A 3.30x2.95mm^2 1/6-inch 250k-pixel IT-CCD image sensor

Atsushi Asai, Yoshinori Toumiya, Koji Matsuzaki*, Kazushige Nigawara,
Satoshi Kitayama*, Yukinobu Wataya and Ko-ichi Masuda

CCD System Division, Semiconductor Company, SONY Corporation
4-14-1 Asahi-cho, Atsugi-shi, Kanagawa 243 JAPAN
Phone: +81-462-30-5111 ext.5449, Fax: +81-462-30-6170
E-mail: asai@saccd.semicon.sony.co.jp
* CCD Development Center, SONY Kokubu Corporation
5-1 Noguchi-kita, Kokubu-shi, Kagoshima 899-43 JAPAN

Abstract

We have newly developed a 1/6-inch 250k-pixel Interline Transfer(IT)-CCD image sensor. This device has small chip size of 3.30 by 2.95mm^2 and the pixel size of 4.80 by 3.75um^2, however, the device characteristics are comparable to our conventional 1/4-inch 250k-pixel type with the pixel size of 7.15 by 5.55 μ m^2. Development of such a small device will stimulate many applications of image sensors.

1. Introduction

Video imaging products with small size and with high mobility have rapidly been growing their market. Many of image sensor developments have focused how to shrink the device size in response to such strong demand; the optical format was ranging from 2/3-, 1/2-, 1/3- to 1/4-inch(1-3) as shown in Fig.1. To further satisfy the demand for even smaller devices, we have newly developed a 1/6-inch 250k-pixel Interline Transfer(IT)-CCD image sensor whose pixel area is as small as 18.00mm^2. Despite the small pixel size, substantial device characteristics like sensitivity or smear are nearly competitive to our conventional 1/4-inch 250k-pixel IT-CCD image sensor with the pixel area of 39.68mm^2.

2. Device Structure

A picture of this fabricated 1/6-inch 250k-pixel IT-CCD image sensor is shown in Fig. 2(a), compared with that of our 1/4-inch 250 k-pixel one shown in Fig.2(b). The chip size is 3.30(H)x2.95(V)mm^2 as drawn in Fig.2(a) and the pixel size is 4.80(H)x3.75(V)mm^2. We adopt a structure with 2-level poly-Si 4 -phase electrodes and 2-phase ones for vertical CCDs and for horizontal CCD, respectively, and with photoshield made of aluminum.

