ISSW 2024

THE INTERNATIONAL SPAD SENSOR WORKSHOP & THE SPAD SENSOR SCHOOL

JUNE 3-6, 2024 - TRENTO, ITALY

ISSW 2024 - International SPAD Sensor Workshop

June 4-6, 2024 - Grand Hotel Trento, Trento, Italy

Technical program

Day 1 - Tuesday, June 4, 2024	
09:00 Welcome	
Session 1 - SPAD technologies and devices (chair: Myung-Jae Lee, co-chair: Sara Pellegrini)	
09:20 R01.1 - Recent advances in SPAD sensor technology: pixel size shrinking and PDE enhancement	Jun Ogi (Sony Semiconductor Solutions Corporation)
10:00 R01.2 - FBK roadmap towards the next-generation of 3D-integrated SiPM and SPAD technologies	Alberto Gola (Fondazione Bruno Kessler - FBK)
10:25 Coffee break + Company demo/poster - Adaps Photonics	
11:25 R01.3 - **Invited** - Rethinking boundaries: 3D integration and advanced packaging as performance drivers	Perceval Coudrain (CEA)
12:05 R01.4 - A 55nm BCDLite® FSI SPAD with Improved NIR Sensitivity and DCR	Francesco Gramuglia (Global Foundries)
12:30 Lunch	
Session 2 - InGaAs/InP SPAD devices (chair: Sara Pellegrini, co-chair: Alberto Tosi)	
14:00 R02.1 - Low-noise InGaAs/InP SPAD with photon detection efficiency exceeding 50% at 1550 nm	Fabio Telesca (Politecnico di Milano)
14:40 R02.2 - 10-µm InGaAsP/InP SPADs for 1064 nm detection with 36% PDP and 118 ps timing jitter	Utku Karaca (EPFL)
15:05 Coffee break + Company demo/poster - Sony Semiconductor Solutions Corporation	
Session 3 - SPAD modeling (chair: Alberto Tosi, co-chair: Myung-Jae Lee)	
16:05 R03.1 - Avalanche build-up field and its impact on the SPAD pulse width and inter-pulse-time distributions	Denis Rideau (STMicroelectronics)
16:30 R03.2 - Transient Measurements of Avalanche Dynamics and Quenching in SPADs	Wilfried Uhring (ICube & Univ. Strasbourg)
Session 4 - Poster session #1 (chair: David Stoppa, co-chair: Claudio Bruschini)	
16:55 Poster flash presentation (90"/poster)	
17:30 Aperitif + Poster session	

Day 2 - Wednesday, June 5, 2024	
08:40 Welcome	
Session 5 - LiDAR (chair: David Stoppa, co-chair: Leonardo Gasparini)	
08:45 R05.1 - **Invited** - Lidar design considerations for self-driving cars	Simon Verghese (Waymo)
09:25 R05.2 - **Invited** - Developing InP SWIR SPAD arrays for an automotive Geiger-mode lidar	Mark Itzler (Luminar technology)
10:05 R05.3 - High-speed, Underwater 3D Imaging with an In-Pixel Histogramming SPAD	Istvan Gyongy (University of Edinburgh)
10:30 Coffee break + Company demo/poster - STMicroelectronics	
11:15 R05.4 - **Invited** - CMOS Flash LiDAR Sensors with In-pixel Zoom Histogramming TDC Architectures	Seong-Jin Kim (Ulsan National Institute of Science and Technology & SolidVUE)
11:55 R05.5 - Comparison of SPAD, SiPM and APD performance for ToF LiDAR application	Andrii Nagai (onsemi)
12:20 Lunch	
Session 6 - Smartphone and edge computing (chair: Robert Henderson, co-chair: Edoardo Charbon)	
13:50 R06.1 - Physical and Cost Comparison of Smartphone Laser Autofocus Solutions	Peter Bonanno (Yole Group)
14:30 R06.2 - A monolithic BSI time-of-flight sensor supporting a resolution of up to 160x120 pixels with on-chip data processing enabling stand-alone or sensor fusion applications	Robert Kappel (ams-OSRAM)
14:55 R06.3 - **Invited** - A New Vision Chip with SPAD Imaging and Spiking Neural Network Processing	Liyuan Liu (Chinese Academy of Sciences)
Session 7 - Poster session #2 (chair: Sara Pellegrini, co-chair: Alberto Tosi)	
15:35 Poster flash presentation (90"/poster)	
16:10 Coffee break + Poster session	
18:10 Social Dinner	

