Pixel Image Formation on a Multi-Layered Organic Film Installed with Pixel-Like Floating Electrodes

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Abstract

We have proposed a novel capacitor-controlled imaging device consisting of an insulator installed with pixel-like middle floating electrodes on a metal substrate. In this device, the corona charged surface potential can be reduced to the value calculated from the capacity of an insulator above the floating electrode by connecting the floating electrode to ground potential.

In this work, by replacing the bottom insulator with organic photoreceptor (OPC), the light addressing was examined for grounding the floating electrodes through photoconduction in the OPC layer. The surface potential of the whole area just above the floating electrode was successfully controlled by light irradiation, even when the light was focused to the area smaller than the floating electrode. This result allows us to construct the digital dot image on the photoreceptor installed with the pixel-type floating electrode array in the future.

Introduction - Digital Imaging in Electrophotography

The electrophotography has accomplished the remarkable development since the invention by C. F. Carlson in 1938, and becomes the leading technology of the hardcopy field.[1] The recent great progress of the computer technology brought a big change from the analog to the digital system even in the imaging technology, and laser beam printers (LBPs) have emerged as the digital printer. Although in these LBPs, the images are handled as a digital type, these digital image signals are still converted on the analog photoreceptor and printed images are obtained through the conventional xerographic process. Thus, it might be hard to call true digital imaging devices. And, configuration of laser beam and fluctuation of the laser intensity greatly influence the image quality of the reproduction image. In this sense, many attempts have been made to develop digital photoreceptors so far,[2,3] but unfortunately resulted in un-success.

Capacitor-Controlled Imaging Device

On the other hand, we have proposed a novel capacitor-controlled imaging device consisting of an insulator installed with pixel-like middle floating electrodes on a metal substrate as shown in Fig. 1.[4,5]

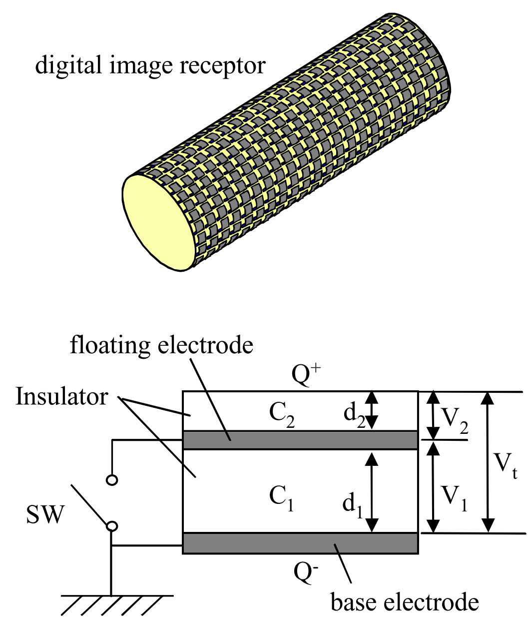

Figure 1. Our proposed digital image receptor (top) and the structure of a pixel (bottom) consisting of insulator, the middle floating electrode, metal substrate, and switch.

When an insulator on metal substrate is charged, its surface charge Q is given by

$$Q = C\,V = (S\,\kappa\,\varepsilon_0 / e\,d)\,V \qquad (1)$$

where C is the capacitance of insulator, V the surface potential, S the surface area of electrode, κ dielectric constant of insulator, ε_0 permittivity of free space, e the electronic charge, and d film thickness. Then, the surface potential V_t of the insulator having a middle floating electrode as shown in Fig. 1 (bottom) is given using the film thickness of lower and upper layers.

$$V_t = Q\, e\, (d_1+d_2) / (S\, \kappa\, \varepsilon_0) \quad (2)$$

Here, the electrification potential is proportional to sum of the whole film thickness (d_1+d_2). When the middle floating electrode is grounded, the surface potential is decided only by the film thickness of upper layer (d_2).

$$V_2 = Q\, e\, d_2 / (S\, \kappa\, \varepsilon_0) \quad (3)$$

Namely, in this device, the corona charged surface potential can be reduced to the value calculated from the capacity of an insulator above the floating electrode by connecting the floating electrode to ground potential (Fig. 2). Actually, the lowering of the surface potential above the pixel-type floating electrode has been successfully confirmed by the contact shortage for grounding the middle floating electrode.

