CMOS pixel aperture structure for extracting depth information

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Abstract Complementary metal-oxide-semiconductor (CMOS) pixel aperture structure for extracting depth information is presented. The proposed structure uses RGBW pixel patterns and the aperture is located in the white pixel. The focused image is obtained by white pixels and the defocused image by RGB pixels. Both the focused image and the defocused image can be used to obtain depth information of the object.

Keywords: CMOS, pixel structure, aperture, depth information, 3D imaging

1. Introduction

Techniques for 3D imaging include structured light, time-of-fight (TOF) concept, and stereo vision. However, the light source is required for the time-of-fight concept, the structured light camera consists of complex system, and the multi-cameras are needed in stereo vision [1-6].

The pixel aperture technique for 3D imaging has several important advantages compared with conventional 3D imaging techniques. The depth information can be obtained by using a single CMOS image sensor (CIS) with pixel aperture and the aperture is located on the pixel. In addition, the proposed image sensor can simultaneously acquire both depth and color images. The pixel aperture technique is based on the depth from defocus (DFD) concept.

The surface of the CIS is covered with a layer of color filter array (CFA), which is usually red, green, and blue (RGB) Bayer CFA. However, a white filter that has a high sensitivity with a pixel aperture is used as one of the color filters in the proposed CIS [7-10]. In the pixel aperture technology, the aperture is located in the white pixels, which have different characteristics compared to the pixels having RGB color filters without aperture. The proposed image sensor has many applications such as object reconstruction, human-motion detection, and face recognition.

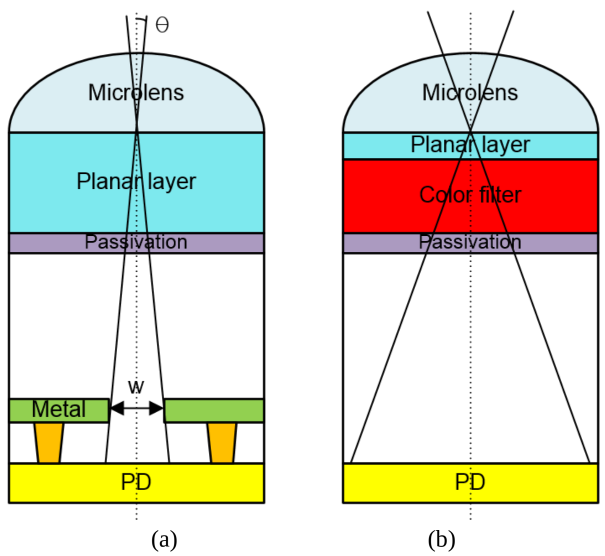

Fig. 1. Vertical structures of the pixel (a) with aperture and (b) without aperture.

2. Operating principle

A vertical structures of the pixel with aperture and without aperture are shown Fig. 1. The pixel size is 2.8 μm × 2.8 μm and the pixel consists of the photodiode (PD), metal layers, a planar layer, and microlens.

Fig. 2 shows a geometrical model of the 3 × 3 pixel array. The model presents a pixel array without microlenses and CFA. The aperture is located on the white pixels which does not have a color filter. The image constructed by the white pixel array will be less blurred than the color image. The two images can be compared to determine the depth of the objects.

The 3D finite-difference time-domain (FDTD) analysis is implemented in the pixel aperture model for optical simulation. The incidence angle of the light is from -15 to 15 degree in the pixel and the refractive index of each material is considered. The optical simulation according to the incidence angle which is related to the f-number is performed.

