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Sensitivity and crosstalk study of the zero gap microlens used in 3.2 μm active pixel image sensors

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ABSTRACT

The microlens has been widely applied to improve the sensitivity and to decrease the spatial crosstalk of image sensors. In order to further decrease the pixel size while improve the image quality, the zero gap microlens has been proposed to make high performance image sensors. In this paper, both the traditional microlens and zero gap microlens are fabricated using TOWER and TOPPAN processes. And their performances are compared and evaluated. The results show that the least sensitivity of the zero gap microlens has been significantly improved by more than 45.8% compared to that of the traditional microlens. The use of the zero gap microlens results in an obvious decrease of the crosstalk among blue, green and red lights. For example, the crosstalk of blue light in red light under the green irradiation has been decreases about 1.33%, and the crosstalk of red light in blue light under the blue irradiation has showed about 2.429 times decrease. Overall, the output colour image of the zero gap microlens is brighter and clearer than that of the traditional microlens. Image quality has been significantly improved due to the use of the zero gap microlens.

1. Introduction

Modern electronics like mobile phones become more and more compact, which raises a requirement for image sensors of smaller size and a denser pixel array. When the size of an image sensor is scaled down, the photoactive area must become smaller accordingly. Theoretically the image sensitivity and the image quality of such image sensors will be decreased [1,2]. However consumers always expect higher image quality. To solve this dilemma, numerous works have been done to optimize the pixel structure and/or the fabrication process to scale down the pixel size, and to improve the circuit design in order to leave more space to the pixel array [3]. The use of a microlens is an effective approach utilized to scale down the sensor size while improve the image quality [4]. As the pixel size scaling down, another problem appears for the traditional microlens: the small microlens cell does not match well with the small pixel array cell so as to increase the crosstalk. Fig. 1 shows the spectral chart where the spatial crosstalk occurs in the overlap regions between blue and green or between green and red. Thus in order to decrease the spatial crosstalk among the adjacent pixels, the concept of a zero gap microlens has been proposed to reduce the crosstalk and therefore to improve the sensitivity [5–7].

The chip and the cross-section structures of both the traditional microlens and the zero gap microlens type are shown in Fig. 2. The basic black and white CMOS image sensor consisting of a 3.2 μm pinned photodiode array of 640 (row) by 480 (column) was fabricated using TOWER 0.18 μm CMOS image process as shown in Fig. 2a. The traditional microlens with a colour filter and the zero gap microlens with a colour filter was fabricated using TOWER and TOPPAN process respectively. Fig. 2b shows the traditional microlens array that has about 0.3 μm gap between any two adjacent microlenses. Fig. 2c shows the new zero gap microlens array where there is no gap between any two adjacent microlenses.

The objective of this work is to systematically study and evaluate the performance of the zero gap microlens in CMOS imaging technology. To best of our knowledge, this work is the first systematical study to demonstrate the advantages of using the zero gap microlens in CMOS imaging technology. We believe this work will be a valuable reference to CMOS imaging industry. This paper is organized as follows. Section 1 introduces the background and microfabrication processes for the traditional microlens and the zero microlens. Section 2 shows the comparison of sensitivity and crosstalk between the traditional microlens and the zero gap microlens. The sensitivity and crosstalk of both traditional type microlens and zero gap microlens in CMOS image sensors have been analyzed according to statistical data of the wafer test, which

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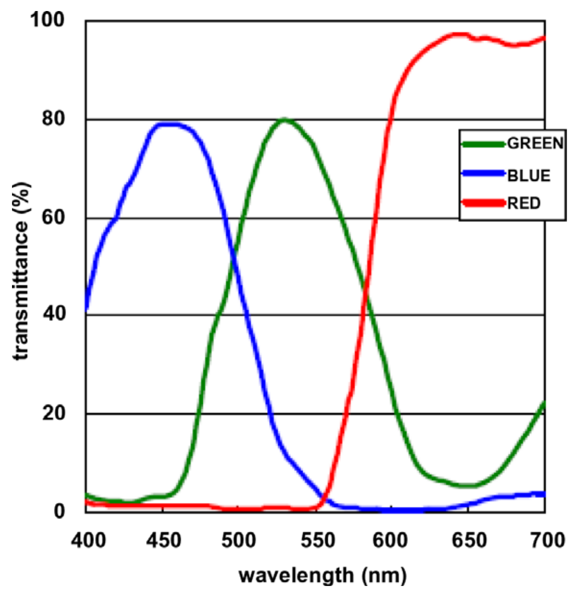

Fig. 1. Spectral chart of a traditional microlens where the spatial crosstalk occurs in the overlap regions between blue and green or between green and red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

was conducted in the test house of KLT company. Section 3 presents the images produced by both the traditional microlens and the zero gap microlens image sensors. The zero gap microlens shows better performance and higher image quality. Section 4 provides a summary and conclusion remarks.

