SESSION XIII: OPTOELECTRONIC CIRCUITS

THPM 13.6: Interline CCD Image Sensor with an Anti Blooming Structure

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THE APPLICATION OF AN overflow drain and barrier positioned beside the photosensitive area[1] has made it possible to suppress blooming of CCD image sensors. However, this method was found to sacrifice photosensitivity and dynamic range. This paper will describe an interline CCD sensor where the vertical overflow drain is positioned under, rather than beside the photodiode. Thus the cell area can now be used effectively for photoelectron generation and storage, and increased photosensitivity and dynamic range can be maintained. Furthermore, this technique eliminates the blooming phenomenon.

A unit cell cross-sectional view of the vertical overflow drain (VOD) CCD image sensor is shown in Figure 1. The cell consists of a photodiode (PD) and a half stage of a 4-phase driven buried channel vertical CCD register (V-CCD) including a threshold controlled transfer gate (TG) region. The PD is made in a lightly doped P-well (1PW), while the rest of the cell is made in a more highly doped thick P-well (2PW). N-type substrate is reverse biased at V_{SUB} from these grounded P-wells.

The potential profiles under the PD and the TG region are shown in Figure 2(*a*) for two operating periods of V-CCD clock pulse (ϕ_V) which is shown in Figure 2(*b*). T_1 and T_2 are charge transfer and charge integration periods, respectively. During T_1, as the photogenerated signal charges are transferred to the corresponding V-CCD, the N-region of the PD is reset at ψ_{TGH} (TG channel potential at $\phi_V = V_H$) as shown by the curve indicated as *Empty*. During the following charge integration period T_2, PD potential decreases with increasing signal charges. In time, the PD potential reaches ($\psi_{PB} + \psi_{bi}$) where ψ_{PB} is the minimum potential in a completely depleted 1PW corresponding to the supplied V_{SUB} and ψ_{bi} is the built-in potential of the PD junction. When V_{SUB} is adjusted in such a way that ($\psi_{PB} + \psi_{bi}$) is always higher than ψ_{TGM} (TG channel potential at $\phi_V = V_M$) as shown by the curve indicated as *Full*, all of the photogenerated excess charges are drained into the N-type substrate, without flowing into the V-CCD. As a result, the overflow blooming is suppressed under strong illumination.

The device was fabricated on a 20 ~ 30Ω-cm N-type silicon substrate using double-layer polysilicon technology. The 1PW and 2PW were made by boron ion implantation. The unit cell size is 23 x 13.5μm; chip size is 10 x 7.9mm, applicable to 2/3" vidicon camera lenses. The number of picture elements is 384(H) x 490(V).

In Figure 3, the relation between V_M and V_{SUB}, which is necessary to suppress blooming, is shown for the VOD CCD sensor. A reproduced image without blooming was obtained from a scene including an incandescent lamp as shown in Figure 4. Blooming was not observed until more than 10^3 times the saturation exposure.

The ratio of the smeared signal to the total signal under 10% vertical height illumination, as a function of incident light wavelength, is shown in Figure 5. The solid line is for the VOD CCD sensor and the broken line is for a device without the VOD. The latter was made on a P-type silicon substrate, using the same photomasks as the VOD CCD sensor with the conventional fabrication technology[2]. An improvement of more than 20 times has been achieved for the sensor in the whole wavelength range, since signal charges generated in the fully depleted 1PW hardly diffuse into the neighboring V-CCDs, because the 1PW potential is always higher than that of the surrounding P^+ channel stop regions, as well as that of 2PW.

Spectral responses of photosensitivity are shown in Figure 6. The near infrared response of the sensor is lowered due to the decrease in the effective photosensitive layer thickness. As a result, the spectral response of the sensor reaches a similarity to the spectrum luminous efficiency curve and permits a reduction of the IR-cut filter thickness, to minimize energy loss in the visible range. No charge-transfer efficiency and blemish differences were found between the VOD CCD sensor and the device without the VOD.

Characteristics are summarized in Table 1.

Acknowledgments

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Parameter		Units
Saturation Output Voltage	1.0	V
Dark Current	0.5	nA
Saturation Exposure	0.2	Lux• sec(2856 K)
Limiting Resolution		
Horizontal	280	TVL/PH
Vertical	480	TVL/PH
Signal to Noise Ratio	72	dB
Noise Equivalent Electrons	65	electrons

TABLE 1—Characteristics of the vertical overflow drain CCD image sensor.

[1] Furukawa, A., Matsunaga, Y., Suzuki, N., Harada, N., Endo, Y., Hayashimoto, H., Sato, S., Egawa, Y., and Yoshida, O., "An Interline Transfer CCD for Single Sensor 2/3" Color Camera", *IEDM Digest of Technical Papers*, p. 346-349; Dec., 1980.

[2] Ishihara, Y., Takeuchi, E., Teranishi, N., Kohno, A., Aizawa, T., Arai, K., and Shiraki, H., "CCD Image Sensor for Single Sensor Color Camera", *ISSCC DIGEST OF TECHNICAL PAPERS*, p. 24-25; Feb., 1980.

