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A CCD Image Sensor Overlaid with An a-Si:H/a-SiC:H Photoconversion Layer

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A new CCD image sensor overlaid with an a-Si:H (intrinsic) / a-SiC:H (p-type) photoconversion layer has been fabricated. An interline transfer CCD, having 500(V) x 400(H) cells, is used as a scanner to read-out signal charges generated in the a-Si:H/ a-SiC:H layer. The image area corresponds to a 2/3" format. A polyimide film is employed for CCD scanner surface smoothing. This device features high sensitivity, low blooming, low lag, and low burning.

§1. Introduction

Solid state image sensors overlaid with photoconductive layers have attracted various interests for their promising characteristics such as high spectral sensitivity and low blooming[1),2),3)].
A MOS sensor using RF sputtering hydrogenerated amorphous silicon (a-Si:H) film as a photoconductor has been reported[3)]. The a-Si:H film is suitable for a color sensor because the supply voltage can be reduced and the film can survive in on-wafer color filter process after the film deposition. In the sensor, an a-Si:H/ITO (Indium-Tin-Oxide) Schottky barrier junction has been employed to stop minority carrier (electron) injection from the ITO electrode.

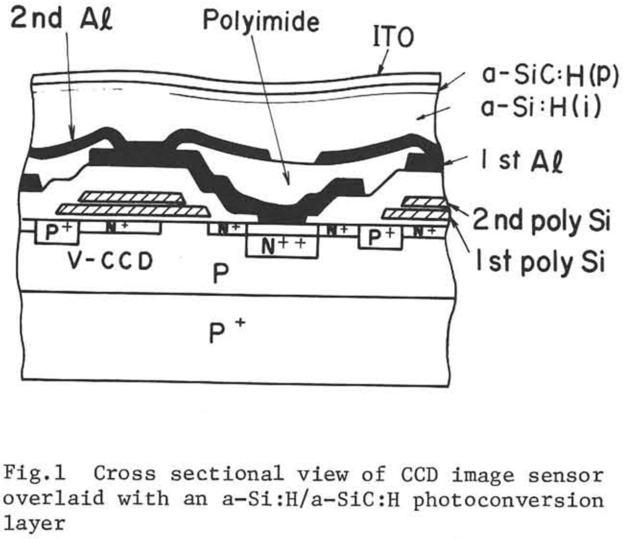

Fig.1 Cross sectional view of CCD image sensor overlaid with an a-Si:H/a-SiC:H photoconversion layer

We have fabricated a new CCD image sensor overlaid with an a-Si:H (intrinsic) / a-SiC:H (p-type) photoconversion layer produced by glow discharge. The p-i junction blocks the previously mentioned minority carrier injection as does the Schottky barrier in the MOS sensor. Device structure, fabrication and performance are described in this paper.

§2. Device Structure and the Fabrication

Figure 1 shows a cross sectional view of a unit cell in the device. The unit cell consists

