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High Speed Contact Type Linear Sensor Array Using a-Si pin Diodes

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A new contact type linear sensor array has been successfully developed which employs a-Si pin diodes as blocking diodes and photo-diodes. This sensor consists of 400-bit (8 bit/mm) photosensors, and its overall length is 50 mm. It has the advantages of easy fabrication and connection with a scanning circuit. Moreover, it is possible for this sensor to read an A4 size document at a speed of less than 5 ms/line. Therefore, it is useful as a contact imager for small size facsimile equipment.

§1. Introduction

Recently, much effort has been devoted to applying amorphous silicon (a-Si) to practical electron devices such as field-effect-transistors, image pick-up devices, electrographic printers and image sensors. In particular, the application to a contact type linear sensor array has been actively investigated.[1-4] As this sensor is the same size as the document width, for example, 216 mm in the case of A4 size, it can read the document without an optical lens system. Therefore, this sensor holds great promise for small-sized facsimile equipment. Several examples of such type of sensor have already been proposed.[1-4] However, these sensors have problems in that a large number of switching transistors are required, and their structures are complicated. In order to avoid these difficulties, we have developed a new-type linear sensor using a-Si pin diodes for blocking diodes as well as photo-diodes.

The fabricated sensor is a 400-bit (8 bit/mm) photosensor array, and its overall length is 50 mm. It takes full advantage of the characteristics of a-Si pin diode, which exhibit good photo-sensitivity, high response speed, excellent rectification, and the capability for deposition over long or large areas. An attractive feature of this sensor is that the number of terminals connected to the scanning circuit can be reduced by employing a 20 x 20 matrix-drive method. Moreover, it is possible for this sensor to read an A4 size document at a speed of less than 5 ms/line, fast enough for the GIII mode facsimile. In this paper, the drive-method, structure, fabrication procedures and the performance of this sensor are described.

§2. Equivalent Circuit and Drive-Method

Figure 1 shows the equivalent circuit configuration of this sensor. In order to drive a matrix configuration, each photo-diode is connected in series, in the reverse direction to its blocking diode. The operational principle of the drive-method employed here will be described briefly by

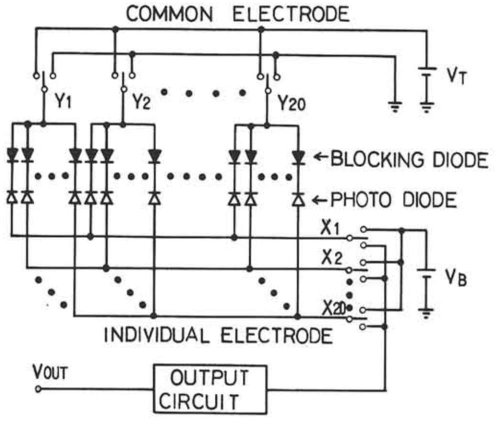

Fig. 1 Equivalent circuit configuration for the fabricated sensor.

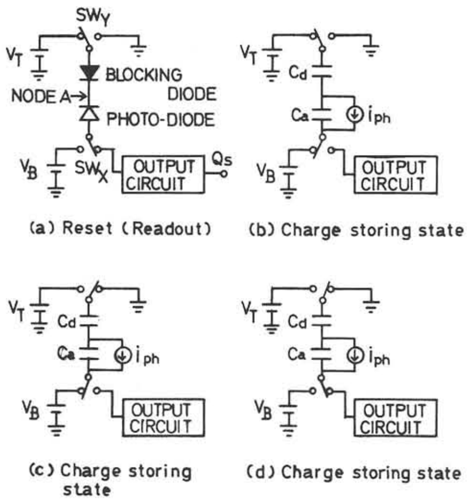

Fig. 2 Four states of the picture element.

way of equivalent circuits as shown in Fig.2. A pair of a blocking diode and a photo-diode are illustrated in this figure, which shows four states selected by a pair of switches SW_Y and SW_X . First, the sensor is connected to the voltage source V_T through the switch SW_Y and to the output circuit through the switch SW_X. Thus, the initial charge is provided to node A through the blocking diode (Fig.2(a)). Then, the sensor is connected to the voltage source V_B, so that the blocking diode is reverse-biased (Fig.2(b)). As reverse current of a blocking diode is extremely small, the photo-diode is isolated from the other circuits, and thus, cross-talk between photo-diodes is prevented. At this time, the blocking diode and photo-diode act as the equivalent capacitors C_d and C_a, respectively. Consequently, the charge at node A is discharged by the photo-current i_{ph}, and the photo-signal charge is stored at node A. This stored charge (Qs) is read out by the output circuit applying a reset pulse to the sensor. Although the three states shown in Fig.2(b),(c),(d) are charge storing states, the charge (Qs) is primarily stored in that state shown in Fig.2(c).

