HASPIDE – WP3
Device Simulations

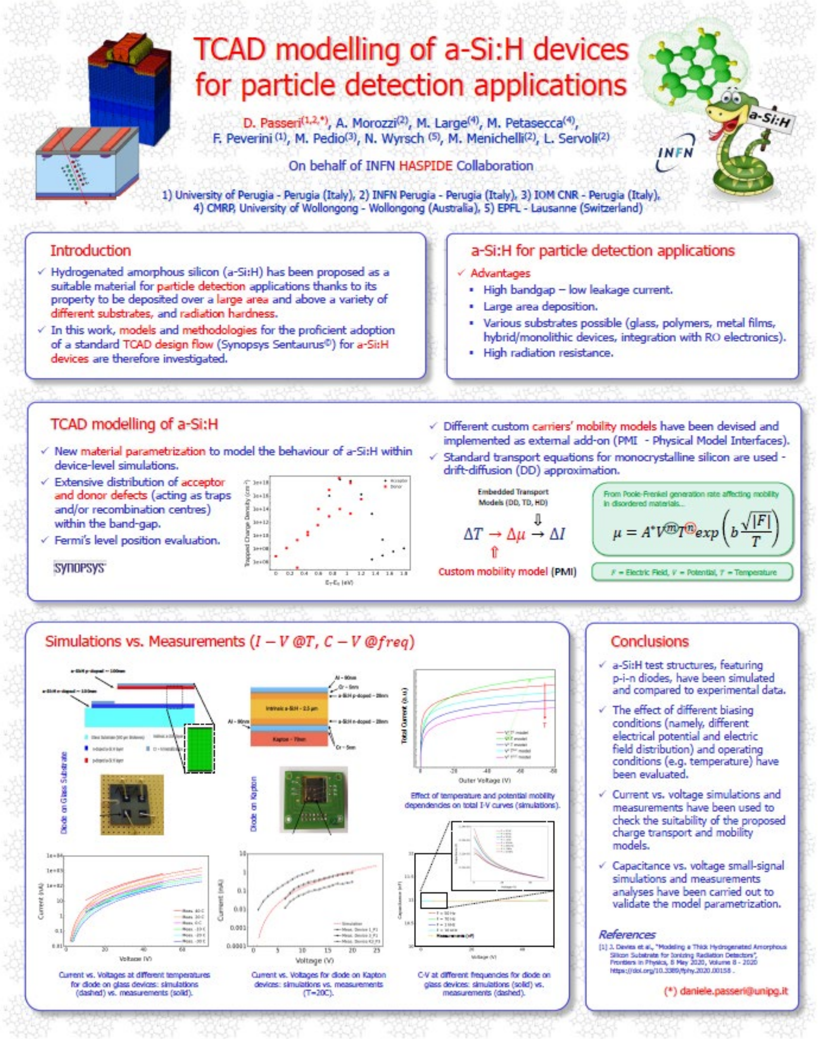
Status Activities

WP3: Device simulation
- *Responsible:* **Passeri Daniele**
- *Working group: (PG, LNS, UOW)*

Name	Position	FTE-WP3
Daniele Passeri	Professore Associato (PG)	0.2
Francesco Moscatelli	Ricercatore (PG)	0.1
Arianna Morozzi	Tecnologo (PG)	0.1
Tommaso Croci	Dottorando (PG)	0.1
Marco Petasecca	Associate Professor (UOW)	
Matthew Large	PhD student (UOW)	
	TOTAL	0.65

09/02/24

Poster presentation at E-MRS 2023 Spring Symposium.



European Materials Research Society

- ✓ Huge congress (21 symposiums/parallel sessions!).
- ✓ M - Materials engineering for advanced semiconductor devices (more than 250 submission -> accepted 70 orals, 80 posters)
- ✓ Plenty of materials -> … no additional evidence of a-Si:H
- ✓ Few interactions – traps characterization.