Day 3 - Thursday, June 6, 2024	
09:00 Welcome	
Session 8 - SPADs and photonic integrated circuits (chair: Edoardo Charbon, co-chair: Sara Pellegrini)	
09:05 R08.1 - Silicon SPAD monolithically integrated with SiON-based photonic circuit	Fabio Acerbi (Fondazione Bruno Kessler - FBK)
09:45 R08.2 - Direct coupling of a laser-written photonic integrated circuit to a SPAD array	Giulio Gualandi (Politecnico di Milano)
10:10 Coffee break	
Session 9 - Medical and quantum applications (chair: Claudio Bruschini, co-chair: Robert Henderson)	
10:55 R09.1 - **Invited** - Applications of CMOS SPAD arrays in clinical imaging and spectroscopy	Michael Tanner (Heriot-Watt University)
11:35 R09.2 - Enhancing Chemiluminescence-Detection with Dark-Count Rate Optimization Strategies for SPADs in Conventional CMOS Technologies	Benjamin Saft (IMMS)
12:00 Lunch	
13:30 R09.3 - **Invited** - Quantum imaging with SPAD array cameras	Alexander Demuth (ICFO)
14:10 Coffee break	
Session 10 - Time to digital converters (chair: Leonardo Gasparini, co-chair: Claudio Bruschini)	
14:55 R10.1 - A PVT-Insensitive Body-Biased Time-to-Digital Converter in 28nm FD-SOI CMOS Technology	Yining Wang (University of Edinburgh)
15:20 R10.2 - Cascaded Vernier Time-to-Digital Converter : Toward Integration in an Array	Guillaume Théberge-Dupuis (Université de Sherbrooke)
15:45 Closing	

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Poster sessions

Poster #	Title	Presenter
	Day 1 - Tuesday, June 4, 2024	
	Session 4 - Poster session #1 - Flash presentations at 16:55 - Poster session from 17:30 to 19:30	
P1.01 -	A Guard Ring-Optimized Single-Photon Avalanche Diode with 70% PDP at 420 nm in 55 nm BCD Technology	Hyun-Seung Choi (Korea Institute of Science and Technology - KIST)
P1.02 -	Back-Illuminated Non-Isolated Single-Photon Avalanche Diode in 110 nm Standard CMOS Image Sensor Technology	Doyoon Eom (Korea Institute of Science and Technology - KIST)
P1.03 -	Room temperature 96x96 InGaAs/InP SPAD array for SWIR imaging	Pascal Rustige (Fraunhofer HHI)
P1.04 -	New Crosstalk Insight and Characterization Methods in CMOS based SPADs	Julia Kölbel (Elmos Semiconductor SE)
P1.05 -	Test Bench for Characterization of CMOS SPADs	Joo-Hyun Kim (Korea Institute of Science and Technology - KIST)
P1.06 -	Radiation Damage on SiPM for High Energy Physics Experiments in space missions	Celeste Guerrisi (Politecnico di Bari)
P1.07 -	Glass-free SiPMs with Through Silicon Vias for VUV/NUV light detection	Jacopo Dalmasson (Fondazione Bruno Kessler - FBK)
P1.08 -	Position-Sensitive Silicon Photomultiplier Array with enhanced position reconstruciton by means of a Deep Neural Network	Cyril M Alispach (Université de Genève)
P1.09 -	Fabrication method of SPAD sensor for automotive LiDAR to compensate the process fluctuation by feedforward system	Yoshiaki Tashiro (Sony Semiconductor Solutions Corporation)
P1.10 -	Extended Dynamic Range SPAD Front-End Using Near-Threshold Inverter-Based Comparator	Maciej Wojtkiewicz (University of Edinburgh)
P1.11 -	A 1.8-µm pitch, 47-ps jitter SPAD Array in 130nm SiGe BiCMOS Process	Feng Liu (EPFL/Microparity)
P1.12 -	Histogram-less SPAD/SiPM-based dTOF imaging with parallel ML processing	Tommaso Milanese (EPFL)
P1.13 -	Linearized SPAD response for high photon flux and histogram-less d-ToF systems	Alessandro Tontini (Fondazione Bruno Kessler - FBK)
P1.14 -	Towards arbitrary photon statistics characterization with realistic SPAD arrays	Niki Di Giano (Politecnico di Milano)
P1.15 -	Count-Free Single-Photon LiDAR with Equi-Depth Histograms: An FPGA Implementation	Hayden T Galante (Portland State University)
P1.16 -	Flash LiDAR for Bathymetry Using a 2D SPAD Array	Eleonoor Bosch (CSEM)
P1.17 -	40-nm SPAD-Array System for Ultra-Fast Raman Spectroscopy	Henri Haka (Politecnico di Milano)
P1.18 -	Fluorescence Based Multi-Color Two-Dimensional Flow Cytometer Utilizing Masked SPAD Array	Kunihiko Iizuka (University of Tokyo)
P1.19 -	The Single Particle Avalanche Diode concept	Fabrice Retiere (TRIUMF)
P1.20 -	TCAD simulation of the inefficiency of a Single Electron Bipolar Avalanche Transistor (SEBAT) coupled to a THz detector	Abderrezak Boughedda (Fondazione Bruno Kessler - FBK)

