Performance Optimization of Functional Fumed Metallic Oxide Based External Additives for Toner

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Introduction

Surface modified inorganic fine particles such as silica, titania and alumina are used as external additives to toners in order to enhance the flowability, tribo-electrostatic charge behavior, image property and other performance factors. Due to the adhesion of fumed oxide based additives to the toner surface, the selection of specific external additives has a significant impact on final toner performance. Each external additive has distinctive properties that are affected by diameter, surface conditions, structure, and electric charge.[1,2] *Smaller particles enhance the flowability of the toner. Coating of toner with titania and alumina stabilizes the electrostatic values when charged by friction. This is because, the external additives have a weaker tribo-electrostatic charge and lower electric resistance compared to silica.*[3,4] *These inorganic particles are also believed to prevent filming by minimizing the toner impaction process due to enhanced free flow*[5] *and by polishing the toner adhering to the photo conductor. In this paper, we would like to present an experimental set up to simulate the performance of fumed oxide particles in terms of polishing the filming toner particles.*

This paper summarizes the influence of various external additives on aspects of toner performance such as flowability, tribo-electrostatic charge (T-ESC) and cleaning properties.

Experiment

Sample Preparation

The additives were surface modified fumed silica, titania and alumina with average primary particle diameters of around 12 nm, 14 nm and 13 nm respectively. These fine particles were hydrophobized by silicone oil or octylsilane (Table 1). The toner used for this experiment was pulverized negative polyester toner with an average diameter of 8 µm. The toner with surface modified fine particles was prepared by mixing all components for 1 minute at 12000 rpm, using a high-speed mixer. The addition quantity of fumed fine particles was 1% relative to the toner. Additionally, fumed silica and alumina with average primary particle diameters of 12 to 40 nm and 13 nm respectively were evaluated in terms of their polishing properties.

Evaluation of Free Flow and Charge Properties

The free flow properties of the toner in combination with additives, as well as the repose angle and passage rate were evaluated using a POWDER CHARACTERISTICS TESTER (Type PT-S, HOSOKAWA MICRON CO., LTD.). The toner/additive mixture (2g) and a non-coated ferrite carrier (48g) were dry-blended with a TURBULA MIXER (Type T2C, WBA) at 90 rpm. After blending, the T-ESC was measured using a blow-off type ELECTROSTATIC CHARGE METER (Type TB-200, TOSHIBA CHEMICAL Co., LTD). The T-ESC of additives (0.1g) against non-coated ferrite carrier (50g) was also measured using the same method.

Table 1: Fumed Oxide External Additives

	Sample name	Primary particle size	Surface treatment agent
Silica	Si-DMPS	12 nm	Silicone oil
	Si-C8	12 nm	Octylsilane
Titania	Ti-DMPS	14 nm	Silicone oil
	Ti-C8	14 nm	Octylsilane
Alumina	Al-DMPS	13 nm	Silicone oil
	Al-C8	13 nm	Octylsilane

Evaluation of Polishing Properties

A gelatin coated film was fixed to the outer edge of the rear side of a disk and dipped completely into the inorganic powder. The disk was then rotated at 2000 rpm for 30 to 60 minutes, with the linear velocity of the film 4.2 m/sec. After polishing, the film was washed using isopropyl alcohol in an ultra sonic bath for 3 minutes and dried at room temperature. The gloss value of the gelatin layer on the PET film was measured using a GLOSS METER (Type 1001DP, NIPPON DENSYOKU KOGYO). The angle of incidence was 60 degrees. The film was covered before measurement using a standard plate with a gloss value of 89.

Result

Charge Properties

Figure 1 shows the T-ESC of each additive after agitation for 5 and 30 minutes respectively. While the surface modified silica showed a strongly negative charge, the corresponding surface modified titania and alumina showed weaker negative charges. Silicone oil modified particles resulted in a strong shift towards a negative charge compared with octylsilane modified particles under the measurement conditions described.

Figure 2 shows the T-ESC of the toner with additive as a function of agitation time. When surface modified silica was added to the toner, the T-ESC of the toner rose by 10-20 µC/g compared to the addition of surface modified titania or alumina. Figure 3 shows the T-ESC of toner with additive under the condition of high temperature/high humidity (H/H: 40ºC, 85% relative humidity) and low temperature/low humidity (L/L: 10ºC, 20% relative humidity) after 10 minutes agitation respectively. The T-ESC differences of toner with surface modified silica under H/H and L/L conditions respectively were wider than that of the toner with surface modified titania or alumina. Particularly when subject to L/L condition, the T-ESC of toner with silica showed a stronger negative charge. Moreover, this result showed how the addition of surface modified titania and alumina could prevent charge up of the toner under L/L condition.

