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Amorphous Silicon Thin Film Phototransistor

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Amorphous Silicon thin film phototransistor was made on glass substrate. Preliminary results showed that the design principle is feasible, the device is stable. Nevertheless, the collector current of 45 A exhibits a gain of 15 at a level of an input illumination power of 500 $\mu w/cm^2$ under 660nm LED light. The device area is $7x10^{-2}cm^2$. The switching speed of the present device is around 500 micro second.

§1. Introduction

Various electronic devices can be fabricated on glass substrate1) at very low temperature (about 300°C), which opens large amount of application developments for low cost, flat panel display , sensors, such as high efficiency a-Si solar cells2) a-Si FET3) a-Si CCD4) etc. In this report, an a-Si bipolar type of phototransistor was successfully fabricated on glass substrate for the fivst time.

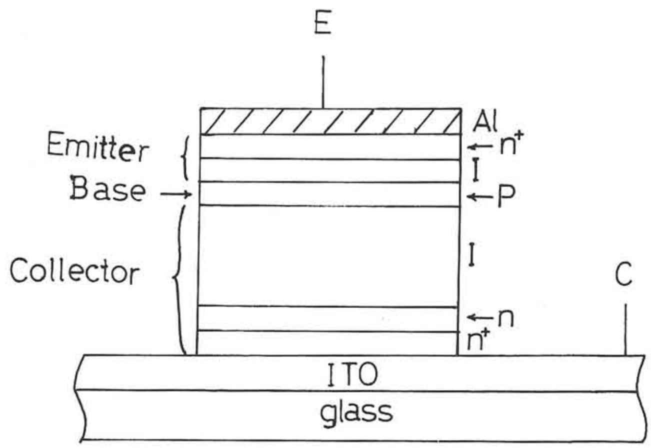

Fig.1 The crosection of a-Si phototransistor.

§2. Experimental

The device structure is shown in Fig. 1. The device area is $7x10^{-2}cm^2$. A ITO coated glass plate was used as the substrate. After the substrate cleaning process, the sample was put into the anelva's model PED 301 Plasma CVD reactor . The vacuum pressure was kept $2x10^{-7}$ torr for further heating cleaning process, during this processing period, the substrate temperature was kept at 250°C for 60 mininutes. Then let the silane/H_2/PH_3 flow into the chamber. Turned on the RF generater to 40W and adjusted the flows to obtain a vacuum pressure of 1 torr and started to grow. By introducing phosphine gas simultaneously, a layer of 50 Å micro-crystalline layer was formed first. Then subsequently reduced the PH_3 flow to grow a layer of 50 Å amorphous N^-, and amorphous I-layer of 5000 Å (evacuating to $2x10^{-7}$ torr again and then introducing SiH_4/H_2 but stopping the PH_3 flow). This $n^+/n^-/i$ layer was formed as the collector region.

In order to grow base (P-type) layer upon it, B_2H_6/H_2 flow was added and proceded the growth for 3 min to get 300 Å P-layer. Then emitter i and n layers with 300 Å and 700 Å thickness respectively were successively grown. Finally aluminum layer of 5000 Å thickness was formed. The energy band diagram are shown in Fig.2 (a), (b).

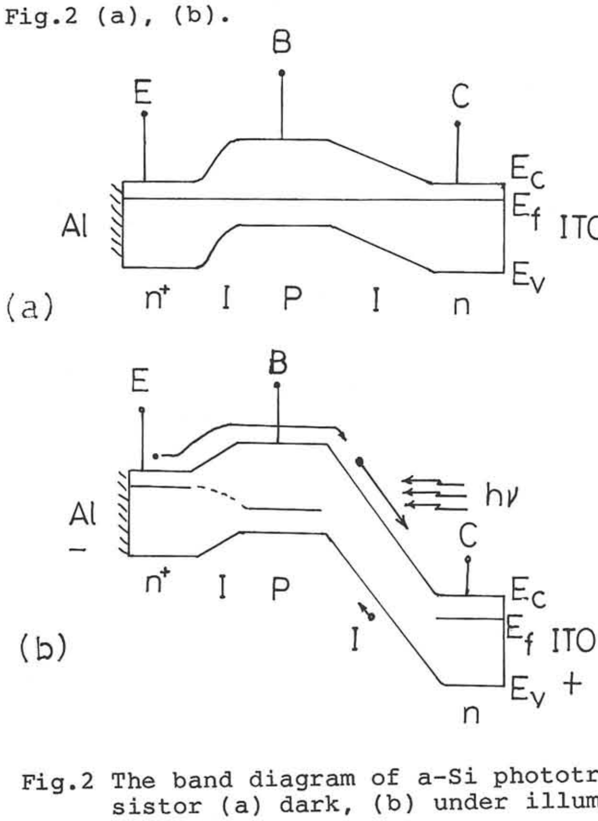

Fig.2 The band diagram of a-Si phototransistor (a) dark, (b) under illumination.

