High Resolution Technology Using Positive-Charge-Type OPC Photoreceptor

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Abstract

High resolution imaging by electrophotography can make it possible to make a bigger business market, for example in the field of "Print on Demand", and the application of a liquid developing technology has been studied hard on this purpose. To realize a high resolution imaging by electrophotography, the resolution depends on not only developing technology but also the latent image on photoreceptors.

As the results of this study, diffusion on the diffusion theory revealed the advantage of a positive-charge-type single–layer organic photoreceptor (OPC) due to the photoconduction mechanism. And also, the latent images developed by liquid toner on single-layer and a dual-layer OPC have supported the diffusion theory discussion as a single-layer OPC can only resolve the 100 pair lines / mm although the dual-layer can not. This means a single-layer OPC have an advantage for the high resolution imaging technology utilizing electrophotography.

Introduction

Electrophotography has become as a mature imaging technology being common to every office workers, and we can not carry out our business without electrophotographic equipment. But, the electrophotographic business scarcely makes expansion except for China, Southern Asia, and Eastern Europe market. Ink jet technology and electronic paper technology make it difficult for electrophotography to make a growth in imaging business. Then, much effort to apply electrophotography to "Print on Demand (POD)" field has been carried out on this purpose because electrophotography has still many advantages as an imaging technology.[1-2]

Now, electrophotography is thought as a dry process technology generally, and that a resolution of an image by electrophotography is controlled by toner technology as toner has a larger particle diameter like 6 – 10 μm. But, electrophotographic technology depends on not only dry process, but also wet process (liquid development process). In the case of applying wet process, we can use a smaller particle size toner like under 1μm diameter. This technology makes it possible to improve the image quality by electrophotography, and to overcome rapidly the weak point of electrophotography being said in compared with ink jet printing.

If using wet process and realizing a high resolution, we have to optimize the electrophotographic process. To discuss an imaging quality by electrophotography, we have to consider not only developing process, but also an exposure process, a latent image formation, a transfer process, a fixing process, and so on. Many studies on exposure, development, transfer, and fixing were reported, but studies of a latent image on the photoreceptor were scarcely reported. Although there was a study of a latent image resolution applying a potential analysis on the photoreceptor, the resolution range was almost less than 600 or 1,200 dpi, and it is not enough to discuss the high resolution these days.[3] We had tried to discuss the resolution of latent image to reveal the possibility of the high resolution imaging by electrophotography because it is not able to realize a resolution more than the resolution on the photoreceptor.

It is well-known that the major photoreceptor for electrophotography is OPC (Organic Photoconductor), and OPC has two major structures which are a dual-layer type and a single-layer type. Figure 1 shows a schematic diagram of the constructions and their photoconduction mechanism. In the mechanism of OPC, it is thought one of the causes of image resolution drop is due to carrier diffusion,[4-6] and making the migration distance of the carrier to neutralize the surface charges short is effective to reduce the carrier diffusion. As we can understand on Fig. 1, the carrier migration distance is shorter in a single-layer OPC than in a dual-layer one, therefore, a single-layer type must have the advantage to realize the high resolution.

In this study, we confirm the advantage of a single-layer OPC on a latent image resolution based on the diffusion theory at first. Then, we compared the liquid toner image resolutions on a single-layer and a dual-layer OPC developed latent images proceeded by a contact exposing of 100 or 150 pair lines/mm document.[7] These experimental results indicated the hypothesis on OPC resolution was correct, and supported a carrier migration distance to neutralize the carriers on OPC surface was the dominant factor of the resolution.

