Electrostatic Separation of Color Toner Particles for Material Recovery and Reuse

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Abstract

The separation of color toner waste for recycle and reuse is of great interest due to its potential environmental and economic benefits. This research focuses on the separation of two color toner particles by utilizing their charging properties. In order to facilitate separation, charging properties of toner particles and the resulting interactions of the particles with an electric field were analyzed. Varying both internal and external charge control additives (CCAs) and the concentration of carbon black in the black toner were the primary variables considered to alter the charge of the toners. Subsequently, the parameters that influence particle trajectory of toner particles interacting with an electric field were examined. The purpose was to identify key variables that improve the separation of color toner particles. A numerical model of the charge spectrograph was developed in order to test toners with varying properties as well as to analyze the effects of changes to the system (air velocity, electric field, etc.). The numerical model simulates the particle trajectory within the electric field and predicts the location where particle deposition occurs. Both experimental and numerical results of separating toner particles will be discussed in this presentation.

Introduction

The demand for full color documents and color toner has increased and continues to grow. In response to this, xerographic corporations have shifted their focus to provide full color documentation with the associated production of large quantities of color toner. The most common method of producing a full color document uses four colored toners: black, magenta, cyan, and yellow. The manufacturing methods for producing the color toner is very similar to the methods used to produce monochrome (black) toner. One significant difference, however, is the ability in monochrome toner production to recycle toner back into the toner manufacturing process.

When prints are produced using the xerographic process, the transfer efficiency of the toner onto the paper is less than 100%. Therefore, a small percentage of toner does not get transferred onto the paper and is considered to be waste. This waste toner must be removed from the photoreceptor or else it will interfere with image quality of the future prints. It is usually brushed off of the photoconductor during the cleaning step and collected in a waste container in the machine. When producing black and white copies, consumers can return this waste to the manufacturer and the toner industry is able to recycle the black waste toner by screening for debris and reintroducing it into the manufacturing process, thus offsetting the need for raw materials.

The results of a lifecycle inventory (LCI) for a specific black toner manufactured in a conventional toner manufacturing process showed that the production of solid waste was reduced by 24% and raw material usage by 29% through the implementation of recycle loops. The recycle loops consisted of toner waste returned by the consumer and collected from within the manufacturing process[1]. These benefits help Xerox Corporation meet their waste-free environmental goals and reduce toner production costs.

Currently these environmental and economic savings are not achievable with color toner for post-consumer waste. When producing color copies, the waste from the four colors are mixed together and sent to a common waste sump. This mixed waste stream prohibits the recycling of the toner back into the manufacturing process for the four colors. Recycling this mixed toner waste stream would require the four colors be separated first. Currently, this separation is not feasible and all the waste toner goes either to the landfill or waste-to-energy. There is an opportunity to realize environmental and financial gains by segregating and recycling waste toner.

The objective of this paper is to examine components in toner which can be altered to create sufficient differences in charging properties to enable different color toner particles to be separated in an electric field. Rather than concentrating on end-of-pipe solutions, this problem is approached by examining the toner composition to determine how to manipulate charging properties of the toner in order to facilitate separation. The tribocharge value or charge to mass ratio (q/m) of the toner particles depends on many factors such as toner composition, type of carrier, and ratio of toner to carrier. Initially, the tribocharge of the four colored toners without any charge control additives (CCA) was measured. Black and magenta toner had the largest charge difference without the use of any CCAs. As a first step in approaching this problem, these two toners became the focus of the separation experiments. Two primary variables were considered to alter the charge that could be imparted on these toners: CCAs and the concentration of carbon black in the black toner.

The experimental findings show that particle properties such as particle size and tribocharge are critical parameters that have a large effect on the deposition of particles in the charge spectrograph. Particles with a large diameter move further from the point of zero charge than particles with a small diameter with similar composition. An increase in the tribocharge of single toners run through the charge spectrograph resulted in an increase in q/d value, a critical parameter in the displacement of the toner particles in the electric field. Initially it was hypothesized that single toners with large tribocharge differences would result in high separation rates when mixed together and placed in the charge spectrograph. However, it was determined that this was not always the case due to the exchange of external additives between mixed toners during tribocharging. This resulted in an overlap of charge distributions and thus does not allow for a clean separation between some toner mixtures. The best separation results determined experimentally were for a mixture of magenta toner with no CCAs and black toner with 8% carbon black and no CCAs. The tribocharge difference between the two toners was 22 μC/g with magenta having the greater charge. The resulting displacement distributions for both toners had minimal overlap, allowing for recovery rates of greater than 95% for both toners. The use of internal CCAs should result in greater separation rates for the toners due to the lack of external additives on the surface the toner in the mixture which would complicate the particle charging. The largest separation yield is expected for a mixture of 8% carbon black and 0.6% internal CCAs which results in a tribocharge difference of 47 μC/g.

The experimental analysis had its own limitations. For example, results for mixes containing internal CCAs could not be obtained due to the lack of pigment in the toners. Therefore, it was not possible to get results from the charge spectrograph for any of the mixes containing internal CCAs. This was unfortunate, since the high developed charge achieved when using internal CCAs was shown to have a high potential for use in the separation of particles by charge. Also, any desired changes to the toner particles required a large investment in time and energy to produce the new toner. However, by developing a computational model of the charge spectrograph, such changes could be analyzed in a fraction of a time. The model allows the flexibility to test toners with varying properties as well as analyzing the effect of changes to the equipment (velocity, electric field, etc.) that could not be easily implemented in the experimental analysis. Through the use of the charge spectrograph model developed in this paper, the effects of particle and system changes can be analyzed with much less time and effort. The model was used to examine parameters that influence particle trajectory of toner particles interacting with an electric field for purposes of identifying key variables that can be manipulated to improve the separation of colored toner particles.

The results from the model spectrograph determined that varying the toner particle properties such as particle size distribution, particle size, and tribocharge values would have a direct effect on the capacity to separate black and magenta toner particles. The spread of the area of particle deposition can be reduced by reducing the toner particle size distribution. Increasing or decreasing the tribocharge of the particles will result in a proportional shift in the particle deposition location. Changes in the particle size also shifted the location of particle deposition. Once the toner samples are shown to have different deposition locations, the system should be adjusted so that the particle traveling further from the point of zero charge is as close to the outer wall of the separation chamber as possible without running into it. This would maximize the distance between the toner samples and ease the separation of the particle streams. Thus with the computational fluid dynamics model described in this paper, separation of toner particles can be optimized for particle and system properties which would facilitate a high yield of purified toner.

References

[1] A. Ahmadi, B.H. Williamson., T.L. Theis, S.E. Powers, "Life-cycle Inventory of Toner Produced for Xerographic Processes", *Journ. of Cleaner Production*, Volume 11, Issue 5, pg. 573-582. (2003).

Author Biography

Anahita Williamson has a B.S. in Chemical Engineering and an M.S. and Ph.D. in Environmental Engineering from Clarkson University. Her graduate research was performed under the Environmental Manufacturing Management program which promoted green engineering and technology. The program also emphasized pollution prevention tools and techniques to improve and optimize processes and products. Anahita formally joined Xerox Corporation in October 2005. Her current position includes working with manufacturing facilities on process optimization and green engineering design.