	Day 2 - Wednesday, June 5, 2024	
	Session 7 - Poster session #2 - Flash presentations at 15:35 - Poster session from 16:10 to 18:10	
P2.01 -	An Optimized SPAD Equivalent-Circuit Model	Eo-Jin Kim (Korea Institute of Science and Technology - KIST)
P2.02 -	AI-enhanced Non-Line of Sight Imaging	Pierfrancesco Ulpiani (Leonardo SpA)
P2.03 -	SPAD traceable detection efficiency measurement at INRIM	Salvatore Virzì (INRiM)
P2.04 -	Traceable characterisation of free-space and fibre-coupled single-photon avalanche diodes	Luke Arabskyj (National Physical Laboratory)
P2.05 -	Front-Side Photon Detection improvement of SPAD integrated in FD-SOI CMOS Technology thanks to STI patterning	Francis Calmon and Duc Tung Vu (INSA Lyon - INL)
P2.06 -	NIR–Sensitivity Enhancement of a Back-Illuminated Single-Photon Avalanche Diode Through Backside Scattering Patterns	Seyoung Yook (Korea Institute of Science and Technology - KIST)
P2.07 -	Investigation of a novel zinc-diffusion process for the fabrication of InGaAs/InP single-photon avalanche diodes	Andreas Woerl (Fraunhofer IAF)
P2.08 -	A Backside-Illuminated SiPM Array with High NIR PDE for Automotive LIDAR Applications	Tomer Leitner (onsemi)
P2.09 -	Photon-to-Digital Converter Development: 3D Integration Progress and Characterization Platform	Frédéric Vachon (Université de Sherbrooke)
P2.10 -	Conceiving and designing high-performance TCSPC systems for biological and quantum imaging	Serena Farina (Politecnico of Milan)
P2.11 -	Beyond pile-up limits in Time Correlated Single Photon Counting: a new approach	Giulia Acconcia (Politecnico of Milan)
P2.12 -	An Asynchronous Peak Tracking Method for dToF LiDAR Histograms	Yiyang Liu (University of Edinburgh)
P2.13 -	Use of Switched Capacitors in timing-based SPAD Image Sensors	Maarten Kuijk (Vrije Universiteit Brussel)
P2.14 -	Utilizing Switched Capacitors in SPAD-Based Pixel for dToF	Ayman Morsy (Vrije Universiteit Brussel)
P2.15 -	SPAD LiDAR with RADAR Target Prediction	Andre Henschke (Fraunhofer IMS)
P2.16 -	Fluorescence Lifetime Imaging Ophthalmoscope: A Theoretical Study	Jakub Nedbal (Occuity)
P2.17 -	Red-Enhanced SPAD Sensor with 150-ps Gating for FLIM	Augusto Carimatto (Piimaging)
P2.18 -	ANDESPix: A Digital SiPM for Muon Detectors	Alexander F. Elsenhans (Karlsruhe Institute of Technology - KIT)
P2.19 -	Ubiquitous Perception with Single-Photon Cameras	Sebastian Bauer (Ubicept)
P2.20 -	Clinical translation of an early-photon imaging system for safe placement of feeding tubes	András Kufcsák (Heriot-Watt University)

