Ilaria Matacena

Tutor: Santolo Daliento

XXXIII Cycle - III year presentation

Impedance spectroscopy for interface characterization in semiconductor devices

Background

M.Sc.	Ph.D.
Electronic Engineering Date: 14th Dec 2016 Subject: Microelectronics *Prof. Vincenzo d'Alessandro* *Prof. Marco Spirito* Title:"*Ultra-Wideband dielectric spectroscopy using an open-ended coaxial probe at MW frequencies*".	Electronic Engineering- ING-INF/01 Tutor: *Prof. Santolo Daliento* Athenaeum fellowship Microelectronic Technologies Laboratory, Building 2, Via Claudio, 21 Tel: +39 081 76 83800

Cooperation

Enea Portici Research Center

Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Credit summary

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	0	0	4	0	9	9.4	**22**	10		3	4				**7**				1.2	0.3			**1.5**	**31**	30-70
Seminars	5	4	1		0.2	0	0	**5.2**	5	0	1.5	4.6	0		0	**6.1**								**0**	**11**	10-30
Research	35	6	9	6	9.8	1	0.6	**32**	45	10	8.5	0	10	10	10	**49**	60	10	10	8.8	9.7	10	10	**59**	**139**	80-140
	60	10	10	10	10	10	10	**60**	60	0	13	8.6	10	10	10	**62**	60	10	10	10	10	10	10	**60**	**182**	180

Modules	Seminars	PhD Schools
9	8	3

Experience Abroad

3 months as Visiting Researcher at KUAS, Kyoto University of Advanced Science in KYOTO, JAPAN

Impedance Spectroscopy

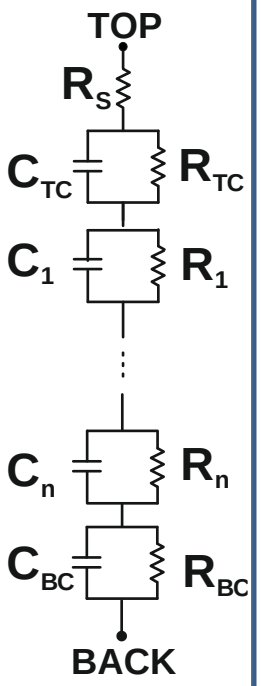
AUTOMATIC PROCEDURE

Top Contact

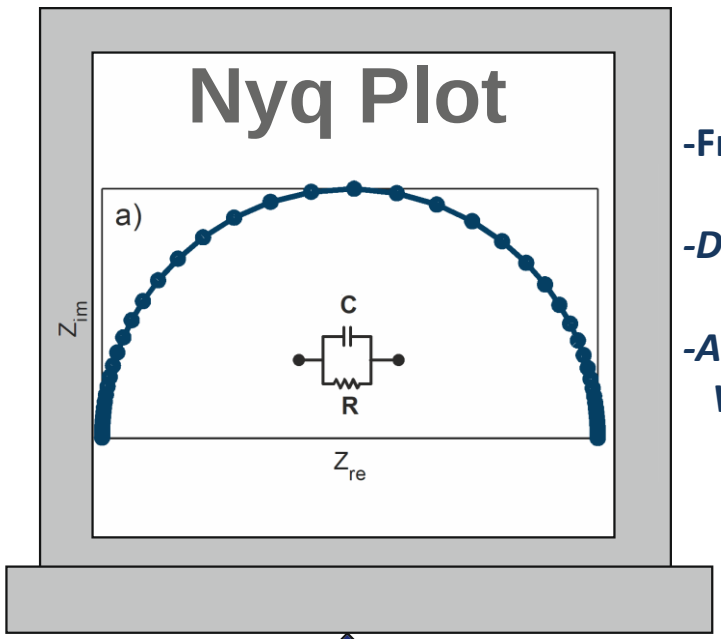
Interface 1

Interface n

Back contact



Experimental setup

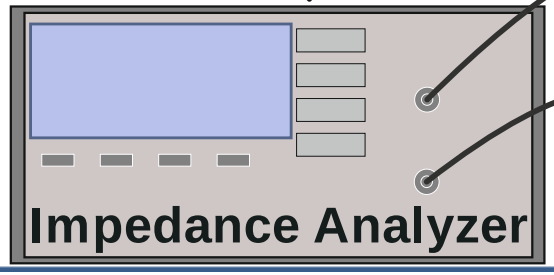


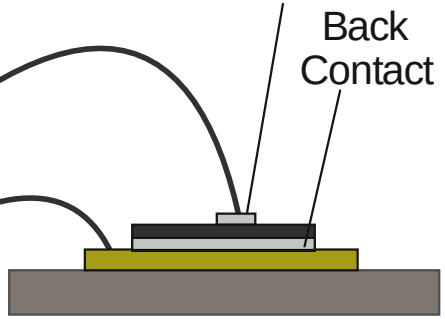
-Frequency sweep

-DC bias sweep

-AC voltage amplitude:
VAC: 10mV

GPIB comunication





Impedance Spectroscopy

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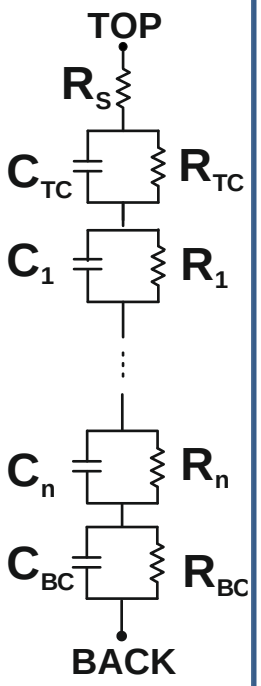

