Observation of Electrostatic Latent Images and Surface Potential Measurement Using Scanning Electron Microscope

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Abstract

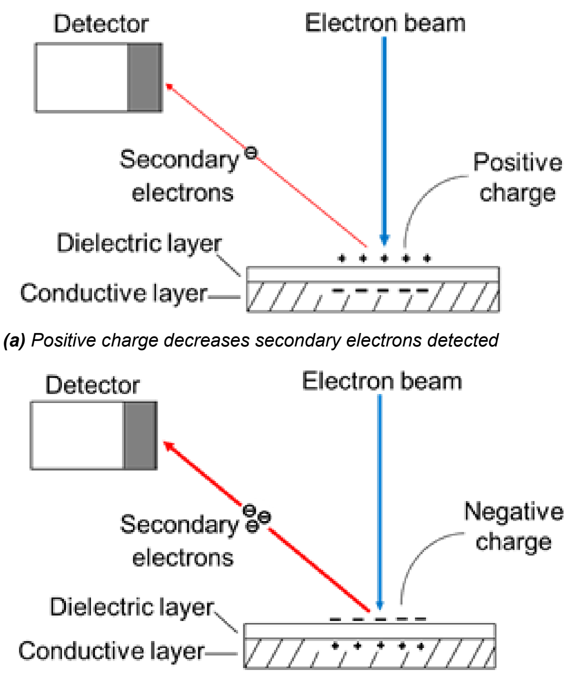
Electrostatic voltmeters are generally used for potential measurements of electrostatic latent images. In this study, we are using SEM (Scanning Electron Microscope) for more detailed observation and potential measurement of electrostatic latent images; SEM can visualize electrostatic latent images as an image brightness distribution. We focused on clarification of the relation between surface potential of electrostatic latent image and brightness of SEM images. Electrostatic latent images were formed on PET (Polyethylene terephthalate) film by a corona discharger. We have observed SEM images of the electrostatic images after measuring surface potential of each latent image by using electrostatic voltmeters. We then measured distributions of brightness of the SEM images. We have successfully shown the relation between the surface potential and the brightness of SEM images. We hope SEM observation can be an alternative method for detail observations and measurements of electrostatic latent images.

1. Introduction

Formation of electrostatic latent image is playing an important role in electrophotography systems. SEM (Scanning Electron Microscope) is a useful tool for observation of electrostatic latent images [1]. SEM can visualize potential distribution of electrostatic latent images as an image brightness distribution [2], [3], [4]. Brightness of SEM images must be related with surface potential of the latent images but the relation has not been quantitatively studied [5]. In this study, we focus on quantitative analysis of SEM images of electrostatic latent images.

2. Principle of SEM observation of electrostatic latent images

Figure 1 shows principle of SEM observation of electrostatic latent images. General principle of the traditional SEM observation is as follows: Secondary electrons are emitted from the surface of a specimen when an electron beam is projected to a specimen. The amount of secondary electron caught by a detector depends on local surface angle of the specimen. Thus, the surface shape of the specimen can be visualized by using the distribution of the amount of detected secondary electrons. A surface charge of a specimen also affects the amount of the secondary electrons which reach to the detector. For example, the amount of detected secondary electron must be decreased by positive surface charge. This is the principle how distribution of surface charge can be visualized by using SEM [6].



(b) Negative charge increases secondary electrons detected

Figure 1 *Principle of SEM observation of electric surface charge distribution*

3. Experimental method

Electrostatic surface charges were formed by a corona discharger (Figure 2). Surface potential of the surface charges were measured by using an electrostatic voltmeter. The surface charges were then visualized by using SEM. Table 1 shows details of experimental conditions. Electrostatic surface charges were formed on PET (Polyethylene terephthalate) films. A wire netting of stainless steel was set between a PET film and the corona discharger. Surface potential of a PET film was controlled by varying a voltage of the wire netting: wire netting was playing a role of potential controller of surface charge images. PET films were scanned by the moving corona discharger with a constant speed. PET films were observed by using SEM (KEYENCE VE -8800), after measuring their surface potential by using an electrostatic voltmeter (Trek MODEL 344). Detection efficiency of secondary electrons of SEM was appropriately adjusted in order to set the coverage of SEM image brightness fit for the dynamic range of the potential of the surface charges on the PET films. We measured brightness of 4 points around the center of images and averaged them. We also observed a latent image in which shadow pattern of the wire netting appeared for the purpose of using as a typical sample for voltage profiling of electrostatic latent images. Voltage of wire netting V =300 V and moving speed of charger v = 900 mm/sec were the conditions for forming the latent image used for the voltage profiling.