§3. Results of Measurement

A LED with peak intensity at 660 nm was used as signal source, and a Tektronix 177 oscilloscope was used to measure the photo response of the a-Si phototransistor. The photograph of the I/V characteristics with incident light power as parameter is shown in Fig.3., which shows that the I/V response of a-Si phototransistor is almost the same as that of c-Si phototransistor (crystalline silicon phototransistor) except in the low voltage saturation region, the collector current Ic increases with increasing reverse bias more slowly.

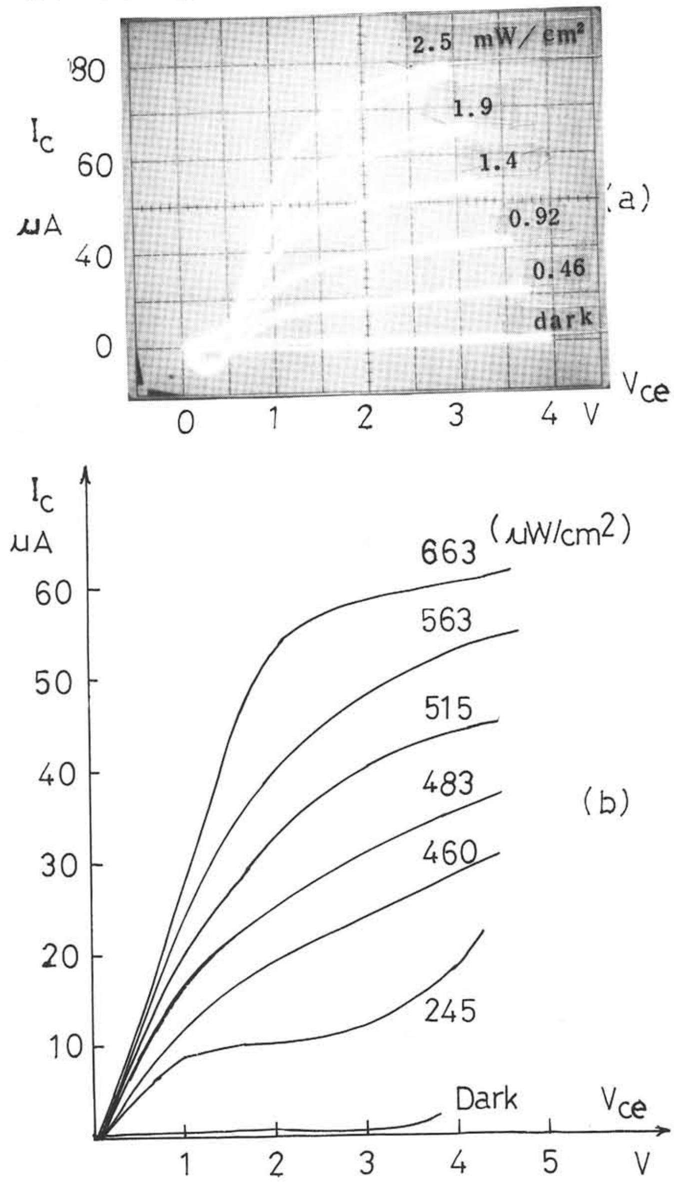

Fig.3 The photo I/V characteristics of a-Si phototransistor (a) under high light intensity (b) under low light intensity.

We propose a simple model as shown in insert of Fig.4 to interprete this phenomenon. The model is composed by putting an additional resistance[5]. This is the effective resistance of a-Si I-layer in collector side of the phototransistor. It is dependent on the photoconductivity of a-Si material and can be obtained from the reciprocal slop of photo I/V characteristics. Fig.4 shows the collector effective series resistance of the a-Si phototransistor which decreases with increasing LED intensity.

