Performances and Calibrations of Disruptive UVC Sensors for New Space Applications

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Performances and Calibrations of Disruptive UVC Sensors for New Space Applications

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Summary: This work overviews the development, selection and test of novel compact compact solid-state photodetectors based on β-Ga_2O_3, and optimized for the UVC. These sensors show inherently low dark currents, permitting room temperature operation without the need for a cooling system (mass and power savings) and thus avoiding cold surfaces trapping of environmental contamination. The oxide detectors have a spectral response peak at around 215-220 nm with a linewidth of 35 nm, providing excellent rejection of wavelengths above 250 nm ("250 nm solar-blindness"). Alloying β-Ga2O3 with Al can boost the natural bandgap of 4.9 eV up to 6 eV, thus offering deeper UV operation. Other key assets of β-Ga_2O_3 detectors for space applications are their intrinsic radiation hardness (longer lifetime), and their high potential gain that allows operation at lower voltages (several hundreds mA/W at -5 V). Presently under characterization (on more than 100 protoflight models) and presenting very promising performances, these detectors, after calibration and selection, will be integrated on a nanosatellite (INSPIRE-Sat 7, a "2U" cubesat) to be launched in early 2023 to monitor the 200–242 nm UVC solar flux. Indeed, amongst other potential uses, these UVC Herzberg continuum detectors are a unique possibility to monitor the UV input from the Sun in the Earth's stratosphere. The sensors are also projected for use in a number of future solar and climate satellite constellation ventures.

Keywords: UVC Detectors, β-Ga_2O_3 Oxides, Nanosatellites, Constellations, New Space Applications.

1. Introduction & Study Rationale

The influence of the Sun on climate and the role of solar variability in climate change, are subjects of sustained scientific and societal interest. Solar variability strongly affects the Earth's climate. Since the variation over time of solar ultraviolet (UV) is much larger, in proportion, than variations in total solar irradiance, it plays an important role in regional climate change through interactions with stratospheric ozone (the photolysis of molecular oxygen by UV is the source of stratospheric ozone). UV solar irradiance and its' variability thus represents a key input for both climate and solar physics (long term understanding of solar variability, e.g. solar minima decrease?).

Solar ultraviolet wavelengths are therefore interesting to observe because of this significant variability. Wavelengths between 200 and 242 nanometers (Herzberg's continuum) are of even more particular interest because this spectral band is absorbed in the stratosphere, and causes oxygen to dissociate and create the ozone layer. These reactions induce temperature and velocity anomalies which, in turn, cause changes in the local climate (cloud cover and water vapor content in the atmosphere, for example).

This work is an innovative development with an ambitious science goal: monitoring the Solar Spectral Irradiance (SSI) at 215/220 nm (Herzberg solar continuum: 200–242 nm) with an accuracy better than 0.5% (5 times better than our previous measurements in Space, e.g. with SOLAR/SOLSPEC [1]).

To achieve this objective we developed disruptive new ultrawide bandgap (≥ 4.9 ev) "solar blind above 250 nm" UVC detectors based on β-(Al)Ga_2O_3.

Furthermore, and since UV observations are to be performed in Space, these innovative detectors are destined for TRL 9 ("flight proven"), as they are to be integrated on the next nanosatellite of LATMOS (INSPIRE-Sat 7, a "2U" cubesat) in the first quarter of 2023.

This paper presents the characterisation, performance evaluation and qualification tests of these new β-Ga_2O_3-based photodetectors developed for New Space observations in the UVC spectral band (Herzberg continuum, 200–242 nm, in particular).

2. Realisation Rationale

For low radiation flux detection between 200 and 242 nm, a very large signal-to-noise ratio is essential. Furthermore, the spectral response of the detector should be selective for the 200–242 nm range, centered at 215–220 nm, with a low full width at half maximum (of the order of 35 nm) and excellent rejection so that the visible spectrum, which is much more intense, does not affect the measurement. In previous work [2] the authors showed that β-Ga_2O_3-based sensors can be engineered to combine both a spectral response peak in the 200–242 nm range and a very large rejection ratio of the visible solar spectrum. Thus, with the β-Ga_2O_3, we can simultaneously obtain the desired maximum response at 215–220 nm, a very high rejection ratio (> 1000 compared to the peak of sensitivity) at wavelengths ≥ 245–250 nm, and thereby achieve an excellent signal-to-noise ratio (dark current is very low: ≤ 1 pA). In practice these detectors are "solar blind above 250 nm" (since insensitive to visible and infrared light, "visible blindness"). Other key properties of detectors are their intrinsic radiation hardness (durable long term performances) and their wide operating temperature range (no need for cooling below 0, neither -20° nor -40°).

