Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 25 (2011) 1277 – 1280

Procedia Engineering

www.elsevier.com/locate/procedia

Proc. Eurosensors XXV, September 4-7, 2011, Athens, Greece

# Stereoscopic image sensor in CMOS technology

J. P. Carmo, M. F. Silva, R. P. Rocha,
J. F. Ribeiro, L. M. Goncalves, and J. H. Correia

*University of Minho, Dept. Industrial Electronics, Campus Azurém, 4800-058 Guimaraes, PORTUGAL*

**Abstract**

This paper presents a stereoscopic image sensor in CMOS technology. An array of microlenses (fabricated with post processing techniques) separates the left and right optical channels to form the stereoscopic image. An array of optical filters tuned to the primary colors allows a multicolor usage. The fill factor is increased by applying the Canon's 1.5 transistor (1.5 T) concept and photodiodes with octagonal shapes for increasing the fill factor. The reflow method applied to the AZ9260 thick photoresist allows the fabrication of microlenses with high reproducibility and low cost.



Stereocopic image sensor, microlens, reflow, AZ9260.

## 1. Introduction

The available image sensors are not ready for stereoscopic acquisition and suffer from two major visualization problems. The first one is the unavailability of image sensors with the necessary specifications, i.e., the present resolution for distal sensors is 800×600 pixels with a pixel-size of 3 μm or above [1]. The second problem is the lack of stereoscopic vision which means exams without or with a deficient depth perception. The stereoscopic vision as well as the high-resolution imaging enhances the quality of the exams. Better resolution allows the medical doctors to understand the status of the patient and to quickly identify health problems. The traditional solution based on two cameras for getting two viewpoints can fail because the viewpoints may be very different amount them, whose consequence is the induction of psicovisual confusion in the medical doctors. This happens due the human brain is significantly more sensitive and less tolerant to bad stereo images. Thus, it can't tolerate differences between the right and left images. To resume, the image sensor presented in this paper provides means to acquire stereoscopic images with high resolution.

1877-7058 © 2011 Published by Elsevier Ltd.
doi:10.1016/j.proeng.2011.12.315

## 2. Architecture

Figure 1(a) shows the general concept of the miniaturized stereoscopic image sensor. The image sensor is composed by two entrance apertures from where the left and right channels are passing before being focused by an objective lens. The objective focus the two incident beams in the direction of the microlens, where the light is concentrated the in a small area. After the passage by the optical filters, the individual rays coming from each entrance aperture are directed towards the respective CMOS photodiodes. Figure 1(b) shows stereoscopic image formation by microlens and the corresponding focus on CMOS photodiodes. The two viewpoints are separated by focussing each side on respective sensor column.

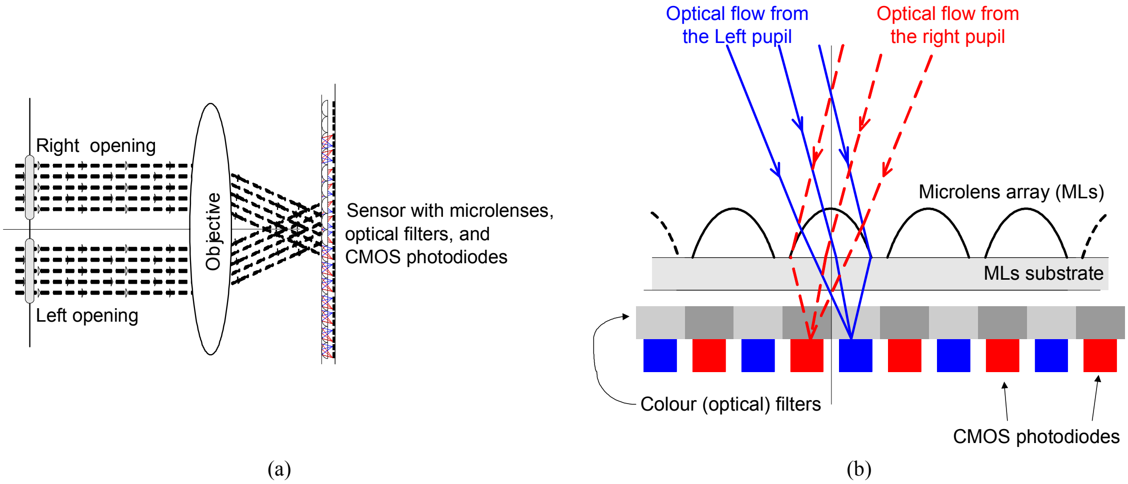



Fig. 1. (a) The architecture of the proposed image sensor in CMOS technology and the concept behind the stereoscopic image formation. (b) The detailed stereoscopic image formation by the microlens..