Open Access Paper in MSSP

Materials Science in Semiconductor Processing 169 (2024) 107870

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

journal homepage: www.elsevier.com/locate/mssp

Full length article

TCAD modelling of a-Si:H devices for particle detection applications

Daniele Passeri [a,b,*], Arianna Morozzi [b], Michele Fabi [c,d], Catia Grimani [c,d], Stefania Pallotta [c,d], Federico Sabbatini [c,d], Cinzia Talamonti [c,d], Mattia Villani [c,d], Lucio Calcagnile [f,g], Anna Paola Caricato [f,g], Maurizio Martino [f,g], Giuseppe Maruccio [f,g], Anna Grazia Monteduro [f,g], Gianluca Quarta [f,g], Silvia Rizzato [f,g], Roberto Catalano [h], Giuseppe Antonio Pablo Cirrone [h], Giacomo Cuttone [h], Giada Petringa [h], Luca Frontini [i], Valentino Liberali [i], Alberto Stabile [i], Tommaso Croci [b], Maria Ionica [b], Keida Kanxheri [b,j], Mauro Menichelli [b], Francesco Moscatelli [b,k], Maddalena Pedio [b,k], Francesca Peverini [b,j], Pisana Placidi [a,b], Luca Tosti [b], Giulia Rossi [b], Leonello Servoli [b], Nicola Zema [b,l], Giovanni Mazza [m], Lorenzo Piccolo [m], Richard Wheadon [m], Luca Antognini [n], Sylvain Dunand [n], Nicolas Wyrsch [n], Aishah Bashiri [o], Matthew Large [o], Marco Petasecca [o]

[a] University of Perugia, Department of Engineering, Via G. Duranti 93, 06125, Perugia, Italy
[b] INFN Sezione di Perugia, Via Pascoli, 06123 Perugia, Italy
[c] Università degli Studi di Firenze, Dip. di Fisica Scienze Biomediche Sperimentali e Cliniche, Viale Morgagni 50, 50135 Firenze (FI), Italy
[d] INFN Sezione di Firenze, Via Bruno Rossi, 1, 50019 Sesto Fiorentino FI Firenze (FI), Italy
[e] DiSPeA, Università di Urbino Carlo Bo, 61029 Urbino (PU), Italy
[f] Department of Mathematics and Physics "Ennio de Giorgi" University of Salento, Via per Arnesano, 73100 Lecce, Italy
[g] INFN Sezione di Lecce, Via Provinciale per Arnesano, 73100 Lecce, Italy
[h] INFN Laboratori Nazionali del Sud, Via S.Sofia 62, 95123 Catania, Italy
[i] INFN Sezione di Milano, Via Celoria 16, 20133 Milano, Italy
[j] Dip. di Fisica e Geologia dell'Università degli Studi di Perugia, via Pascoli s.n.c. 06123 Perugia, Italy
[k] CNR-IOM, via Pascoli s.n.c. 06123 Perugia, Italy
[l] CNR Istituto struttura della Materia, Via Fosso del Cavaliere 100, Roma, Italy
[m] INFN Sezione di Torino Via Pietro Giuria, 1, 10125 Torino, Italy
[n] Ecole Polytechnique Fédérale de Lausanne (EPFL), Photovoltaic and Thin-Film Electronics Laboratory (PV-Lab), Rue de la Maladière 71b, 2000 Neuchâtel, Switzerland
[o] Centre for Medical Radiation Physics, University of Wollongong, Northfields Ave Wollongong NSW 2522, Australia

ARTICLE INFO

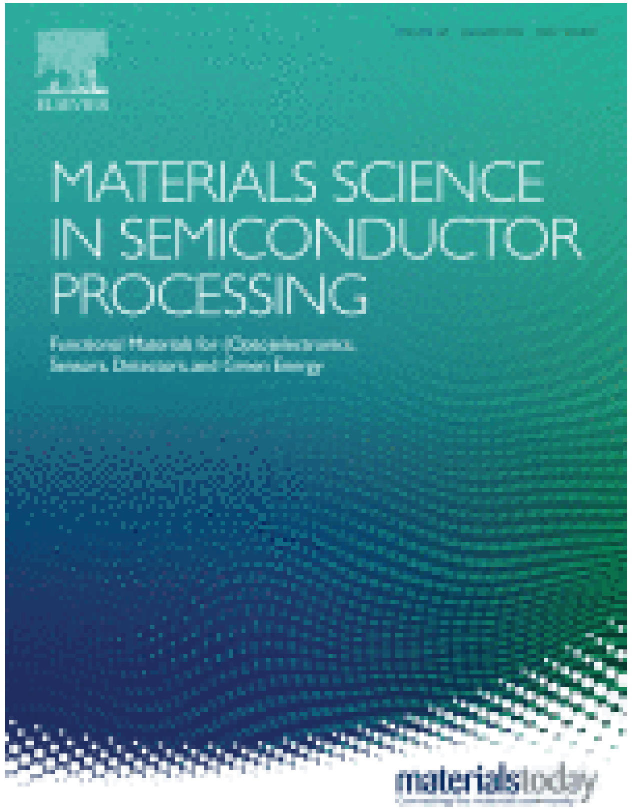
Keywords:
TCAD
Amorphous silicon
Particle detectors
Device simulation