In the framework of the ANR DEVINS program, such detectors were realized right through from the wafer to the final packaged sensors (including device architecture development, photolithography, singulation, contacting, packaging and testing).

3. Performances

Probing tests were performed on hundreds of components to categorize detector performance. So far, up to 3 to 4 orders of magnitude in difference between dark and light currents was achieved at only -5V bias voltage. Dark current was very low (≤ 1 pA) beyond the detection limit of the available electronics. The response time was around 1 to 3s (rise time) and about or less than 80 ms (fall time). Responses were repeatable and stable over extended testing periods.

The above performances are limited by the constraint of the limited bias voltage available on the nanosatellite (-5V). Components would have much better response if biased to -30 or -50V. This is projected in our future space programs.

4. Selection and Tests

Suitable devices were selected from a large number produced (hundreds). A sensitivity minimum of 1 mA/W (before packaging: 10 mA after) and a background (or "dark") signal of < 1 pA were targeted.

The spectral responsivity peak had to be centered at 215 nm (± 5 nm) to properly measure the Herzberg continuum (200–242 nm) UV input in the Earth's atmosphere.

Detector is "solar blind" outside the Herzberg continuum (rejection ratio > 1000 minimum for $\lambda \geq$ 250 nm compared with maximum sensitivity at peak).

After this, device binning and intensive robustness testing was performed (vacuum, thermal cycling, aging, mechanical robustness tests, etc...).

Fig. 1 shows spectral responsivities as a function of wavelengths for a set of 4 flight selected devices before packaging, and Fig. 2 the test bench of detectors after packaging in their TO can.

5. Conclusions

UVC detectors optimized for the 200–242 nm range were realized, tested and selected, and are now ready for intensive calibration (in the BIRA-IASB facilities in Brussels) before integration in the next LATMOS nanosatellite, INSPIRE-Sat 7 (launch planned for early 2023), and in projected future constellations.

Acknowledgements

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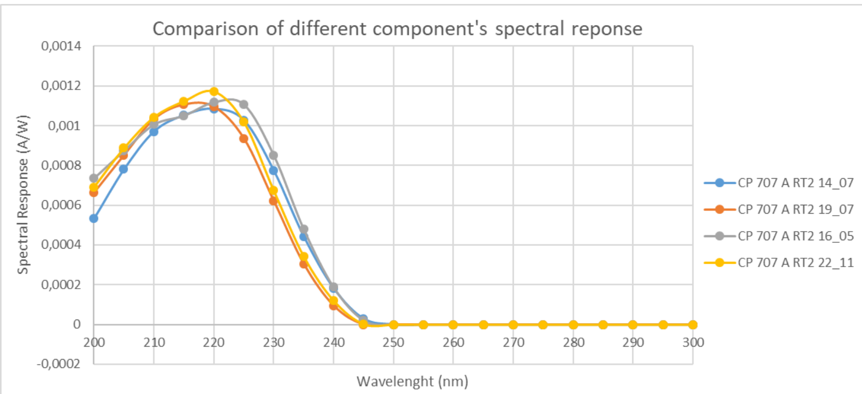

Fig. 1. Group of 4 β-Ga_2O_3 DEVINS components selected for the Nanosatellite INSPIRE-Sat 7 and presenting an excellent rejection (solar blind for λ > 250 nm), centering (peak between 215-220 nm) and FWHM (~35 nm).

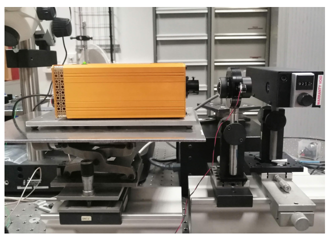

Fig. 2. Test bench for packaged β-Ga_2O_3 comprising a UV lamp and a monochromator.