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RAPID COMMUNICATION

# Effect of chemical mechanical treatment on the optoelectronic properties in CMOS image sensor

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**Abstract**−This paper presents the effect focal length variation by controlling chemical mechanical polishing (CMP) processes on the CIS optical performance. White sensitivity was drastically increased, and saturation signal variation and dead zone deviation were reduced. These experimental results showed that controlled focal length was able to increase CIS optoelectronic performance.

Keywords: CMOS Image Sensor, CMP, Focal Length, White Sensitivity, Dead Zone

## INTRODUCTION

The CMOS image sensor (CIS) has been frequently used for mobile camera phones as well as digital still cameras due to manufacturing costs, low operating power, and low noise. Due to its outstanding properties in terms of power usage and degree of agglomeration, The CMOS image sensor is not only used in digital still cameras but also recently in image sensors of camera phones [1-4]. The CCD image sensor, which can be said to be a competitor, has high resolution but consumes a large amount of electricity compared to the CIS and has high production unit cost. Recently, for the improvement of optical property of CIS, research that includes the technology of silicon processing, color filter array, microlens integration, package miniaturization, pixel design is actively taking place [5-9]. The properties of CIS, like a normal CMOS product, are divided into simple function without light characteristics and those with light characteristics [10]. The image sensor which is related to light properties is a device that basically converts the image of an object into an electronic signal; thus it must convert the image itself depending on the color of the object or brightness of light. And without the distortion of image, it should realize the image of the object in a very dark or bright place [11-15].

The main objective of this study was to investigate the properties that are analyzed to see whether such functions are properly realized are dark current, sensitivity, saturation signal variation, dead zone deviation.

As in Fig. 1, which displays the composition of CIS, the light characteristics of CIS are done by focusing on the photo diode using the microlens of R.G.B., i.e., the three primary colors. To obtain a more improved light characteristic, it is important to optimize the distance and structure of the photo diode located at the substrate.

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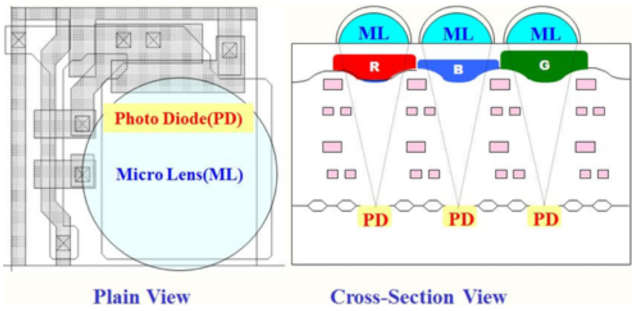


**Fig. 1. Schematic diagram of CMOS image sensor.**

This research, as a means to enhance the light properties of CMOS image sensor, changed the focal length [16] between the microlens and photo diode through the control of CMP process, and observed through experiment how CIS light properties are changed.

## EXPERIMENTAL PROCEDURE

An experiment was done with the method of changing the CIS, applied with 0.18 μm standard CMOS, into oxide CMP process conditions, and the focal length between the microlens and photo diode was mainly controlled by the amount of CMP polishing. CMP polishing was done by using a conventional slurry that includes silica abrasive from a rotary form of CMP polisher that is attached with polyurethane types of pad. The first step CMP with high selective slurries and the final step CMP with low selective slurries was then performed using an IC1010 Pad and SKC Pad on Mirra polisher, respectively. Cleaning involved $NH_4OH$ and HF solutions. The first step CMP process used a high selectivity slurry with very electronegative additive [commercialized name: HS8102-GP with pH 6.78] and $CeO_2$ abrasive [commercialized name: HS8005-HX], maintaining the slurry at pH 8-9, 160 nm mean abrasive size and 5.06% concentration. The final step CMP was treated using low selective slurry with DHPS-11 slurry, maintaining the slurry at pH 11, 110 nm mean abrasive size and 11% concentration. Polishing time was between 20 and 50 s.

Post CMP cleaning used the double brush scrubber using $NH_4OH$/HF chemical. The test equipment that measured the light properties included process control monitor (PCM) test devices, measuring CIS light properties using Teradyne equipment with the model name of st21t and st22t.

## RESULTS AND DISCUSSION

For the test conditions of this experiment, three types of split conditions were evaluated. For convenience sake, using the focal length between microlens and photo diode in condition 1, and by normalizing the photo diode distance of microlens in conditions 2 and 3, the split conditions were stated. As shown in Fig. 2, as a result of observing the change in property of white sensitivity, related to the brightness of light, the most important factor of light property out of the CMP process test item, for the CMP process condition which the NFL is 0.8, there was no significant difference in NFL comparison, and in the case of CMP process condition with the NFL of 0.6. The ratio per person of NFL becomes normalized, increases by about 1.1 times and it can be seen that the sensitivity property was enhanced.