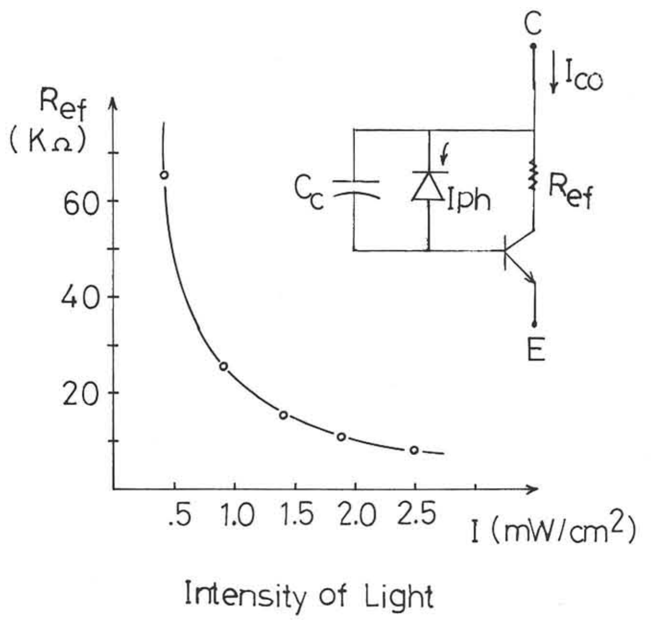

Fig.4 The collector effective resistance vs. light intensity. The insert is the proposed simple a-Si phototransistor model.

To investigate the dynamic response of the a-Si phototransistor, a chopped 6328 Å He-Ne beam was used as input source and HP 1980B oscilloscope. System as output response display to measure the rise time and fall time of the a-Si phototransistor. Fequency of the chopper is 265 Hz. Fig.5 shows the dynamic measuring system and the photograph of these results and are shown in the bottom side of Fig.6.

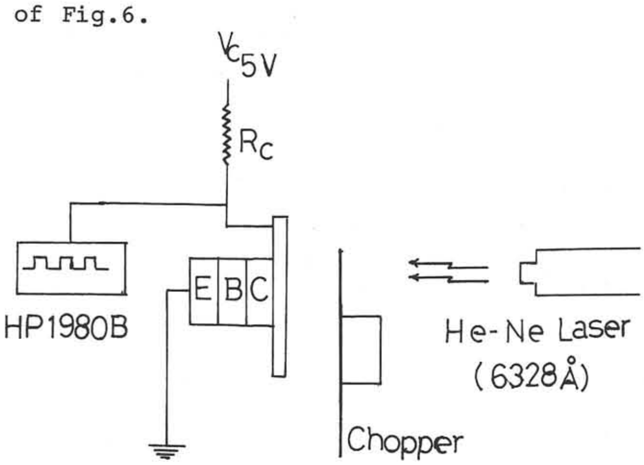

Fig.5 The dynamic photo responce measurement system.

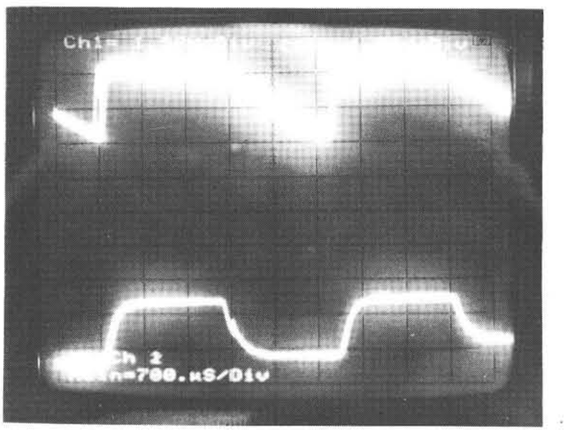

Fig.6 The dynamic response of C-Si phototransistor (the upper side) and the dynamic response of a-Si phototransistor (the bottom side).

In upper side, for the purpose of comparison, we also show the dynamic response of C-Si phototransistor [Fine Products microelectronics cat. No. FPT-0125]. With this figure, we estimated the rise time and fall time of a-Si phototransistor are 300 μsec and 550 μsec respectively. In addition, it is found that the a-Si phototransistor possess longer rise time and shorter fall time than that of C-Si. We suppose this is a results of quick recommination of electron-hole pair, since a-Si is a trap-rich material. The recom-hination rate of light induced electron-hole pair is enhanced. So the amount of electrons and holes reach respective electrode decreses thus the slower rise time and the faster fall time occurs.

§4. Concluding Remarks.

Based on the measured results of our preliminary study, the a-Si phototransistor show some positive performances to be as good as a candidate light switching control elements e.g., its variable collector effective resistance in low bias region, i.e., smaller in low light intensity and larger in high light intensity makes it becomes a higher noise -margin swiching element, than that of phototranistor. Its quick dynamic response also promises in higher frequency switching contral system.

References

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