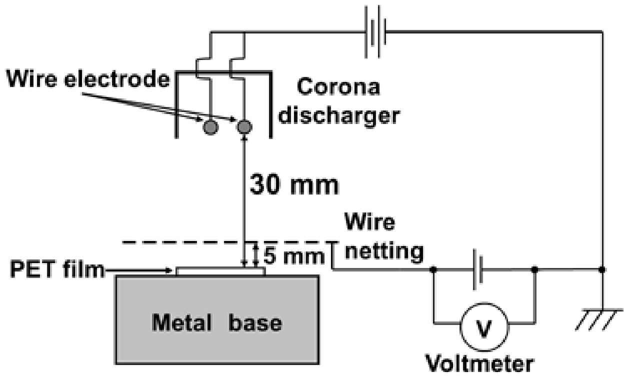


Figure 2 *Experimental apparatus*

Table1 Experimental conditions

Corona discharger	Applied voltage: 6.5 kV Wire diameter: 60 µm Moving speed: 20 mm/s
Wire netting	Applied voltage: 250 V wire diameter: 0.45 mm Wire pitch: 1.8 mm
SEM	Accelerating voltage: 0.5 kV Magnification: x15

4. Results

Table 2 shows observed results of SEM images and their surface potential measured by the electrostatic voltmeter.

Figure 3 shows the relation between the surface potential and SEM image brightness appeared in Table 2. Equations for collinear approximations of the curve in Figure 3 were given as follows:

$$L^* = 7\sim13 \quad : V = (15 - L^*)/0.077 \qquad (1)$$
$$L^* = 13\sim18 \quad : V = (26 - L^*)/0.33 \qquad (2)$$
$$L^* = 18\sim24 \quad : V = (38 - L^*)/0.86 \qquad (3)$$
$$L^* = 24\sim58 \quad : V = (65 - L^*)/2.6 \qquad (4)$$
$$L^* = 58\sim90 \quad : V = (90 - L^*)/10.7 \qquad (5)$$

(L^*: SEM image brightness, V: surface potential)

It should be noted that the curve in high voltage area is too flat for the purpose of using for precise conversions from image brightness to surface potential. We consider that calculation of surface potential by using SEM images brightness is appropriate for relatively low potential range of surface charges because we have found that SEM image brightness saturates at high potential range of surface charges.

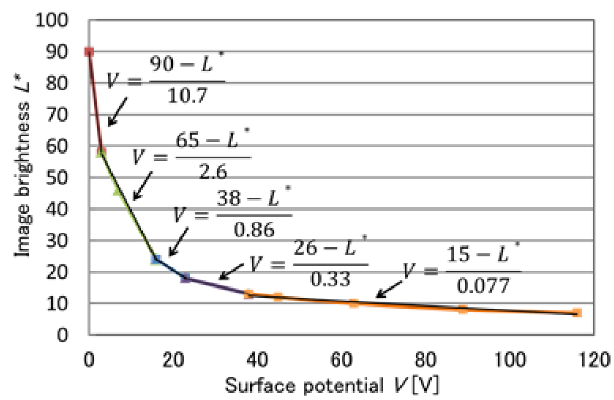
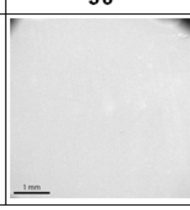
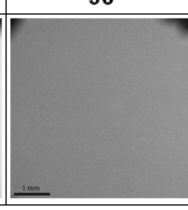
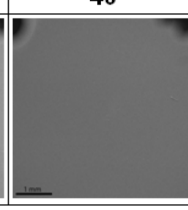
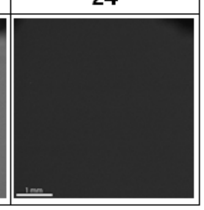


Figure 3 *Relation between surface potential and SEM image brightness*

Table 2 SEM images and measured values of surface potential at various charging conditions

