Resolution Improvement on a-Si Photoreceptor Drums

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Abstract

Resolution improvement was attempted with the following two items :

- Adjustment in Boundary conditions of photosensitive layer and surface

protection layer of amorphous silicon drum.

- Adjustment of doping amount of impurity in photosensitive layer.

To achieve 600(dpi) high resolution, up till today, photosensitive layer thickness had to be reduced. But this time, high resolution was achieved without reducing photosensitive layer thickness. The minimum doping amount of impurity(B2H6) was identified, and by optimizing impurity doping amount, a kind of characteristics which has both charging capability and resolution capability was obtained. Here is the report to explain the details.

Introduction

Due to recent and rapid demand for higher resolution in printer market, 600(dpi) resolution is requested instead of 300(dpi), and 1,200(dpi) is requested instead of 600(dpi) these days. For higher resolution request from the market, thorough consideration of image processing technology and process matching procedure have been done. Therefore, the demand for improvement in photoreceptor itself to realize higher resolution is getting higher and higher.

As for photoreceptor characteristics, receiving image exposure from the exposure light source, forming latent image on the photoreceptor surface, and holding the latent image on the photoreceptor surface is important. This characteristics is determined by light response of photosensitive layer, carrier lifetime, carrier straight transfer, and retentivity of charge. Among them, carrier straight transfer is the most important factor of all for multi layer type photoreceptor drum.

Amorphous silicon drum is multi layer photoreceptor drum. When carrier, which is generated in photosensitive layer, moves to drum surface, it drifts and makes the latent image unclear. This time, by optimizing the boundary conditions between photosensitive layer and surface protection layer, carrier straight transfer is improved, which makes the resolution capability better.

Presently, as seen in the Figure 1, layer thickness is reduced to achieve higher resolution. In the present case, however, charging capability is sacrificed due to reduced layer thickness, thus resolution and charging capability are not satisfied at the same time. Reconfirming the resolution's layer thickness dependency and optimizing impurity doping amount(B2H6) to improve resolution without sacrificing charging capability, improvement was identified. Here is the report to describe the details.

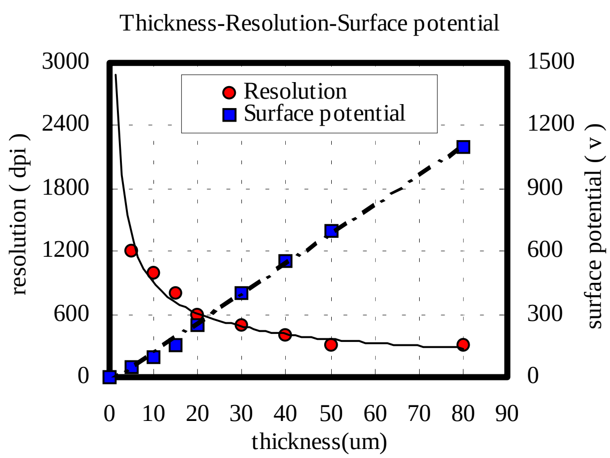

Figure 1. The relation of thickness-resolution-surface potential (before improvement)

Experiments

Amorphous Silicon drum is produced by Plasma CVD.AL substrate is set in the center part of cylindric electrode in a vacuum chamber. Then, gases(SiH4, H2, B2H6, CH4, etc.) are poured into the cylinder, and RF(Radio Frequency:13.56Mhz) is applied. This is how the layer is formed on the AL substrate (see figure 2). Amorphous silicon photoreceptor drum has three-layer structure, which is carrier blocking layer, photosensitive layer(a-Si:H), and surface protection layer(a-SiC:H) (see Figure.3).

For this experiment, an AL cylinder with diameter 30mm x 254mm length is used, and photosensitive layer and surface layer has been modified.

As for photosensitive layer, impurity doping amount (B2H6) is fixed and layer thickness is varied (10, 20, 30, 40, 50, 60, 70 and 80micron).

As for surface layer, the total layer thickness is fixed as 30 micron, but the gas ratio (CH4/SiH4) only is varied. Due to this, the gas ratio becomes higher in a gradual manner as it gets closer to the very surface. Basically, surface layer is formed in non-continuous discharge. After photosensitive layer is formed, RF discharge is stopped to do changing of the gas, and then, RF discharge is restarted again to make surface layer formed.

For resolution evaluation, actual printing is made with Kyocera printer ECOSYS FS-3700(600dpi). 1 dot resolution is mainly eliminated.

