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CMOS Image Sensor with a Thin Overlaid Panchromatic Organic Photoconductive Layer as the Best Candidate for Sensors with Reduced Pixel Size

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Abstract

We propose a new CMOS image sensor with a thin overlaid panchromatic organic photoconductive layer as the best candidate for sensors with reduced pixel size. We experimentally made the trial product of the CMOS image sensor in order to verify the potential capability of our proposal, and to prove the validity of the organic CMOS sensor.

1. Introduction

The light-harvesting efficiency of current CCD and CMOS image sensors is decreasing as a result of repeated efforts to meet the strong demand for a sensor having increased number of pixels by reducing pixel size. In order to overcome this problem, we have proposed a stack-type organic CMOS image sensor[1,2,3] with pixels, each of which captures incident lights of all the three primary colors (Figure 1), and have developed new organic photoconductive layers, each of which is solely sensitive to the light of one of the three primary colors and transmits the lights of the other two (Figure 2). However, recent advances in backside-illuminated CMOS image sensors have forced us to develop an image sensor, which is more effective to reduce pixel size than the stack-type organic CMOS image sensor.

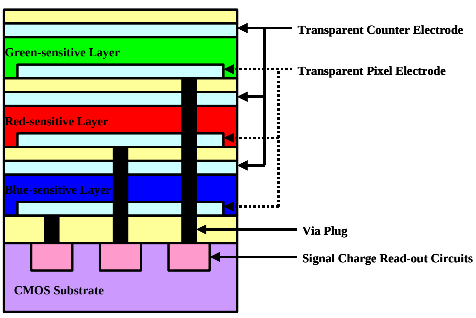
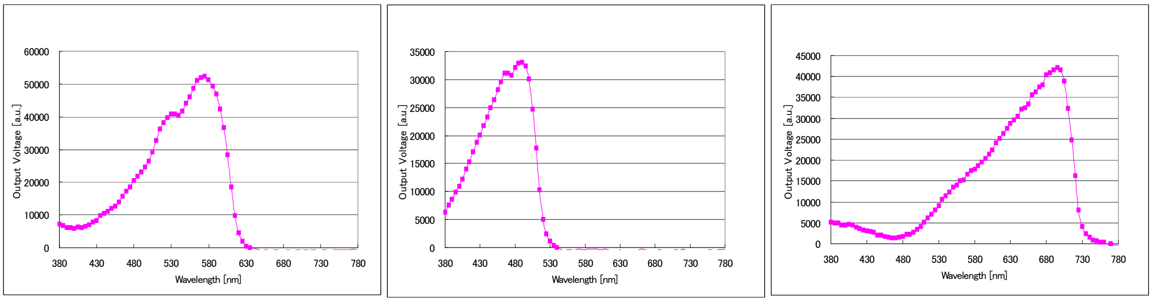


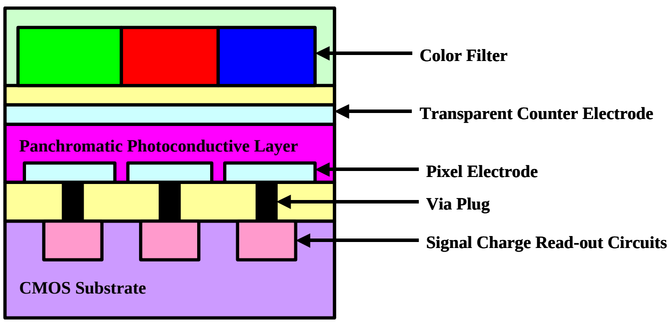
Fig.1 Structure of image sensor with multiple overlaid layers of organic photoconductive materials.



(a) (b) (c)

Fig.2 Spectral sensitivities of organic photoelectric conversion layers composed of (a) Quinacridone for green-sensitive layer, (b) Compound X for blue-sensitive one, and (c) Compound Y for red-sensitive one, which were measured as the output signals of the trial products of the proposed image sensors overlaid with each of the above-stated materials.

We have focused our efforts on the development of a new CMOS image sensor with a thin overlaid panchromatic organic photoconductive layer as the best candidate for sensors with reduced pixel size (Figure 3). The photoelectric conversion layer consists of a very thin panchromatic photoconductive layer, transparent common counter electrode, and pixel electrodes. Since the panchromatic photoconductive layer is free from any structure and is continuously overlaid upon a CMOS substrate, the proposed sensor could be produced in principle with pixel aperture of 100% for incident light without any sophisticated micro-fabrication process. The signal charges are read out by signal charge read-out circuits in a CMOS substrate through via plugs. The separation of three primary colors is achieved by means of micro color filters installed above the photoelectric conversion layer. Since the very thin organic photoelectric conversion layer absorbs incident light with over 90% efficiency, the proposed sensor does not cause spectral cross-talk with slanting rays of light without micro-lenses. Since the spectral sensitivity of the panchromatic organic photoelectric conversion layer is confined in visible light region (Figure 4), the proposed sensor does not need IR-cut filters, which tend to cause the color variance with slanting rays of light in current sensors.



