Thin Film on CMOS Active Pixel Sensor for Space Applications

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Summary

An Active Pixel image Sensor (APS) with integrated analog signal processing, full frame synchronous shutter and random access has been developed especially for applications in the field of star trackers. A thick vertical diode array in Thin Film on CMOS (TFC) technology is explored to achieve radiation hardness and maximum fill factor.

Introduction

Autonomous star trackers determine the position of satellites and space probes by using recorded patterns of star constellations. The design of image sensors used for this application is defined by the capability of chronological assignment and interpolation of the recorded image data combined with a resistance to accumulated and temporary irradiation as well as a minimum of power consumption and weight at system level. Unlike CMOS image sensors [1] the CCD technology most commonly used on the market is unfavorable because of its high demands for electronics and its lack of signal processing integration.

The active pixel imager for space applications with TFC technology presented here combines the advantages of an integrated signal processing with irradiation resistance and a nearly 100 % fill factor of a vertical diode array through deposition of an amorphous silicon layer (fig.1). The pixel having a dimension of 20 x 20 µm² integrates all major functions for analog image optimization such as Correlated Double Sampling (CDS) and Delta Double Sampling (DDS) by storing reset- and signal data. The pixel array with a resolution of 664 x 664 pixels thus enables an integrated full frame synchronous image recording (Global Shutter) with a non-destructive readout mode. The following signal path analyzes the analog signals and the CDS/DDS data of each line by using a two-phase column multiplexer with random address access. The integration of a temperature sensor and an output multiplexer for external signals completes the functionality for space applications.

The low incidence of light in star trackers causes high demands on the photo diodes in terms of the quantum efficiency, dark currents and sensitivity. This requires a low diode capacity, which can only be achieved by amorphous vertical diodes with an α-Si layer thickness >1.7 µm. This film is much thicker than in comparable sensor implementations [2][3][4][5].
Results

The APS for star tracker CMOS substrate was realized in a 0.5 µm technology and has a size of 15.4 x 16.0 mm². With integrated test features the electrical characteristics such as linearity, homogeneity and electronical noise were verifiable with and without a deposited TFC layer.

Initial image data obtained with a p-i-n diode structure exhibited linear and homogenous results (fig.2), but an insufficient quantum efficiency in a TFC layer thickness of 1.5 – 2 µm. In simulations it became apparent that this could be tracked back to the different mobility of the photo-generated charge carriers.

A reverse layer structure (n-i-p diodes) could be fabricated on top of the existing sensor circuitry as well. This configuration leads to the compliance of the specified parameters like a dark current of 70pA/cm² and the quantum efficiency displayed in fig. 3.

Conclusions

A new approach to image sensor for star tracker applications and space applications in general has been presented and its feasibility has been demonstrated. The new concept has an obvious advantage in providing irradiation hardness and maximum fill factor.

References

[4] C. Harendt et al. ” Logarithmic HDRC Image Sensors with Thin-Film-on-CMOS Technology”, Fraunhofer IMS Workshop "CMOS Imaging From Technology to Application", Duisburg, 2002