Effects of Particle Size on Imaging Performance of Chemical Color Toner

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Abstract

With recent broad acceptance of chemical toner technology in electrophotography, toner particle size in use is becoming dramatically small. Intuitively speaking, smaller toner size enables many printing advantages such as higher image resolution, less toner usage, faster fusing, etc. Surprisingly, however, there is little direct and systematic data in the literature.

As an initial step to build a robust database of the particle size effects on EP performance, especially, of chemical toner, spherical polyester toner particles with five different (volume) average diameters (4.5, 5.8, 6.8, 7.8 and 8.8 microns) were prepared using chemical milling process and an identical external additive formulation was applied to prepare the toner compositions. Their physical characteristics (charging, fusing, particle flow, etc.) were determined. Also, their printing performance characteristics such as color intensity, image uniformity, image defects, toner consumption, etc. were determined using a HP CP1215 printer. The results are then to be interpreted in terms of expanded surface area of smaller size toner.

Introduction

Chemical toner use is becoming more prevalent than pulverized toner use in the color laser printing market. This has to do with that color printing print images and it requires better image resolution, better color, better image quality and less image defects. The chemical toner, in comparison with the pulverized toner, intrinsically can have better control of particle shape, particle size and size distribution. This engenders more consistent and high quality electrophotographic images[1]. As such, most of recently released color laser printers utilizes a chemical toner with the average particle size in the range of 6 – 7 ㎛. As s part of an effort to establish a robust database on the effects of chemical toner particle size on the printing imaging performance, we prepared a set of five spherical polyester toners with a different particle diameter and determined how these toners perform under an identical printing condition. From the data, we suggest a direction for development of better performing chemical toner.

Experimental

Polyester-based cyan CM toners with spherical particle shape with the volume average diameter of 4.5 ㎛, 5.8 ㎛, 6.8 ㎛, 7.8 ㎛, and 8.8 ㎛ were prepared using the chemical milling process of DPI Solutions[2,3]. The particle size of each toner sample was measuted with a coulter PSA LS-230. The base toners all had the same set of internal additives (CCA, wax, stabilizer) in the same amounts. In this first study, a same set of external additive formulation was used for all the toners.

A set of physical characteristics of toner such as the cohesion (measure of toner fluidity), powder bulk density, and toner charge on the printer developer roller were determined. The printing test was conducted using a HP CP 1215 printer with a 5% bar pattern and the printing data were determined at 500+500+500+300pages. To maintain an identical test condition, all test cartridges were built using a once-used cartridge and each cartridge was tested 500 page printing on each day.

Results and Discussion

Toner Powder Properties

The bulk density was determined by a tapping method; 10 gr of toner powder in a container was vertically tapped for 15 minutes at 900 cycle/minute and its volume (and the density) was determined. The density value decreased with the particle size (Figure 1). The density is dependent on powder shape and the charge developed during tapping. With the spherical toners, the shape dependence was largely insignificant. The size dependence was primarily due to that increased surface area due to smaller particle diameter engenders higher charge per unit volume and this causes larger particle separation.

The cohesion value slowly increased with the decrease in the particle size. A sudden increase of the cohesion value was observed for the 4.5 ㎛ toner. This is believed due to that the amount of additives was not sufficient to cover the increased surface of such small particle toner.

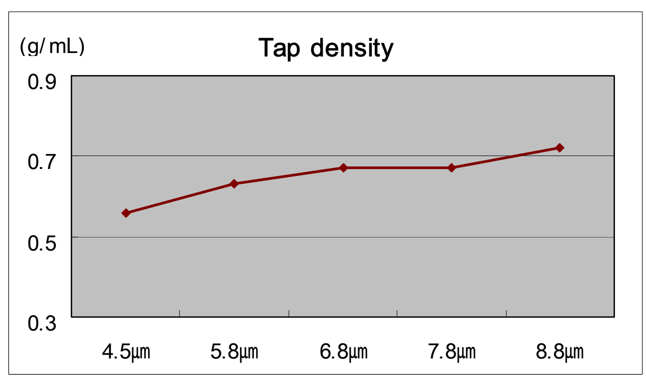

Figure 1. Tap density of different size toner particle

Charging property

Charge per unit mass (Q/m) value markedly increased as the toner particle size decreased (Figure 2). Q/m was determined by the suction method off the developer roller of CP 1215 printer during the printing test. This is not too surprising in that the charging is s surface phenomenon.

The data of 4.5 ㎛ toner also show that Q/m quickly dropped after printing about 1500 pages (Figure 3). This again is due to that the amount of external additive for this diameter was not sufficient. Well-charged, additive coated particles were used up first in the initial phase and the remaining toners do not get well charged because of paucity of additives at the later portion of cartridge life.

