Microlenses for Improved Space Imagers

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Microlenses are widely used within consumer imaging products, not only in order to compensate for non 100% fill factor but also in view of improving the Modulation Transfer Function (MTF) and cross-talk between adjacent pixels. Such microlenses are manufactured within the standard flow of CMOS foundries and are directed at consumer electronics imagers with pixel pitch in the 1 to 5 µm range. They rarely address the requirements of typical space imagers with pitch from about 5 to 100 µm. However, there is a clear need for performance improvement of space CMOS imagers enabled by microlenses. CSEM was mandated by the European Space Agency (ESA) to lead an activity with the objective to design, manufacture and test the application of microlenses on a back thinned and back illuminated CMOS image sensor (BI-CIS) under space environment conditions.

CSEM has a long track-record in the fabrication and deposition of custom microlens arrays on various type of imagers. Microlens arrays can increase the sensitivity of imager sensors, reduce their angular dependency and vignetting or improve their resolution by maximizing their MTF and minimizing their parasitic light sensitivity.

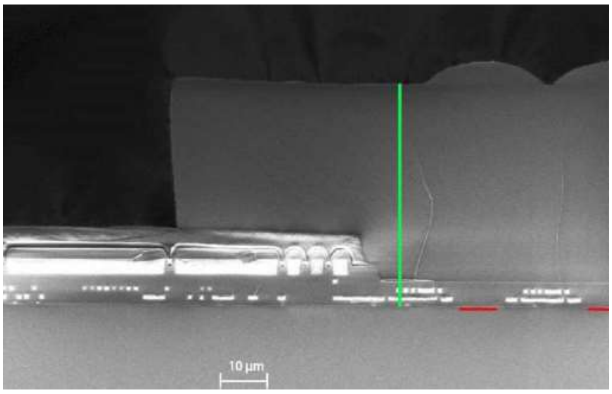

Figure 1: Scanning Electronic Microscope cross-section view of an image sensor covered by microlenses produced by CSEM. Red horizontal segments (bottom-right corner): sensitive areas of the imager. White: metal contacts and interconnects [1].

Designing and manufacturing microlens arrays requires an excellent understanding of the imager pixel geometry, an accurate ray-tracing simulations for the tolerancing and a perfect design for manufacturability optimization. And also all the information about the light incidence distribution.

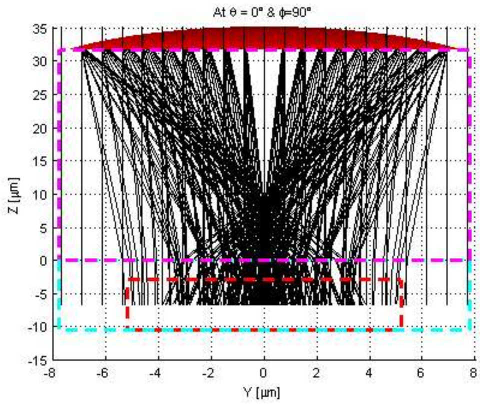

Figure 2: Ray-tracing (Matlab®) cross-section of a single BI-CIS pixel covered with a square microlens at normal light incidence. X & Y scales in microns, λ = 530 nm. The red dashed rectangle (centered bottom one) highlights the sensitive volume of the pixel.

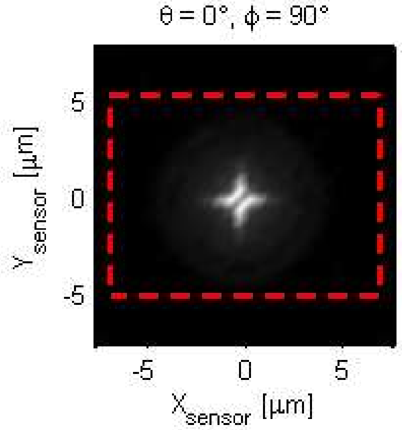

Figure 3: Result of the ray tracing from Figure 2 showing the light distribution on the pixel. The red dashed rectangle highlights the sensitive area of the pixel.

Manufacturing microlens arrays for state-of-the-art imagers to be used in space environments requires various testing and validations to ensure the robustness of the microlenses and their material e.g., to thermal shock and cycles, to vibrations and to UV and other (protons etc.) irradiations.

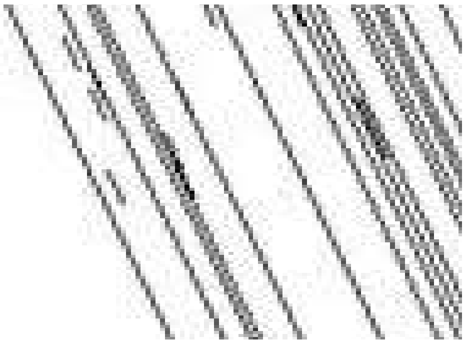

Figure 4: Ray-tracing (LightTools®) of a 3×3 pixel BI-CIS array covered with square microlenses at normal light incidence. The blue rectangles at the bottom highlight the sensitive area of the pixels.

In the scope of the ESA activity EXPRO+ AO/1-8624/16/NL/PS/gp, CSEM is designing microlens arrays and their complete space proof testing in order to address the needs of the space industry.

Higher resolution imagers will translate in better imaging systems in satellite and space probes. This will enable a higher accuracy in Earth observations and deep space scientific missions imaging.

[1] J. M. Pavia, M. Wolf, E. Charbon, "Measurement and modeling of microlenses fabricated on single-photon avalanche diode arrays for fill factor recovery." Optics express 22.4 (2014): 4202-4213.