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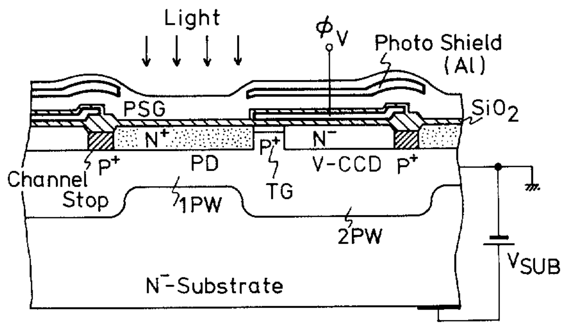

FIGURE 1—Cross sectional view of a unit cell for vertical overflow drain CCD image sensor.

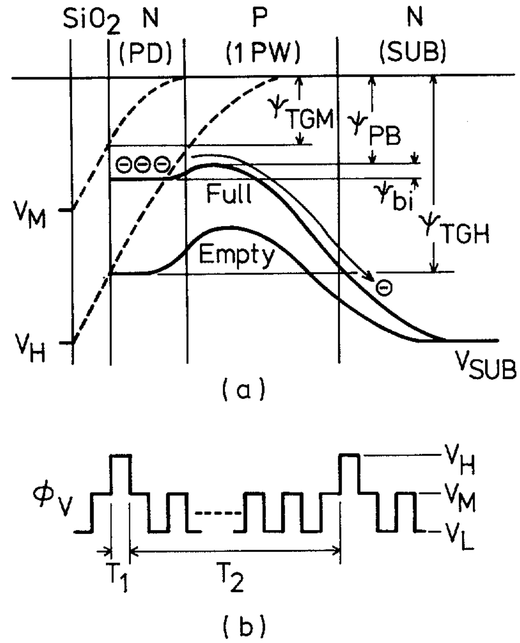

FIGURE 2—(*a*) Potential profiles under the PD and the TG region, and (*b*) one of the V-CCD clock pulses ϕ_V.

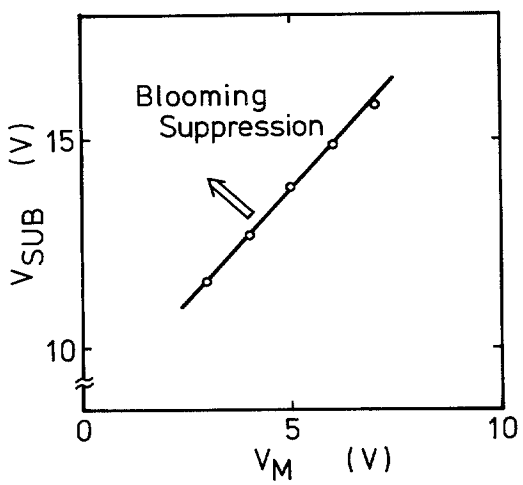

FIGURE 3—Relation between V_M and V_{SUB} required to suppress blooming.

[See page 314 for Figure 6.]

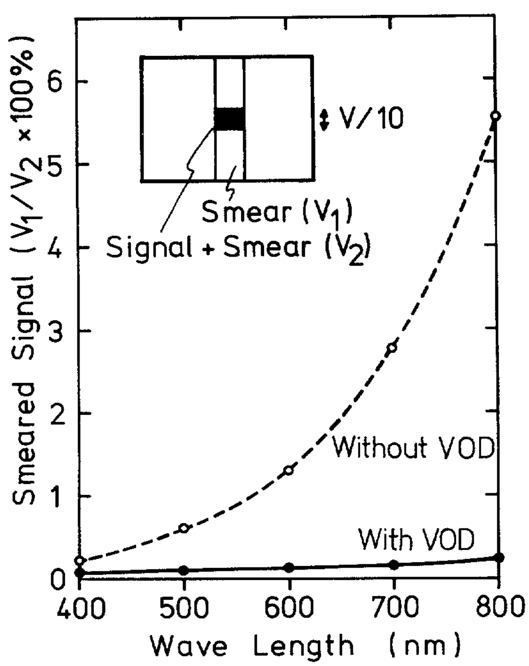

FIGURE 5—Percentages of smeared signal as a function of

FIGURE 4—Reproduced image for V_{SUB} = 6V, V_H = 12 V,

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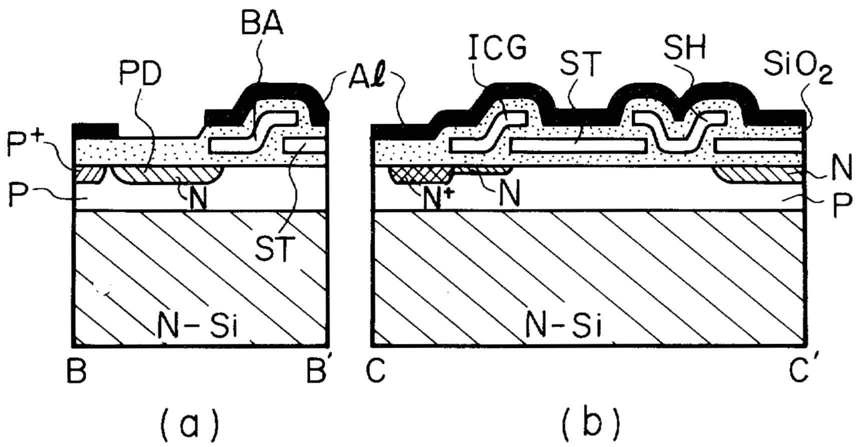

FIGURE 6—Cross sectional view of buried drain structure.

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