Free Flow Properties

Figures 4 and 5 show the repose angle and passage rate (45 µm screen) of toner with additive. The repose angle and passage rate of toner without additive are 53.8 degrees and 21% respectively. The addition of surface modified inorganic fine particles enhanced the flowability of the toner. Moreover, the free flow effect of the surface modified alumina was slightly lower than that of the surface modified silica and titania, according to the repose angle result. The surface modified titania showed the lowest free flow effect of all the additives according to the passage rate result while in case of octylsilane treated titania, a better free flow tendency according to the repose angle measurement was observed. In general, surface modified silica showed the best overall free flow properties of all the materials tested.

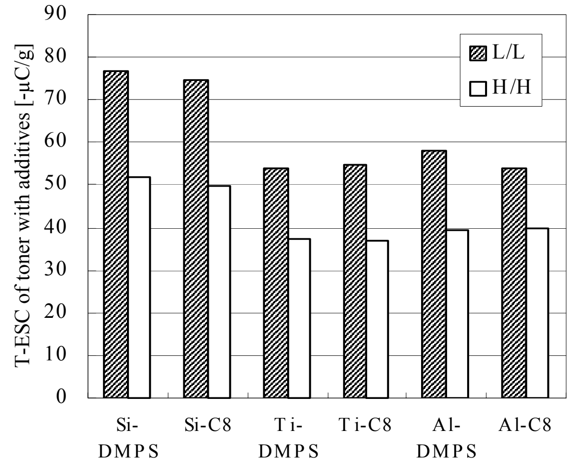

Figure 3. T-ESC of toner with additives under the condition of H/H and L/L after 10 minutes agitation