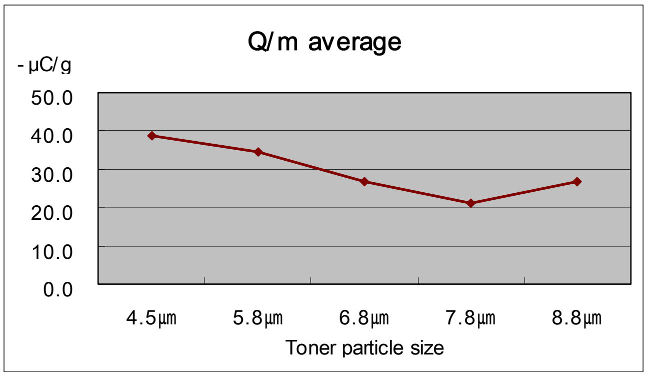

Figure 2. Q/m average of different size particle

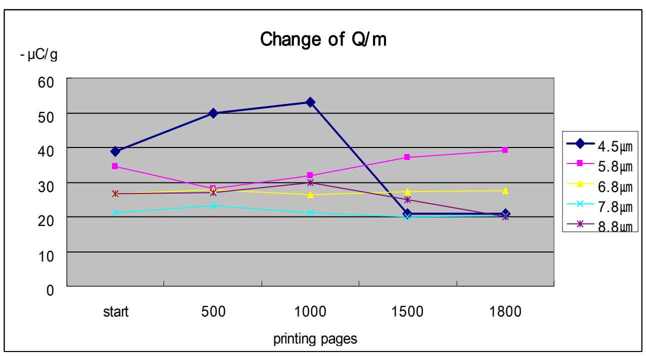

Figure 3. Change of Q/m with printing

Printing performance

Image density (ID) of a solid page was, for the most part, was about 1.45 and independent of the toner size. However, ID for the 4.5 ㎛ toner was substantially lower at about 1.0 (Figure 4). This is due to that the particle charge for the 4.5 ㎛ toner is so high that the printer's ID correction routine cannot adequately counteract. This also reflects on the high printing yield for the toner. The mass/area was 0.71 mg/cm2 for the 8.8 ㎛ toner was 0.71 mg while was 0.35 mg for the 4.5 ㎛ toner.

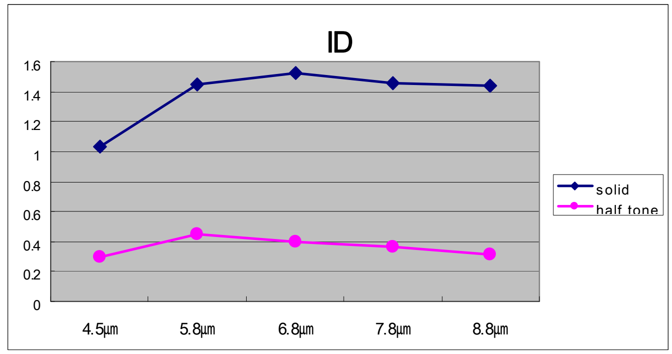

Figure 4. ID of different size toner particle, solid & half tone

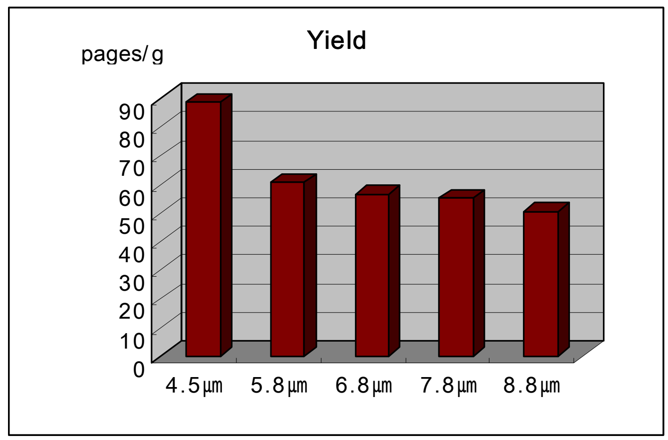

Figure 5. Yield of different size toner particle with printing

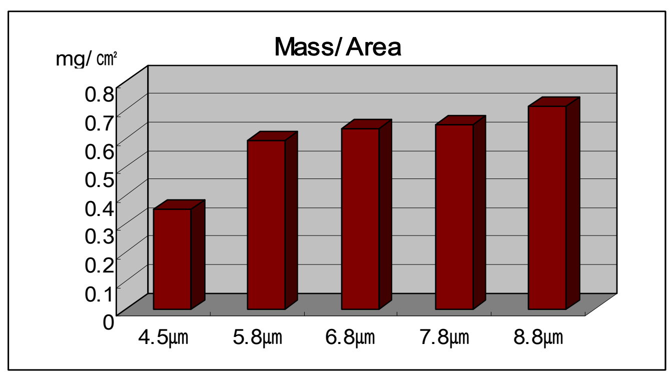

Figure 6. M/A of different size toner particle with printing

Printing Image

High image resolution requires small size toner particles(4,5). To ascertain the statement, 2 mm size letter "a" was printed with the toner samples. Figure 7 is 100-fold magnification of the printed letter. Enhanced line acuity and uniformity of solid section with smaller toner size were apparent although the reduced ID of the 4.5 ㎛ toner is also apparent.

