER

Samsung Fine Chemicals' ACE Toner adopts a size and shape control process to produce an eco-friendly toner. It is composed of polyester binder resin, colorants and lubricant. Using a proprietary process, SFC produces toner particles with narrow size distribution and uniform shape. This method can consistently produce spherical toners possessing smooth or rough surface. As it is shown on Figure 1, this process offers morphology control of the toner surface. Figure 1 (A) shows toner particles with smooth surface and Figure 1 (B) shows toner particles with rather rough surface.

To describe the process in brief, the polyester resin, which has a proprietary composition, is dispersed using a neutralization emulsification method. The resin dispersion process requires minimal amount of an organic solvent and the solvent is completely removed once the sub-micrometer resin particles are stabilized in the dispersion medium. The colorants and wax are individually dispersed in water-based systems using a high pressure homogenizer. These dispersion methods generate sub-micrometer particles in water-based systems. These dispersions of polyester resin, colorant and lubricant are mixed together to produce toner particles through a size and shape control process. Because of the chemical structures of the ingredients and the chemical composition of the water-based system, the dispersed system is stable thus the resulting toner particles feature a uniform internal structure.

The ACE Toner is characterized as an eco-friendly toner because of the following aspects. First of all, it requires the least possible amount of organic solvents along the entire manufacturing process. Secondly, it needs reduced amount of water to wash the toner compared to other CPTs. Finally, the toner has low level of VOC emissions.

Control of Particle Size and Morphology

One of the many advantages of CPTs over MPTs is that CPT offers narrow particle size distribution thus allowing uniform charge distribution and requiring no classification. The ACE Toner also has uniform shape and narrow particle size distribution. The particle characteristics of the ACE Toner were measured using Multisizer™ 3 COULTER COUNTER® (Beckman Coulter, Inc.; Brea, CA US). As it is listed in Table 1, the average particle diameter ranges from 6.0 µm to 6.5 µm. However, the particle diameter can be easily modified as needed without compromising the geometric size distribution.

Table1 Particle Characteristics

D50, v[1)]	GSD_p[2)]	GSD_v[3)]	> 10 µm[4)]	Circularity[5)]
6.0~6.5	≤ 1.300	≤ 1.250	< 2.0	≥ 0.985

1) Average particle diameter (µm)
2) Geometric size distribution of number data where
$$GSD_p = \sqrt{D_{84}, n / D_{16}, n}$$
3) Geometric size distribution of volume data where
$$GSD_v = \sqrt{D_{84}, v / D_{16}, v}$$
4) Percentage of particles of volume data whose diameter is larger than 10 µm
5) Ration of circle circumference to perimeter of projected particle image

Figure 1 depicts the spherical shape of the ACE Toners with circularity over 0.985 measured using Sysmex FPIA-3000 (Malvern Instruments, Ltd.; Worcestershire WR14 1XZ UK). Spherical toners are advantageous because they produce even triboelectric charge distribution and deliver controlled amount of toners to the substrate (paper). While maintaining the circularity, our proprietary process allows morphology control to facilitate cleaning process using blades in laser printers.

Total Volatile Organic Compounds

One of the outstanding features of the ACE Toner is that it has low amount of TVOC and extremely low level of benzene, styrene as well as volatile carcinogenic, mutagenic, reprod-toxic substances (CMR). The VOC levels of the ACE Toner are compliant to the criteria of the LGA (Landesgewerbeanstalt Bayern) certificate, "LGA-tested for contaminants." LGA is one of the two institutes whose tests meet the requirements of the Blue Angel Award Standard. The other institue is BAM (Bundesanstalt für Materialwirtschaft). Table 2 lists the LGA criteria regarding the volatile organic emissions of toners and the LGA results of the VOC level of the ACE toner.

Table2 LGA Criteria of Volatile Organic Emissions and the VOCs of the ACE toner

Test List	LGA Limit (mg/kg)	ACE toner (mg/kg)
TVOC	< 300	248
Benzene	< 0.35	< 0.3
Styrene	< 40	0.6
CMR*	< 1	< 0.3

*CMR= Carcinogenic, Mutagenic, Reprod-toxic substances

Quantitative analyses of VOC levels of several commercially available toners were performed in our laboratory according to the procedure of the Blue Angel Standard for the emission from toner to compare the VOC levels of the ACE toners to those of others. The analyzed toners included an OEM toner of a leading brand 20/20 ppm color laser printing system as well as other two aftermarket refill toners suited for the same printer model. The results showed that the TVOC of the ACE toner were significantly lower than that of the others' were (data not presented).

Performance and Image Quality

The performance of the ACE Toner was evaluated using a leading brand 20/20 ppm color laser printing system and/or a custom built test station modified from the same printer model. The results were compared to the OEM toner and aftermarket refill toners suited for the same printer model. The overall performance of the ACE Toner was equivalent to the OEM toner and was superior to the tested aftermarket refill toners. Brief descriptions of the performance of the ACE Toner evaluated for degree of fusion, gloss and resolution are as follows.