§3. Structure and Fabrication Procedures

The schematic cross-section and diagram of this sensor are shown in Fig.3 and Fig.4, respectively. The fabrication procedures are as follows. First, 0.2 μm thick Cr stripe electrodes are formed on a glass substrate measuring 30 mm by 75 mm. Next, a-Si film is deposited to a total thickness of 0.6 μm, with the n-layer first, to be followed by the i-layer and p-layer. The thickness of each layer is 0.03, 0.55, 0.02 μm, respectively. This deposition is performed in an R.F. glow discharge chamber using SiH_4 gas diluted with H_2 gas at a substrate temperature of 230 °C. The doping is done using phosphine (for n-layer) and diborane (p-layer). This a-Si film is patterned photolithographically to a size of 100 x 150 μm by dry-etching using CF_4 gas. Then, a 2 μm thick SiO_2 film is formed by an R.F. sputtering method. This serves both as a cover to prevent the a-Si edge portion from shorting out, and as an insulator for double layer inter-connection. Contact holes 70 x 100 μm are formed in this SiO_2 film as shown in Fig.3. Then, a 0.5 μm thick ITO (Indium Tin Oxide) film is deposited by R.F. sputtering and becomes the transparent electrode of the photo-diode. Finally, Al (1.5 μm thick) is deposited by means of vacuum-evaporation so as to form blocking diode electrodes

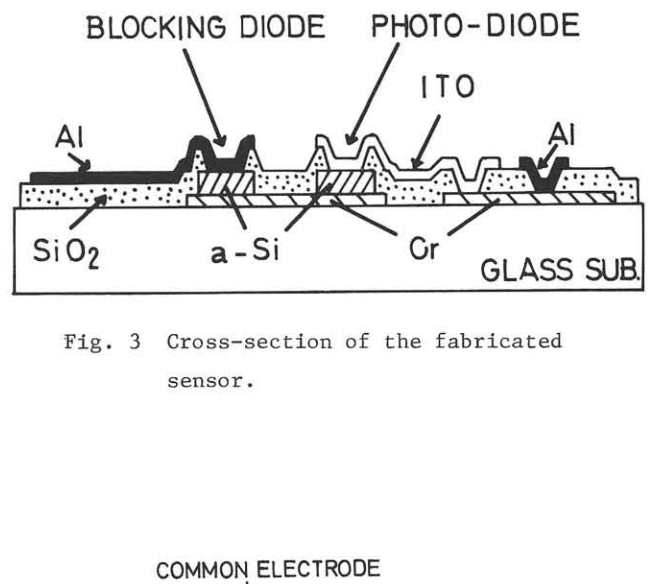

Fig. 3 Cross-section of the fabricated sensor.

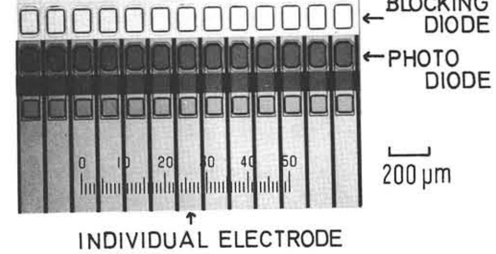

Fig. 4 Diagram of the fabricated sensor.

as well as common and individual electrodes. The Al electrodes for the blocking diodes serve as light shielding film. In this sensor, the photo and blocking diodes are made from the same a-Si pin film. This fact results in a greatly simplified sensor fabrication process. The appearance of the fabricated sensor is shown in Fig.5.

§4. Characteristics of Blocking and Photo Diode

The blocking diode is used to suppress cross-talk between picture elements. Therefore, it has to display excellent rectifying properties. The typical I-V characteristics of a blocking diode fabricated for this purpose are shown in Fig.6. As a result of the optimized a-Si deposition condition, a rectifying ratio of as high as 10^{10} or more has been obtained at voltages higher than 2 V with a diode quality factor of about 1.2. In case of one chamber R.F. glow discharge equipment, a-Si pin diode with a top p-layer show better rectifying properties than diode fabricated with a top n-layer. The reverse and forward characteristics of a-Si pin diodes are determined by area of the a-Si film and contact hole, respectively. No leakage current through the a-Si edge is observed. The typical irreversible break-down voltage is about 25 v.