The photodetector is a $n^+$/p-epilayer junction photodiode fabricated in a CMOS process, because it provides the best possible quantum efficiency in the desired spectral range of photodiodes available in a CMOS process, at the same time yielding the highest possible fill factor, since a deep n-well is not required for every pixels [2]. A shared-pixel architecture (proposed by the Canon company) uses the 1.5-transistor concept to maximize the fill factor - see the Figure 2(a) [3]. The pixel consists of transfer transistors ($M_1$, $M_2$, $M_3$ and $M_4$), reset transistor ($M_5$), amplifying transistor ($M_6$) and four photodiodes. By using $M_5$ as a row select transistor, a conventional row select transistor becomes unnecessary. In this architecture, the reset transistor ($M_5$) and the amplifying transistor ($M_6$) are shared by four photodiodes ($PD_1$ to $PD_4$). As a result, a minimum number of transistors per pixel are necessary. Further improvements of fill factor are expected by using the octogonal shape in the 4-neigbors pixels, because it provides a shared chip-area to integrate the next-to-the-pixel circuitry [4] – Figure 2(b).

The fabrication of thin films with a band-pass around a given wavelength is done by successively depositing different dielectric materials in order to obtain a dielectric multilayer structure. For each primary color, the thin films yield a passband around the respective wavelengths. The green colour requires a special care, since each pixel is composed by a transfer MOSFET, and the amplifier circuit - M6 in Figure 2(a) - is shared - shading in Figure 2(a) - by four neighbours pixels, thus the Figure 2(a) arrangement must be provided: GREEN near red (GnR), red (R), blue (B) and GREEN near blue (GNB), all arranged in two lines [5]. The dielectric materials containing in the optical filters are composed by a stack of TiO2 and SiO2 thin films (refractive indexes in the visible spectrum: about 3.0 and 1.5, respectively). A huge pass-band optical filter on top blocks the nonvisible part of the spectrum.

Previous simulations made with the TFCalc program demonstrated that the photodiode structure without two of the three dielectric layers above the pn-junction provide the best possible quantum efficiency in the desired spectral range of photodiode structures available in the CMOS process. Thus, this requires the removal of the $SiO_2$ oxide and the silicon nitride layers. This removable process can be performed using the Reactive Ion Etching (RIE) method.

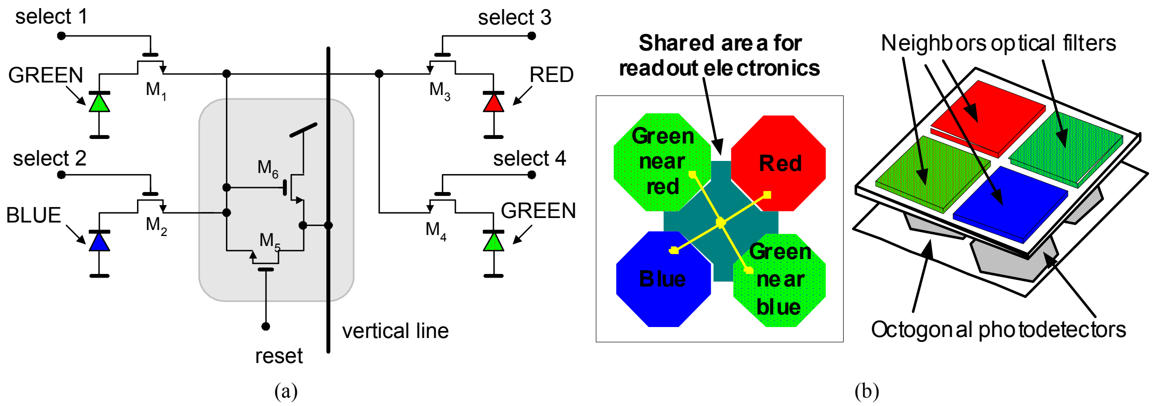



Fig. 2. For the arrangement of four neighboring pixels: (a) a configuration showing the shared electronics ($M_5/M_6$); (b) the spectral sensitivities of the optical filters and the respective photodetectors (each one with an octagonal shape).