ABSTRACT

Hydrogenated amorphous silicon (a-Si:H) has been proposed as a suitable material for particle detection applications thanks to its property to be deposited over a large area and above a variety of different substrates, including flexible materials. Moreover, the low cost and intrinsic radiation tolerance made this material appealing in applications where high fluences are expected, e.g. in high energy physics experiments. In order to optimize the device geometry and to evaluate its electrical behaviour in different operating conditions, a suitable Technology CAD (TCAD) design methodology can be applied. In this work, carried out in the framework of the HASPIDE INFN project, we propose an innovative approach to the study of charge transport within the material, using the state-of-the-art Synopsys Advanced TCAD Suite. Different custom mobility models have been devised and implemented within the code as external PMI (Physical Model Interfaces), starting from the Poole-Frenkel model and accounting for different dependencies on temperature and internal potential distribution, thus resulting in a new mobility model embedded within the code. Simple test structures, featuring p-i-n diodes have been simulated and compared to experimental data as a benchmark. The overall aim was to account for the effect of different biasing conditions (namely, different electrical potential and electric field distribution within the device) and operating conditions (e.g. temperature). This work fosters the use of commercially available TCAD suite such as Synopsys Sentaurus, largely diffused in the radiation detection scientific community, for the design and optimization of innovative a-Si:H devices for particle detection applications.

* Corresponding author at: University of Perugia, Department of Engineering, Via G. Duranti 93, 06125, Perugia, Italy.
E-mail address: daniele.passeri@unipg.it (D. Passeri).
URL: https://www.unipg.it/personale/daniele.passeri/en/ (D. Passeri).

https://doi.org/10.1016/j.mssp.2023.107870
Received 3 August 2023; Received in revised form 20 September 2023; Accepted 26 September 2023
Available online 7 October 2023