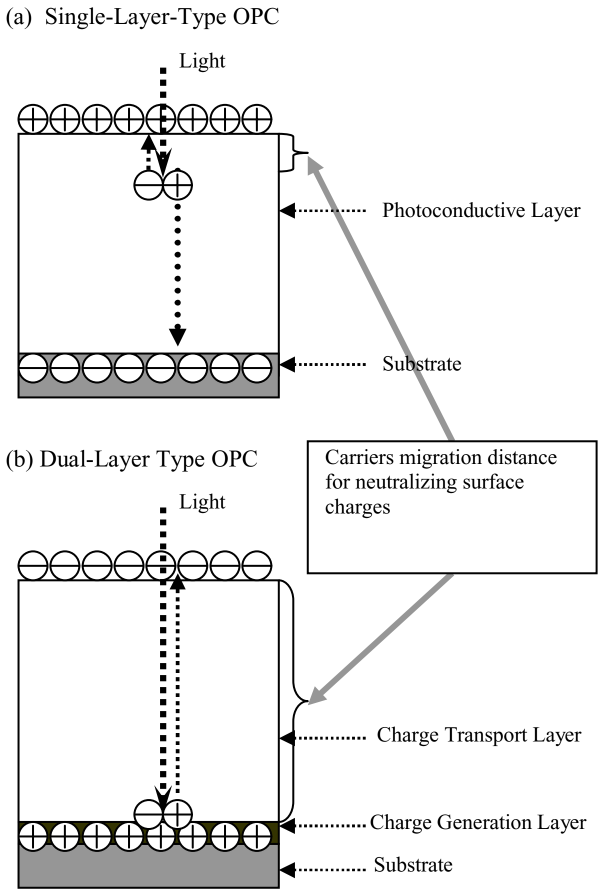

Figure 1. Schematic diagram and carrier transport mechanism of single-layer and dual layer type OPC.

Experimental

(Preparation of Photoreceptor Samples)

Single-layer OPC was prepared by following manner; 3 or 10 weight part ratio of *N*, *N*-Bis(3, 5-dimethylphenyl)-3,4-9,10-perylene bis(carboximido) (Pe) pigment as charge generation material (CGM) was dispersed in tetrahydro-furan (THF) by ultrasonic welder, and dispersed again after adding 100 weight part ratio of Z-type polycarbonate resin as a THF solution. This solution was coated onto the aluminum substrate by bar drawing method 12μm thick photoreceptor layer was formed after drying.

On the other hand, the manner of the preparation of dual-layer OPC was follows; 50 weight part ratio of Pe was dispersed into polyvinylbutyral as a THF solution (poly-vinylbutyral solid content was 100 weight part ratio.), and coated onto the aluminum substrate of which the surface was anodized as ca. 0.5 μm thick charge generation layer was formed after drying by bar drawing method. Then, a THF solution consist of 50 weight part ratio of *N*, *N*'-Dimethylaminobenzaldehyde-diphenylhydrazone as charge transport material and 100 weight part ratio of Z-type polycarbonate resin was coated onto the charge generation layer by bar drawing as 12 um thick after drying.

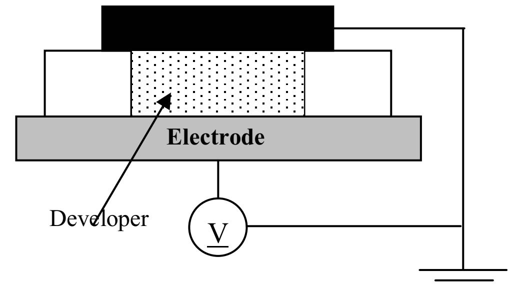

Figure 2. Schematic diagram of developing experiment

(Formation of a Latent Image and Development)

Latent image was formed by following; a single-layer OPC and a dual-layer OPC were charged to 800V and -800V respectively utilizing electric paper analyzer (Model EPA-8100, Kawaguchi Electric Works), and the charged photoreceptors were exposed by Hirera Copy (Mitsubishi Paper Mills) on condition that the document adhered to the photoreceptors. Ronchi slide glass (100 or 150 lines pair/mm; Edumund Optics) was applied as a document for detecting a resolution.

After then, the latent image was developed with liquid toner using the equipment in Fig. 2. The surface potential of non-exposed was 600V or -600V, the surface potential of exposed was 100V or -100V, and a bias potential of development was set to 400V or -400V. The gap between OPC and the electrode was kept 100μm. Positive and negative charged liquid toners in developer were used in the experiment of a single-layer and a dual-layer OPC respectively.

(Observation of the Toner Image on the Photoreceptor)

The toner image on the photoreceptors was observed by 3 dimensional interference microscope (Model WYKONT 1100; Veeco).

