

Development of Negative Charge a-Si Photoreceptor Drum

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Abstract

It has been said that when manufacturing negative charge photoreceptor drum using high frequency plasma CVD, doping V-group element to carrier blocking layer has been considered necessary. However, by investigating the influence of impurity-doping on the characteristics of a photoreceptor drum, we found that it is possible to manufacture a negative charge a-Si photoreceptor drum without doping. We've confirmed that the electric potential characteristics and reliability of a negative charge a-Si photoreceptor drum are almost the same as a existing positive charge a-Si photoreceptor drum.

In addition, the fact that potential drop by erase light of longer wavelength is smaller at a negative charge a-Si photoreceptor drum shows the possibility for developing a high charge type a-Si drum for use with near infrared light.

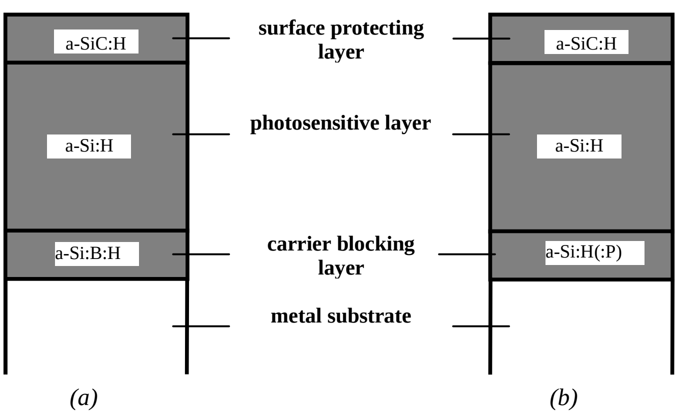

Figure 1. Layer constructions of (a) positive charge a-Si drum and (b) negative charge a-Si drum

Introduction

Amorphous silicon (a-Si) photoreceptor drums are used in the electro-photographic equipments featuring long life and high sensitivity. A-Si photoreceptor drums are also expanding their share in the market, because they are environmentally friendly and nontoxic. The standard charging polarity of photoreceptor drums in the market has been negative. On the other hand, a-Si photoreceptor drums under mass-production are charged only positive. So, in order to make the best use of a-Si's characteristics, it is necessary to develop a negative charge a-Si drum.

An a-Si photoreceptor is manufactured using high frequency plasma CVD. Fig. 1 (a) shows the layer construction of a positive charge a-Si photoreceptor drum manufactured presently and it consists of 3 layers. The first layer is carrier blocking layer since it is to prevent carrier injection from the metal substrate to photoreceptor. For the positive charge a-Si photoreceptor drum, p-type a-Si:B:H, which III-group element, boron (B) is doped to, is adopted to prevent electrons from injection. Second layer is photosensitive layer and third is surface protecting layer.

To manufacture negative charge a-Si photoreceptor drum, it is supposed necessary to dope V-group element such as phosphorus (P) to the carrier blocking layer to make it n-type semiconductor, thus preventing the injection of holes to photoreceptor, shown in fig. 1 (b).

We investigated the necessity of impurity-doping to the carrier blocking layer and optimized CVD process conditions. We'll report the way to manufacture a negative charge drum, the drum's characteristics and results of its reliability evaluations.

Experiment and Discussion

We actually manufactured the photoreceptor drums by various process conditions and evaluated drums' characteristics. In this development, we used high frequency plasma CVD onto ϕ 100 mm aluminum cylinder substrate and the layer structure consists of 3 layers, as same as a positive charge drum. The process conditions of the carrier blocking and photosensitive layers were varied, and a-SiC:H, which is adopted in the production of positive charge drums was applied for the surface protecting layer all the time.

Impurity-Doping to Carrier Blocking Layer

First, we manufactured drums with a-Si:P:H as carrier blocking layer by varying the flow amount of dopant gas, phosphine (PH_3). Here, in this experiment, photosensitive layer was undoped. Fig. 2 shows the relation between PH_3/SiH_4 ratio and surface potential of drum. It shows that, regardless of doping amount of phosphorous, the charge amount doesn't change and, as you can see, at 0 ppm doping the charge amount is same. This implies that doping any of impurities to the carrier blocking layer is considered unnecessary, and a semiconductor characteristics of n-type which undoped a-Si:H slightly indicates is enough to prevent injection of the holes. So, we decided to keep carrier blocking layer undoped for the following investigations.

