

A Guard Ring-Optimized SPAD with 86% PDP at 420 nm in 55 nm BCD Technology



Hyun-Seung Choi^{1,2}, Doyoon Eom^{1,2}, Francesco Gramuglia³, Eng Huat³, Ping Zheng³, Vinit Dhulla³, Yew Tuck Chow³, Elgin Quek³, Youngcheol Chae² and Myung-Jae Lee^{1,*}

¹Post-Silicon Semiconductor Institute, Korea Institute of Science and Technology, Seoul, Korea ²Department of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea ³GlobalFoundries Singapore Pte. Ltd., Singapore

Email: mj.lee@kist.re.kr*

Applications



Measurements



(Source: Willis Knighton Health) [Positron Emission Tomography]

[X-ray Detector]

 Single-photon avalanche diodes (SPADs) are widely used for bio-applications such as positron emission tomography (PET) and X-ray detectors.

Structure and Fill Factor



- Breakdown Voltage: Standard (16.15 V) > Optimized (15.55 V)
- Saturation Current: Standard (~1.1 mA) < Optimized (~3.2 mA)
 - → Higher avalanche triggering probability for optimized structure

Photon Detection Probability (PDP) Characteristics



	Standard Structure	Optimized Structure
Junction	P+/NW	
Guard Ring	PW	Optimized NW
Active Area (µm)	9	
Guard-Ring Width (µm)	1.8	

[Light Emission Tests]



No bias



No bias

 $V_{EX} = 5 V$

Even though the drawn active area of the two structures are identical, the effective active area of the optimized structure has extended from the horizontal active area of the junction to the vertical area between the anode and the guard ring. 300 400 500 600 700 800 900 Wavelength [nm]

- Excess bias voltage (V_{EX}) = 5 V
- Peak PDP (Wavelength) for drawn area (active area diameter = $9 \mu m$)
 - Standard Structure: 38.6% (440 nm)
 - Optimized Structure: 87% (420 nm)

Timing Jitter Characteristics (for Optimized Structure)



- This fill factor improvement of the optimized structure is clearly shown in the light emission test (LET).
- Excess bias voltage $\uparrow \rightarrow$ Electric field $\uparrow \rightarrow$ Better jitter performance
- Full width at tenth maximum (FWTM) has improved up to 70 ps.
- Full width at half maximum (FWHM) has improved up to 32 ps.

Conclusion

Summary

- Guard ring is optimized for better efficiency.
- Fill factor and avalanche triggering probability are enhanced which are confirmed by IV and LET characteristics.
- PDP has been greatly increased especially in shorter wavelengths.
- Excellent timing jitter performance is measured at near 420 nm.

Research Plans (in progress)

- Verification of accurate fill factor improvement of the optimized structure (e.g., by using laser scanning microscopy (LSM) measurement)
- Investigation on the improvement of the avalanche triggering probability with the optimized guard ring.