Multi-storied photodiode CMOS image sensor with wire grid polarizer to detect polarization information

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Abstract We demonstrated multi-storied photodiode CMOS image sensor with a wire grid layer to capture color image and polarization information at the same time in the exact same frame composed of the two types of images. This image sensor consists of stacked two layers of photodiode (PD) arrays and a wire grid layer between PD arrays. This sensor detects not only optical image with top PD array but also polarization information with bottom PD one. In this paper we report the characteristics of PD array which detect polarization information. In the sensor wire grid layer consist metal layer on the semiconductor substrate and the polarized light extinction ratio is over three at 640nm wave length with 200mm/200mm metal wire grid line /space.

Keyword CMOS Image Sensor, 3D Stacked, Polarization, Near Infrared

1. Background

Imaging systems continue to improve their functions to detect not only visible image but also additional information like near infrared (NIR), distance information, polarization information and so on. Conventionally two difference type of image sensors have been used for such functions [1-3]. Those systems are costly and complex because of position adjustment of sensors and calibration between two images to make two images fitted in the exact same frame. There have been demands for image sensors to capture different types of images just by one [4, 5]. We demonstrated and realized multi-storied CMOS image sensor which can capture two types of images at the same time with high quality of color images [6, 7].

2. Concept and structure

We reported the image sensor which comprise 3D stacked two photodiode (PD) arrays to capture color images and near infrared (NIR) images at the same time. In this paper we report multi-storied photodiode CMOS image sensor with a wire grid polarizer as shown in figure 1. The top PD array with a back illuminated structure, is stacked on the bottom PD array with a surface illuminated one, which means both top and bottom wire layers facing each other and being placed between two PD arrays. The wire grid structure to split polarization information consists of the closest metal layer to the bottom PD array.

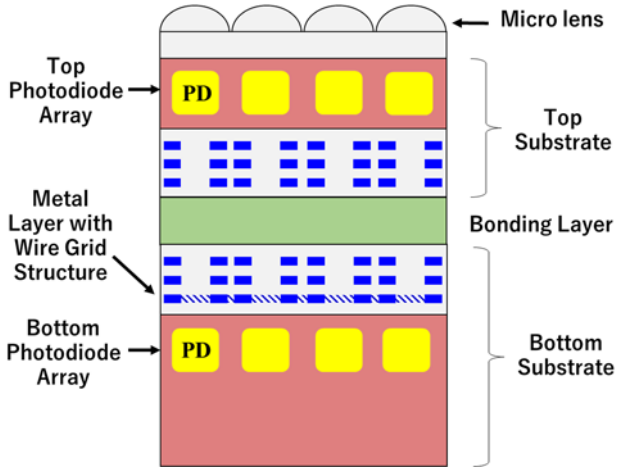

Figure 1. Cross-sectional diagram of multi-storied photodiode CMOS image sensor with wire grid polarizer

Figure 2 shows the layout of the polarizing wire layer on the bottom PD. The pixel size of both PD is 3μm by 3μm, and the aperture size defined by the metal layer, shown as slant hatched in the figure, is 1.75 by 1.75μm. The wire grid layer, shown as solid area, is 400nm pitch and 200nm width. In this configuration, linearly polarized light would be reflected in case that its θ is aligned as 180 degree parallel to the wire grid lines, and transmitted in case that its θ is 90 degree different from the wire grid lines. By using this structure pixels which has various types of wire grid angle can be put under the top PD array.

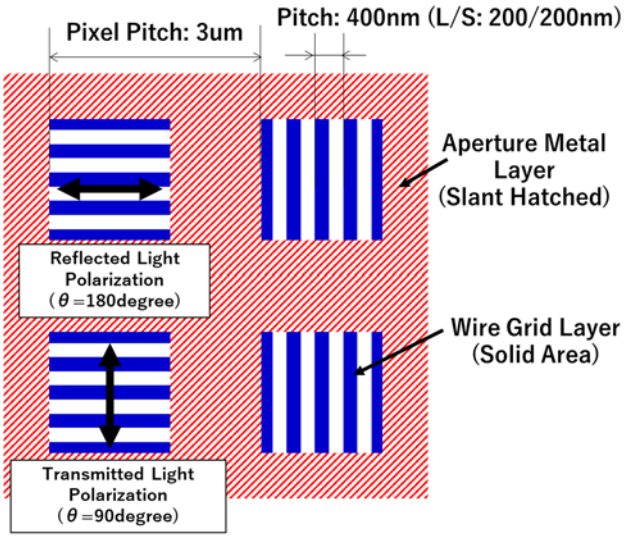

Figure 2. Wire grid metal layer and aperture metal layer located between two PD arrays

3. Experimental results

Figure 3 shows the measurement condition of spectral sensitivity with linearly polarized light. The light source is a halogen light because of broadband wavelength characteristics. Only the specific wavelength light is transmitted through the spectrometer with parallel light condition, and then linearly polarized by a polarizing plate. In the measurements we controlled the angle of polarizer, shown as θ in the figure, to measure a sensitivity of the image sensors.

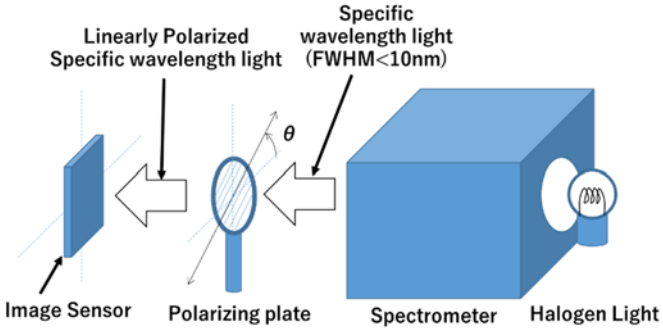

Figure 3. Condition to measure spectral sensitivity with linearly polarized light.

We measured the spectral sensitivity of the bottom PD array and calculate extinction ratio, which is the ratio of sensitivity between θ=90 and 180 degree. Figure 4 shows measured extinction ratio. The polarization extinction ratio of the bottom PD array shows more than three at 640nm.

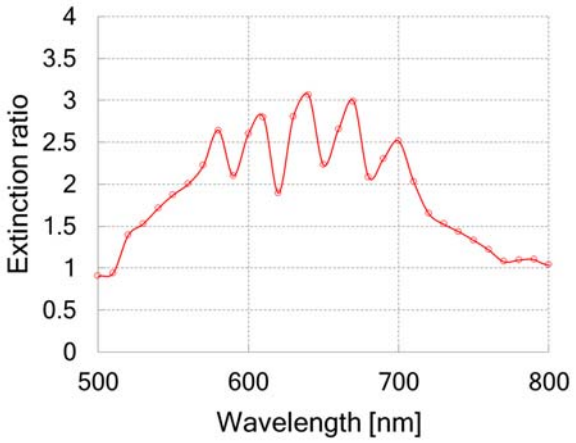

Figure 4. Wavelength dependence of extinction ratio in the bottom PD array.

4. Conclusion

We demonstrated that the multi-storied CMOS image sensor with wire grid polarizer detect polarization information and can capture color image and polarization information image at the same time. This concept will push the envelope of capturing the color image with additional information image giving distance information or enhancing object surface structure.

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