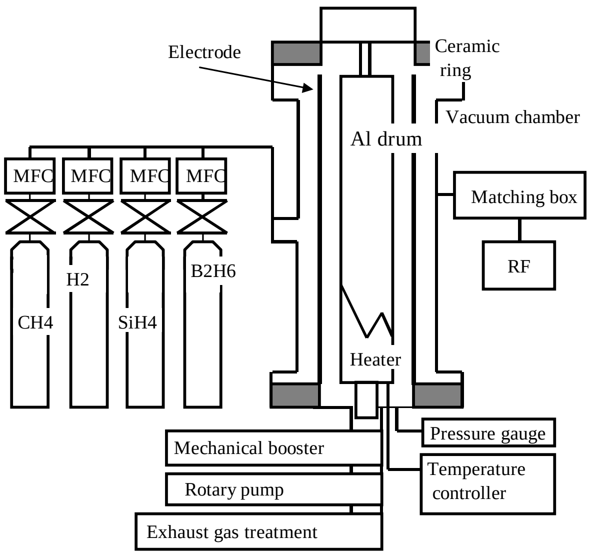

Figure 2. The schematics of diagram of plasma CVD equipment

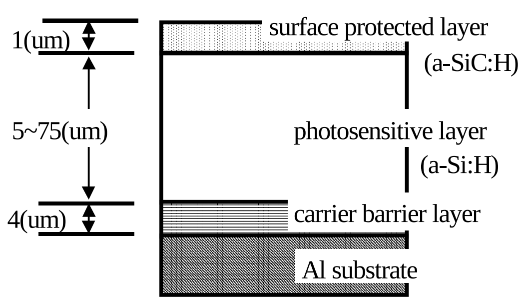

Figure 3. The structure of a-Si photoreceptor

Results

(a) Reconfirmation of Resolution's Layer Thickness Dependency

Figure 4 shows relationship between 1-dot diameter and layer thickness. When layer thickness is less than 20micron, diameter of 1-dot is 70micron.But when diameter becomes more than 30 micron, diameter of 1-dot keeps getting smaller and smaller, and when diameter becomes 60micron, the dot disappeared. These can be explained that spread of static latent image is in proportion to layer thickness (Mr.Williams).

$$W=(uEx)\cdot(d/uEx)=(Ex/Ez)\cdot d\ (cm) \quad (1)$$

where W is spread, Ex, Ez is internal field's factor in horizontal and vertical direction. d is layer thickness of photosensitive layer, u is dielectric factor.

When generated carrier by exposure moves up to the upper side of the surface layer due to internal field, the carrier is affected by vertical factor of the electric field. Because of this, carriers spreads apart by repelling force, and neutralize wider area than exposed area. As a result, toner's transfer area becomes wider in case of forward development which leads to larger dot diameter, while toner's transfer area becomes smaller in case of reversal development which leads to smaller 1 dot diameter. Though we took notice of the career moves to upper part of surface layer for this evaluation, as for a-Si photoreceptor, carrier generated area exist the upper part of photosensitive layer, so the carrier moving down towards the Al substrate (hole) cannot be ignored, however, we do not yet clarify the details.

Above is common in photoreceptor material, but in case of multi layer photoreceptor, carrier's spread in horizontal direction is more due to the fact that the carrier has to go from one layer to another which cause drift of the carrier. Improvement in resolution may be achievable as long as carrier's spread in layer boundary can be controlled.

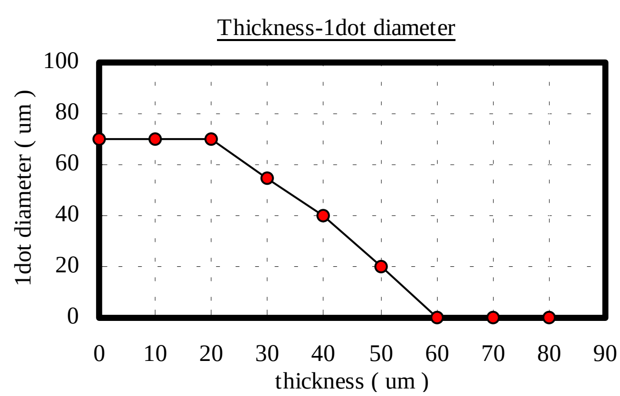

Figure 4. The relation with thickness and 1-dot diameter (before interface condition changed)

(b) Investigation in Interface Conditions

Though we kept photosensitive layer conditions by adding fixed amount of impurity doping (B2H6).

We only changed conditions of interface of surface layer by adding fixed amount of impurity –doping(B2H6).