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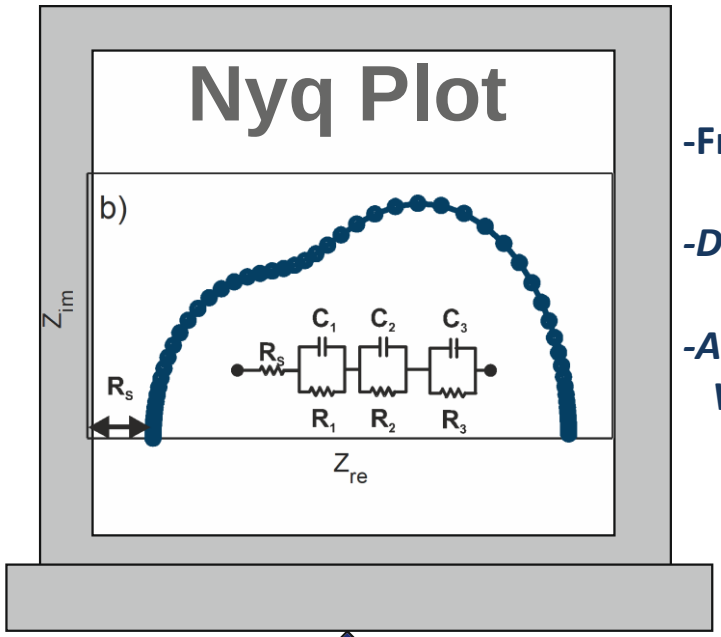

-Frequency sweep

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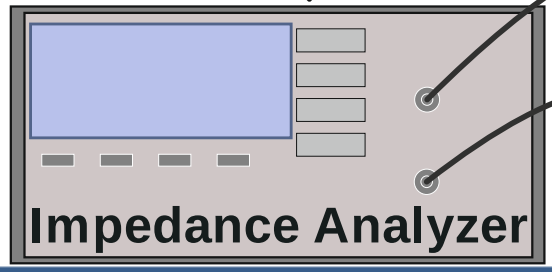
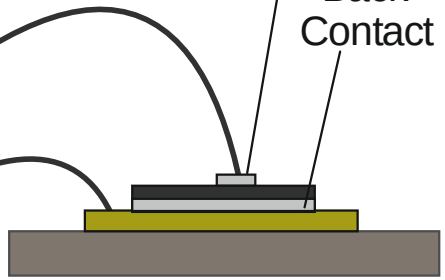
-AC voltage amplitude: VAC: 10mV

