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Evaluation of Microlenses, Color Filters and Polarizing Filters in CIS for Space Applications

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ABSTRACT

For the last two decades, CNES optoelectronic detection department has studied and evaluated space environment effects on a large panel of CMOS image sensors (CIS), coming from a wide range of commercial foundries and device providers (cf. Table 1). Many environmental tests have been realized in order to bring insights on detection chain degradation in modern CIS for space applications (cf. Table 2).

Thanks to their good electro-optical performances, high integration level, low power consumption and tolerance to the space radiation environment, CIS are more and more preferred over Charged Coupled Devices (CCD) in many future space imaging missions. Moreover, the CIS technology has drastically improved during the las decade, reaching very high performances in term of Quantum Efficiency (QE) and spectral selectivity. These improvements are obtained thanks to the introduction of various components in the pixel optical stack such as microlenses[1], color filters[2] and polarizing filters[3]. However, since these parts have been developed for a commercial purpose, it is crucial to evaluate if these technologies can handle space environment for future imaging missions and very few literatures exist on that robustness. Several space imaging systems have thus been able to benefit from these technologies on which these tests have been carried out, such as the Remote Micro-Imager (RMI) in the SuperCam instrument aboard the Mars 2020 rover Perseverance[4].

This CNES work demonstrates that these kinds of optical stacks show little variation in terms of efficiency when exposed to space environment. It also allowed studying the response of various optical systems at pixel level for various technologies such as microlenses, color filters and polarizing filters (shown respectively in Figures 1, 2 and 3).

In the presentation, an overview of environmental tests results (cf. Table 2) on many CIS from different commercial technologies and several optical stacks are compared and show that they are suitable for space applications. Thanks to their robustness, they can significantly increase CIS performances without being a limiting path for them along the mission.

Since the full paper containing data and more will be published later in MDPI Sensors[5], it is on purpose that we prefer submitting a more consistent abstract with detailed Tables showing the amount of realized tests, and CNES photos of the optical stacks we are talking about.

Keywords: Image sensor, optical stack, microlenses, filters, space environment

TABLE 1 – Example of irradiation profiles performed on several technologies

Commercial CMOS imaging technology	Technology node (nm)	Pixel pitch (µm)	Illumination	Microlenses	Color Filter Array	Polarizing filters	Particle type	Total Ionizing Dose (krad SiO_2)	Displacement Damage Dose (TeV/g Si)	Bias	Radiation Hardened
A.1	180	5.5	FSI	Y	Y	N	50 MeV p+ 150 MeV p+	56 21	3100 645	grounded grounded	N
B.1	180	5	FSI	Y	N	N	50 MeV p+ 150 MeV p+	56 21	3100 645	grounded grounded	N
B.2	180	7	FSI	Y	N	N	Co60 g	100	-	biased	Y
B.3	180	10	FSI	N	Y	N	Co60 g	0.6×10^6	-	biased	Y
B.4	180	10	FSI	N	Y	N	10 keV X	1×10^6	-	biased	N
C.1	65	3.45	FSI	Y	Y	N	50 MeV p+ Co60 g	300 150	7560 -	grounded grounded	N
C.2	65	4.63	BSI	Y	Y	N	50 MeV p+ Co60 g	300 150	7560 -	grounded grounded	N
C.3	65	1.1	BSI	Y	Y	N	62 MeV p+ Co60 g	100 1×10^3	2160 -	grounded grounded	N
C.4	65	3.45	FSI	Y	N	Y	50 MeV p+ Co60 g	50 150	1930 -	grounded grounded	N
D.1	90 FEOL 65 BEOL	13/26	FSI	Y	N	N	60 MeV p+	10	250	grounded	N
E.1	110	2.8	FSI	Y	Y	N	50 MeV p+	100	2510	grounded	N

Table 2 – Environmental tests

Test type	**Test characteristics**
Humidity Cycling	500 hours @ 70°C and 70% RH
Thermal Cycling	50 cycles [-55°C / +125°C]
High Temperature Storage	1000 hours @ 100°C
Vacuum	1 week @ $<10^{-6}$ Torr
UV	48 hours @ 1 Solar Unit
Irradiations	50 MeV p+ / 150 MeV p+
Physical analysis	Microsection, FTIR and cleaning solvent

