PhD position @ ISAE-SUPAERO

Research of innovative solutions for the implementation of pinned photodiodes in high resistive substrates for infrared detection or particles detection

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Summary: Silicon image sensors based on CMOS microelectronic processes are nowadays widely used for consumer and scientific applications. In particular, they play an important role in space instruments and are involved in mission devoted to earth observation, event detections, scientific missions… Due to their continuous improvement, CMOS Image Sensor (CIS) have actually almost replaced CCD detectors. This has been made possible thanks to technological improvement such as backside illumination, pinned photodiode, optimization of doping profiles, and improvement of oxide quality.

The development of Pinned PhotoDiode (PPD) for CMOS imaging processes has brought very low dark current and noise level compared to classical photodiodes, leading to an increased sensibility. This has been made possible thanks to the isolation of the photodiode with respect to the surface oxide and to the introduction of transfer gate between the photodiode and the storage node. In this way, CMOS imagers including PPD are being developed for future CNES projects, as for example TDI XS CMOS for “THR NG”.

Generally, CIS photodiodes are realized in non-resistive substrate (in the range of 1 Ohm.cm), and the PPD key parameters all well-known and understood: dark current, transfer efficiency, pinning voltage, full well capacity … This kind of commonly used substrate allows for photo-detection in the visible range, with weak performances in near infrared or long wavelength (> 700 nm), because the charge collection region (depleted area) does not extend deeply and cannot efficiently collect electrons generated by long wavelength illumination. However, there is a strong demand for near-infrared detection. One alternative is to use more resistive substrate, which leads to a deeper depleted region and therefore to a better collection of charge generated by infra-red illumination. However, the behavior of the pinned photodiode in more resistive substrate is unknown, and especially it is particularly unclear how the PPD key parameters are going to change and why. The predictable blocking points are:

- The modification of the doping environment around the PPD and therefore a degradation of the charge transfer, an increase of the lag (charge transfer inefficiency), and the appearance of leakage between the sense node and the substrate or the PPD.
- Modification of the pinning voltage and full well capacity
- Change of the amount of dark current
- Need for additional ground contacts, as the substrate will be more resistive

The challenge is therefore to understand and predict the PPD characteristic, and also to propose innovative solutions in order to use the PPD with advanced substrates.

The PhD goals are as the following:

- Understand the impact of more resistive substrate on PPD key parameters and on the physic of charge transfer. This work will be based on the use of TCAD simulation, and on the measurement and analysis of test structures and an imager.
- Evaluate the perspective to design a fully depleted PPD
- Propose new models for the estimation of PPD parameters (pinning voltage, dark current) taking into account the substrate resistivity
- Define a guideline for the realization of PPD in high resistive substrate.

The PhD work will take place at the CIMI laboratory at ISAE, which is an expert in the CMOS image sensor development since 20 years. CIMI has a large expertise of existing CIS processes, and has developed a strong knowledge in the understanding of the physic of photo-detection; moreover, CIMI has a strong expertise in device simulation and in detector characterization.

PhD workplan:

- Carry out a literature survey of the state of the art concerning the physic of photodetection, CMOS imaging processes, pinned photodiode devices
- Understand what are the parameters influenced by the substrate resistivity and model / predict their behavior. Propose solutions or compensations in order to compensate an eventual degradation of the PPD key parameters.
- Design test structure, and / or an imager on more resistive substrates with the aim to validate the assumptions and the models.
- Measure and analyze the test ship
- Synthesize the work developed during the thesis.