GPIB comunication



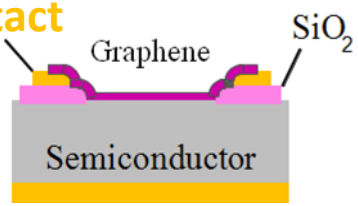


Impedance Spectroscopy

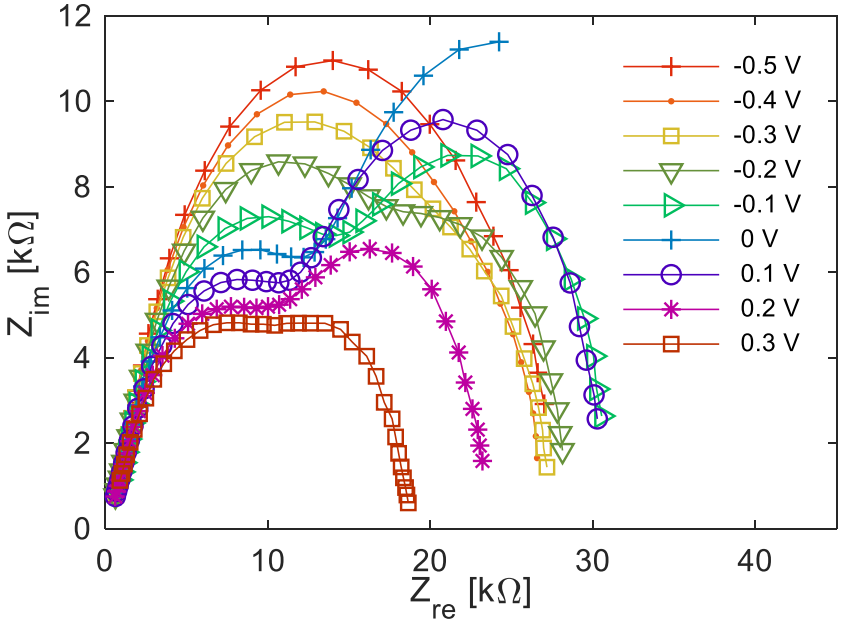
Graphene/Silicon solar cells

Conventional front contacts solar cell

Gold contact

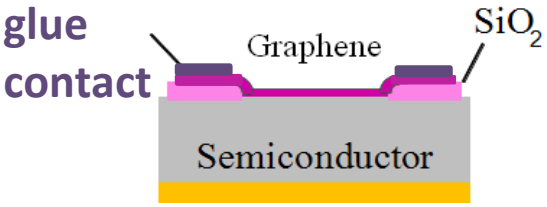


Metal back contact

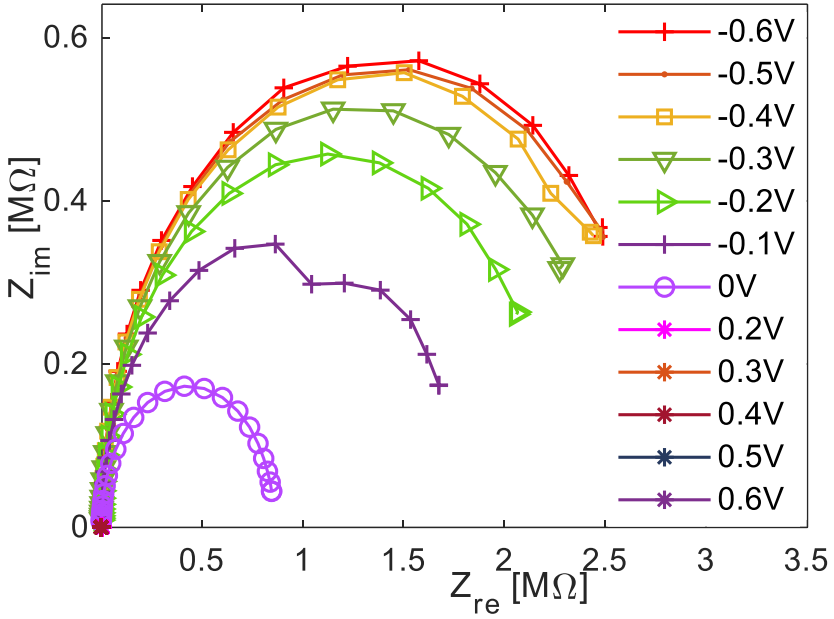


Improved front contacts solar cell

Graphitic glue contact



Metal back contact



Impedance Spectroscopy

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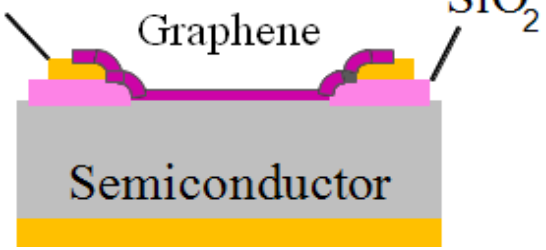
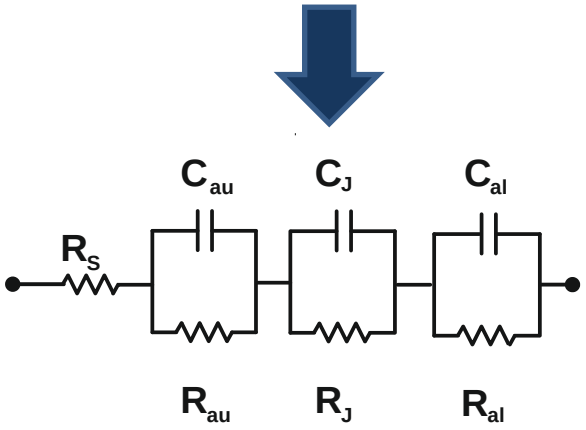


Metal back contact



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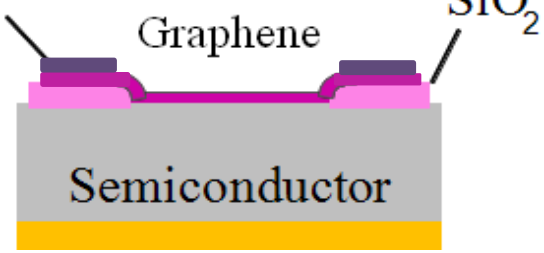