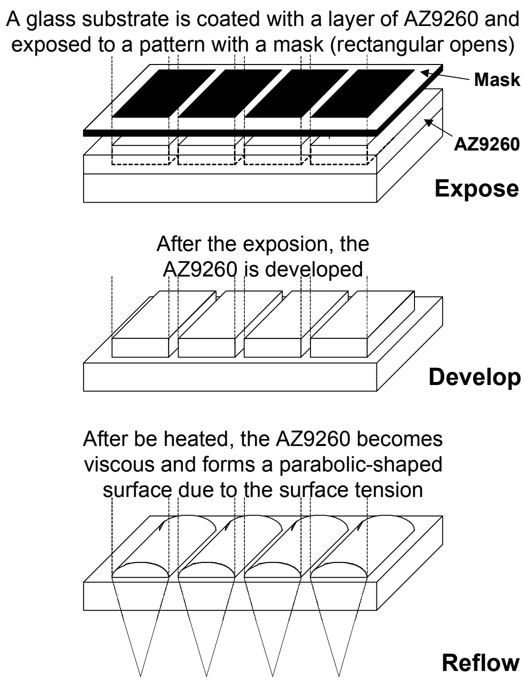
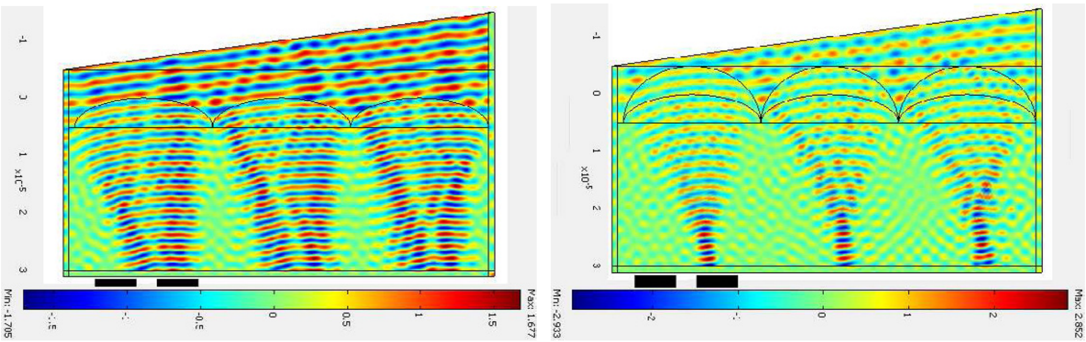



Fig. 3. The reflow process applied to the AZ9260 photoresist for fabricating microlenses arrays.

## 3. Microlens fabrication and simulation

Candidate photoresists for fabricating the microlens include the SU-8/2, AZ9260 and AZ4562 by way of the reflow method, whose processing steps are presented in the Figure 3. This allows the production of arrays containing a million or more microlens of good optical quality in just a few minutes and with high degree of reproducibility of their characteristics [6]. Figure 4 shows FEM simulations considering impinging light from the left channel (the concept can be applied to the right channel, as well as overlapped to get the global effect) with an angle of approximately 7.6º (near the practical angles) for two cases: lenses with (a) 24 μm×5 μm and (b) 24 μm×10 μm. The lenses behaviour was simulated taking in account a silicon dioxide ($SiO_2$) substrate with a thickness of 25 μm. It is possible to observe the concentration of light into the direction of photodiodes (represented in the figures by pairs of black rectangles on bottom). The simulations show that the best results (light more concentrated) are achieved with high curvature lenses. The simulations also confirm the viability to separate the left and right channels for focusing in the respective photodiodes and for getting an estimate of the cross-talk between adjacent photodiodes (the cross-talk is smaller in the second simulation where the curvature is higher).



(a) (b)

Fig. 4. FEM simulations showing the light concentration into the right photodiode. The simulations where obtained respectively for lenses measuring (a) 24μm×5μm and (b) 24μm×10μm. The simulations also allows to roughly estimate the degree of cross-talk between two adjacent photodiodes (e.g., between the left and right channels).

**Acknowledgements**

This work was fully supported by the Portuguese Foundation for Science and Technology, under the FCT/PTDC/EEA ELC/109936/2009 and FCT/PTDC/EEA ELC/114713/2009 projects.

## References

[1] W. Yang, O.-B. Kwon, J.-I. Lee, G.-T. Hwang, S.-J. Lee, "An integrated 800×600 CMOS imaging system", in Proc. ISSCC., pp. 304-305, 1999.

[2] G. Minas, R. F. Wolffenbuttel, and J. H. Correia, “An array of highly selective Fabry–Perot optical channels for biological fluid analysis by optical absorption using a white light source for illumination”, Journal of Optics A: IOP Publishing, Vol. 8, pp. 272 278, 2006.

[3] H. Takahashi, M. Kinoshita, K. Morita, T. Shirai, T. Sato, T. Kimura, H. Yuzurihara, S. Inoue, and S. Matsumoto, “A 3.9 μm pixel pitch VGA format 10 b digital output CMOS image sensor with 1.5 transistor/pixel”, IEEE Journal of Solid State Circuits, Vol. 39, pp. 2417 2424, 2004.

[4] J. Dubois, D. Ginhac, M. Paindavoine, Member, and B. Heyrman, "A 10 000 fps CMOS sensor with massively parallel image processing", IEEE Journal of Solid-State Circuits, Vol. 43, pp. 706 717, 2008.

[5] M. Mori, M. Katsuno, S. Kasuga, T. Murata, and T. Yamaguchi, “1/4 Inch 2 Mpixel MOS image sensor with 1.75 transistors/pixel”, IEEE Journal of Solid State Circuits, Vol. 39, pp. 2426 2430, 2004.

[6] Z. D. Popovic, R. A. Sprague, and G. A. N. Connell, "Technique for the monolithic fabrication of microlens arrays", Applied Optics, Vol. 27, pp. 1281 1284, 1988.