

Amorphous Silicon Photoreceptors: Homogeneity of Electrophotographic Properties

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Abstract

Small pixel size or high resolution necessary for gray scale and color reproduction requires a high uniformity of the electrophotographic properties of the photoreceptor. The uniformity of the properties depends mainly on the thickness of thin layers and interfaces in the multilayer photoreceptor structure and doping uniformity. Structure and properties of a-Si:H photoreceptors meet these essential requirements. We investigated the preparation of a-Si:H photoreceptors and the electrophotographic properties: charge acceptance, dark decay, exposure-voltage-(E-V-) characteristic, residual potential and sensitivity. We have shown that an non-uniformity below ± 3 % in respect of the full photoreceptor surface can be achieved.

Introduction

Amorphous Silicon photoreceptors have many excellent futures such as high sensitivity in the visible area of light, very high photoresponse and resistance to heat favorable for high-speed copiers.[1,2,3] Resistance to solvents makes it possible to use a-Si:H photoreceptors for liquid development. The good sensitivity in the long wavelength region makes a-Si:H photoreceptors suitable for LED and Laser printers.

However the main advantages are the abrasion resistance of the photoreceptor surface and the long life stability of the photo and dark characteristics. These are the prerequisites to make several million copies with nearly no degradation and therefore the same image quality.

The most promising method for industrial production of high quality amorphous silicon devices is the high rate Plasma Enhanced Chemical Vapour Deposition (PECVD) from Silane diluted in H_2 or Helium.[3]

The deposition process is comparatively time-consuming – an economic drawback. However this feature comprise the main advantages: it enables a definite adjustment of process conditions within a wide range to meet customers requirements and a high reproducibility in the realisation of layers and interfaces of the nanometer-scale.

The one chamber-manufacturing process eliminates the contamination of interfaces also.

High quality prints necessary for grey scale and colour reproduction require no visible point defects and a high uniformity of electrophotographic properties such as charge acceptance and the exposure-voltage-characteristics on the full photoreceptor surface.[4]

The multilayer structure of the a-Si:H photoreceptor on the one hand and the uniformity of layers, interfaces and the aluminium drum surface on the other hand are responsible for the high uniformity of these electrophotographic properties.

We have developed a-Si:H photoreceptors realized by high rate plasma CVD in a capacitively-coupled coaxial diode rf glow discharge with high uniformity of the electrophotographic properties and investigated the electrophotographic properties: charge acceptance, dark decay, residual potential and sensitivity.

Experimental

A schematic depiction of the capacitively-coupled glow discharge deposition system is shown in Fig. 1. In the centre of the reaction chamber is the aluminium drum as substrate with 80 mm in diameter and 358 mm in length.

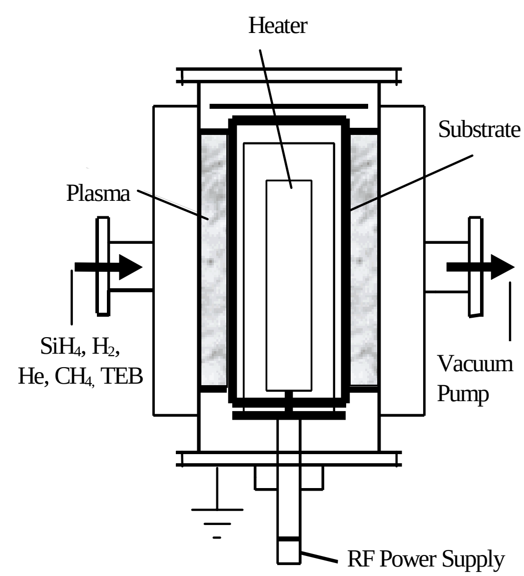

Figure 1. Coaxial glow discharge system.

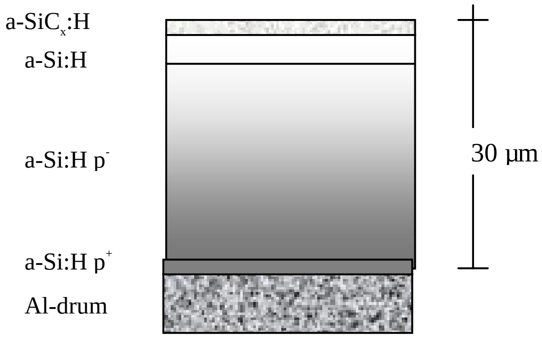

Figure 2. Photoreceptor structure.

The substrate is heated to temperatures ranging from 150°C to 300°C and rotated at the rate of 5 to 15 rpm.

The r.f. power of 27.12 MHz was applied to the aluminium drum.

The flow rates of different reactant gases during deposition of the multilayer structure (Fig. 2) were precisely controlled by mass flow controllers and introduced into the reaction chamber by a special gas feeding system of the grounded electrode.

Figure 3. Photoreceptor tester FAP-TM250.

