Latest Developments in Toner Technology

Dinesh Tyagi, Lloyd Lobo, Kevin Lofftus, and Peter Alexandrovich
NexPress Solutions Inc.
Rochester, New York, USA

Abstract

Increasing number of xerographic printers are now utilizing chemically prepared toners as marking particles. There are various methods of making chemically prepared toners and each method had its own advantages and disadvantages. In general, the chemically prepared toners can be produced to a much smaller particle size than the conventional melt-pulverized toners. Further, it is possible to impart some unique and specific properties to chemical toners to aid with the simplification of electrophotographic process. In the meantime, progress is being continuously made with the manufacturing processes used in the production of conventional toner by melt compounding and pulverizing methods. Both approaches of manufacturing face tough challenges as they attempt to deliver marking particles that must meet the new printer requirements in future products. A comparison between the two technologies is made along with the hurdles that each must overcome in order to be successful.

Introduction

With increasing demands that are being placed on higher image quality and lower cost for printing, improvements in printer capability and reliability are being continuously explored. The image quality and cost benefits, which once was only possible with offset printing, are being increasingly realized with new digital printers. In order to attain this equality, digital printers are undergoing constant improve-ment in reliability and sophistication. One area that has seen tremendous amount of activity in recent years is toner manufacturing processes. Until about a decade ago, majority of marking toner particle were prepared with conventional melt-pulverized process (MPT). Although basic research on chemically prepared toners (CPT) manufacturing methods has been ongoing for many years, only recently several printers have been successfully commercialized that are based on this novel technology.

There are many unique advantages that are offered by chemically prepared toners. The term "CPT", however, encompasses more than several different approaches to manufacturing such chemical toners. Each method of CPT manufacturing comes with its unique advantages and limitations. In the meantime, improvements in pulverizing and classification process are being continuously made such that MPT still remains a viable option for toner manufacturing technique.

Melt Pulverized Toners

The conventional method for toner manufacturing involves kneading or melt compounding of toner ingredients in an extruder. Resulting material is pulverized and classified to yield the desired particle size and distribution. Early toners particles were quite large and consisted of a broad particle size distribution. However, as shown in Figure 1, the volume average particle diameter of MPT has been continuously decreasing as advances in toner manufacturing processes are implemented.

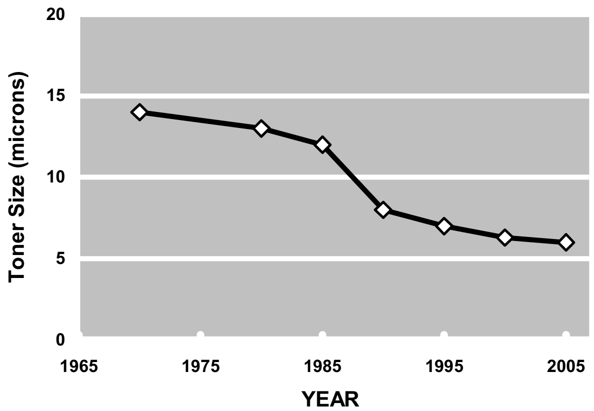


Figure 1.Changes in typical toner particle size over the years

One of the biggest advantages with MPT is its ability to utilize existing manufacturing capacity. All improve-ments that have taken place in area of grinding and classification can be easily implemented at the end of compounding process. Improved in-line monitors that provide instant measurements for particle size and other factors such as, bed weight in the classifier, can be used as feedback control to maximize the toner yield. Improved classification techniques such as double classification have contributed to make smaller and narrow particle size toners with high yields. It was often thought that particle size less than 8 microns could only be made with chemicals means. With equipment improvements, this limits has been easily lowered to less than 5 microns. One of the benefits with MPT manufacturing techniques is, that all fines generated during pulverizing and classification can be completely recycled.

Along with the equipment changes, optimization in material design is also being constantly explored. In typical grinding process, the energy required to break down particles increases with the amount of surface area created (or as the size of the particle goes down). This relationship is described in Figure 2. On a first glance, this would appear to suggest that making small toner particles would be a severe limitation for MPT manufacturing process. But advances are being made in toner binders that allow the grinding energy to be lowered significantly without generating excessive fines.

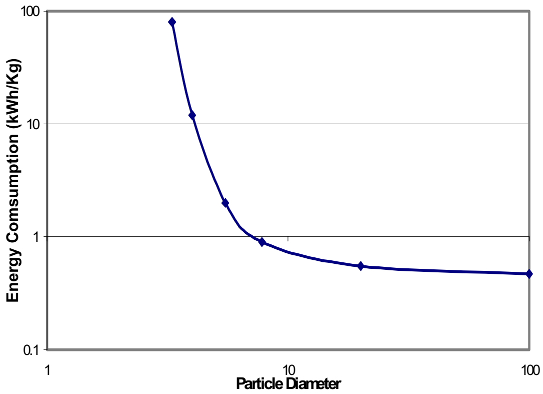


Figure 2. Plot showing the increase in energy consumption as toner particle size is reduced.