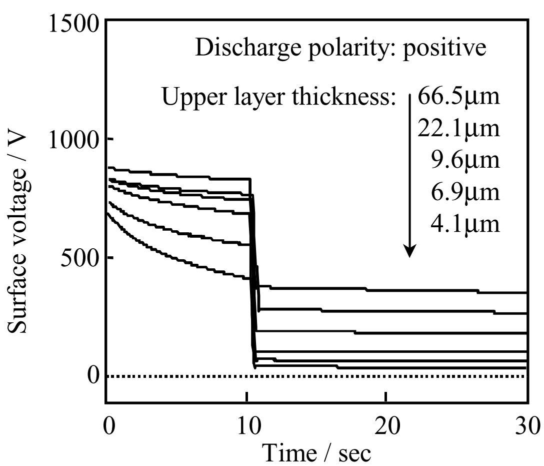

Figure 2. Decay curves of surface voltage in samples as shown in figure 1 with different upper insulator thickness.

As a similar approach for pixel-like electrification on the insulating medium, "Contact Electrography" was reported.[6] In this "Contact Electrography", the addressing for pixel array of surface metal electrodes was achieved by the mechanical contact through finger electrodes. On the other hand, in our device, the addressing can be assumed to be driven by such as organic field-effect-transistor (OFET) or organic photoconductor incorporated for each pixel to ground the floating electrodes by electrical or optical signals supplied from PC, respectively. However, the integration of such addressing unit complicates the manufacturing process of the device, and the present performance of OFET is not enough for our purpose.

Incorporating OPC Layer as Switch

In this work, therefore, by replacing the bottom insulator with organic photoreceptor (OPC), the light addressing was examined for grounding the floating electrodes through photoconduction in the OPC layer (Fig. 3). In this device, the surface potential of the whole area just above the pixel-like floating electrode may be controlled by light irradiation, even when the light was focused to the area smaller than the floating electrode, because the carriers which generated and moved the OPC, can diffuse in the whole electrode. This feature would be able to solve the problem that the fluctuation of laser beam and slippage of the position deteriorates the image quality in currently used laser-beam-printers. And, the present device can be fabricated easily by utilizing the lamination technology.

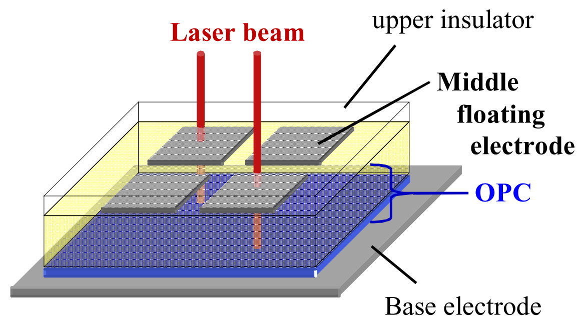

Figure 3. Pixel image formation device consisting of upper insulator, pixel-like middle floating electrodes, and bottom OPC layer.

Experimental

Sample Preparation

First, a layered-OPC formed by laminating a TiOPc dispersed PVB film as carrier generation layer (CGL, thickness: 500 nm) and a DEH doped PCz film as carrier transport layer (CTL, thickness: 23.0 - 45.0 µm) on aluminum substrate. Next, poly(α-methyl styrene) resin was provided for the upper insulator (thickness: 2.4 - 14.7 µm), after the vaccum deposition of aluminum (thickness: 5 - 7 nm) as a middle float electrode on OPC. The chemical structures of compounds are shown in Fig. 4.