An Optimized SPAD Equivalent-Circuit Model

Eo-Jin Kim[1,2], Hyun-Seung Choi[1,2], Woo-Young Choi[2], and Myung-Jae Lee[1]

mj.lee@kist.re.kr

1. Post-Silicon Semiconductor Institute, Korea Institute of Science and Technology, South Korea
2. Department of Electrical and Electric Engineering, Yonsei University, South Korea

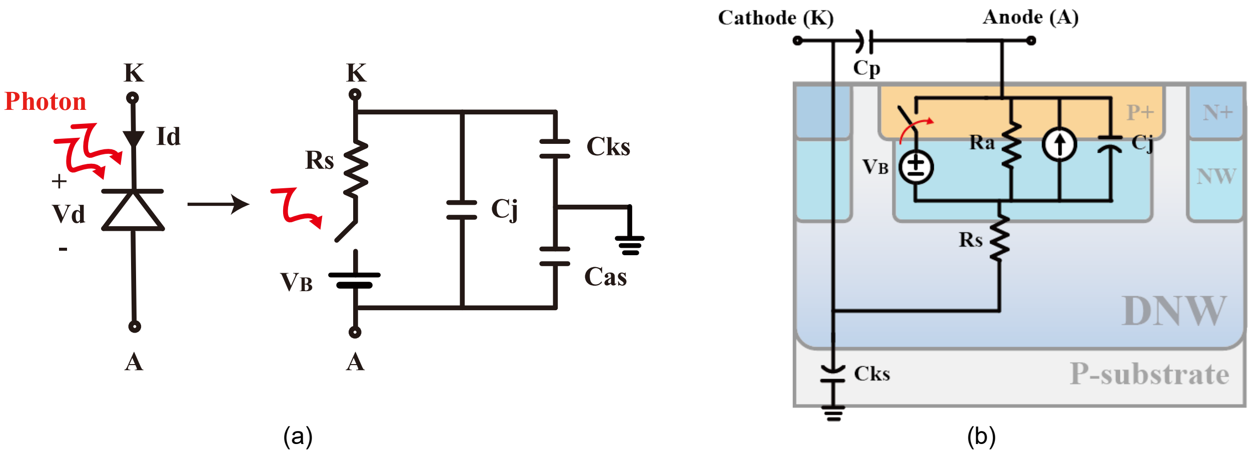

Fig. 1: (a) A traditional SPAD model [1] and (b) an optimized SPAD equivalent-circuit model

In this study, we present an optimized equivalent-circuit model for single-photon avalanche diodes (SPADs), which can provide significantly improved precision in circuit simulation. The model is based on the SPAD behavioral model introduced in [1], but its accuracy is enhanced by incorporating components whose values are directly extracted from the measurement.

The previous analytical model of SPADs, which emulates both the static and dynamic behaviors of SPADs, has been implemented in Verilog-A hardware description language and can be visualized as shown in Fig. 1(a) [1]. To improve the precision of the circuit simulation using this model, it is essential to integrate the physical parameters of the device. Within this process of integrating, we can proceed to optimize the SPAD equivalent circuit – a process that involves several key steps.

Firstly, SPAD samples with GSG PADs are designed and fabricated to enable accurate characterization, with their influences de-embedded. Then, RF measurements are conducted, and numerical values for device parameters are extracted from the measurement results. Finally, incorporating the extracted parameter components into the established analytical model [1] results in the completion of the SPAD equivalent-circuit model.

In Fig. 1(b), the resulting SPAD circuit model is shown. R_a serves a dual purpose within the model, encapsulating the finite reverse saturation current that contributes to dissipative effects and representing the resistance associated with the depletion region. This unified representation simplifies the overall equivalent circuit. C_j models the junction capacitance of the SPAD, while R_s accounts for the resistant in the inactive region (i.e., N-well (NW) and deep N-well (DNW)). C_p indicates the parasitic capacitance between the cathode and anode. C_{ks} is the capacitance component of the DNW/P-substrate junction.

Through the optimized SPAD equivalent-circuit model, it becomes possible to perform more precise circuit simulations including the device and customize simulations based on the SPAD structure by modifying parameters according to its design.

Acknowledgment

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Reference

[1] G. Giustolisi, R. Mita, and G. Palumbo, “Behavioral modelling of statistical phenomena of single-photon avalanche diodes”, *International Journal of Circuit Theory and Applications*, vol. 40, no. 7, pp. 661-679, 2012.