The spectral sensitivity of the photo-diode at a reverse-biase of 2 V is shown in Fig.7. The sensitivity has a peak at about 550 nm where its quantum efficiency is 0.7 . The photocurrent of the diode is about 60 nA/lx.cm^2 . On the other

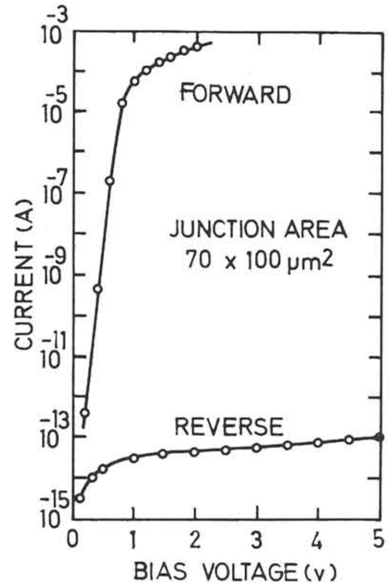

Fig. 6 I-V characteristics for the blocking diode.

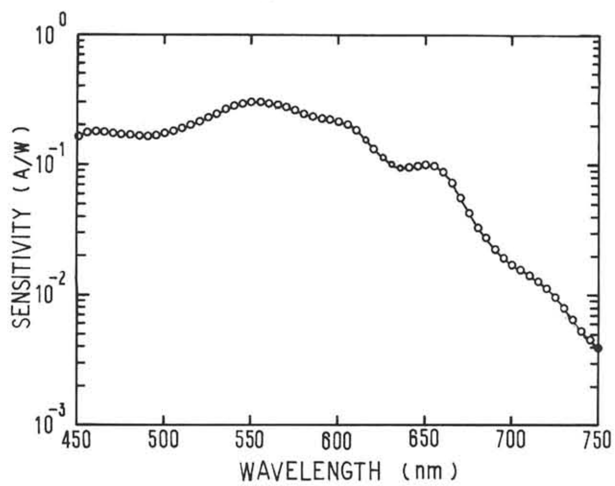

Fig. 7 Spectral sensitivity of the photo-diode.

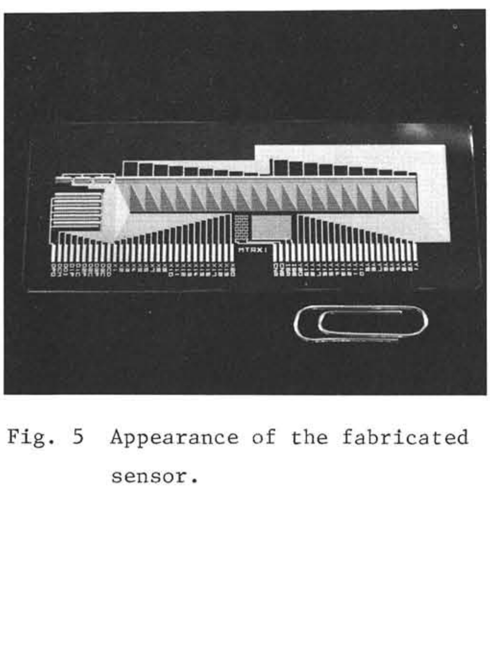

Fig. 5 Appearance of the fabricated sensor.

hand, its dark current is the same as the reverse current of the blocking diode. Thus, the ratio of the photo current under an illumination of 100 lx to the dark current is greater than 6 x 10^3. In addition, it has a high speed responsivity with a response time of less than 3 μs.

§5. Performance

This sensor is connected to the scanning circuit by a flexible cable. Experimental results obtained using this sensor are summarized in Table 1. As the readout time per pixel is 2.23 μs, it is possible for this sensor to read an A4 size document at a speed of less than 5 ms/line. The saturation exposure is about 0.5 lx.s. Deviation of the sensitivity is in the range of ± 7 %, and the S/N ratio is about 20 dB. The noise component is primarily due to clock noise, and therefore can be reduced.

§6. Summary

A new-type linear sensor has been developed which employs a-Si pin diodes as the blocking and photo-diodes. This sensor permits easy fabrication and can be elongated to 216 mm or more. It exhibits satisfactory performance and can read an A4 size document at a speed of less than 5 ms/line.

It has been confirmed that this sensor can be used as a contact imager for facsimile equipment.

Acknowledgements

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Table 1 Characteristics of the fabricated sensor.

Item	Characteristics
Readout time	2.23 μs/bit
Saturation exposure	0.5 1x.s
Uniformity	± 7 %
S/N ratio	20 dB

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