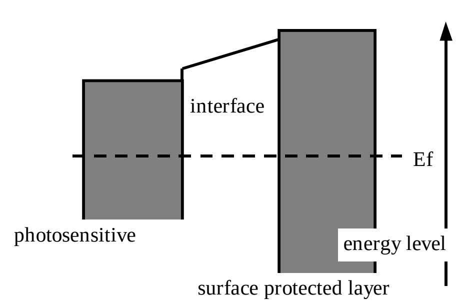

Figure 5. The image of interface between photosensitive layer and surface protection layer

Figure 5 shows an image of the interface between photosensitive layer and surface protection layer, and figure.6 and figure.7 shows the evaluation results. Surface layer thickness is approximately 1 micron.

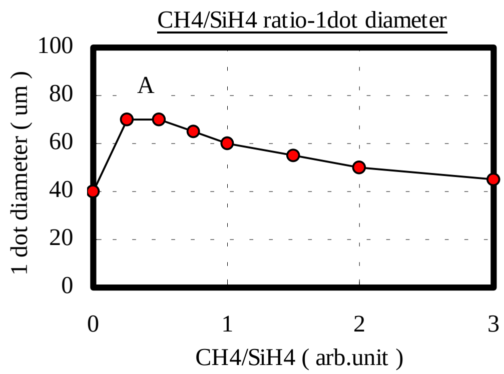

Figure 6. The relation with CH4/SiH4 and 1 dot diameter

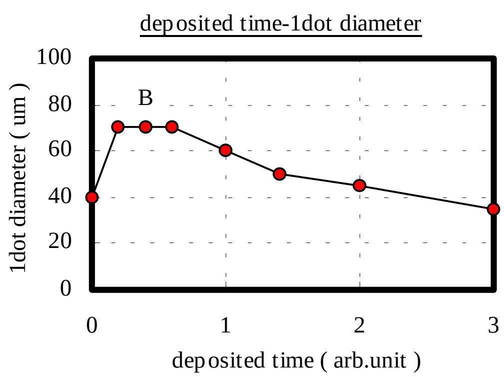

Figure 7. The relation with deposited time and 1 dot diameter

Under the condition that interface deposition time is defined, 1 dot diameter have a peak on a range from 0.25 to 0.50 (point A) at CH4/SiH4 ratio. Moving from point A, an edge part of a dot becomes blurred and 1 dot diameter is smaller gradually. Figure.7 shows that 1 dot diameter has a peak at point B under the condition that at CH4/SiH4 = 0.5.

Therefor, it is confirmed that the deposited time have a suitable range, too. According to these observations, it is confirmed that interface condition influences the resolution, also, necessity of interface and suitable condition of it will improve the resolution. From above, it is assumed that smaller CH4/SiH4 and thinner interface thickness can improve the straight transfer of carrier from photosensitive layer to surface layer.

(c) Investigation in Photosensitive Layer Condition

We reduced impurity doping amount (B2H6) to photosensitive layer from the suitable interface conditions which is mentioned (b), an edge part of one dot starts becoming blurred at point C in Figure.8, and further decrease in doping amount significantly worsen the resolution.

Reduction in B2H6 doping amount will make the layer more towards n type, therefore, the energy gap at interface between photosensitive layer and surface layer becomes larger, which leads to worse carrier straight transfer.

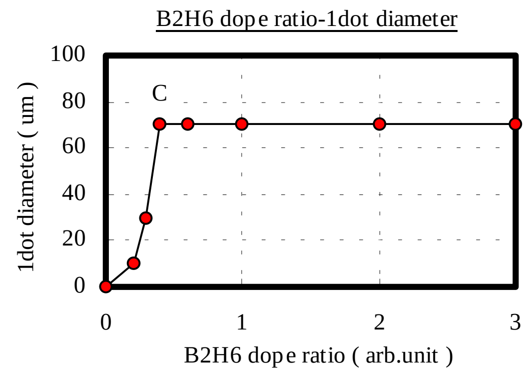

Figure 8. The relation with B2H6 dope ratio and 1 dot diameter

From above, we confirmed following point is necessary to improve resolution :

(1) Adjusted B2H6 doping amount in photosensitive layer

(2) Adjusted CH4/SiH4 ratio and the deposited time in interface condition.

By adopting the suitable condition, 1-dot resolution improves to the level where 1-dot diameter of 70micron with 40 micron layer thickness. (see Figure.9).