2. Results, comparison and analysis in silicon wafer tests

2.1. Sensitivity results, comparison and analysis of silicon wafer tests

Figs. 3–5 have shown the sensitivity results of red, blue and green under irradiation of red light, green light and blue light respectively. All types of irradiation lasted 30 ms. The dosage of red light is 50 Lux; the dosage of green light is 45 Lux; and the dosage of blue is 140 Lux. In Figs. 3–5, the red curve with square symbols denotes the sensitivity of the zero gap microlens type, and the blue curve with diamond symbols denotes the sensitivity of the traditional microlens type. It is obvious that the sensitivity of the zero gap microlens has been largely improved compared to that of the traditional microlens type according to Figs. 3–5. The least sensitivity improvement is the sensitivity of blue light under the red irradiation which is about 45.8% improvement as shown in

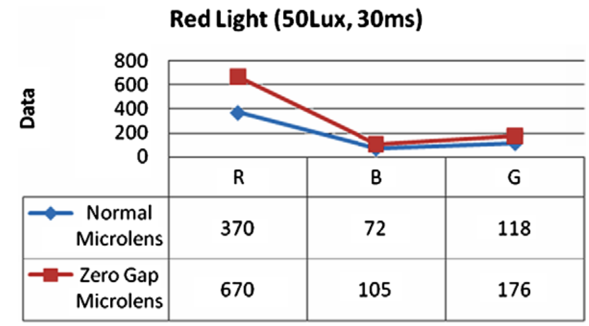

Fig. 3. Sensitivity results under red light (50 Lux, 30 ms). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

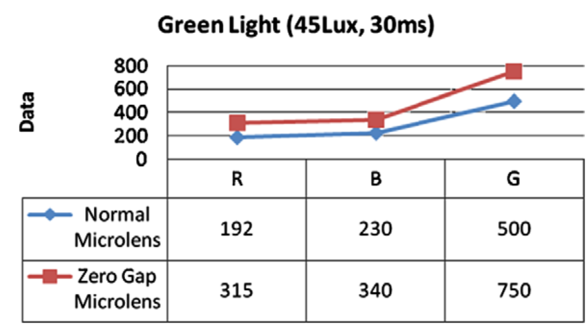

Fig. 4. Sensitivity results under green light (45 Lux, 30 ms). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

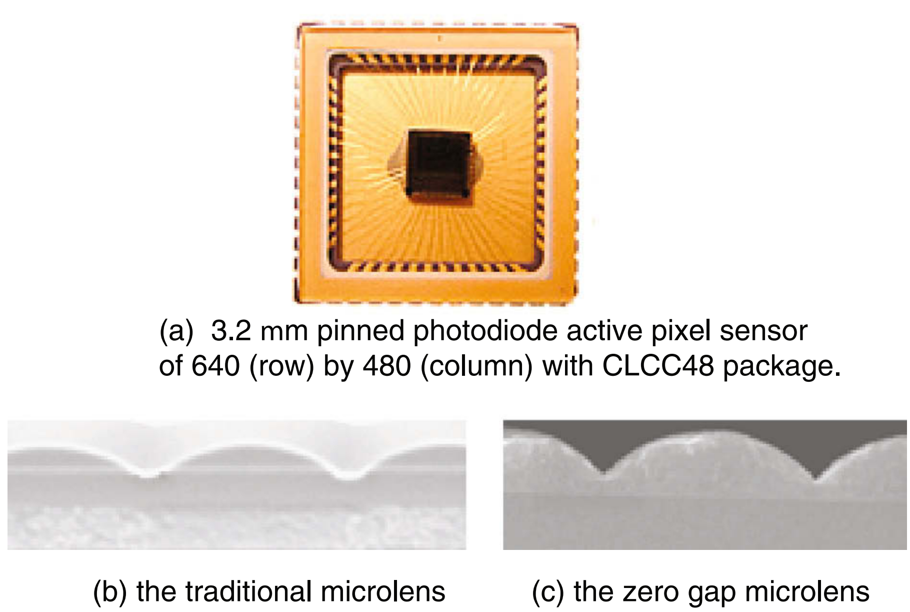

Fig. 2. Images of the image sensor chip and the traditional microlens array and the zero gap microlens array.