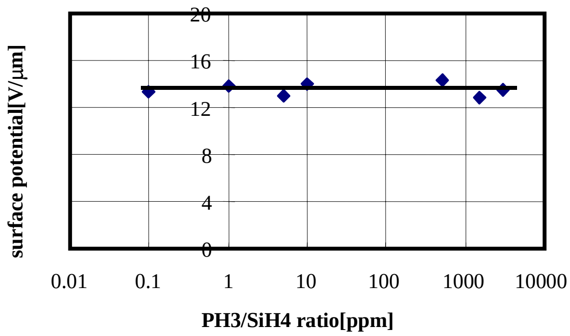

Figure 2. Relation between PH_3/SiH_4 ratio in carrier blocking layer and surface potential normalized by film thickness when charge amount Q is 0.3μC/cm^2.

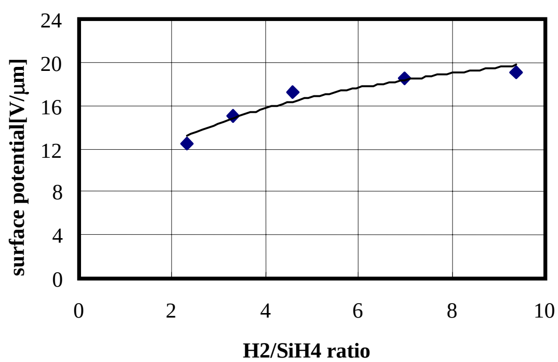

Figure 3. Relation between H_2 / SiH_4 ratio in photosensitive layer and surface potential normalized by film thickness when charge amount is 0.3μC/cm^2.

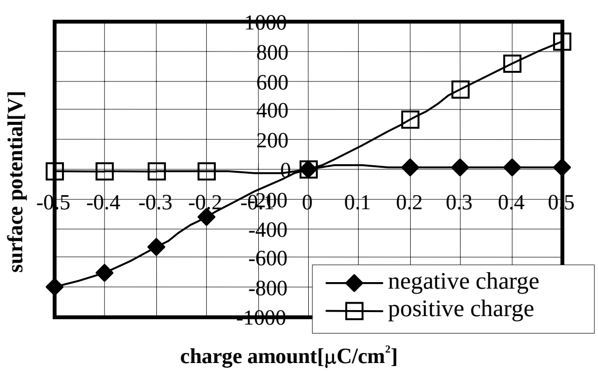

Figure 4. Q-V characteristics of negative and positive charge drums.

Dilution Adjustment

The second point is about the photosensitive layer. We found that charge amount changes by adjusting dilution. The relationship between H_2/SiH_4 ratio and surface potential is shown in Fig. 3. It can be considered that's due to the difference in combination state of silicon and hydrogen atoms.

Characteristics and Reliability of the Drum

Fig. 4 and Fig. 5 show Q-V and spectral sensitivity characteristics of the negative charge drum achieved under a optimum CVD process condition. It is confirmed that the electric potential characteristics of a negative charge drum are almost the same as a positive charge drum. And we found that it is possible to manufacture a negative charge a-Si photoreceptor drum without impurity-doping.

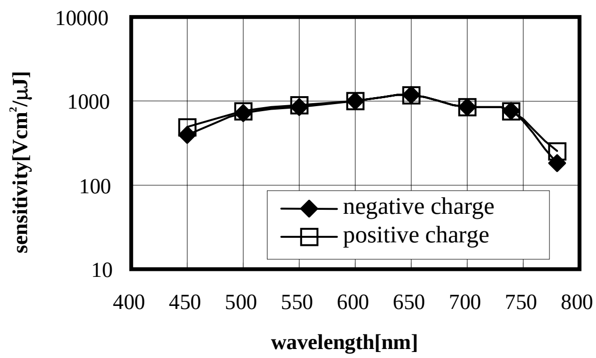

Figure 5. Spectral sensitivity characteristics of negative and positive charge drums to reduce surface potential from 500V to 50V .

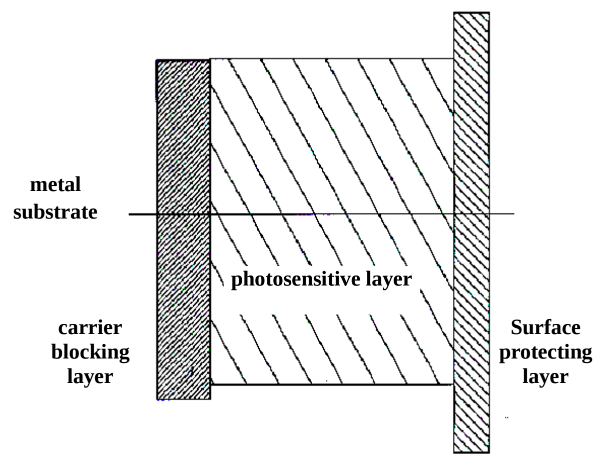

Figure 6. Band diagram of a negative charge a-Si photoreceptor drum.