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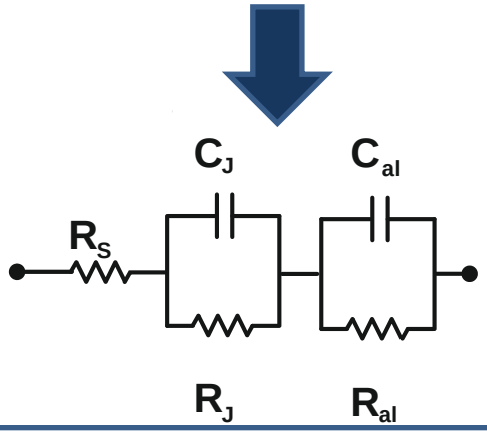
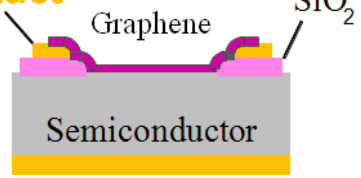


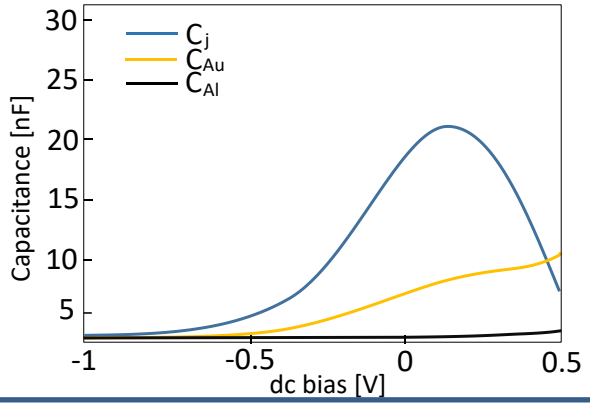
Impedance Spectroscopy

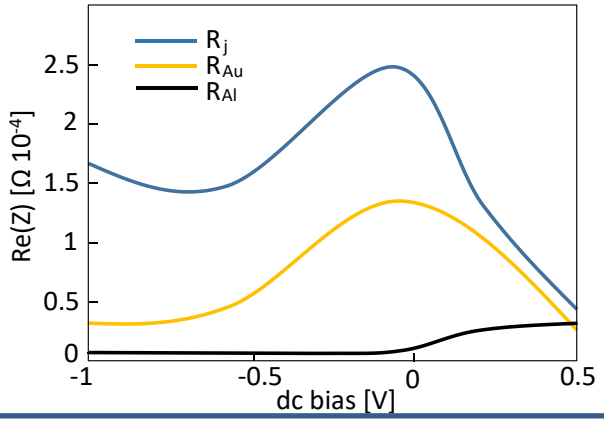
Graphene/Silicon solar cells

Gold contact



Metal back contact





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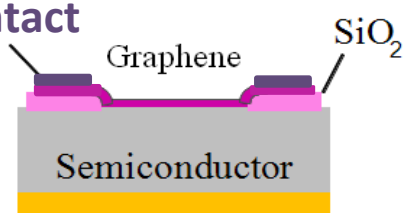

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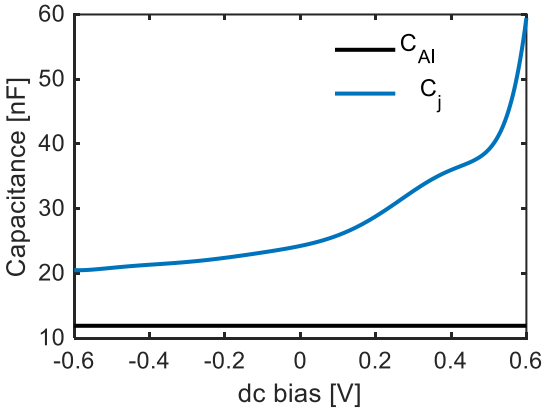
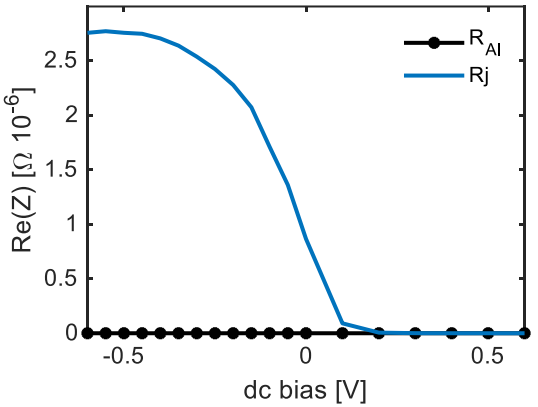
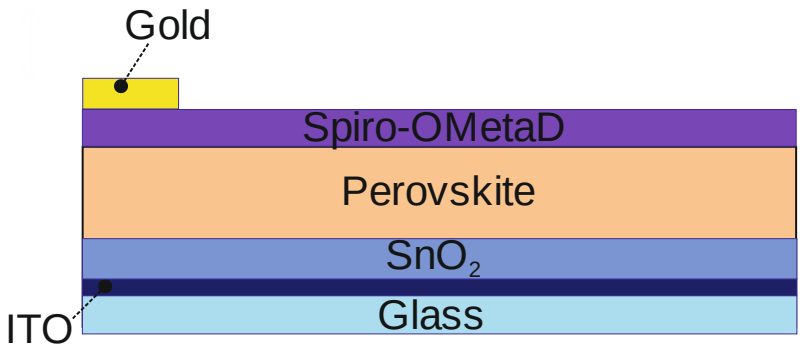