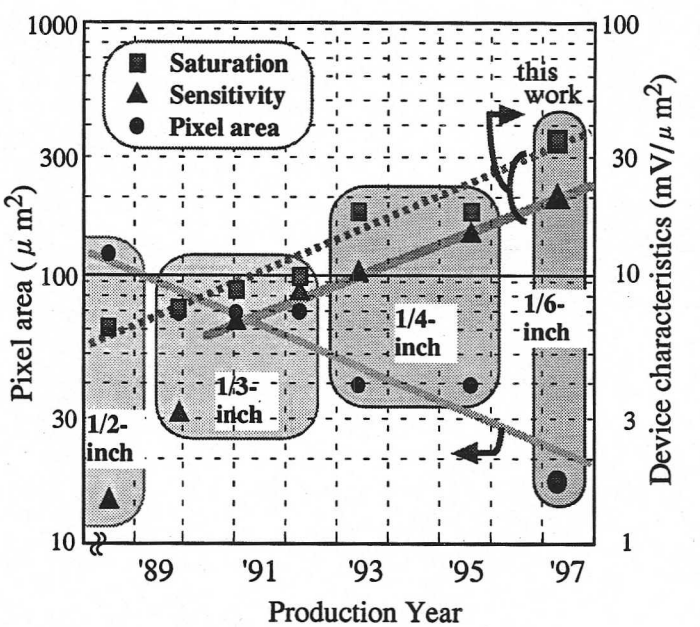


Fig.1 Trend of device characteristics in our 250k-pixel IT-CCD line-up

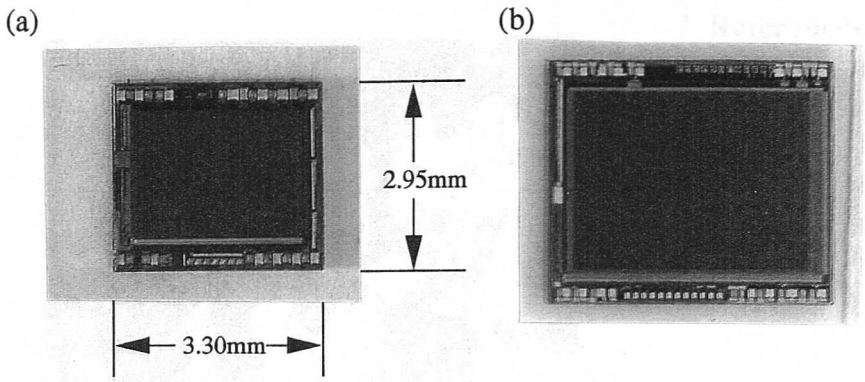


Fig.2 (a) Chip top view of 1/6-inch 250k-pixel IT-CCD; the chip size is $3.30 \times 2.95 = 9.28 mm^2$. (b) our 1/4-inch type; the chip size is $4.47 \times 3.80 = 16.99 mm^2$.

On-chip color filters of complementary color checkered arrays are placed on the planarization layer and on-chip microlenses of convexity are on the top of the device as illustrated in Fig.3.

Effect of on-chip microlenses to increase sensitivity is well-known. However, as the pixel size shrinks, reduction of on-chip microlens fill-factor can no longer be negligible. More specifically, as shown in Fig.4, the fill-factor of 250k-pixel IT-CCD sensors are 0.90, 0.86, and 0.82 in 1/2-, 1/3-, and 1/4-inch size device, respectively. Without any advanced technique incorporated, the fill-factor woule be 0.71 in 1/6-inch size with resultant low sensitivity.

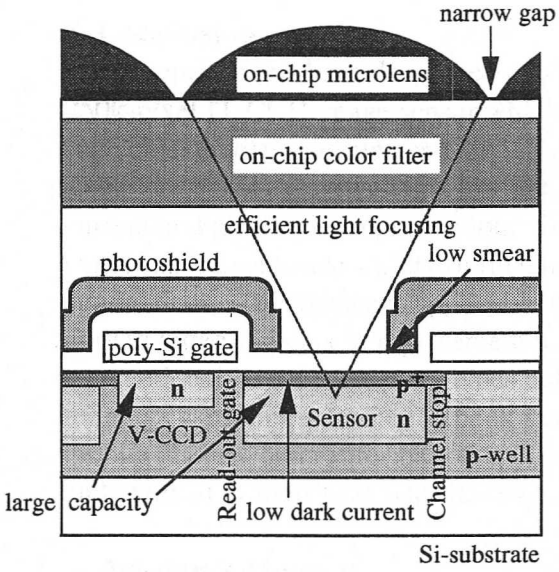


Fig.3 Horizontal cross-sectional view; Key technologies are indicated.

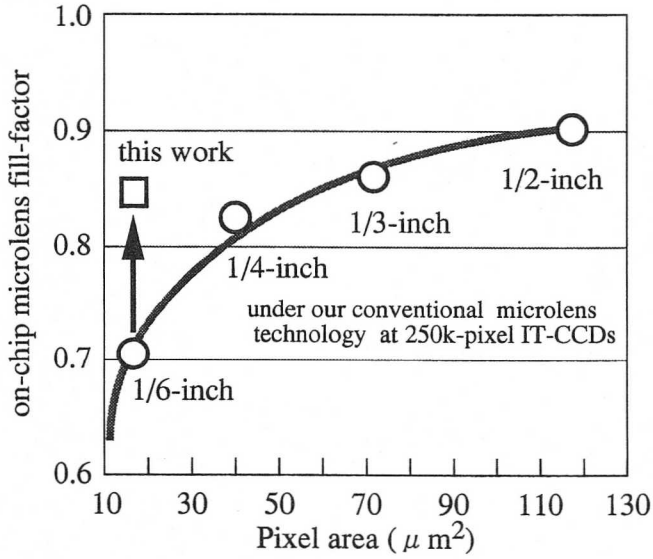


Fig.4 Decrease of on-chip microlens effect at 0.50 μ m design rule

V.O.D.

Table.1 Device Structure and driving specifications

Optical format	1/6-inch (3.0mm ϕ)
Number of effective pixels	510(H) x 492(V)
Pixel size	4.80(H) x 3.75(V) μ m^2
Chip size	3.30(H) x 2.95(V)mm^2
Color filter	complementary color checkered array
Horizontal CCD register	3 to 5V drive, 9.5MHz (NTSC)
Power supply	15 / 5 / -7.5V

"so no external adjustment needed"

Here, by means of optimized process conditions the microlens structure is improved to increase sensitivity as described later.