Measurement for PIDC

Photo-induced discharge curves (PIDCs) of the samples were measured with an electrostatic paper analyzer (EPA-8100; Kawaguchi Electric Works Co., Ltd.) in static mode. The corona charging voltage was 7 kV. Changes in surface potential by light exposure were also examined. The photo-response was carried out using the 780 nm light from xenon lamp (500 W) through the narrow light path filter (KL78; Toshiba Glass Co., Ltd.), in which TiOPc has the high sensitivity.

Image Reproduction

In order to check the pixel-type image reproduction, the device with the pixel-type metal floating electrodes (2 by 2) was prepared and provided to test the toner development.

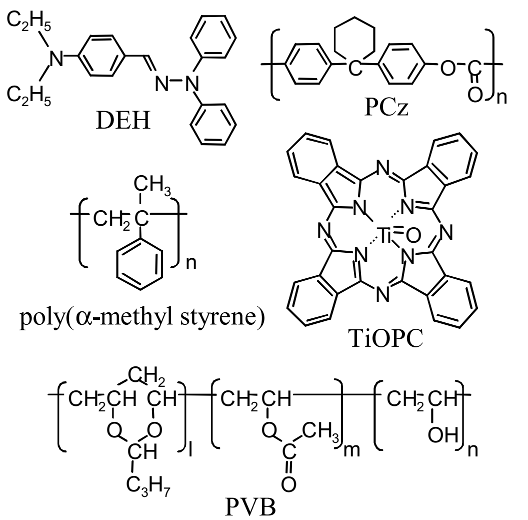

Figure 4. Chemical structures of compounds used in this study

Results and Discussion

Photo-Induced Discharge Properties

In Fig. 5 are shown PIDCs for the samples with upper PVB layer of various film thicknesses. After the corona charging, surface potentials of each sample were gradually decreased. When the light was exposed after 5 seconds, the surface potential decreased very rapidly. The residual potentials show the well-defined dependence on the thickness of upper layer, that is, thinner samples showed lower values. These results indicate that the middle floating electrode was successfully grounded by the action of OPC and the surface potential was lowered to the value which was determined by thickness of upper insulator. Actually, the ratio of potential changes (residual potential / initial potential) almost agreed with the ratio of the thickness (insulator thickness / total film thickness, $d_2/(d_1+d_2)$).

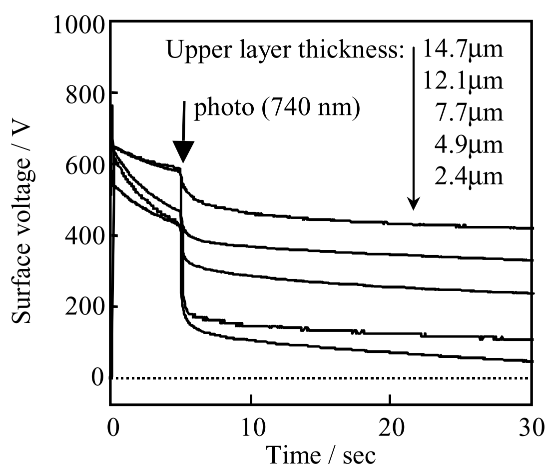

Figure 5. Photo-induced discharge curves in samples with different upper insulator thickness.

These results mean that the surface potential can be controlled in a given value which depends on the thickness of upper insulator and "binary of the image concentration", which is one of the demand of the digital image formation, can be achieved.