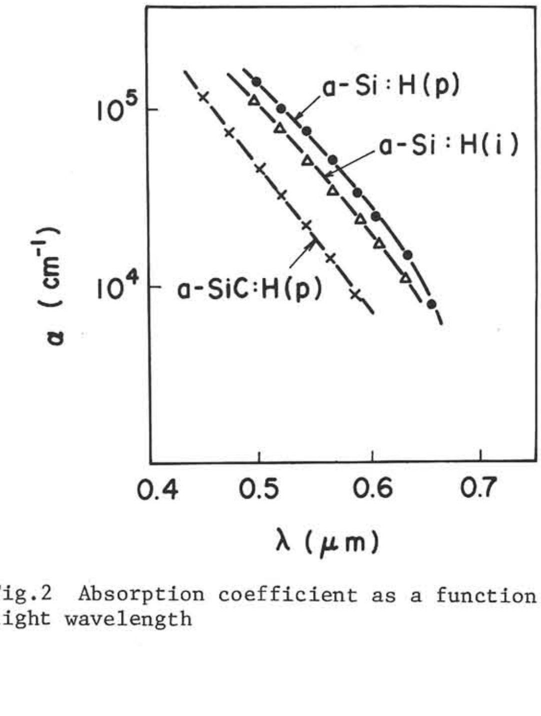

Fig.2 Absorption coefficient as a function of light wavelength

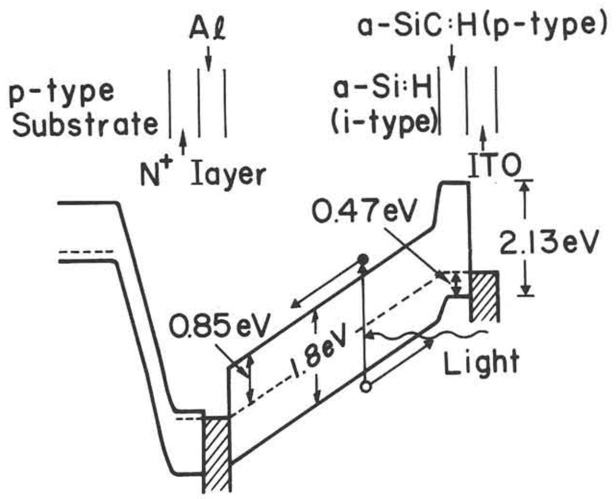

Fig.3 An energy band diagram for the photoconversion region and the storage region

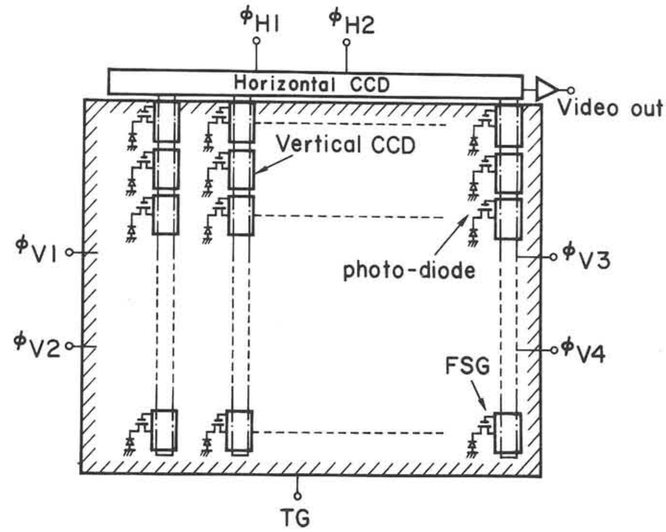

Fig.4 A device organization diagram

of an a-Si:H/a-SiC:H photoconversion layer, a storage diode and a half stage of vertical CCD (V-CCD). The a-Si:H/a-SiC:H layer, produced by glow discharge, is formed on top of the CCD scanner. The CCD scanner for reading out signal charges generated in the photoconversion layer is constructed with an interline transfer CCD (IT-CCD) having double poly Si electrodes and two-level Al electrodes. The device is fabricated on a P/P^+ epitaxial Si substrate. The P type layer has 5 Ω·cm resistivity, and 10 μm thickness. The P^+ substrate has a low life-time for minority carrier diffusion, and the resistivity is 0.05 Ω·cm. With this substrate, those unnecessary charges which are generated in the bulk or at the back of the chips and flow into a P type active region are successfully avoided. A polyimide film is employed for surface smoothing and acts as an insulative layer between those two-level metals. The surface smoothing contributes to considerably decreasing image defects.

