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A Pb_2CrO_5 Thin Film Photo-Sensing Device with High Line Image Density

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A photodetector array for line image sensing is fabricated using an Au-diffused Pb_2CrO_5 thin film evaporated on a glass plate. The device has a very high line image density of 48 elements per mm, and operates in the visible and ultraviolet regions. The ratio of photocurrent to darkcurrent of the device is 360. The device has a fast reading time of 62.5 μs/line using a simple matrix-driving readout circuit.

The contact-type line image sensor has found increasing applications in office automation equipment such as facsimiles, which generally use an amorphous or crystal Si diode array or a CdS-CdSe photoconductor array.(1–4) These two types of arrays have problems in terms of compatibility of high resolution and high reading speed. The conventional array has a line image density of 8 or 16 elements per mm. In this report we describe a technique for fabricating photodetector arrays for line image sensing using an Au-diffused Pb_2CrO_5 thin film evaporated on a glass plate. The device can be operated under a construction composed of a very high line image density of 48 elements per mm.

Si photodiode arrays respond much faster than CdS/CdSe arrays but have a problem in that their complicated reading circuits use numerous analog switches. The CdS/CdSe photoconductor arrays are capable of operating using a matrix driving method with a simple reading circuit,(2) although the photoresponse of the arrays is slow. Pb_2CrO_5 has been regarded as a dielectric material since Negas first discovered it in 1968.(5) Photovoltaic and photoconductive effects have been observed in Pb_2CrO_5 ceramic disks of this material.(6,7) We have previously reported on Pb_2CrO_5 thin film 8-element photodetector arrays.(8)

A 0.16-μm-thick Pb_2CrO_5 thin film was deposited on a glass plate (Corning, No. 7059, 35 × 35 × 0.4 mm^3) by means of an electron-beam evaporation (EBE) deposition technique[5] under the conditions of gas pressure less than 4×10^{-5} Torr, substrate temperature of 300°C, and an emission current of 10 mA. The source was a Pb_2CrO_5 ceramic formed by the solid-phase reaction between PbO and Cr_2O_3 powders. A 300-μm-thick Au film was subsequently deposited on the Pb_2CrO_5 thin film, and then thermally diffused by heat treatment in air at 400°C for 4.5 h. The thermal diffusion of Au was attempted to improve the photosensitivity of the Pb_2CrO_5 thin film. The undiffused Au, which remained on the surface, was removed by Ar beam irradiation. A (310) orientation and a high degree of crystallization of the Au-diffused thin film were recognized by X-ray diffraction analysis.

An electrode pattern prepared for an Au-diffused Pb_2CrO_5 device for line image sensing is shown in Fig. 1. The top Au electrode pattern was formed by electron-beam lithography after the deposition of a 400-Å-thick Au thin film. The individual electrodes are 17 μm in width and are separated by 3 μm, corresponding to a line image density of 48 elements per mm. The photosensitive region is the 3 μm space between an individual electrode and the common electrode. The wavelength dependence of the photocurrent in one of the individual electrodes which covers over the visible and ultraviolet regions is shown in Fig. 2.

The normalized photocurrent deviation as a function of chopping frequency is shown in Fig. 3 for 543.5 nm He-Ne laser irradation, chopped by an acoustooptic modulator. The radiation intensity was varied between 0 and 12 mW/cm^2, and the applied voltage between an individual electrode and the common electrode was −40 V. The response speed estimated from the cut-off frequency of 16 kHz corresponds to the reading time of 62.5 μs/line, which is fast enough for application to line image sensing.

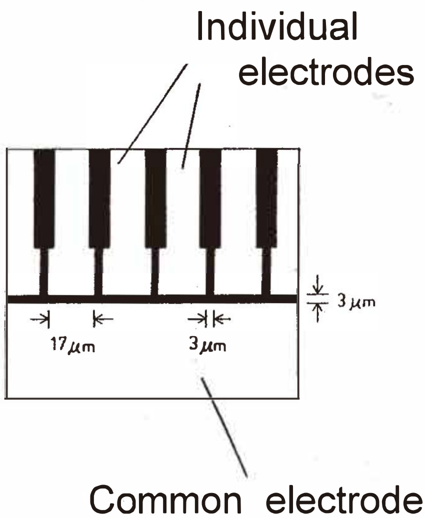

Fig. 1. Pattern of Au electrodes on Au-diffused Pb_2CrO_5 thin film layer.