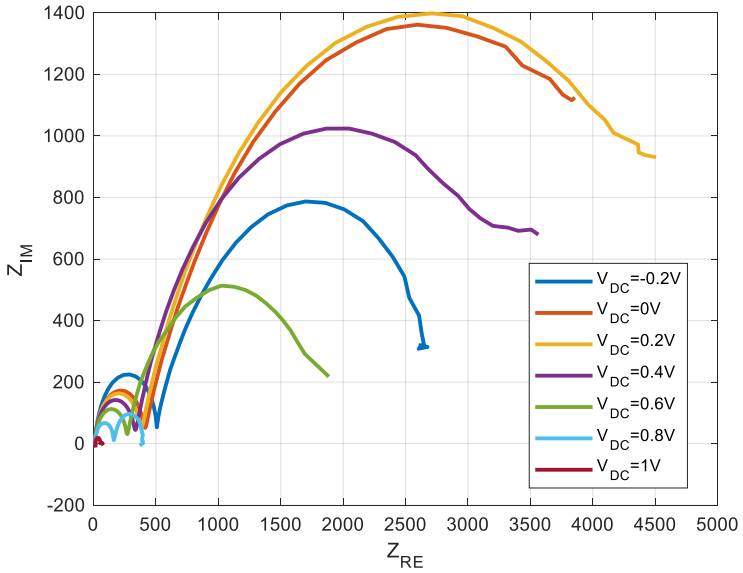


Impedance Spectroscopy

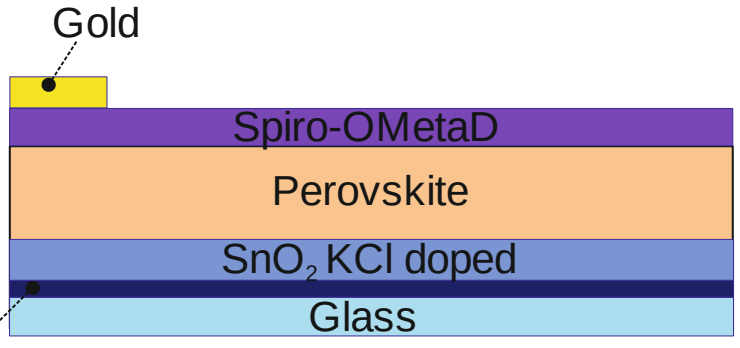
Perovskite solar cells

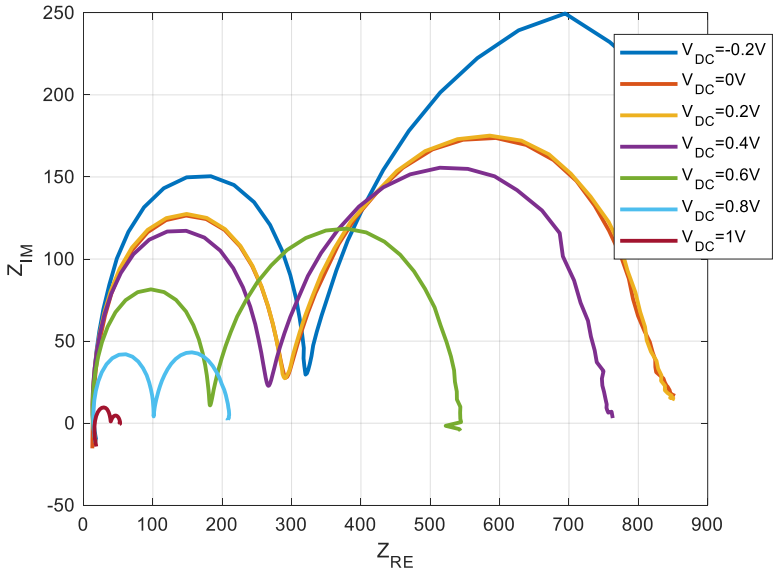
Sample S1