Results and Discussion

(Dependence of Image Resolution on Carrier Diffusion)

It is well-pointed out that latent image on a photoreceptor is affected by exposed light and photo-carrier diffusion in photoconductive layer. In this study, a hypothesis focused on a carrier diffusion theory is discussed referring to studies previously reported.[4]

It is thought that the general diffusion theory can be applicable to a carrier diffusion phenomenon in OPC photoreceptor. The diffusion theory can be given by following equation;

$$\frac{\partial c}{\partial t} = D\Delta c + div(ucF) \quad \text{(eq. 1)}$$

D : diffusion coefficient, c : particle density, u : mobility, F : external force

Then, the diffusion length (L) is given as follows due to this theory;

$$L = \sqrt{Dt} \qquad \text{(eq. 2)}$$

t : Diffusion time

In the case of OPC, the factors required to determine a carrier diffusion length as follows;

$$E = V / Lt \qquad \text{(eq. 3)}$$

$$v = u \cdot E \qquad \text{(eq. 4)}$$

$$t = d / v \qquad \text{(eq. 5)}$$

E : Electric field, Lt : Layer thickness, v : Speed of carrier,
u : a carrier mobility for neutralizing a surface charge,
d : migration length of carrier for neutralizing a surface charge

Therefore, carrier diffusion is determined by following equation 6 due to hypothesis mentioned above;

$$L_e = \sqrt{\frac{D \cdot Lt \cdot d}{V_{sp} \cdot \mu}} \qquad \text{(eq. 6)}$$

Referring this equation, we can understand it is so important to make the carrier migration length (d) to neutralize the surface charge on OPC shorter for improving a latent image resolution on OPC.

In a discussion to think that there is an advantage of resolution on a single-layer or a dual-layer OPC, it is evident that a single-layer OPC is predominant because the carrier migration length of a single-layer is so shorter than one of a dual-layer. In the case of a dual-layer OPC, a carrier is generated at the bottom of the photoconductive layer, so the carriers generated have to migrate to the surface through the photoconductive layer thickness to neutralize charges on the surface of the photoreceptor. On the other hand, carriers are generated nearby the surface of the photoconductive layer in the case of a single-layer OPC because a single-layer OPC absorbs photons exposed by a bulk following Lambert-Beer law, then carriers (electrons in this case) to neutralize the carriers (holes) on the surface of the photoreceptor have to migrate shorter clearly than one of a dual-layer.

It is thought carrier diffusion definitely gives a latent image resolution in the case of a dual-layer OPC, but it is not governed in the case of a single-layer one.

Due to the results of previous study by Hirao et al. about the carrier diffusion of the hole transport molecular doped polymer film, a carrier diffuses almost 3.5 μm by only carrier diffusion in a case of a common dual-layer OPC model. In actual OPC, a light diffusion has to be considered as the factor of the resolution drop, so it is thought this result indicates it is very difficult for a dual-layer OPC to resolute 1,200 dpi as a latent image on it.

In the case of a single-layer OPC, it is thought that the carrier migration length is more tenth shorter than one of a dual-layer one, and incident dept of the light exposed is shorter as same as a carrier migration.

Therefore, a single-layer OPC has an advantage in the high resolution technology compared with a dual-layer OPC.

(Latent Image Resolution on a Single-Layer OPC)

Figure 3-(a) shows the interference microscopy toner image on the single-layer OPC which-in the CGM density was 10 weight part ratio using a 100 pair-lines slide glass as a document. It is not completely clear, but it seems the lines have been almost developed, and the lines interval was 10 um. Therefore, It has been revealed this single-layer OPC has an ability to resolve 100 pair-lines on latent image be electrophotography.

(Latent Image Resolution on a Dual-Layer OPC)

As same manner mentioned above, the latent image on the dual-layer OPC was developed, but a solid lines developed were not observed as a toner image at all. Then, it is thought a dual-layer OPC does not have an ability to resolve 100 pair-lines on latent image, and the difference on image resolution between a single-layer and a dual-layer OPC has been concerted to the carrier diffusion theory mentioned above.

Therefore, these results indicate that a single-layer OPC definitely has an advantage on the high resolution technology utilizing electrophotography, too.

(Resolution Dependence on CGM Density of a Single-Layer OPC)

It is able to think that the image resolution on a photoreceptor is governed by carrier migration length as a dominant factor, and the resolution will also be dropped if a carrier migration length is made longer in the case of a single-layer OPC. A carrier migration length to govern the latent image resolution is defined by the CGM density as a photo absorbent in the case of a single-layer OPC, and it is assumed a resolution of a single-layer OPC shows dependence on CGM density.

Figure 3-(b) shows the interference microscopy toner image on the single-layer OPC which-in the CGM density was 3 weight part ratio using a 100 pair-lines slide glass as a document as the same manner mentioned above. A drop of resolution is observed but the solid lines were almost developed. It is not necessary to think this result indicates a high resolution imaging technology utilizing a single-layer OPC is governed by the CGM density, but it is thought a factor giving effect.