Optical band gap and activation energy of each layer's film were measured and, in Fig. 6, we can know the band structure of a negative charge a-Si photoreceptor drum. Though the potential barriers are subtle, it is confirmed that the figure of the diagram is desirable for negative charging as a whole.

We tested the reliability of a negative charge drum in the same way as the positive charge drums. Regarding its stability against repeating charge / exposure / erasure process, as fig. 7 shows, characteristics fatigue was not recognized even as time went by. Also, it wasn't found even under the severe temperature change. Adhesion between the deposited film and the aluminum substrate was excellent and light-induced fatigue characteristics was as same as that of positive charge drums. Therefore, the negative charge a-Si photoreceptor drum which has been developed has the same reliability as the positive charge drums under mass-production.

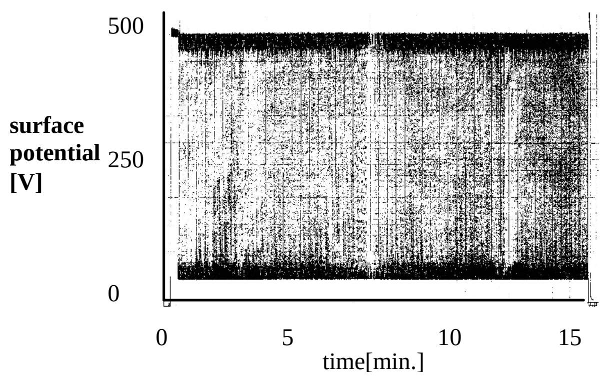

Figure 7. Characteristics stability against repeating charge / exposure / erasure process of a negative charge drum.

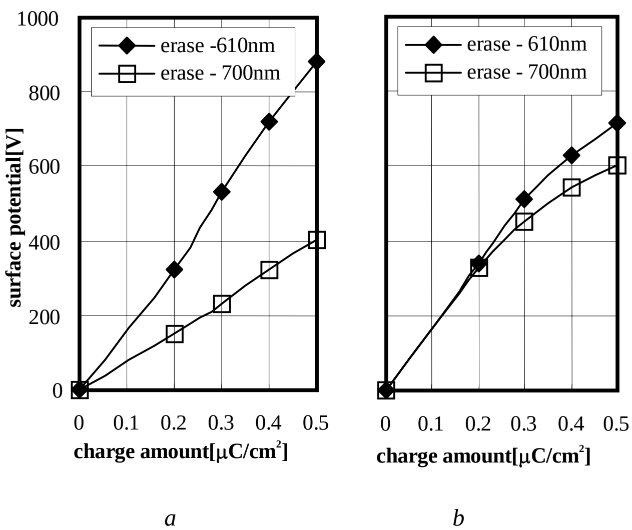

Figure 8. Difference in Q-V characteristics when wavelength of erase lamp is varied for (a) positive charge and (b) negative charge drum.

Future Possibility

Fig. 8 shows Q-V characteristics using erase lamps of different wavelengths for both positive and negative charge drums. The positive charge drum tends to have relatively inferior charging capability when using longer wavelength. In the case of negative charge drum, on the other hand, this variance wasn't shown remarkably. While the reason for the difference hasn't been well-investigated, it can be said that the number of carriers in negative charge photoreceptor, which are generated by erase light, trapped in photoreceptor film and moved to photoreceptor surface by next charging process, is smaller than that in positive one and reduces surface potential not so much. This means that it may be possible to develop a high charge type of a-Si photoreceptor drum for use in printers having exposure source of wavelength longer than 700nm for negative charging, though it has not been developed yet for positive charging.

Conclusion

We've successfully developed a negative charge a-Si photoreceptor drum which exhibits the same characteristics and reliability as positive charge a-Si drums under mass-production. It had been surprising result that impurity-doping is not necessary to manufacture a negative charge a-Si photoreceptor drum. However, safer and greater cost-off production can be realized because of reducing the need to use highly poisonous and expensive dopant gas. We obtained a fairly satisfactory printed image at its primary stage in an image evaluation of negative charge a-Si photoreceptor drum using Kyocera's printer, ECOSYS (which was remodeled for negative charging use). So its development for the use of near infrared light exposure and high charging is expected.

Reference

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Biography

Michinobu Tsuda received his B.S. and M.S. in electrical engineering from Mie University, Japan in 1994 and 1996, respectively. He joined Shiga plant, Kyocera Corporation in 1996 working on production engineering a-Si photoreceptor drum since 1996, and development of negative charge drum since 1997.