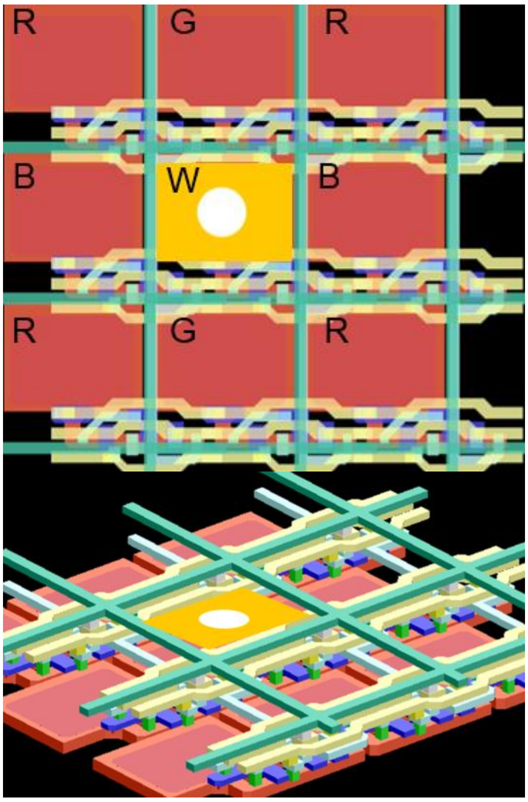

Fig. 2. Geometrical model of the pixel array.

3. Results and discussion

Fig. 3 shows the pixel structure with the pixel aperture and the simulation results that demonstrate the variation of the optical power on the surface of photodiode with the incidence angle is shown Fig. 4. The diameter of the pixel aperture is 0.6 μm and the metal layer in the CMOS process is used for the pixel aperture. Most of the light with 0° of incidence angle is transmitted through the pixel aperture. The optical power decreases with the incidence angle because the light is gradually blocked by the pixel aperture.

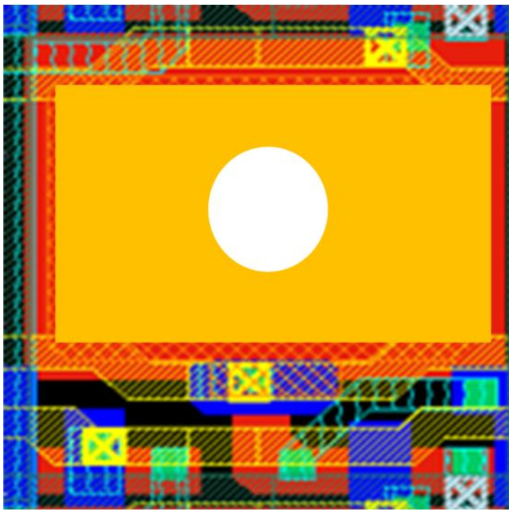

Fig. 3. Pixel structure with the pixel aperture.

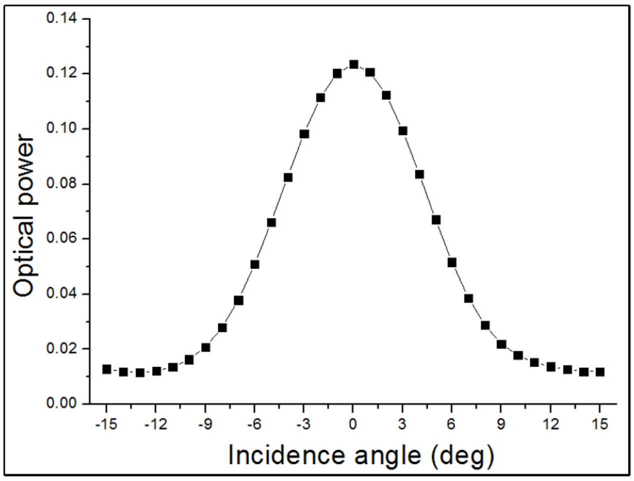

Fig. 4. Variation of the optical power with the incidence angle as a function of the diameter of pixel aperture (simulation results).

Table. 1. Characteristics of the proposed pixel.

Process	0.11um CIS process
Pixel size	2.8 μm × 2.8 μm
Incidence angle	-15° – 15°
Diameter of aperture	0.6 μm
Microlens	Polynomial model (0.6 μm)
Analysis	FDTD method

4. Conclusion

In this paper, we designed and developed the pixel aperture technique to obtain depth information. The depth information can be extracted by comparing sharp image from the white pixels and blurred image from the color pixels. We simulated the pixel aperture technology according to incidence angle. The performance of pixel aperture have been demonstrated by using FDTD optical simulation. The characteristics of the proposed pixel are summarized in Table 1.

Acknowledgements

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