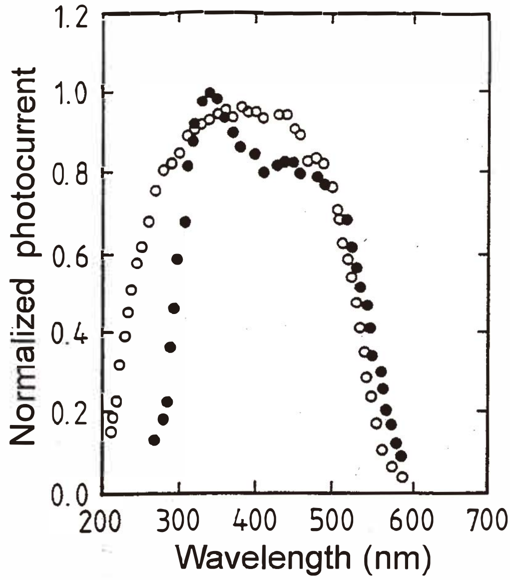

Fig. 2. Wavelength dependence of photocurrent measured from two different illumination directions:○ for illumination from electrodeside, ● for illumination from glass plateside.

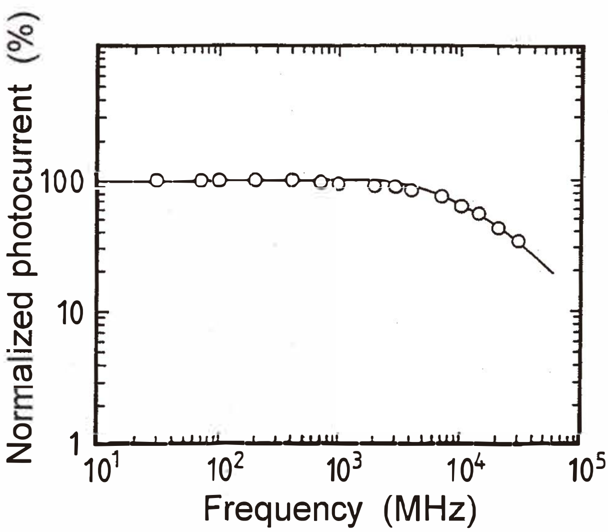

Fig. 3. Frequency dependence of photocurrent deviation measured under modulated illumination condition.

Figure 4 shows the signal waveforms from two elements placed side by side under the illumination with a modulation frequency of 5 kHz. The lower trace was obtained from the element in the dark state and indicates that the crosstalk between two neighboring elements is small. It is clear from the result that the 3 μm space is sufficient to suppress crosstalk.

Figure 5 shows the photocurrent and darkcurrent measured as a function of voltage applied to one of the individual electrodes in the device. The ratio of the photocurrent to the darkcurrent is 360 for a bias voltage of 40 V at a light intensity of 36 mW/cm^2. The photocurrent of the Au-diffused device is 150 times higher than that of the undiffused device, without degradation of the spectral response characteristics or the photocurrent/dark current ratio. This indicates that Au diffusion into the Pb_2CrO_5 thin film is effective for increasing the photocurrent.

Figure 6 shows a block diagram of a contact-type line image sensor using the above-described photosensing device. A photodetector array and matrix writing were constructed on the device surface. Each of the individual electrodes was operated at a pulsed bias voltage. The magnitude of the current signal is related to the illumination conditions of the individual electrodes. An experiment on image reading was performed using a document with a bar code pattern. The obtained negative pattern is consistent with the original pattern, as shown in Fig. 7.