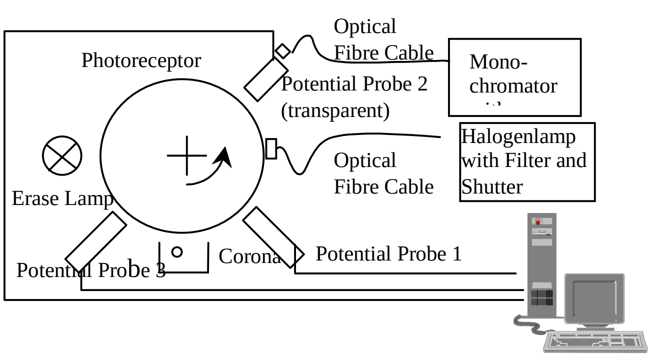

Figure 4. Schematic set-up of the photoreceptor-tester FAP TM250.

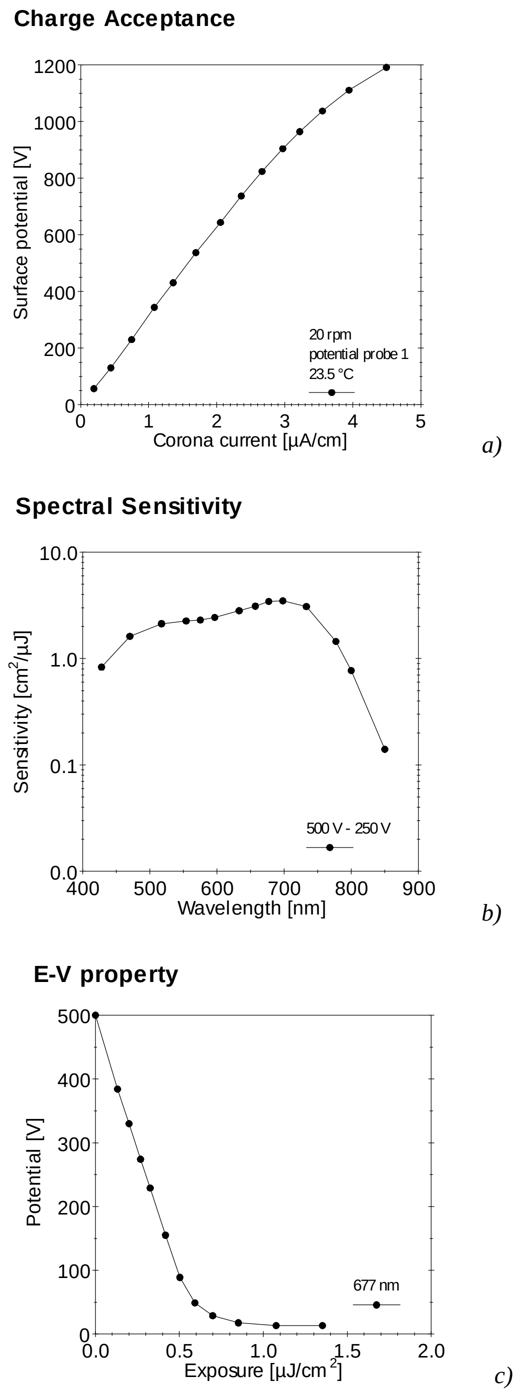

Figure 5. Charge acceptance a), sensitivity b) and the E-V property at 677 nm c) of the tested photoreceptor.

Measurement

A full automatic photoreceptor tester FAP- TM250 (Fig.3) was developed with a measurement set up (Fig.4) to adapt to customers' requirements for printers or copiers.

The FAP-TM250 photoreceptor tester allows an automatic scanning of the full photoreceptor surface (with the exception of an edge of 25 mm) inclusive data recording and visualisation. We used this mode to investigate the uniformity of the photoreceptor properties: charge acceptance, dark decay, residual potential and the exposure-voltage characteristic.

Layer thickness was measured by a commercial probe, point defects by an CCD based inspection system developed for a-Si:H drums.

Results and Discussion

The charge acceptance, spectral sensitivity and E-V characteristic at 677 nm of the tested photoreceptor is shown in Fig. 5.

The a-Si:H photoreceptor shows excellent properties, especially high sensitivity in the visible spectrum of light. The charge acceptance is lower in comparison with OPC due to the higher dielectric constant of the amorphous silicon.

In general the homogeneity of the properties is strongly controlled by the thickness of single layers. A thickness uniformity of +/- 3% was achieved.

Charge acceptance depends mainly on the electronic contact properties of the substrate-photoreceptor interface, the passivation layer interface and the thermally excited carrier generation in the photoreceptor volume.

The relatively thin thickness of the photoreceptor blocking and passivation layer requires a high uniformity in the deposition rate. Doping concentration controls the electronic contact substrate-photoreceptor and strongly the number of thermally excited carriers in the photoreceptor volume and with it the potential drop between charging and development of the latent image.

Fig. 6 shows a surface-map of charge acceptance and Fig. 7 the potential drop between probe 1 and 2, see Fig.4, over the measured range of the photoreceptor surface.

It shows that the uniformity of the charge acceptance is better than +/- 3 %.

