

Tribocharging Mechanism In A Model Xerographic Toner

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Abstract

The tribocharging mechanism of xerographic toner has been studied using a model toner prepared by solution coating a negative charge control agent, cesium 3,5-di-t-butylsalicylate (0.15% by wt.), on the surface of 9 μm styrene-butadiene toner particles. The tribocharge was generated by tumbling the toner particles with metal carrier beads (130 μm) and was measured by the standard blow-off technique. Analyses of the surfaces of the toner and carrier particles, before and after blow-off, by time-of-flight secondary ion mass spectrometry and X-ray photoelectron spectroscopy show that there is a preferential transfer of Cs^+ ion from the toner surface to the carrier during toner charging. Evidence is provided that the transferred Cs^+ ion correlates not only to the sign, but also the magnitude of the toner charge.

Introduction

Our interest in contact charging lies in its relevance to the xerographic process. For instance, after charging and imagewise photodischarging of a photoconductor, electrostatic latent images are formed. These electrostatic images are then developed using dry xerographic toner by means of electrostatic forces. The electrostatic charges are usually generated by a charging process which requires contacts between toner particles and carrier beads inside a developer housing.¹ Fundamental understanding of the charging process would obviously be beneficial not only for the development of better electrostatic control for xerographic marking, but also for the design and synthesis of improved toner in future engines.

While the mechanism of contact charging between two dissimilar metals is well understood, knowledge of the contacts between metals and insulators or between two dissimilar insulators is relatively poor.² Nevertheless, studies of the contact charging involving organic-polymeric materials have been documented.³⁻¹² There has been growing evidence to suggest that the charging mechanism of these materials is by ion transfer. Key issues, such as the visualization of the transferring process and the accountability of the transferred ions to charges, which will enable the establishment of the toner charging mechanism have yet to be reported. In this study, we synthesize a model xerographic toner by solution coating a negative charge control agent (cesium 3,5 di-t-dibutylsalicylate, **CstBSA**) on the surface of 9 μm toner particles of styrene-butadiene. The tribocharge was generated by tumbling the toner particles with carrier beads and measured on a standard blow-off

apparatus.¹³ The surfaces of the toner and carrier particles, before and after the blow-off experiments, were analyzed by time-of-flight secondary ion mass spectrometry and X-ray photoelectron spectroscopy. A preferential transfer of Cs^+ ions during the toner-carrier contacts is observed. The toner charging mechanism is discussed.

Results and Discussion

Preparation and Characterization of the Model CstBSA Coated Styrene-Butadiene Toner

CstBSA is a white solid powder prepared by neutralizing 3,5-di-t-butylsalicylic acid with CsOH in methanol. Figures 1 and 2 show the positive ion and negative ion mass spectra of **CstBSA** taken on our TOF SIMS spectrometer. Intense Cs^+ at m/z 133 and tBSA^- at m/z 249 are observed in the respective spectrum. This data and the recording conditions are then used as references for the surface analyses of the toner and carrier particles.

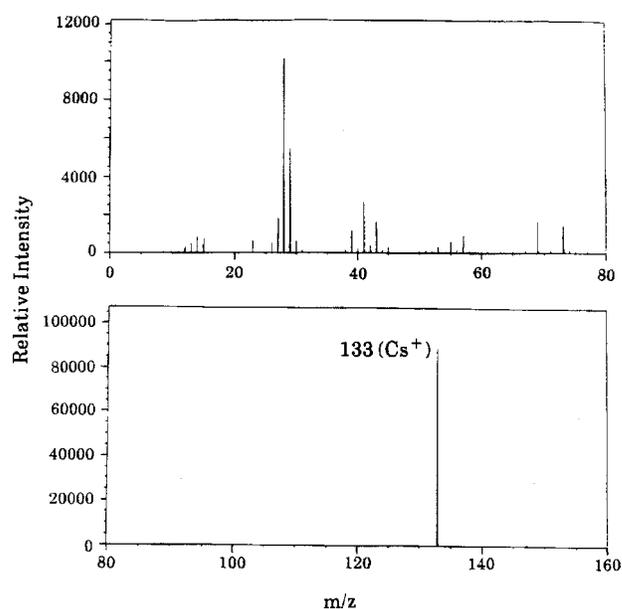


Figure 1. TOF SIMS positive mass spectrum of **CstBSA**.