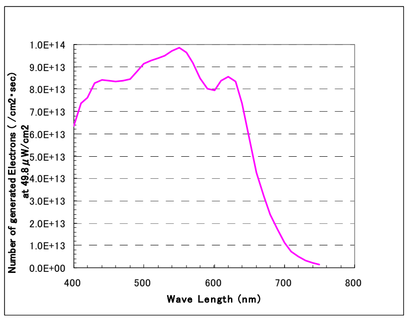


Fig.3 Structure of image sensor with a thin overlaid panchromatic organic photoconductive layer.

Fig.4 Spectral sensitivity of a panchromatic organic photoelectric conversion layer, which was measured as the output signal of the photoconductive layer.

2. Experiments

We experimentally made a trial product of the CMOS image sensor with a thin overlaid panchromatic organic photoconductive layer in order to verify the potential capability of our proposal, and to prove the validity of the organic CMOS sensor.

The structure of the organic CMOS sensor is the same as that shown in Figure 3 and the specifications are shown in Table 1. We installed some kinds of signal charge read-out circuits in order to evaluate S/N ratio and lag at the stage of signal charge read-out from a thin panchromatic organic photoconductive layer. One of the signal charge read-out circuits consists of usual three- transistor mechanism (Figure 5). The others consist of more sophisticated mechanisms, because there are particular interests for the depression of kTC reset noise in the organic CMOS sensor.

Pixel Number	**360×256**
Pixel Size	**3μm□**
Read-Out Speed	**60fps**

Table 1　Specifications for the trial product of the organic CMOS sensor.

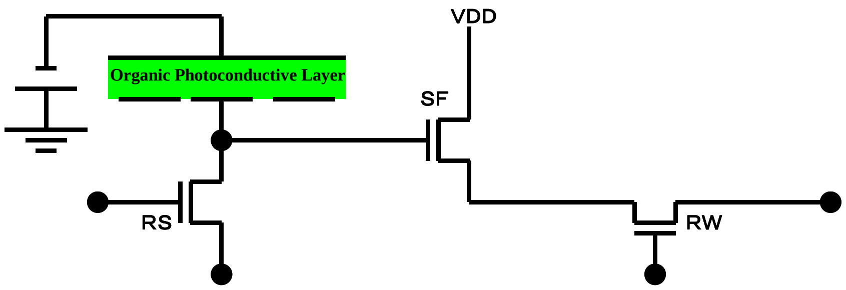


Fig.5　One of the signal charge read-out circuits for the organic CMOS sensor: Three-transistor mechanism.

The ratio of the area of a pixel electrode to the area of a pixel determines the pixel aperture for incident light. Figure 6 shows an electron micrograph of pixel electrodes for the trial product. The gap between pixel electrodes is 0.24μm and the pixel aperture for incident light is 85%. Figure 7 shows a photograph of the assembled organic CMOS sensor.

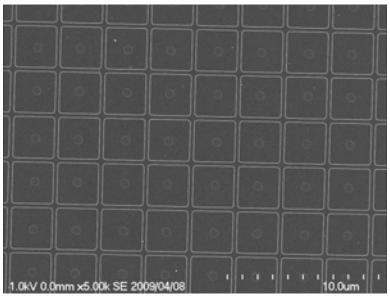


Fig.6　Electron micrograph of pixel electrode.

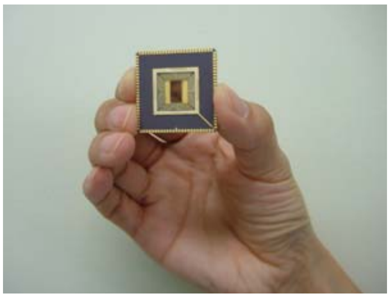


Fig.7　Photograph of assembled chip.

3. Results and Discussions

A resolution chart, which was taken by the trial product without micro color filters, is shown in Figure 8. This indicates that the organic CMOS sensor could exhibit the limit of the resolution (i.e., 250TV lines) as predicted by the number of vertical pixels in the image sensor.

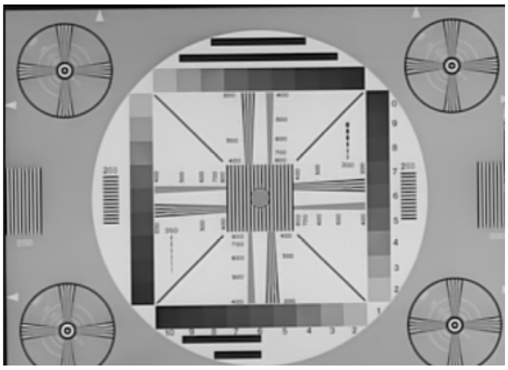


Fig.8 Resolution chart, which was taken by the trial product without micro color filters.

The evaluation of S/N ratio and other characteristics by new signal read-out circuits and the process for setting micro color filters on this panchromatic organic CMOS sensor are now going on. We would show the detailed data and discuss about the organic CMOS sensor.

4. References

(1) S. Takada, M. Ihama, M. Inuiya, IS&T/SPIE's Electronic Imaging 2006, San Jose, CA

(2) M. Ihama, M. Hayashi, Y. Maehara, T. Mitsui, S. Takada, SPIE's Optics&Photonics 2007, San Diego, CA

(3) S. Takada, M. Ihama, M. Inuiya, T. Komatsu, T. Saito, IS&T/SPIE's Electronic Imaging 2007, San Jose, CA