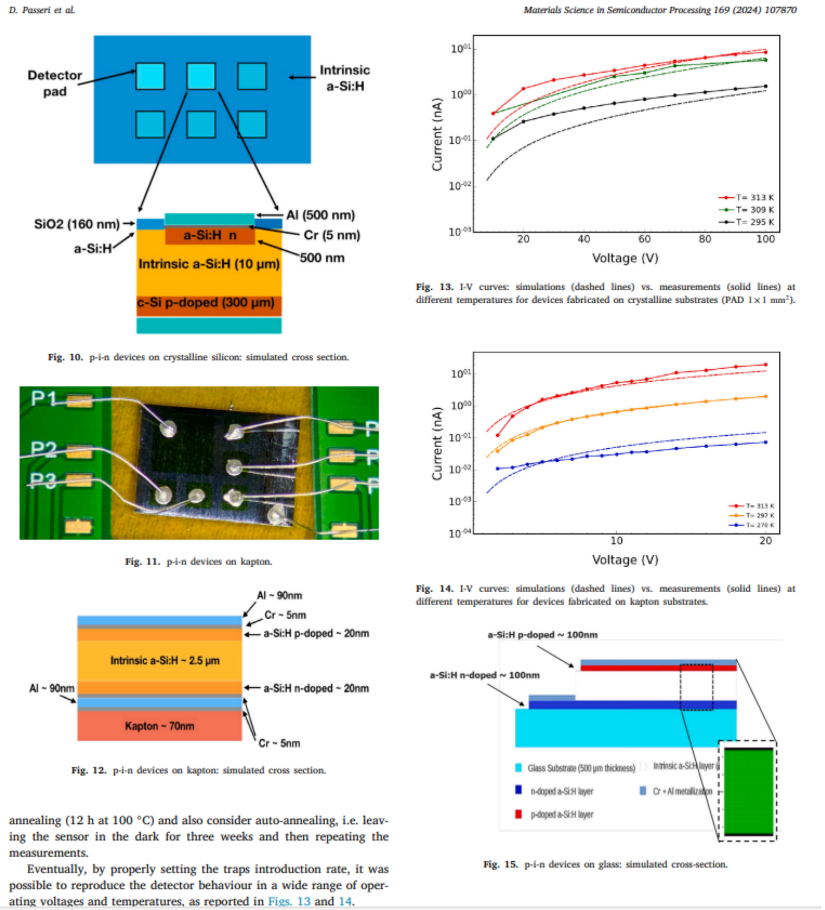


Fig. 10. p-i-n devices on crystalline silicon: simulated cross section.

Fig. 11. p-i-n devices on kapton.

Fig. 12. p-i-n devices on kapton: simulated cross section.

Fig. 13. I-V curves: simulations (dashed lines) vs. measurements (solid lines) at different temperatures for devices fabricated on crystalline substrates (PAD 1 × 1 mm²).

Fig. 14. I-V curves: simulations (dashed lines) vs. measurements (solid lines) at different temperatures for devices fabricated on kapton substrates.

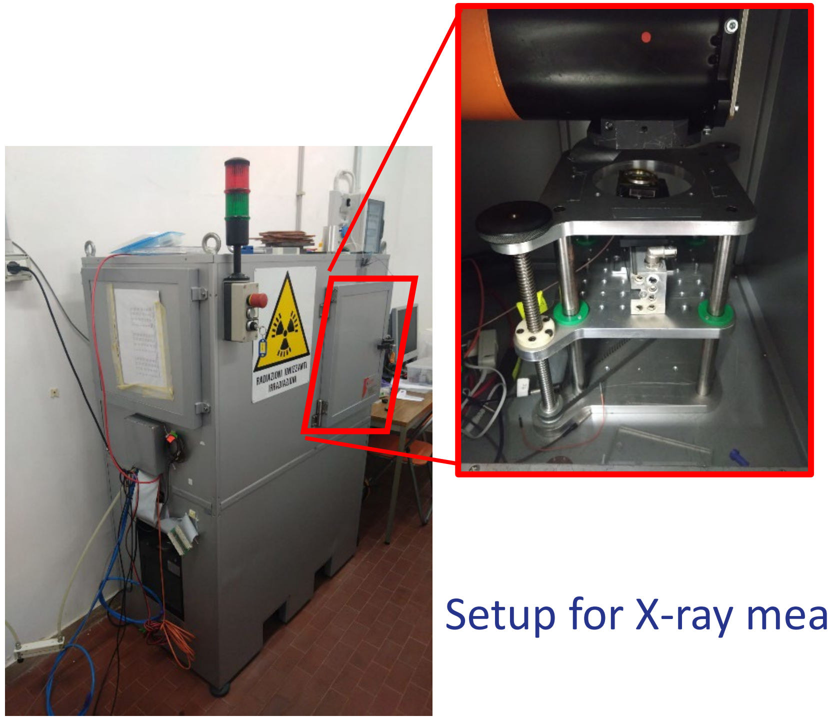
Fig. 15. p-i-n devices on glass: simulated cross-section.

annealing (12 h at 100 °C) and also consider auto-annealing, i.e. leaving the sensor in the dark for three weeks and then repeating the measurements.