(Higher Resolution Technology)

Figure 3-(c) indicates the interference microscopy toner image on a single-layer OPC which-in the CGM density was 10 weight part ratio using a 150 pair-lines slide glass as a document. A clear solid line could not be observed, but we think a latent was formed on the surface of the single-layer OPC because the experimental conditions were not optimized.

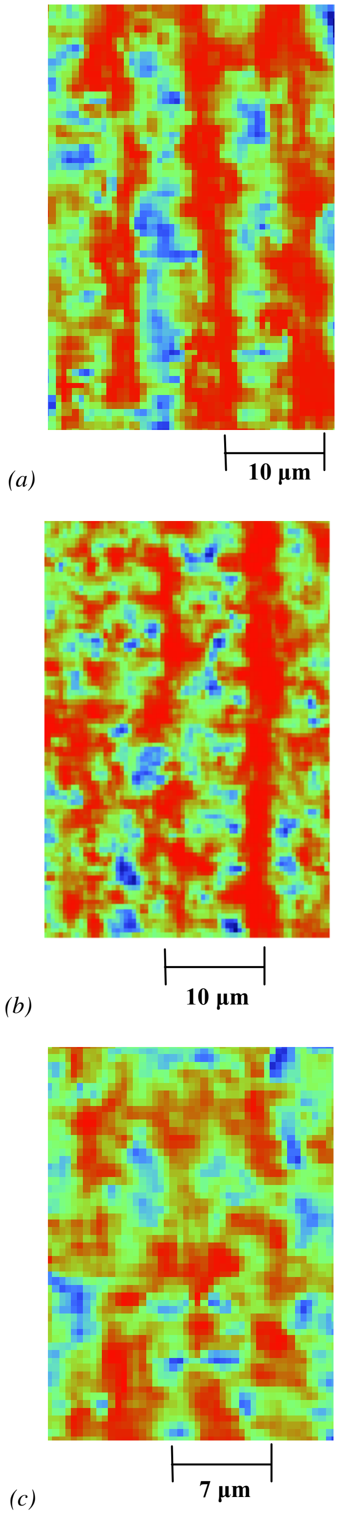

Figure 3. Liquid toner images on the single-layer OPC. (a) OPC : CGM = 10 weight part ratio ; Exposure = 100 Lines/mm, (b) OPC : CGM = 3 weight part ratio ; Exposure = 100 Lines/mm, (c) OPC : CGM = 10 weight part ratio ; Exposure = 150 Lines/mm

Conclusion

To reveal the high resolution technology utilizing electrophotography, the potential of the latent image on a photoreceptor was studied with a discussion on the carrier diffusion in the OPC photoreceptor and experiments applying a contact exposure and a liquid development.

As results, it would be confirmed that the electrophotography utilizing a single-layer OPC as a photoreceptor more superior that a dual-layer one, and 100 pair-lines could be developed on a single-layer OPC as a latent image. Then, it is thought the electrophotography utilizing a single-layer OPC has an advantage for the application of the electrophotography to the high resolution imaging field.

References

1. M. Hosoya, H. Yagi, Y. Shinjo, S. O-oka, S. Saito, K. Ishii, Proc. Japan Hardcopy 2000, pg. 161 (2000).
2. Y. Shinjo, I. Takasu, H. Yagi, M. Takahashi, M. Hosoya, Proc. Japan Hardcopy 2004, pg. 31 (2004).
3. K. Aizawa, Y. Ueno, M. Takeshima, Fuji-Giho, 75(3), pg. 194(2002).
4. A. Hirao, H. Nishizawa, Proc. Japan Hardcopy '96, pg. 271 (1996).
5. K. Oka, M. Fujiwara, J. Imag. Sci. Jpn., 38 (4), 296 (1999).
6. Y. Watanabe, H. Kawamoto, H. Shoji, H. Suzuki, Y. Kishi, J. Imag. Sci. Tech., 45 (6), 579 (2001).
7. Y. Mizuta, E. Miyamoto, J. Azuma, T. Nakazawa, Proc. Japan Hardcopy 2004, pg. 179(2004).

Biography

Yasufumi Mizuta received his B.S. degree in Applied Chemistry from the Osaka Prefecture University in 1987.Since 1987 he has worked in the Photoreceptor Project Division of Mita Industrial Co. Ltd., (Now, Kyoceramita Corporation). His work has primarily focused on the Organic Photoreceptor Materials development and device design. He is a member of the Imaging Society of Japan and the Chemical Society of Japan.