The model **CstBSA**/styrene-butadiene toner was prepared by solution coating **CstBSA** (~0.15% by weight) onto the surface of the toner particles (9 μm) in methanol. Examination of the SEM micrograph of the toner reveals that the solution coating process has no effect on the morphology of the toner. It is important to note that particles

of **CstBSA** are neither observed in the toner sample nor on the toner surface. On the other hand, strong Cs^+ and tBSA^- signals are observed in the positive ion and negative ion mass spectra, respectively, when the toner is examined by the TOF SIMS technique. Figure 3 shows a Cs^+ TOF SIMS image of the model toner, which shows that the toner is indeed $\sim 9\ \mu\text{m}$ and Cs^+ ions are uniformly distributed on the toner surface. A similar toner image based on the tBSA^- anion has been elusive owing to the build-up of electrostatic charges in the negative imaging mode. Nevertheless, we conclude that **CstBSA** is uniformly distributed on the surface of the model toner.

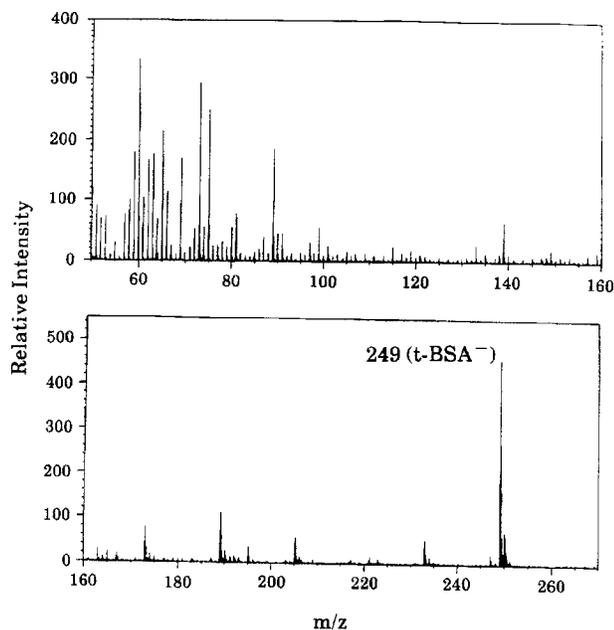


Figure 2. TOF SIMS negative mass spectrum of **CstBSA**.

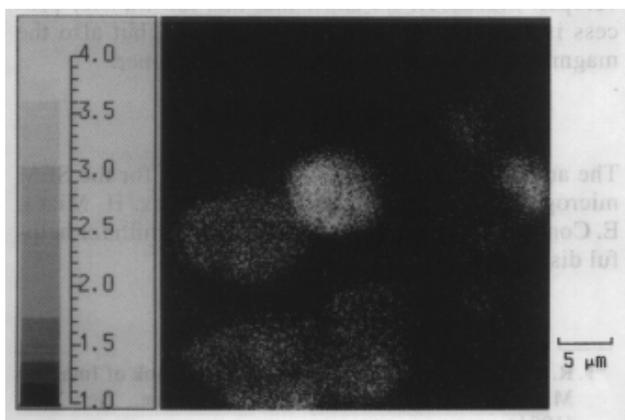


Figure 3. A TOF SIMS image (from the Cs^+ ion) of the model **CstBSA**/styrene butadiene toner.

Tribocharging of the Model Toner

The model toner was charged by first mixing the toner (1.25 g) with 60 g of carrier beads inside a 2-oz bottle, followed by conditioning the contents at $\sim 20\%$ RH for 16 hours and then tumbling the toner particles with the carrier

beads inside the bottle on a roll-mill at a speed of 90 ft/min. The generated tribocharge was determined by the blow-off technique.¹³ Figure 4 shows the build-up of the negative tribocharges as a function of the roll-milling time. The carrier is made of steel. It is $\sim 130\ \mu\text{m}$ in size and consists of a Kynar/PMMA (20/80) surface coating (0.7% by weight).¹⁴ The results show that the toner acquires a negative charge rapidly upon contact with the carrier beads. The charging process becomes saturated when the toner is rolled for ≥ 30 minutes.