The present photosensing device composed of Au diffused Pb_2CrO_5 thin film and a glass plate is promising for high-density line image sensing under high-speed operation, which is compatible with a simple matrix-driving readout circuit. No special technique to separate the individual array elements is necessary, because of the high resistivity of the Pb_2CrO_5 thin film.

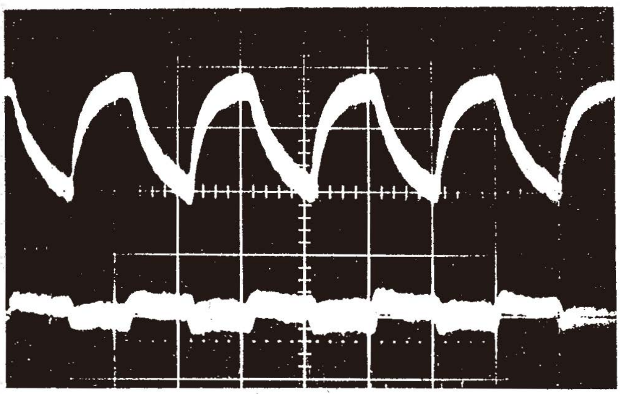

Fig. 4. Observed signal waveforms from elements placed side by side. Upper and lower traces are signals from irradiated and nonirradiated elements, respectively. Vertical: 20 pA/div; horizontal: 0.1 ms/div.

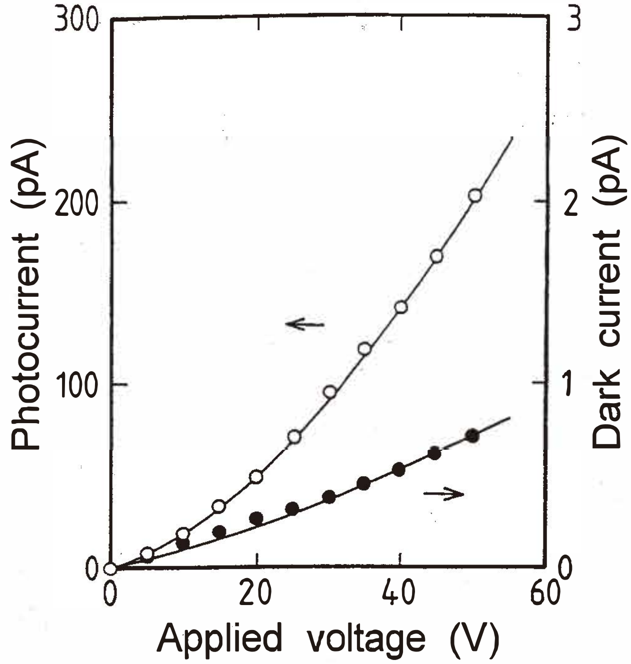

Fig. 5. Measured photocurrent and darkcurrent as functions of applied voltage, under illumination from He-Ne laser (543.5 nm, 36 mW/cm^2).

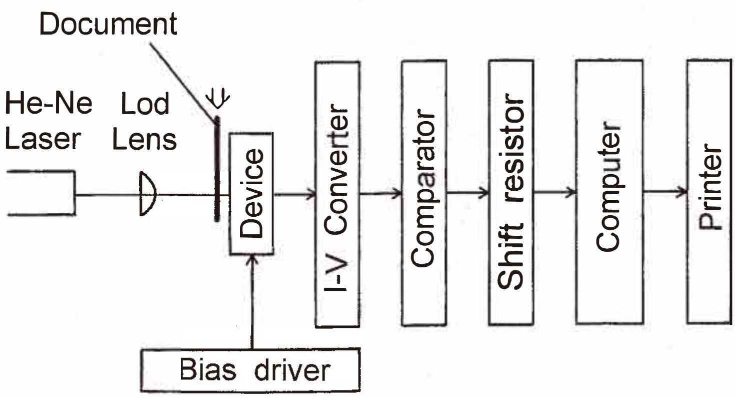

Fig. 6. Block diagram of Pb_2CrO_5 thin-film line image sensor.

(a)

(b)

Fig. 7. Example of reading image. (a) Original pattern and (b) obtained image.

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