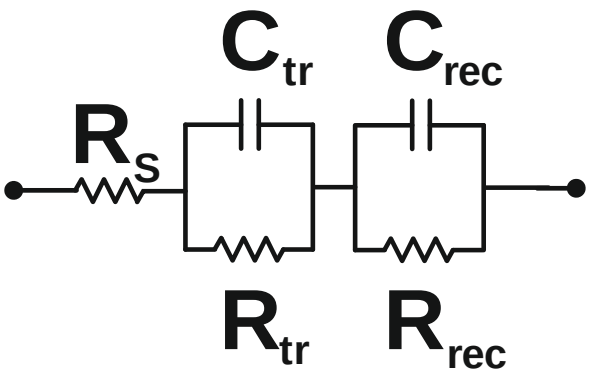
Sample S2

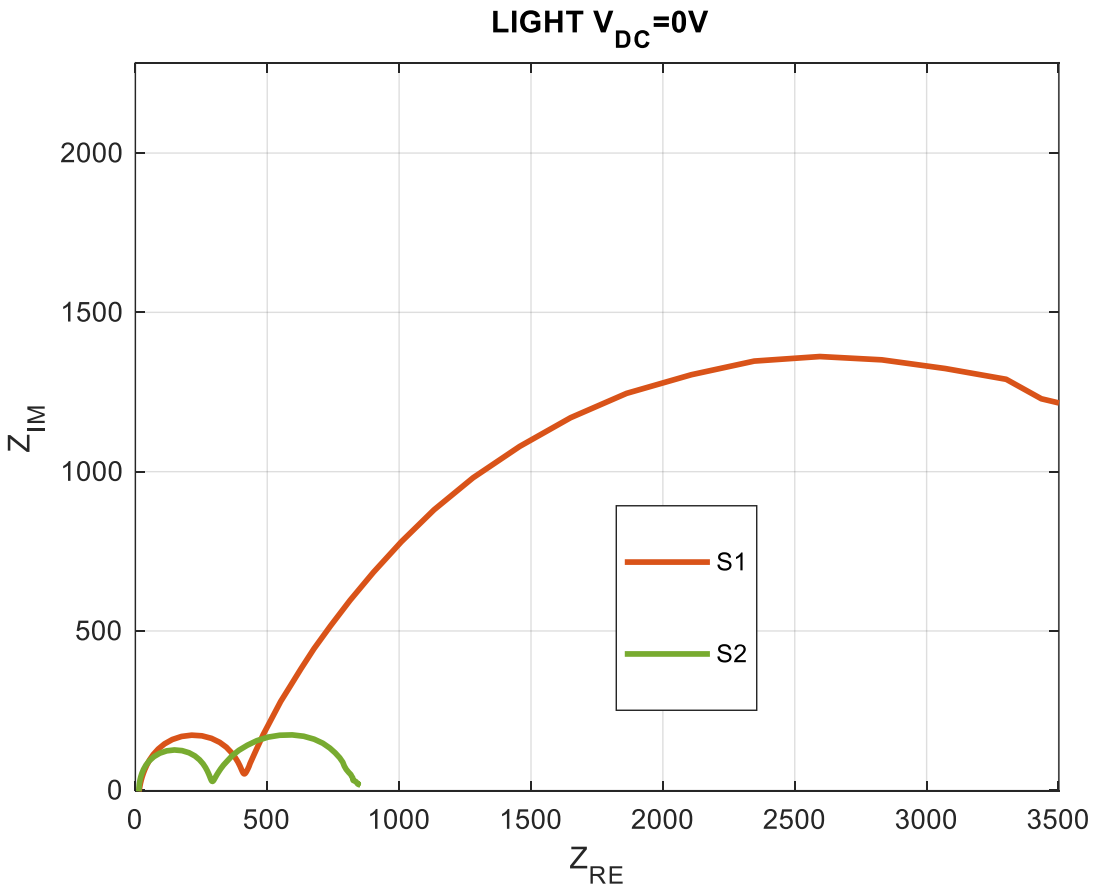




Impedance Spectroscopy

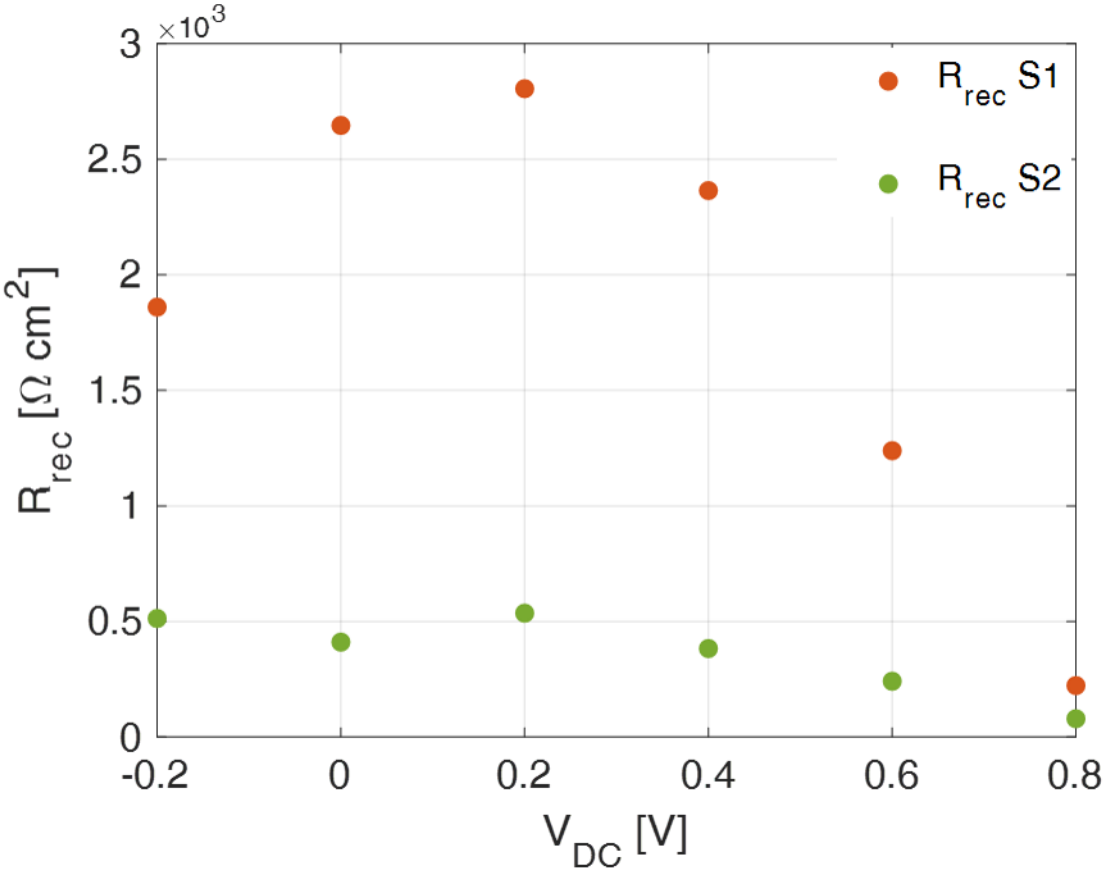
Perovskite solar cells