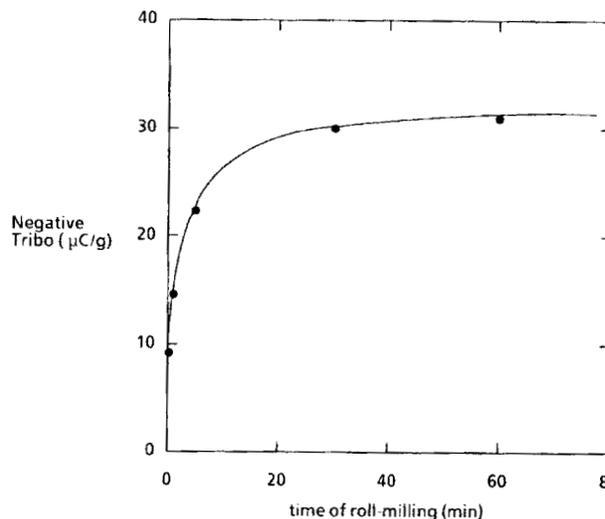


Figure 4. A time-track plot for the generation of negative tribo as function of roll-milling time.

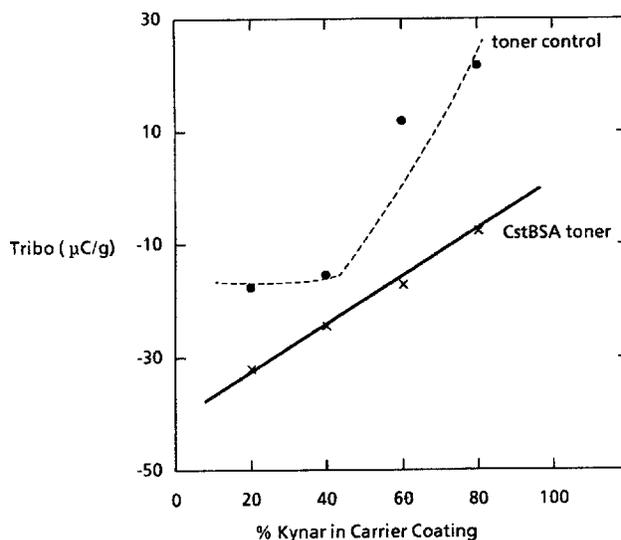


Figure 5. A tribo plot for the **CstBSA**/styrene butadiene model toner.

The charging behavior of the model toner was examined by roll-milling it against a series of carriers of varying electronegativity for 60 minutes. The electronegativity of the carrier is tailored by the polymeric coating on the surface, which consists of a mixture of Kynar and PMMA. Carrier with a coating of high Kynar content is expected to

drive the toner less negative (or positive), and vice versa.^{1,14} Even though the Kynar/PMMA pair is designed for contact charging based on the electron-transfer model, there is recent evidence that the same driving force applies to the ion-transfer model.⁶ The equilibrated tribocharges acquired by the toner are plotted against the Kynar concentration in the carrier coating (Figure 5). The toner charges negatively against all carriers, the negative charge increases monotonically as the Kynar/PMMA ratio decreases. A controlled experiment (dashed line in Figure 5) studying the charging of the uncoated toner suggests that the added **CstBSA** on the toner surface dominates the charging characteristic of the model toner.