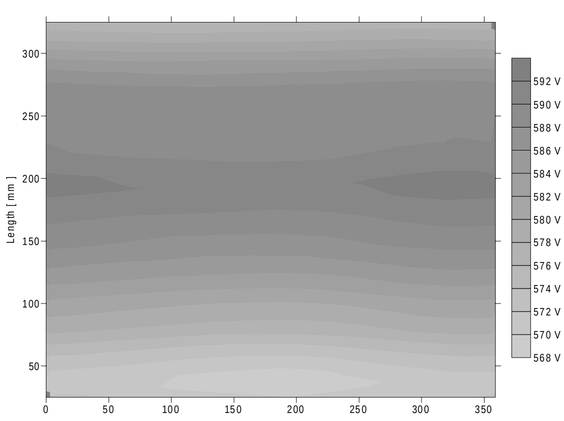

Figure 6. Surface-map of the charge acceptance of the measured range of the photoreceptor surface.

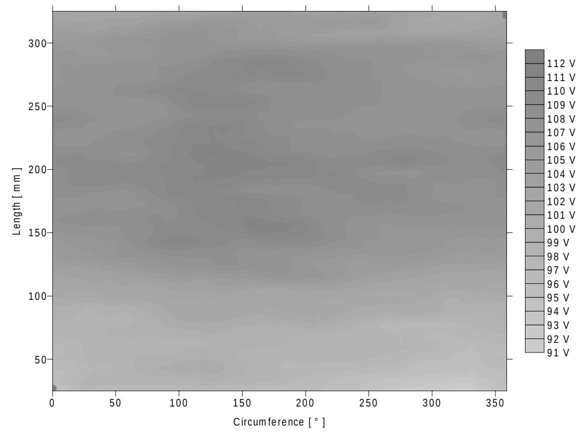

Figure 7. Surface-map of the dark decay between probe 1 and 2 of the measured range of the photoreceptor surface.

The homogeneity of the photoelectric properties is controlled by several factors.

The thickness of the photoreceptor determines for a definite potential the quantity of charges on the photoreceptor surface and with it the potential drop at a defined exposure.

The uniformity of doping controls the charge transport properties and with it the space charge distribution in the volume of the photoreceptor after exposure.

The thickness, the optical gap and the refractive index of the passivation layer are very important for the transmittance of light in the photoreceptor volume. Non-uniformity in the passivation layer results in a different potential drop at a defined exposure. This is particularly striking in the short wavelength range of exposure if the transmittance of the passivation layer is insufficient.

To demonstrate the homogeneity of photoelectric properties an examination of the potential drop at 500 nm for E = 0.5 µJ/cm^2 (Fig. 8) and the residual potential at probe 3 (Fig. 9) was done.

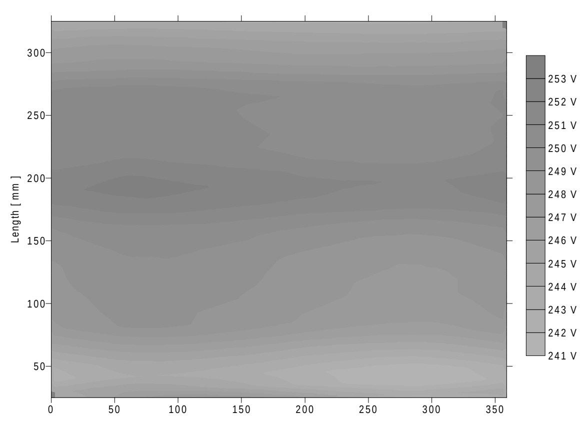

Figure 8. Surface-map of the potential drop at 500 nm for E = 0.5 µJ/cm^2 of the measured range of the photoreceptor surface.

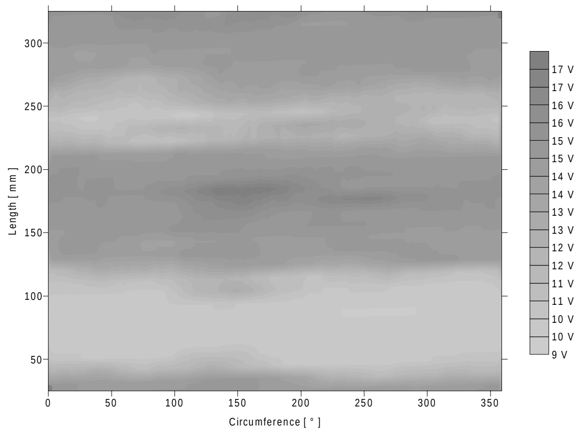

Figure 9. Surface-map of the residual potential at probe 3 of the measured range of the photoreceptor surface.

Conclusions

The multilayer structure and deposition process of amorphous silicon photoreceptors enables a definite adjustment of process conditions in a wide range and a high reproducibility in the realisation of nanometer-scale layers and interfaces. Surface-maps of the charge acceptance, dark decay, residual potential and potential drop at 500 nm show a good uniformity in the photoelectric properties. In conjunction with the long life stability the homogeneity of the electrophotographic properties of amorphous silicon photoreceptors will be a favourable feature require in high quality digital electrophotography.

References

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