PhD Position at ISAE-SUPAERO

Space Radiation Environment Effects on Infrared Detectors

PhD advisor : Vincent Goiffon
Supervisors :

- CNES : Cédric Virmontois
- Airbus Defence and Space : Olivier Saint-Pé
- CEA LETI : Olivier Gravrand

Funding : CNES and Airbus DS
Main PhD position location : CEA LETI (Grenoble, France)

Contact : vincent.goiffon@isae-supaero.fr

Scientific domains: Optoelectronics, Infrared Detection, Microelectronics, Semiconducteur Device Physics, Photodetection

Keywords : Infrared detectors, space radiation environment, radiation effects on semiconductor devices, II-VI materials, semiconductor defects, displacement damage, ionization, Earth Observation, Dark Current, Leakage Current, MCT, HgCdTe, Total Ionizing Dose, Displacement Damage Dose.

Summary :

Infrared detectors have been a key technology for Earth Observation from space, especially for

Infrared (IR) detectors have long played an important role in the field of Earth observation from space, especially for meteorological, climatological and atmospheric chemistry applications. Given the wide range of wavelengths to be studied (from 1 to 16 microns), the need for high sensitivity and rapid response as well as the interest of operating at the highest possible temperature, the detectors based on the semiconductor material CdHgTe (also called MCT) are by far the most used.

This technology of IR detectors has been used since the first generations of high-performance European Earth observation instruments in the IR domain (since the 1970s). However, few scientific studies have been conducted so far in Europe to understand and control the interactions between these detectors and the space radiative environment, unlike detectors based on silicon technologies.

Beyond this lack of scientific background, the need for further studies on the effect of radiation (protons, gamma ...) on multiplexed MCT photodiode IR detectors is also justified by several other reasons:

- The increase in the number of pixels and their operating temperature amplify the degradations induced by the space environment
- It is critical to anticipate the degradation of the performance of on-board detectors aboard observation satellites in order to be able to size them as accurately as possible
- Several detection technologies are now trying to compete with the MCT material for IR space observation. In order to make an exhaustive comparison of the various candidate technologies for future missions, it is of primary importance to take into account their behavior in the space radiation environment.

The aim of this PhD thesis project is to characterize, analyze and understand the impairments induced by the cumulative ionizing dose and the displacement effects generated by the space radiation environment in infrared detectors. The target technology for this study is the standard LETI-Sofradir CdHgTe n/p technology used by the vast majority of European IR instruments currently under development. In order to decorrelate the sources of damage, the following variations will be explored on dedicated test structures:

- geometric variations of the samples studied to highlight the role of the different regions and interfaces of the detectors
- manufacturing process variations to evaluate their impact on radiation resistance
- the use of different radiation sources (protons, gamma, neutron, etc.) to discriminate the behavior of the defects induced by the cumulative ionizing dose of the defects induced by the atomic displacements

This subject proposes to address two main challenges:

- The first is to improve the knowledge of electrically active defects that limit the performances of infrared detectors, both after fabrication and after irradiation. These results will potentially improve these performances or enhance the radiation resistance of this technology.

- The second aims at obtaining a clear vision of the resistance to the radiation space environment of this type of imagers, to validate that they can be used in future space missions and to anticipate their behavior in a given mission, possibly through the development of predictive models.

The behavior of the infrared detectors studied will be compared to the literature, and in particular with the better-known behavior of silicon-based detectors widely used in a radiation environments. Among the parameters of interest for this study, the quantum efficiency, the dark current and the phenomenon of "Random Telegraph Signal (RTS)" will be the main targets.
The PhD work will be done mainly at CEA LETI (Grenoble, France), in the optronic department DOPT / SICM / LIR, with occasional stays at ISAE-SUPAERO (Toulouse), in the CIMI group dedicated to research on integrated imagers, in close collaboration with the AIRBUS Defense and Space and CNES (Toulouse) architectures and detector chain development departments.

In more details, the PhD student will have to:

- Perform a review of the state of the art:
    - physics of CdHgTe infrared detectors n / p doped Mercury gap and their manufacturing process
    - the effects of ionizing radiation and the effects of atomic displacements on the CdHgTe material
- Choose among the available objects (several geometries, doping or passivation) the most relevant pixel arrays, based on his bibliographical study. She/he will also have to identify the most relevant radiation sources to complete the study.
- Identify the radiation induced degradation and determine the parameters that influence these mechanisms. This will be done by irradiating the selected pixel arrays and by characterizing them, in terms of static performance, but also in terms of blinking pixels (RTS). Analytical models will possibly be developed to carry out an exhaustive study of the phenomena observed.
- Summarizes the results obtained by highlighting the effects identified and their origin. Depending on the level of understanding achieved during the thesis, models to anticipate the effects of the space radiative environment on the technologies studied may be proposed. This analysis work may also be based on flight data acquired in orbit on IR detectors using similar technologies, produced and qualified by Sofradir.
- The doctoral student will have to valorize his results in the form of scientific publications and communications in international conferences.

Required profile :

Master Degree (or equivalent) in at least one of the following specialties:
- nano / microelectronics (design, manufacturing processes ...)
- optoelectronics
- semiconductor (device) physics
- solid-state physics
- particle physics
- particle-matter interaction
- space radiative environment and effects on electronic components