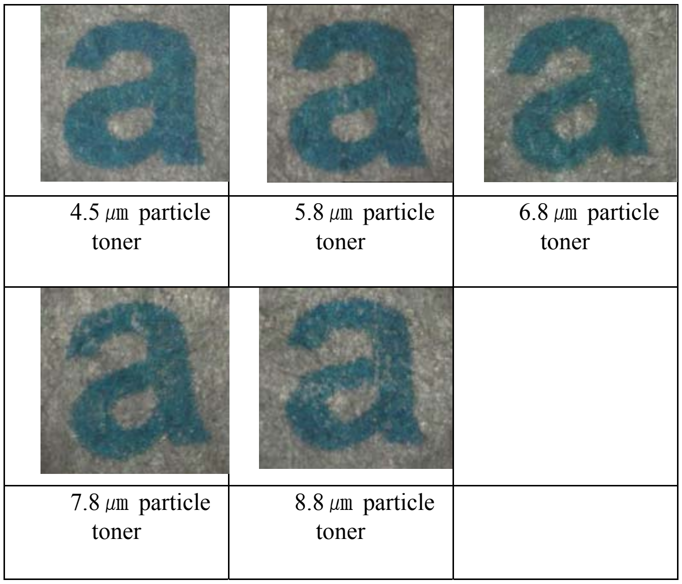

Figure 7. Resolution difference of 4.5 ㎛ toner & 8.8 ㎛ toner

Image defects

Original cartridge of HP CP1215 uses 6.3 ㎛ toner. When the CM toner samples of similar size (5.8 and 6.8 ㎛) were used in the printing test, no image defect was observed throughout the cartridge life (1800 pages). In the case of 4.5 ㎛ toner, mottling in the image was observed after about 1000 pages. This is believed due to the sudden decrease in Q/m and toner mobility associated with insufficient amount of external additives. For the 7.8 and 8.8 ㎛ toners, both mottling and streaks in image were observed after 1500 pages. This is interpreted as due from that smaller and well-charged toner particles are used up first in the printing cycle and the particle size distribution is shifting toward the larger particle side as the printing progresses.

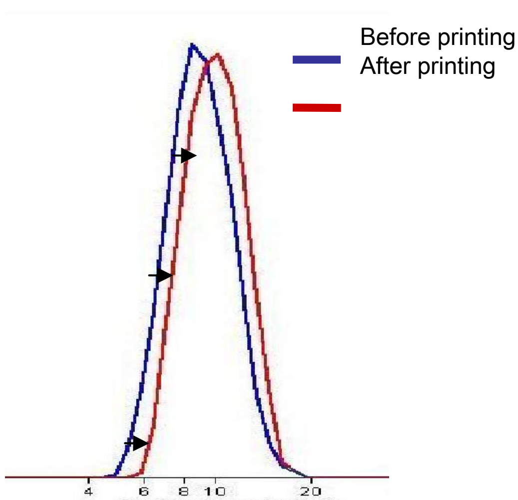

Figure 8. Change of toner particle size distribution with printing

As can be seen in Figure 8, there was a significant shift of the particle size distribution of the 8.8 ㎛ toner as charged and the left-over toner after 1800 pages. The volume average diameter changed from 8.8 ㎛ to 10.0 ㎛.

Conclusion

Comparison of printing behavior of five toners of spherical particles with a different mean diameter showed that, as the particle size gets smaller, it leads to higher Q/m and higher printing yield (albeit with a lower ID vale). The image resolutions (in terms of line acuity and uniformity of solid image section) significantly improved with the smaller toner. While the larger size toners showed streaking-type image defects, no such image defects were noticeable with the smaller size toners.

Although the 4.5 ㎛ toner showed an exceptionally clear and sharp image (with a drastically low image density), there is an indication that the external additive package could still be improved further. An effort to optimize the additive package for the toner in relation to CP 1215 printer is planned to complete prior to NIP 25.

References

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Biography

Dr. Eui-Jun Choi is the Technical Director of DPI Solutions, Inc. He is responsible for developing chemical toner technologies, and also contributes to designing and developing novel toner products reflecting the various market needs of color EP industry. 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 (KAIST).