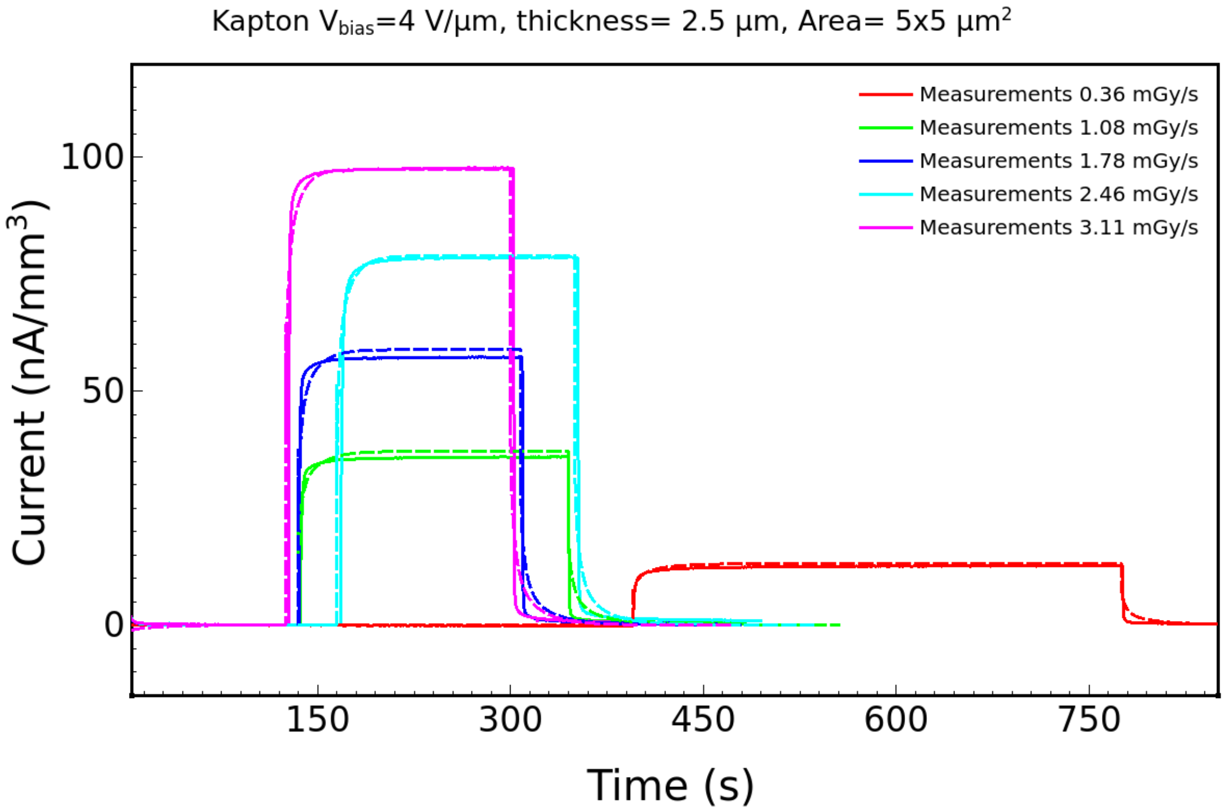
Eventually, by properly setting the traps introduction rate, it was possible to reproduce the detector behaviour in a wide range of operating voltages and temperatures, as reported in Figs. 13 and 14.

Ongoing work – Application of the numerical model

- Comparison between measurements (solid line) and simulations (dashed line) at different X-ray doses.
- Measurements performed at Perugia.



Setup for X-ray measurements



WP3 TCAD Simulation Outlines

- Assessment of model / methods for TCAD DC / AC a-Si:H device simulations
- Further validation in progress / comparison with new data/measurements
  - Florence (Cinzia -> Arianna)
  - Rome (Domenico -> Daniele, Arianna)
- Time varying analysis with different stimuli:
  - Gamma Radiation
  - Heavy Ion

- Milestone -> 15/11/2024 TCAD simulation of the transient response ofa-Si:H devices for charge collection efficiency studies.

WP3 Financial Request

			Year 1	Year 2	Year 3
Software / Licenses	PG	Synopsys Advanced TCAD Maintenance and Licenses	2 k€	2 k€	2 k€
	LNS				
	Wollongong				
Consumables	PG		2 k€	2 k€	2 k€
	LNS				
	Wollongong				
Equipment	PG	1 WorkStation (80 core, 256 GB RAM)	8 k€	3 k€ (1)	
	LNS				
	Wollongong				
Man Power	PG	1Y AR	~~25 k€~~		
	LNS				
	Wollongong				

- Charge Transport and Carriers Mobility Models
- An extensive acvitity has been devoted to the modeling of the charge transport within the a-Si:H, relying on standard transport equations for monocrystlline silicon - drift-diffusion (DD) approximation and using a custom defined charge mobility, looking at the current-voltage responses at different temperatures.

Embedded Transport Models
(DD, TD, HD)

F = Electric Field
V = Potential
T = Temperature

$$\Delta T \rightarrow \Delta \mu \rightarrow \Delta I$$

Custom mobility model
(PMI)

$$\mu = A^{*} V^{m} T^{n} exp\left(b \frac{\sqrt{|F| + F_{\min}}}{T} \right)$$