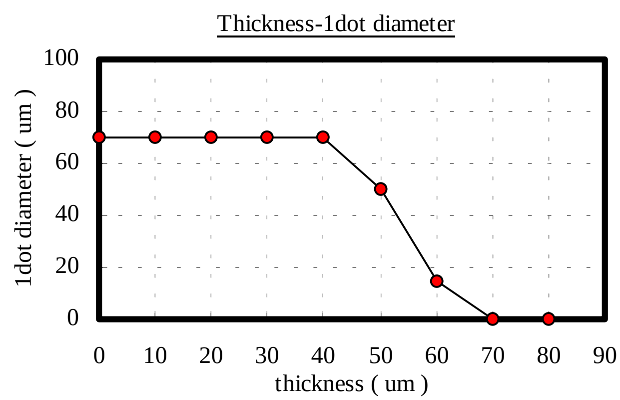

Figure 9. The relation with thickness and diameter (after interface condition changed)

(d) Addition of Low Rate Layer

Amorphous silicon photoreceptor has higher dielectric constant, therefore, charging efficiency is quite low. Therefore, charging capability can only be increased by increased layer thickness, which means increased capacity. As mentioned earlier, however, increase in layer thickness can not go beyond 40micron when considering high resolution capability. Increase in impurity doping amount (B2H6) is a method to increase charging efficiency. Although this is an option to consider, it is not the best option since it can cause lower resolution and lower sensitivity. In addition, it is known that decreased layer formation speed from 5(um/h) to 2.5(um/h) can increase the charging efficiency by 20%. However, it is not practical to implement since production efficiency will severely go down. Taking the positive side of above two ideas, a layer which is formed with half the speed and has impurity doping amount of point A in Figure.8 is added to the photosensitive layer which has appropriate doping amount of impurity. The added layer is called low rate layer. Because of this added low rate layer, charging efficiency is increased by 40%,maintaining sensitivity and resolution (see Figure 10).

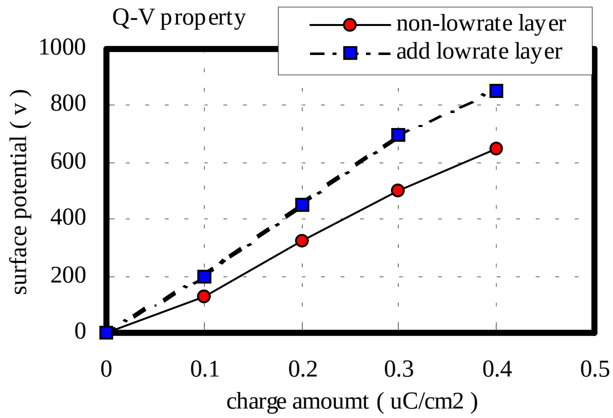

Figure 10. Q-V property (the effect of low rate layer)

Conclusion

Layer thickness adjustment, optimization of boundary and addition of low rate layer could improve both resolution and charging capability. Figure.11 shows relationship between improved layer's layer thickness and resolution and charging capability respectively.

Continuous improvement in resolution and charging capability is a vital points to pursuit in amorphous Silicon photoreceptor drum. Therefore, deep consideration will be given to further improve the amorphous silicon photoreceptor drum.

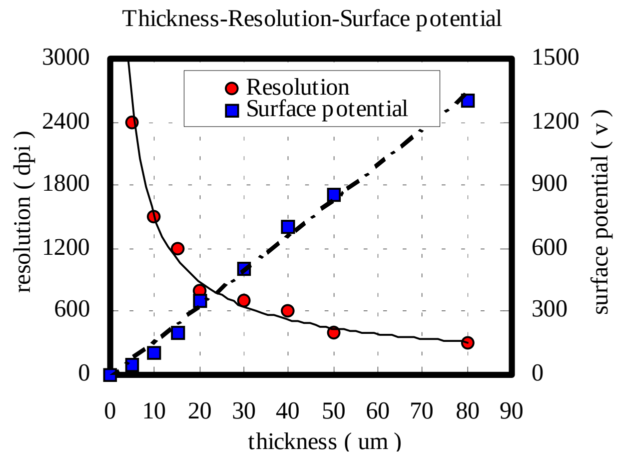

Figure 11. The relation to thickness-resolution-surface potential

Reference

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Biography

Masamitsu Sasahara graduated from Ibaraki University in 1992, then Graduated school of Ibaraki University in 1994 with the degree of MS in Electrical Engineering. Joined KYOCERA CORPORATION in 1994 and assigned at a-Si Photoreceptor Development Division in Shiga Plant, has been engaged in improvement of high resolution on a-Si photoreceptor drum up to the present.