Also, as a result of measuring the property change in white sensitivity on WIW (within wafer uniformity), as seen in Fig. 3, when the CMP condition is changed in NFL of 0.6 in wafer center and edge die, it can be seen that the sensitivity properties were improved while maintaining the same standard. Fig. 4 shows the property of saturation signal variation, related to image recognition but has no relation to the brightness of light. As shown in the picture, the condition at which NFL is 0.8 has almost no difference from the basic conditions of NFL 1 in terms of saturation signal variation. Whereas, in the condition of NFL 0.6, the variation value is greatly reduced from 0.8 to 0.4; thus there is an improvement in property taking place. Fig. 5 is the result of evaluating the dead zone deviation properties following the CMP conditions; thus unlike the aforementioned two properties, there is no tendency of focal length reduction following the CMP condition, but in the condition of NFL 0.6, it identically shows an outstanding property.

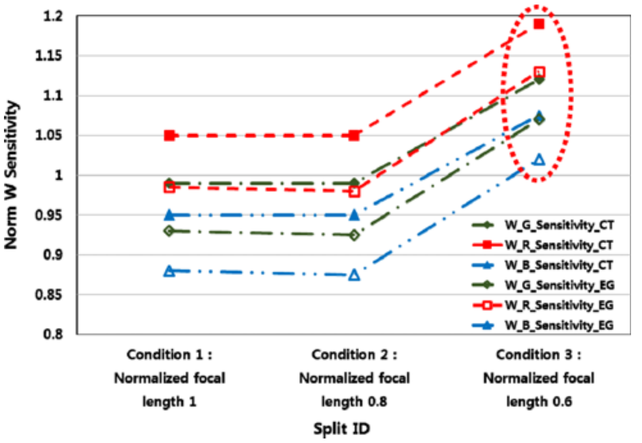


**Fig. 2. Variation of white sensitivity characteristics with CMP conditions.**

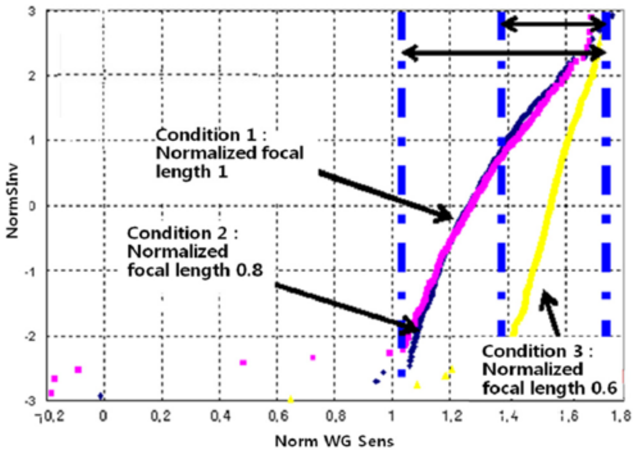


**Fig. 4. Characteristics of saturation signal variation with various CMP conditions.**

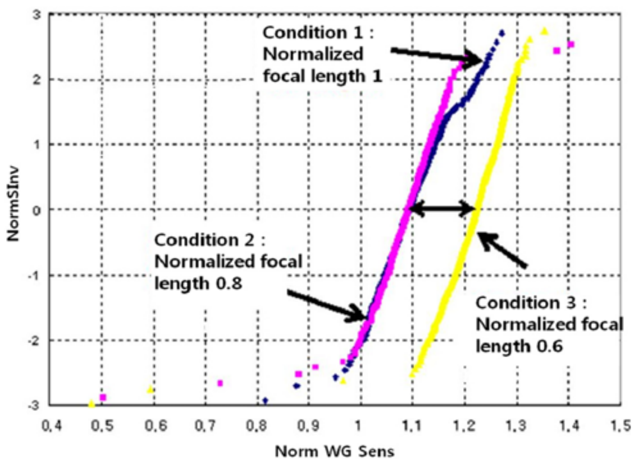


**Fig. 3. Variation of white sensitivity characteristics in within wafer (WIW).**

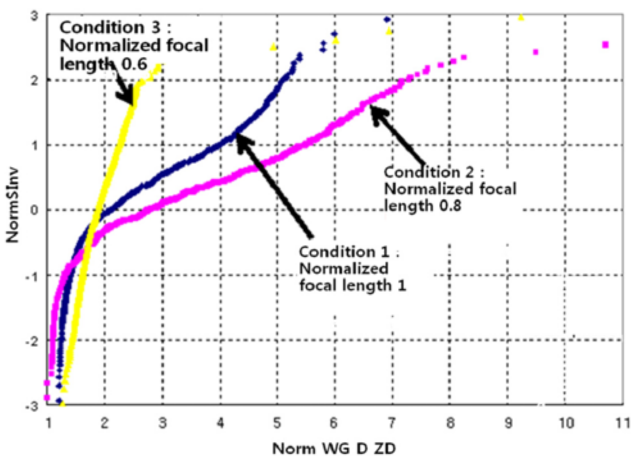


**Fig. 5. Effect of dead zone deviation (DZD) with various CMP conditions.**

## CONCLUSIONS

An experiment has been conducted by changing the distance between a microlens and photo diode as means to enhance the light properties of CIS devices. For the case of white sensitivity, an important factor of light properties, the sensitivity can be seen to improve regardless of the center of the edge of the wafer as the focal length between the photo diode and microlens is reduced. Also, as signal variation and dead zone deviation, both properties of image recognition, are changed into the optimized CMP process conditions, the properties were shown to have improved. Thus, the change of focal length through CMP process conditions has been confirmed to contribute to the CIS light property enhancement.

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