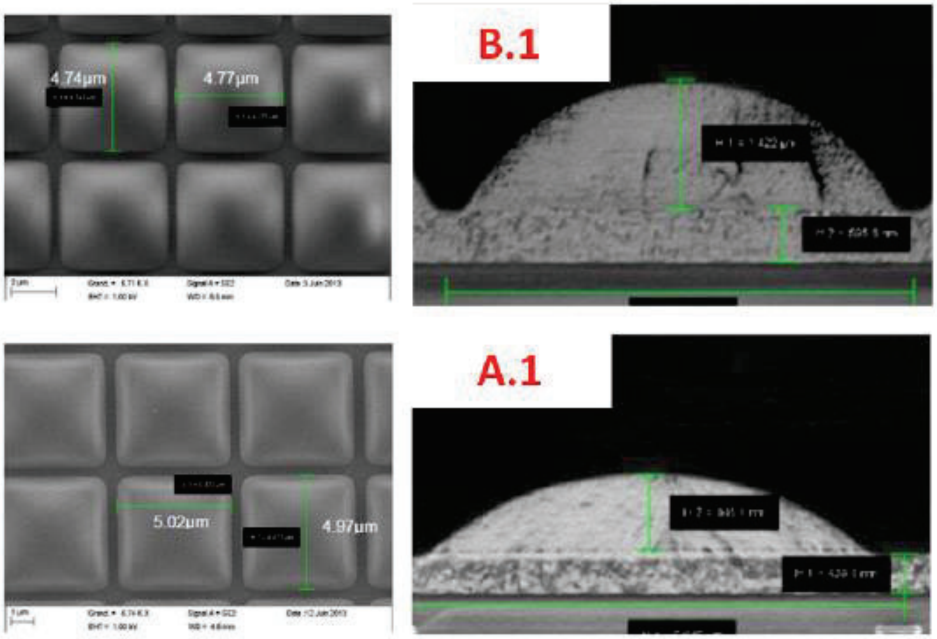

Figure 1 – SEM views of microlenses

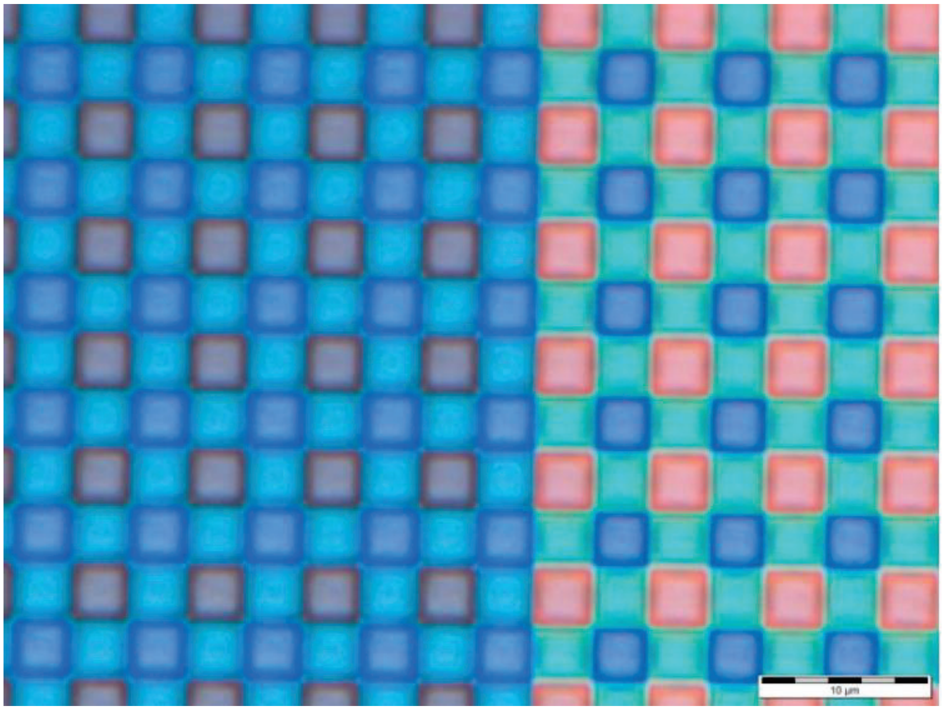

Figure 2 – Microscope view of a Bayer Filter (Color Filter Array)

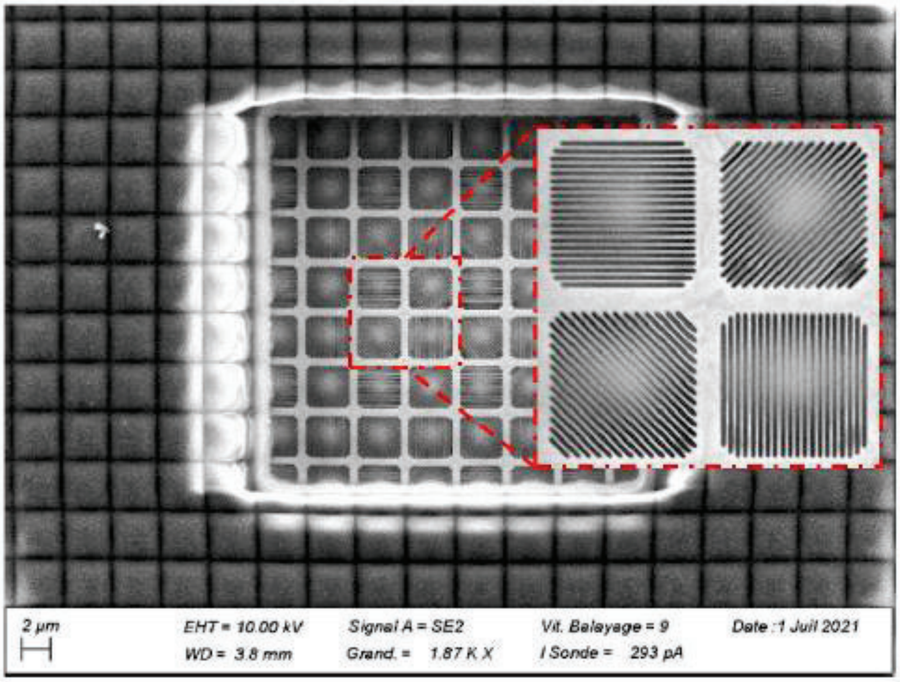

Figure 3 – SEM view of Polarizing grids (C.4 device)

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