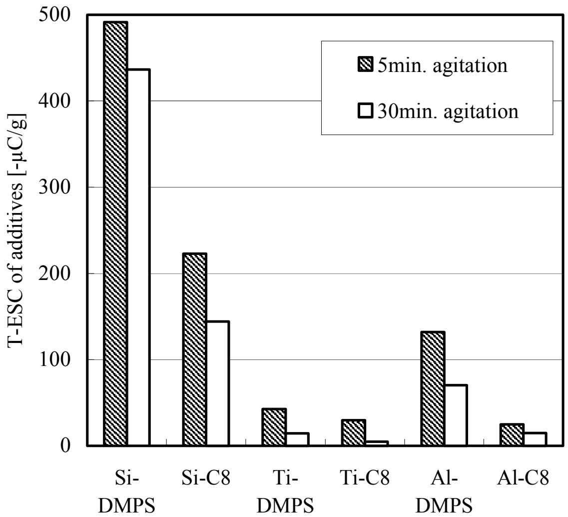

Figure 1. T-ESC of additives

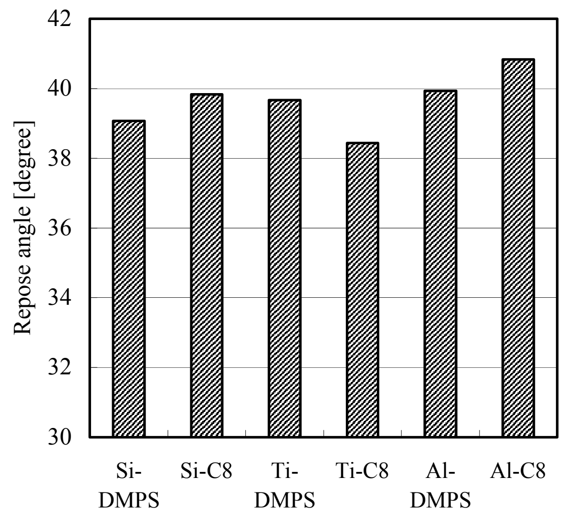

Figure 4. Repose angle of toner with additives

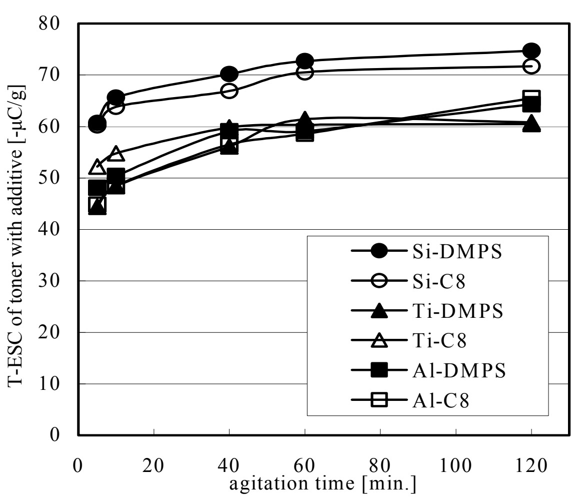

Figure 2. T-ESC of toner with additives

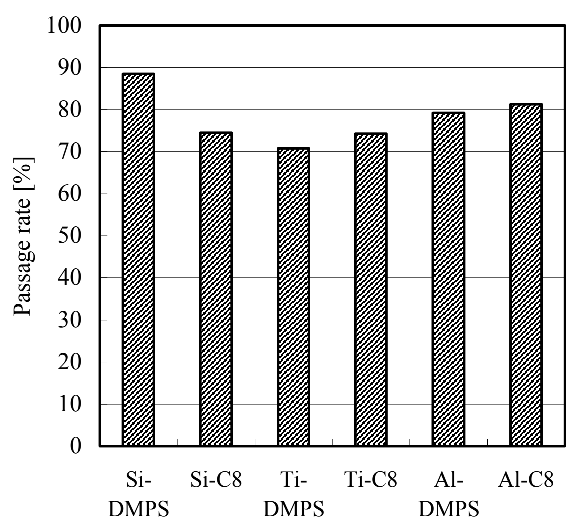

Figure 5. Passage rate of toner with additives

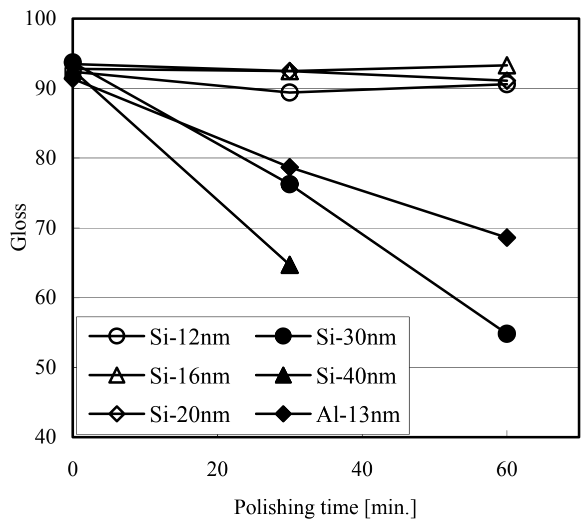

Figure 6. Gloss value of gelatin layer on PET

Polishing Properties

Figure 6 shows the gloss value of film after polishing using silica particles of various size and alumina for comparison. In the case of silica with an average particle diameter of 12 to 20 nm, the gloss value remained constant after 60 minutes of polishing. However, the gloss value of silica with a diameter exceeding 30 nm plummeted after polishing and also decreased after being polished by alumina with 13 nm diameter. Figure 7 shows an optical microscope photo of the gelatin layer polished by alumina for 60 minutes, with obvious change in the surface condition. We can presume that in general, larger particles are more effective for polishing and moreover, that alumina has a superior polishing ability compared to silica. This also correlates with practical application experience when these materials were used as external additives to toner. Our quite simple experimental set up seems to be suitable to simulate the polishing of the toner on OPC drum by external toner additives.

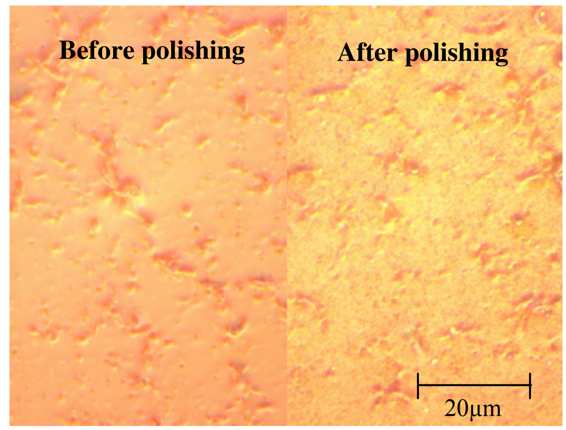

Figure 7. Optical microscope photo of gelatin layer polished by alumina for 60 minutes

Conclusion

Several kinds of surface modified inorganic particles were evaluated in respect of charge properties and free flow and polishing properties. Each surface modified inorganic particle showed different characteristics. Silica displayed a strong negative charge and high free flow effect on the toner compared with the corresponding titania and alumina. The polishing of toner on OPC drum by fumed oxide was simulated for the first time. In case of silica, it could be proven that larger particles have a stronger polishing ability, while alumina in general has a superior polishing ability compared to silica. Those polishing results are in line with the practical application experience and may open a window to evaluate new fumed oxides in respect of polishing behavior.

References

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Author Biography

Akira Inoue received his Master degree in Applied chemistry at Kyushu University in 1997. He has worked for NIPPON AEROSIL in R&D and Applied Technology for 7 years. Since 2004 he has been R&D manager for the development of surface modified fumed oxides – especially for toner applications.