Voltage of wire netting [V]		5	10	30
Surface potential V [V]	0	3	7	23
Image brightness L^*	90	58	46	24
SEM images 1 mm				

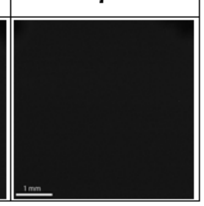
Voltage of wire netting [V]	40	50	100	120
Surface potential V [V]	38	45	89	116
Image brightness L^*	13	12	8	7
SEM images 1 mm				

Figure 4 is a SEM image that was used for a calculation of voltage profiling of electrostatic latent images. We measured the image brightness distribution along the dotted line marked on the SEM image shown in Figure 4, and then converted it into a surface potential distribution by using the equation (1) ~ (5). Figure 5 shows the distribution of brightness of the SEM image shown in Figure 4. Figure 6 show a converted result of surface potential distribution calculated using the equations (1) ~ (5).

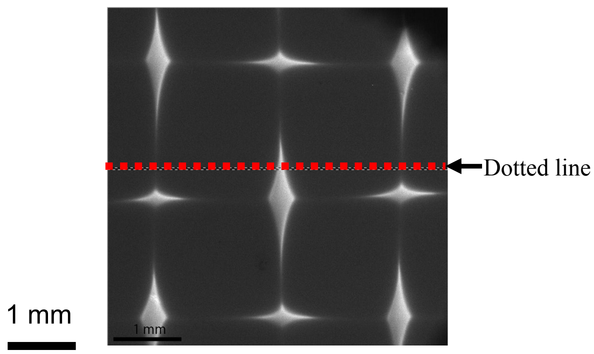


Figure 4 *SEM image of an electric charge used for voltage profiling*

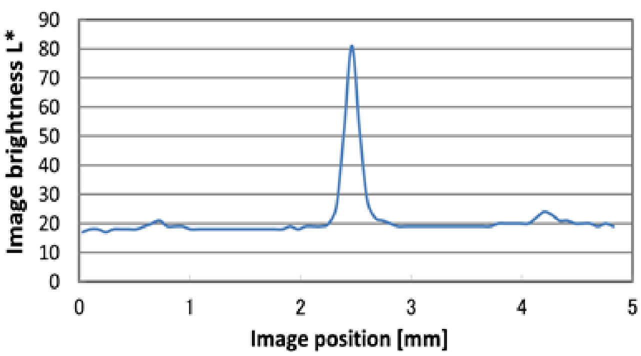


Figure 5 *Image brightness profile of the SEM image shown in Figure 4*

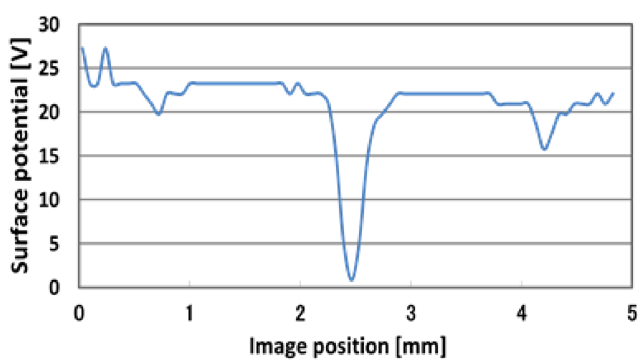


Figure 6 *Surface potential profile transformed from the brightness profile shown in Figure 5*

5. Conclusion

We have carried out quantitative analysis of the relation between potential of surface charges and their SEM image brightness. Essential results are listed as follows:

1) Utility of SEM observation of electrostatic latent images was reconfirmed; a curve between potential of surface charges and their SEM image brightness was shown for positive charges.

2) Voltage profile of a typical latent image was successfully shown using a brightness distribution of SEM image.

3) We consider that calculation of surface potential by using SEM images brightness is appropriate for relatively low potential range of surface charges because SEM image brightness tends to saturate at high potential range of surface charges.

Reference

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Author Biography

Naotaro Kumagai was born in 1990. He received his B.E. degree in 2012 from Tokai University. He is expected to receive his M.E. degree from the graduate school of Tokai University in 2014. He is now engaged in a study of SEM (Scanning Electron Microscope) observation of electrostatic latent images.