Chemically Prepared Toners

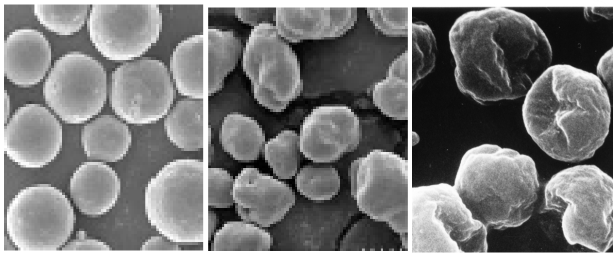
Manufacturing of chemically prepared toners offers so much flexibility that there exist many different ways to prepare them. Each method has its advantages and disadvantages that are unique to them. In general, CPTs can be prepared these following techniques:

- Emulsion Aggregation (EA)
- Suspension polymerization
- Encapsulation
- Solvent Dispersion/Evaporation
- Chemical Milling

The first commercial CPT introduced was based on the suspension polymerization process. But more recently, several printer manufacturers have commercialized machines that utilize toner prepared by EA process.

One of the biggest advantages of chemical process is that unit manufacturing cost is not strongly dependent on toner size, thereby making them ideally suited for making smaller sized toner particles. When it comes down to reducing the cost of printing/page, then smaller particles size toners can make the large difference. Other factors such as ease of fusing and image relief are also benefit from smaller particle size. However, one of the biggest reasons for pursuing smaller toner particle size is the improved dot addressability and the resulting image quality that can only be produced with smaller dots.

The shape of the CPT has been a source of debate for quite some time now. With early suspension polymerization based chemical toners, the resulting spherical shape of toners was not conducive to good cleaning. This was especially true in smaller printers where blade cleaning is quite often the preferred choice for cleaning technology. Since then a great deal of work has gone into making irregular chemical toner particles. As shown in Figure 3, various types of toners shapes can be created with chemical methods of making toners. Although ground toner can made somewhat spherical, the range of irregular shapes that are possible with CPT is definitely lot broader. At the moment, there is an ongoing debate as to what precise toner particle shape provides the most optimum performance in the machine.



(a) (b) (c)

Figure 3. Various toner shapes that can be created by chemical manufacturing processes.

One of the intangible benefits that is being heavily pursued with CPTs is the ability of chemical process to lend itself in creating a unique and custom toner particles. A toner can be made to have core-shell structure or some desirable feature can be incorporated in layers or distinct domains for some specific purpose. This has the potential to simplify the electrophotographic (EP) process and could lower the cost of print/page even further.

There are some challenges that limit the use of chemical toner over the MPTs. Except for the chemical toners that based on solvents, the choice of binder in chemical toner is typically limited to styrene-acrylate type of vinyl polymers. These vinyl resins are normally less expensive than polyesters but are not as tough at low molecular weights. In high-speed color applications, where low viscosity is desirable, these low molecular weight resins tend to be extremely brittle and can cause problems in the EP process. With high molecular weight based vinyl resins, it is far more difficult to achieve higher gloss, which is an extremely desirable feature in digital color printing. Many of the printers that use EA toners resort to extended nip fuser concepts to improve image gloss with limited success. Polyester resins offer the best balance of mechanical toughness and melt viscosity at low molecular weight, which makes them very attractive for high-speed applications. Furthermore, the fusing quality obtained with polyester resins has always been superior to that obtained with styrene-acrylic copolymers. Dispersion of pigments and charge agents is typically better in polyester based toners than in vinyl copolymers because of the large number of functional groups present in polyesters backbone.

Incorporation of semi-crystalline additives or waxes in CPT is usually not a straightforward process. For conventional MPT, adding these components to toner formulation during melt compounding can result is good dispersion as long as appropriate shear forces are applied. With chemical toners extra steps have to taken in order to CPTs that contain wax particles on the inside.

Even though a number of new CPT manufacturing plants have been erected, most conventional manufacturer cannot easily convert to CPT manufacturing processes. At the same time some newcomers to the toner manufacturing include those who have excess chemical manufacturing capacity. One of the issues that has been often associated with CPT is the lack of consistency in behavior and the effect residual dispersants/surfactants have on the toner performance. As the technology matures, some of these shortcomings will likely be solved with either manufacturing improvements or better process control inside the printer.

Conclusion

Both melt pulverized and chemically prepared toners are now viable options for electrophography based digital print engines. Each method has its unique capabilities and benefits. At the same time each method for toner manufacturing also faces serious challenges. Much needed and long overdue advances are being pursued in pulverizing and classification operation along with better process control. When it comes to making very small toner particles, then chemical toners have the distinct advantage. However, limitation in binder selection and their ability to produce toners with higher melt viscosity has limited their usage to smaller and low speed printers only.

References

1. Dinesh Tyagi "Toner for High Quality Digital Production Printing" Proceeding of International Conference on Digital Production Printing and Industrial Applications, Barcelona 2003.
2. A. Eida, S. Omatsu and J. Shimizu, IS&T's NIP 20: International Conference on Digital Printing Technologies (Salt Lake City, UT, Oct 31-Nov 5, 2004) 102-106.
3. Y. Matsumura, P. Burns, and T Fuchiwaki, IS&T's NIP 17: International Conference on Digital Printing Technologies (Sept 30-Oct 5, 2001) 341-344.

Biography

Dinesh Tyagi received his Ph.D. degree from Virginia Tech in 1985 from the Department of Chemical Engineering with a thesis entitled "Structure-Property Relationships in Segmented Polymers". After one year of post-doctoral position there, he joined Eastman Kodak Company as a Research Scientist where he started worked in the toner development area. He was promoted to Senior Research Scientist in 1989 and in 1993 he was appointed Research Associate. Following year he was inducted into Kodak's Distinguished Inventors Gallery. In 1999 he joined NexPress Solutions and has continued to work in the area of toners and electrophotography. He has over 75 patents worldwide.