Reliability of Quantum Dot-Based Photodiode

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Introduction

STMicroelectronics has developed Quantum Dot (QD) based photodiode sensors for imaging applications in the near infrared (NIR) and shortwave infrared (SWIR) regions, with high performance relative to other sensors targeting the same wavelengths [1]. Quantum Efficiency (QE), which refers to the ratio of the collected charges to the incident photons, is an essential performance indicator [2]. This study investigates the aging mechanisms of the QE, based on the influence of the operating conditions.

Experimental Description

The photodiode devices have been subjected to three types of reliability tests at wafer level for 30ks and 60°C: The Constant Bias and Irradiance (CBI), the Alternating Bias at Constant Irradiance (AB), and the Alternating Irradiance at Constant Bias (AI). The “OFF-State” time scales between 1ms and 100ms and the “ON-State” time (t_{ON}) is 10ms.

Results

For CBI, the QE recovers only at the beginning of each stress period (during characterization). Devices stressed by AB conditions, however, experience a continuous QE recovery, and eventually, the degradation has reduced by 70%. On the other hand, the QE degradation depends on the “OFF-state” time for the AI conditions, the longer the t_{OFF} the lower the degradation (Fig.1).

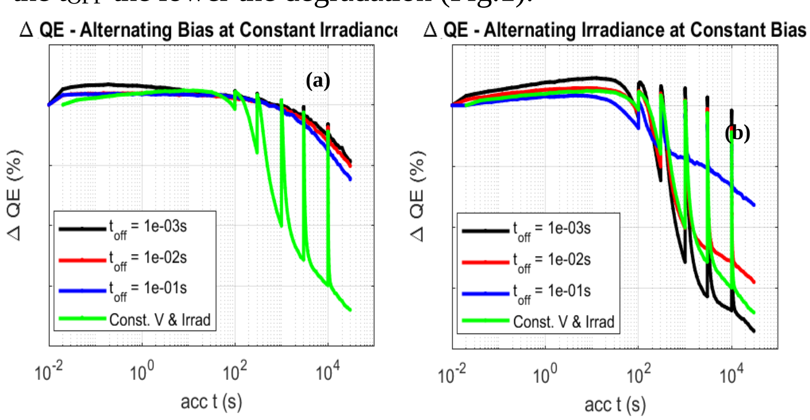

Fig. 1: Quantum Efficiency drift for (a) “AB” and (b) “AI” conditions

Discussion

Photogeneration and photocurrent collection are triggered instantly in the "ON-State". As the number of the photogenerated charges is greater than the device's extraction ability, the difference gradually accumulates inside the device. The trapped photo-charges build up an electric field opposite to the external one, resulting in shielding the photocurrent, which is seen as a non-permanent QE degradation.

During the "OFF-State" for AB conditions, the bias switches from high voltage to low voltage (from extraction to recombination mode), where the trapped photo-charges recombine. Eventually, the opposite electric field, hence the photocurrent shielding, diminishes and the QE recovers for the next "ON-State".

For AI conditions, photogeneration stops during the "OFF-State", and the trapped photo-charges are extracted as a dark current under the influence of the external electric field. The longer OFF time allows the disposal of more photo-charges, consequently weakening the photocurrent shielding and partially recovering the QE.

Conclusion

The QD-based photodiodes show high QE reliability performance, with the capability of reducing the degradation through operating the device with alternating the bias or the light intensity.

References

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