engineering proceedings

Abstract

Optical Studies of a High-Performance Predictable Quantum Efficient Detector Based on Induced-Junction Photodiodes Passivated with SiO_2/SiN_x †

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† Presented at the 9th International Symposium on Sensor Science, Warsaw, Poland, 20–22 June 2022.

Keywords: silicon photodetector; inversion layer photodiode; induced-junction; primary standard; predictable quantum efficiency

The Predictable Quantum Efficient Detector (PQED) is a silicon-based optical sensor which is designed to convert every photon in the incident photon flux to an electron–hole pair. The sensor thus produces a photocurrent with the spectral responsivity of $R(\lambda) = e\lambda/hc$ depending only on fundamental constants and wavelength. In this work, we describe recent advances in achieving the ideal photon-to-electron conversion ratio within the uncertainty of a few tens of ppm (parts per million) [1].

We performed optical studies of silicon p-type 7-reflection trap detectors made of two induced-junction photodiodes with SiO_2/SiN_x passivation layer. The PQED has 50 ppm spatial uniformity of responsivity in the center of the aperture and exceptionally low reflectance below 1 ppm in the spectral range from 400 nm to 800 nm. Very small reflectance allows to avoid correction due to reflectance losses and makes the PQED insensitive to small shifts of incidence angle. The recombination loss of the electron–hole pairs was determined by measuring the photocurrent ratio of the SiO_2/SiN_x PQED and earlier SiO_2 passivated PQED [2] using the same incident photon flux in both sensors. The results indicate that at 488 nm wavelength the losses of both types of sensors are similar within the measurement uncertainty of 30 ppm. At the 785 nm wavelength, the recombination loss of the SiO_2/SiN_x PQED is 75 ppm lower than that of the earlier SiO_2 PQED.

The responsivity of the earlier SiO_2 passivated PQED was compared with a cryogenic electrical substitution radiometer [3] with the result that the photon-to-electron conversion losses are (76 ± 60) ppm and (117 ± 60) ppm at the wavelengths of 532 nm and 760 nm, respectively [4]. The conclusion is that the PQED with SiO_2/SiN_x passivation layer tends to have recombination losses at the level of a few tens of ppm, a value that is lower than achieved with any other silicon sensor produced earlier.

Funding: This work was funded by the project chipS·CALe (contract 18SIB10) of the European Metrology Programme for Innovation and Research (EMPIR). The EMPIR is jointly funded by the EMPIR participating countries within EURAMET and the European Union's Horizon 2020 Programme. The work was supported by the Academy of Finland Flagship Programme, Photonics Research and Innovation (PREIN), decision number: 320167.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Citation: Korpusenko, M.; Koybasi, O.; Manoocheri, F.; Gran, J.; Ikonen, E. Optical Studies of a High -Performance Predictable Quantum Efficient Detector Based on Induced-Junction Photodiodes Passivated with SiO_2/SiN_x. *Eng. Proc.* **2022**, *21*, 39. https://doi.org/10.3390/engproc2022021039

Academic Editors: Piotr Lesiak, Tomasz Woliński and Leszek Jaroszewicz

Published: 30 August 2022

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Data Availability Statement: Data underlying the results presented in this paper are not publicly available at this time but may be obtained from the authors upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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