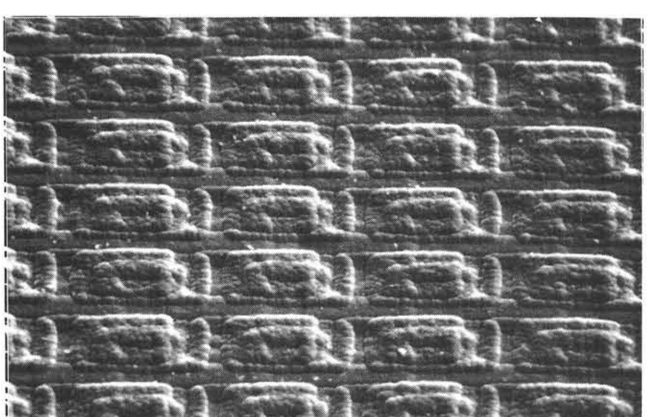

Fig.5 SEM photomicrograph showing device surface

An intrinsic a-Si:H film (undoped) and a P type a-SiC:H film (B doped) are continuously deposited on the IT-CCD scanner. The average a-Si:H film thickness is 3 μm. Resistivities for each film are 1.5×10^{10} Ω·cm for a-Si:H film and 5×10^{6} Ω·cm for a-SiC:H film, respectively. Figure 2 shows an absorption coefficients (α) as a function of light wavelength for these films, in comparison with that for a P type a-SiH: film (B doped). As shown in the figure, the a-SiC:H film acts as a desirable window, as in the case of a solar cell. The ITO (Indium-Tin-Oxide) film for applying voltages to the amorphous p-i junction is formed on top of the P-type a-SiC:H layer by dc-magnetron sputtering. It acts as an overflow drain for excess charges under intense light illumination.

Figure 3 shows an energy band diagram for the photoconversion region and the storage diode region. The P-type a-SiC:H film acts as a barrier to stop minority carrier injection from the ITO electrode. Signal charges, electrons, generated in the a-Si:H film, are transfered to the storage diode by an electric field in the film, and stored there. Band gaps for each film are 1.8 eV for a-Si:H film and 2.13 eV for a-SiC:H film, respectively. Activation energy values are 0.85 eV for a-Si:H film and 0.47 eV for a-SiC:H film, respectively. A diagram showing the device organization is shown in Fig. 4. The read-out elements from the

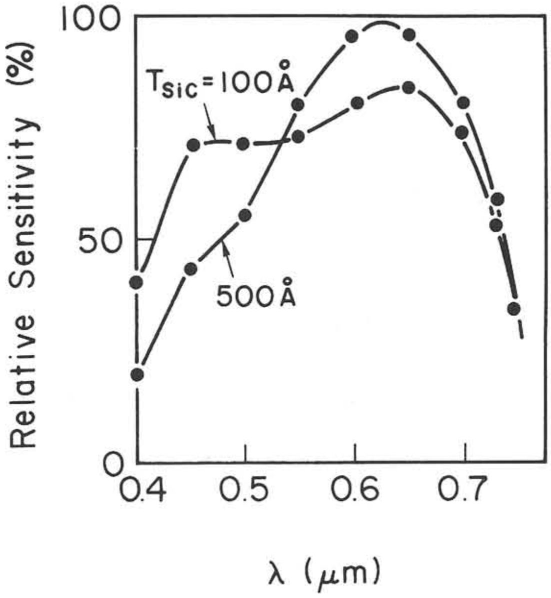

Fig.6 Relative spectral response curves for devices with different thicknesses

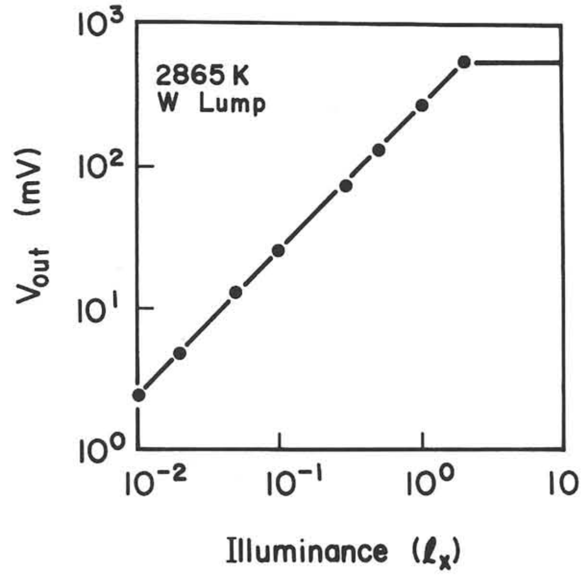

Fig.7 Device photoconversion characteristic

device are 400 (H) x 500 (V). Effective picture elements in the imaging area are 378 (H) x 486 (V). Driving modes for CCDs used in this device are four phase operation for V-CCD and two phase operation for H-CCD, respectively.