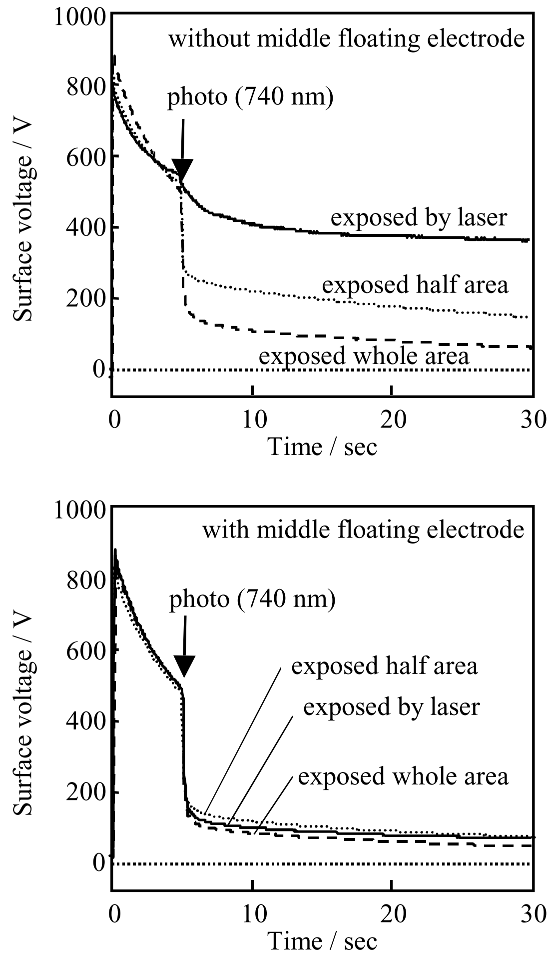

Figure 6. The light exposure area dependence on PIDC of surface voltage in samples consisting of upper insulator and bottom OPC layer with or without middle floating electrode.

Role of the Middle Floating Electrode

In order to examine the effect of the middle floating electrode, how the photo-induced discharge characteristic varied in the existence of the electrode was examined. In Fig.6 are compared the light exposed area dependence of photo-induced discharge for both cases with and without the middle floating electrode. The light exposure was conducted at sample full face, half area, or spot like tiny area by using laser beam. With no middle floating electrode, the amount of discharge showed the strong dependence on the exposure area. On the other hand, in the case of without middle floating electrode, the amount of discharge showed almost the equivalent residual potential irrespective of the exposure conditions, as was expected. These results indicate clearly that the surface potential on the upper insulator just above the middle floating electrode can be controlled uniformly even by the light exposure within the area of the electrode. In other word, "the position control of the binary potential" necessary for the digital image formation can be achieved by handling this middle float electrode as one pixel.

Toner Image Formation

Finally, the toner image reproduction was examined using the present pixel-type device. The sample configuration and the photograph of a printing sample are shown in Fig. 7. In this case, two electrodes were exposed by laser beam within a electrode area. The toner particle adhered only on the pixels, which were not exposed. This result indicates clearly that the surface potential difference enough for toner development was obtained between exposed and un-exposed pixels. Although it was the result of the sample with the big pixel (1 by 1 cm in size), the achievement of the high-resolution digital image formation device can be expected by fining pixel shape.

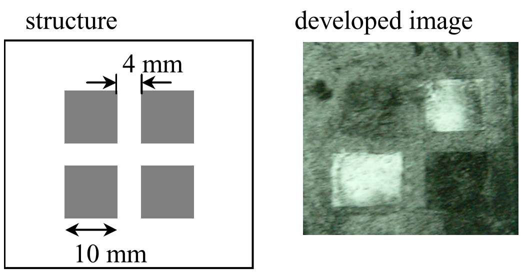

Figure 7. The image reproduction by toner development using the pixel type capacitor- controlled digital imaging device.

Conclusion

A novel type of photoreceptor device consisting of insulator layer, pixel-like middle floating electrode, and OPC layer on the metal substrate was fabricated. The corona charged surface potential of the device was successfully reduced in a pixel-shape defined by the middle floating electrode through photoconduction of the subjacent OPC. The present result may provide a new approach to the future digital imaging device.

Reference

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Biography

Norio Nagayama was born in 1969. He received his B. Eng. and M. Eng. degrees in imaging science from Chiba University in 1992 and 1994, and received his D. Eng. degree in process engineering from Osaka University in 2000. He has been a Research Associate at Osaka University since 1998. He is a member of the Imaging Society of Japan, and he received Research Encouragement Award of the Society of Electrophotography of Japan in 1997 and same Award of the Imaging Society of Japan in 2004.