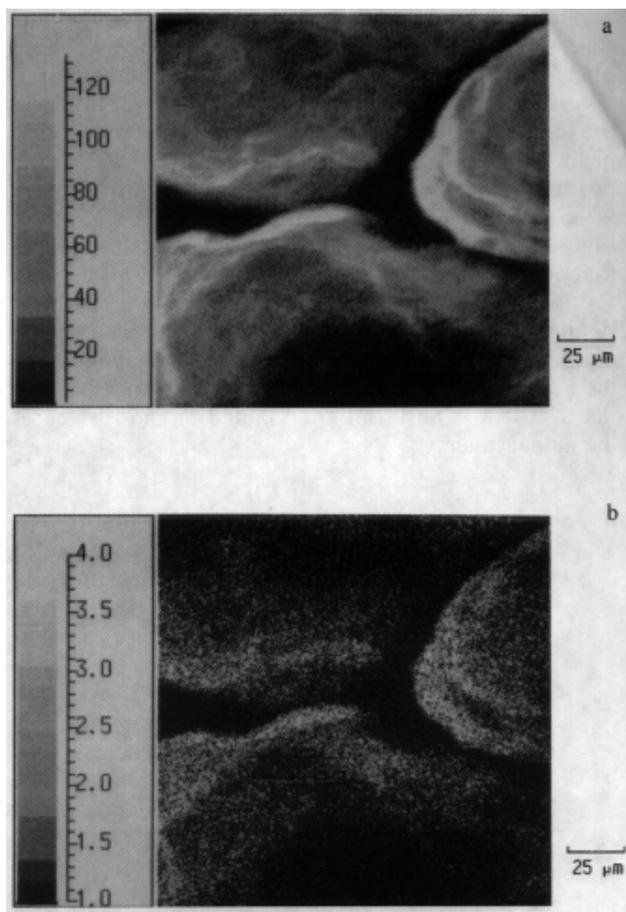


Figure 6. TOF SIMS images of carrier beads recovered from a blow-off experiment (a) from all cations; (b) from the Cs^+ ion.

Surface Analysis—Evidence for Ion Transfer

After each blow-off experiment, the carrier beads were recovered for surface analysis. For carriers that were contacted with the **CstBSA** model toner, we detected a strong signal at m/z 133, attributable to the Cs^+ ion in the positive mass spectrum. Figure 6a shows a total positive ion TOF SIMS image of a recovered carrier sample. The TOF SIMS image of the same sample imaged from the Cs^+ ion is given in Figure 6b. Identical ion images are obtained, indicating that Cs^+ ions are uniformly distributed on the surface of the carrier beads after contact charging. The corresponding anion, tBSA^- at m/z 249, is absent in the negative mass

spectrum. This observation leads to the conclusions that (1) Cs^+ is transferred from the surface of the model toner to the surface of the carrier preferentially; (2) mass transfer (or transfer of **CstBSA**) does not occur during toner charging.

A parallel analysis was also performed by the XPS technique and the results support the conclusion that Cs^+ ion is transferred from the surface of the toner to the surface of the carrier.

Mechanism of Toner Charging

The transfer of Cs^+ ion from the surface of toner particles to the surface of the carrier beads suggests that the negative charge acquired by the toner may be by an ion-transfer mechanism. In this work, we attempt to address the charge-to-ion issue through measurement of the relative Cs^+ density on the carrier surface. A plot of the negative tribo acquired by a series of toners in the time-dependent experiment (Figure 4) as a function of the Cs^+ density on the surface of the recovered carriers is given in Figure 7. A linear relationship with good correlation coefficient is obtained. The intercept of the linear fit is close to zero, suggesting that the transfer of Cs^+ ion is not only responsible for the sign, but also the magnitude of the toner charge.

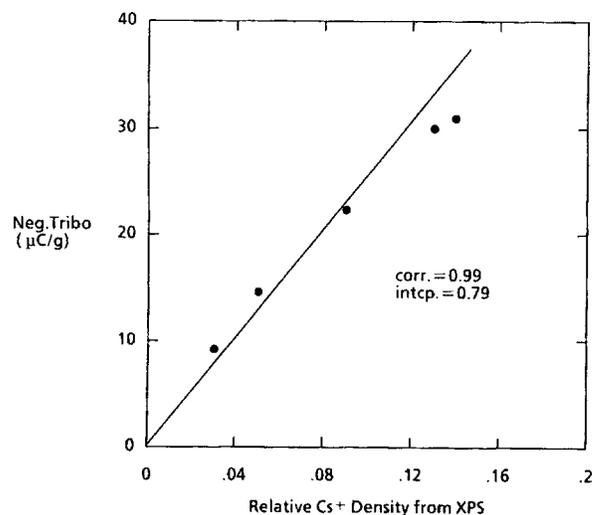


Figure 7. Plot of the negative tribo of the toner versus the relative Cs^+ count on the carrier surface by XPS.

Conclusion

This work visually demonstrates for the first time that ions are being transferred from the surface of the model **CstBSA**/styrene-butadiene toner to the surface of metal carrier beads during toner charging in a xerographic developer. Moreover, we show that this ion transfer process is accountable for not only the sign, but also the magnitude of the charge acquired by the toner.

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