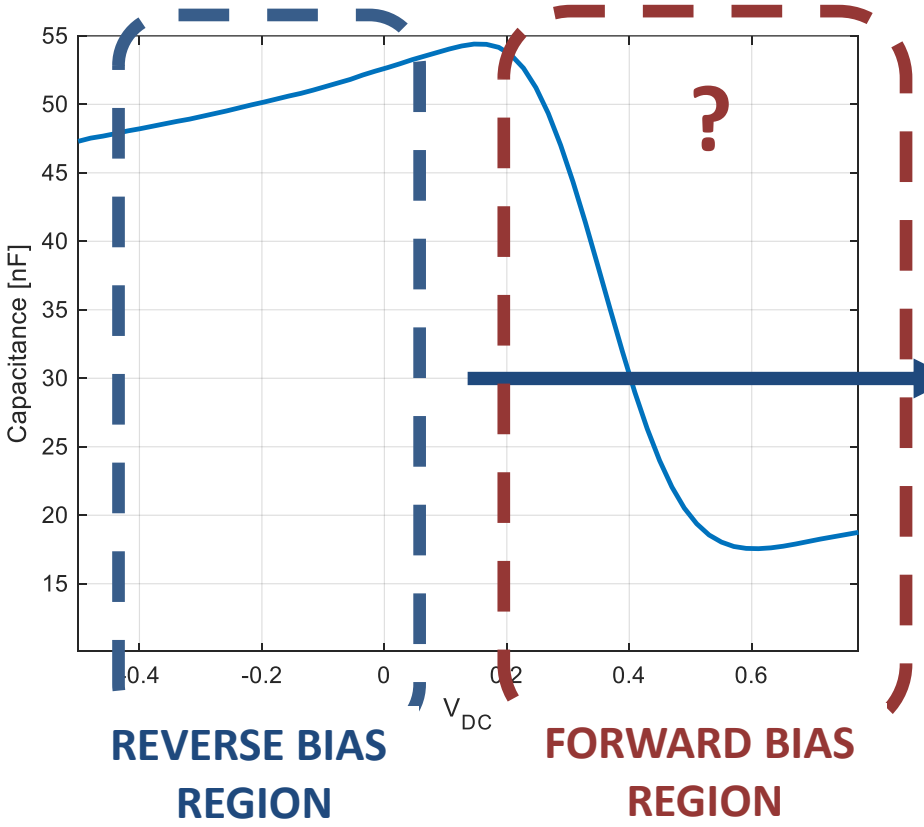
Impedance Spectroscopy

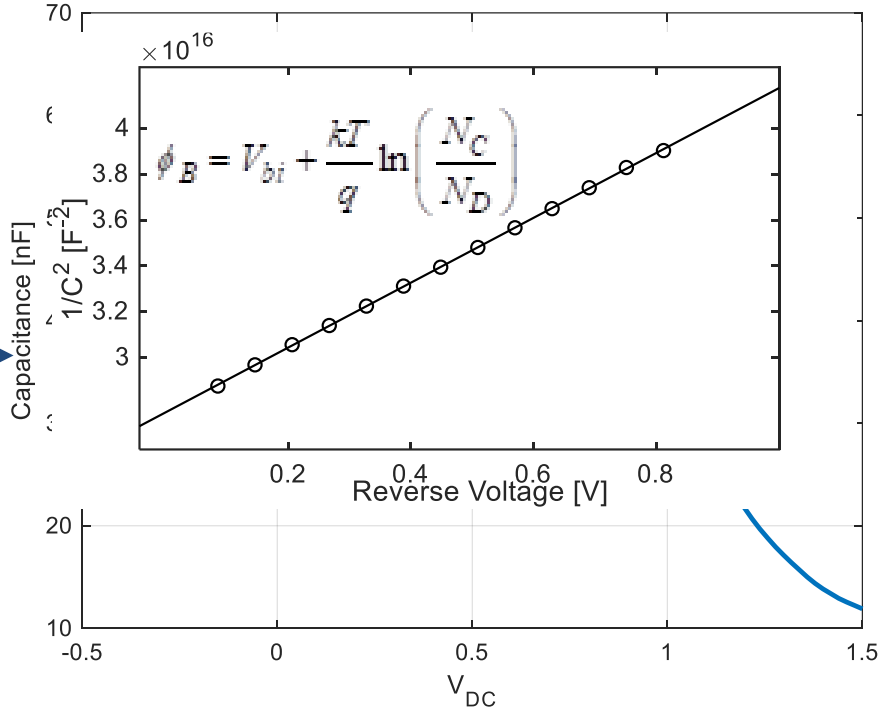
Perovskite solar cells



$$R_{rec} = \frac{1}{A}\left(\frac{\delta j_{rec}}{\delta V}\right)^{-1}$$