Furthermore, this device has an advanced substrate bias adjustment circuit to reduce the occupied area. Poly-Si fuses in parallel configuration are selectively burnt out under a designated condition on imposed voltage and current. The device structure and driving specifications are summarized in Table1.

3. Characteristics

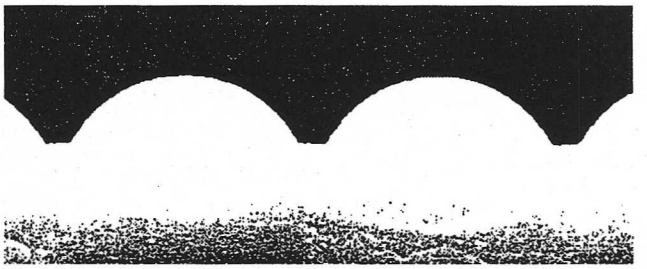
To achieve more than 1100mV/(lx s) sensitivity which provides usefullness in general applications, we have mainly developed two techniques; the first is narrower gap in on-chip microlens as shown in Fig.3. The averaged width of the gap is about 0.15mm with enough uniformity in mass production and then the filled area is increased by a factor of about 20%. Maximization of light detection efficiency naturally determines both the layer thickness between on-chip microlens and silicon substrate and curvature of the microlens. the second is optimization of the pixel pattern. Our new pixel design enlarges sensor aperture area of the photoshield by 1 5% in comparison to a conventional design and maintains the smear level at -94dB in spite of the reduced pixel size.

Impurity profile in both vertical and horizontal CCD registers is totally refined so that the capacity of handling charge is increased by 20%. To obtain enough margin of antiblooming and large saturation voltage, thermal budget process is also redesigned.

We also adopt HAD(Hole-Accumulation Diode) sensor structure(1-3) for low dark current and thin insulating film between poly-Si electrodes for high transfer efficiency.(4) This device's driving specifications, pinout and spectral sensitivity distribution are consistent with our 1/4-inch 250k-pixel types. Therefore, the same system ICs can be used. Table2 shows device characteristics.

Fig.5 SEM micrographs of on-chip microlens

(a) Conventional on-chip microlens



(b) Narrow gap on-chip microlens in this work

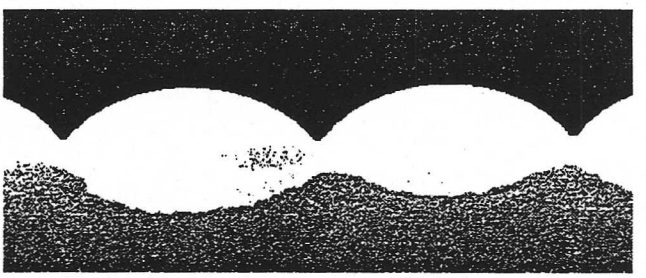


Table.2 Device Characteristics

Sensitivity	1350mV/(lx • s) (color, 3200K)
Smear(V/10)	-94dB
Saturation voltage	600mV (60℃)
Dark current level	< 1mV (60℃)
Electronic shutter speed	1/60 to 1/10000s
Blooming suppression	> x1000
Image lag	< measurement limit

conversion gain "SECRET"

Fig.6 A photograph of reproduced image (still life)

4. Examples of Picture

In Fig.6, a photograph of reproduced image are shown.

5. Conclusion

In conclusion, we have developed a 1/6-inch 250k-pixel IT-CCD image sensor which had such characteristics as high sensitivity, low smear, large saturation voltage, low dark current and good color reproduction. This small size can enhance variety of imaging applications. This device is applicable not only to video cameras as replacement to conventional larger 250k-pixel types but also to image capturing into subnotebook size PCs, mobile phones, other information appliances and medical or industrial inspection systems.

6. Acknowledgement

The authors would like to thank Mr.H. Matsumoto, Mr.Y.Nakata, Mr.A.Kayanuma for thier encouragement and valuable suggestions and many people in SONY Kokubu Corporation and SONY Atsugi Technology Center for their cooperation to development of this new CCD.

7. References

(1) M. Yamamura *et al.*, SPIE Vol.765(1987)
(2) J. Hojo *et al.*, IEEE Trans. on Electron Devices, Vol.38(5), 954(1991)
(3) J. Suzuki *et al.*, IEEE Trans. on Consumer Electronics, Vol.39(3), 392(1993)
(4) K. Fujikawa *et al.*, ISSCC'95/S13/TP13.1 (1995)