Figure 5 shows an SEM photomicrograph of the device surface. Cell size is 22 μm (H) x 13 μm (V). The second Al electrode, which contacts the a-Si:H film, is 19 μm (H) x 10 μm (V). Thus, the effective aperture occupies 66 % of the unit cell area.

§3. Performance

In this device, signal charges generated in P-type a-SiC:H layer do not effect the signal output voltage from the device, because of the low photoconductivity and the low electric field built in the film. Therefore, a thin a-SiC:H film, having good uniformity, needs to obtain high sensitivity over the whole visible light spectral region. Figure 6 shows relative spectral response curves for devices with different a-SiC:H film thicknesses. As shown in the figure, a device with 100 Å thick film has a flat spectral response

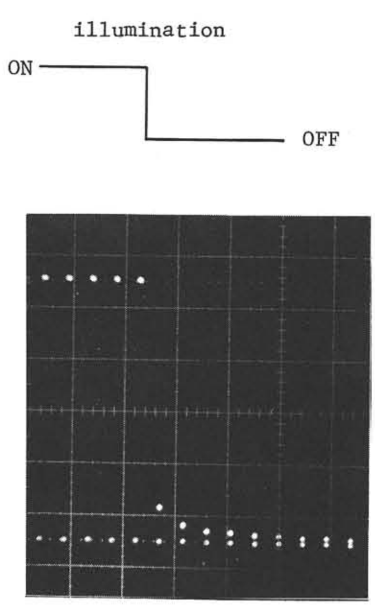

Fig.8 Decay lag characteristic

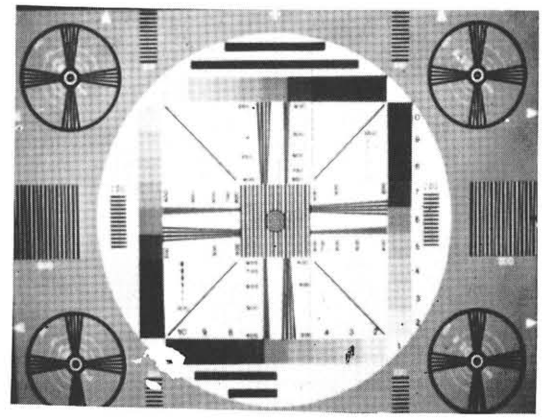
Fig.9 An image picture of a RETMA resolution chart

thoughout the visible light region. On the other hand, the sensitivity of a device with 500 Å thick film is low at the short wavelength region.

Figure 7 shows photoconversion characteristics for the device with 100 Å thick a-SiC:H film. The sensitivity is 0.14 μA/lx under 2856 K illumination. The measured γ value is nearly equal to unity. The dark current was 2 nA at 27°C.

Figure 8 shows a decay lag characteristic. For the light source, 550 nm radiations emitted from LEDs, are used. The signal level under the light illumination is a half of the saturation level. The image lag value was 5 % at the third field. In this device, the lag is mainly decided by a photoconductive phenomena in the a-Si:H film. An image picture of a RETMA resolution chart, taken by this device, is shown in Fig. 9. Horizontal and vertical limiting resolutions are 280 TV lines and 400 TV lines, respectively.

§4. Conclusion

A new CCD image sensor overlaid with an a-SiH/a-SiC:H photoconversion layer has been fabricated. These double layers are produced by glow discharge deposition. The CCD scanner is constructed with IT-CCD having 400 (H) x 500 (V) elements. CCD scanner surface smoothing has been achieved by using a polyimide film. This device features high sensitivity, low blooming, low lag and low burn in.

Acknowledgements

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