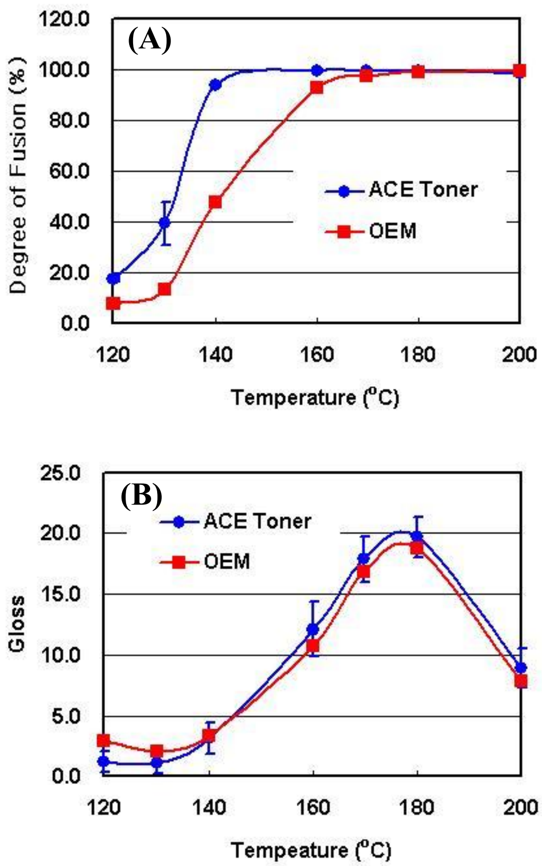

***Figure 2**. Degree of fusion (A) and gloss (B) data of the ACE Toner at corresponding temperatures, which are compared to the OEM toner of the tested printing system.*

To acquire temperature dependent degree of fusion data, a custom built fuser and a Taber® abrasion system were used. The custom built fuser is composed of a fusing system adopted from the 20/20 ppm color laser printing system and a temperature controller which can accurately generate temperature within a range between 100 °C and 200 °C. The Taber® abrasion system is equipped with Scotch® Tape and generates periodic motion while tangentially touching the surface thus peeling off loosely fused toner from the surface with controlled amount of force applied. The degree of fusion to paper is indicated in ratio of optical density (OD) of the image after abrasion test to OD of the original image in percentage (%). Figure 2 shows the degree of fusion to paper (A) and gloss (B) at various temperatures for the ACE Toner and the OEM toner. The ACE Toner showed 100 % fusion approximately between 140 °C and 200 °C.

The gloss data depicted in Figure 2 (B) were collected by measuring the gloss at 60° angle of printed patterns fused at each temperature using a Glossmeter (BYK-Gardner USA; Columbia, MD USA). The same custom built test station was used to print out patterns at desired temperatures. As the results indicate, the ACE Toner presented equivalent performance in comparison with the OEM toner within the observed fusing temperature range.

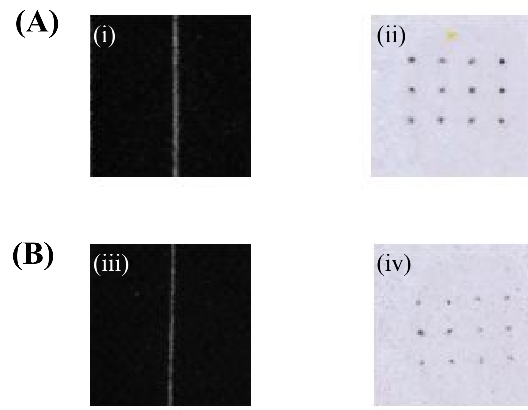

***Figure 3**. Comparison of resolution of the ACE Toner (A) and an aftermarket refill toner (B) prepared by melt pulverization. (i) and (iii) show the images of 2 dots white lines and (ii) and (iv) show the images of 1x1 dots, which were printed using a 20/20 ppm color laser printer with 600 dpi resolution.*

To evaluate the resolution of the ACE Toner, 2 dots white lines and 1x1 dots were printed using the 20/20 ppm color laser printing system with 600 dpi resolution. Figure 3 presents the comparison of those images. In Figure 3 (A), (i) shows the 2 dots white line and (ii) shows the 1x1 dots printed using the ACE toner. In Figure 3 (B), (iii) shows the 2 dots white line and (iv) shows the 1x1 dots printed using after market refill toner prepared by melt pulverization process. As it is depicted in Figure 3, the ACE Toner, with small particle size and narrow size distribution, showed significantly better performance than the aftermarket refill toner.

Concluding Remarks

We have presented apparent properties and performance of Samsung Fine Chemicals' ACE Toner produced using a proprietary method. The chemically prepared polyester-based toner features outstanding quality as well as extremely low level emission of hazardous substances that is compliant to the criteria of the LGA certificate. To the best of our knowledge, there are few companies that manufacture aftermarket toners compliant to the voluntary environmental regulations.

In addition, our unique process allows SFC to prepare uniform toner particles based on polyester resin with controlled morphology. Furthermore, because our process adopts controlled bottom up approach, thermal properties of the toner can be modified to meet the specifications of digital printing devices by combining resin dispersions with distinct properties without redesigning the resin or the entire manufacturing process.

References

[1] K. Berger; T. Nakamura, Blue Angel Award Criteria for Electrophotographic Toner, Proc. IS&T NIP21: International Conference on Digital Printing Technologies, 521 (2007)

[2] D. Tyagi, Polyester-Based Chemically Prepared Toner for High-Speed Digital Production Printing, Proc. IS&T NIP23: International Conference on Digital Printing Technologies, 270 (2007)

[3] Korean Patent Application No. 2009-0125689

[4] Korean Patent Application No. 2010-0011177

[5] Korean Patent Application No. 2010-0011178

[6] Korean Patent Application No. 2010-0023411

[7] ACE Toner: Aggregation & Shape Control Process for Eco-friendly Toner

Author Biography

Bo Young Kim received her B. S. and M. S. in chemistry from the Ewha Womans University and her Ph. D. in chemistry from the University of Illinois at Urbana-Champaign (2008). She is currently working at Samsung Fine Chemicals Co., LTD, R&D Center in Daejeon, South Korea. Her work has focused on the process development for a polyester-based chemical toner preparation.