Capacitance versus voltage curves





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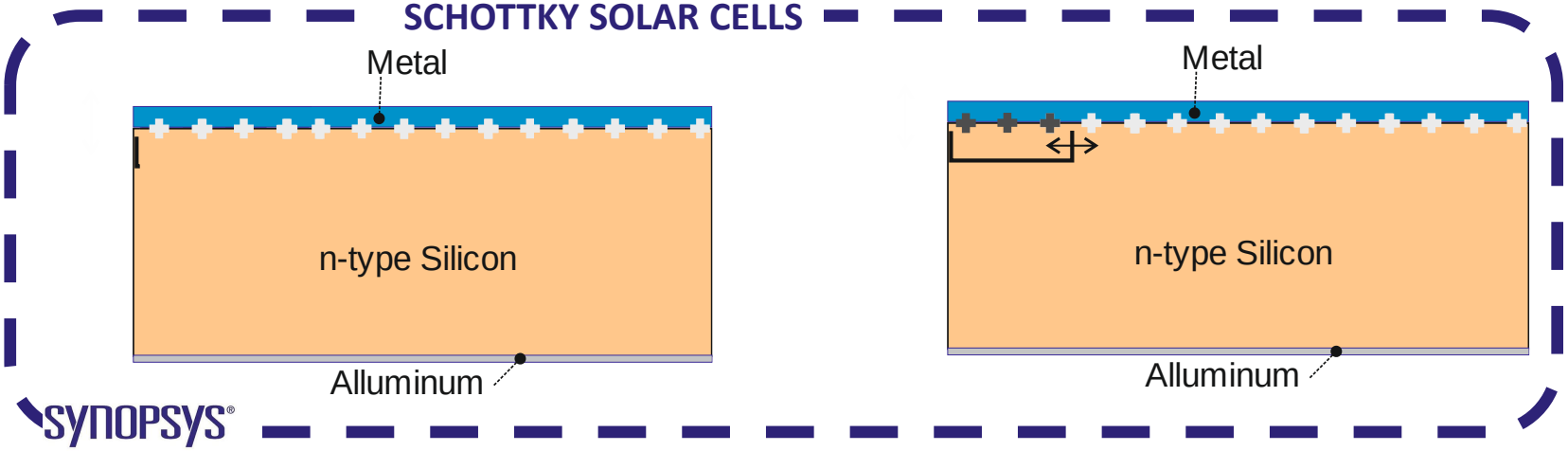

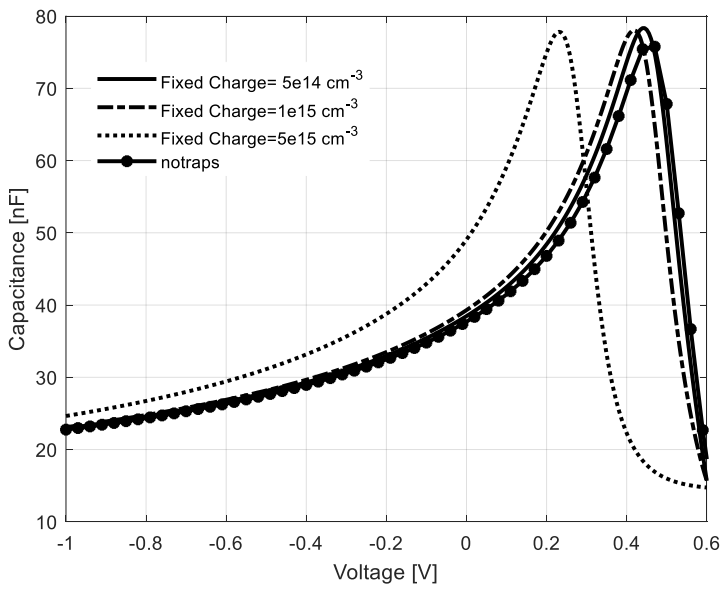

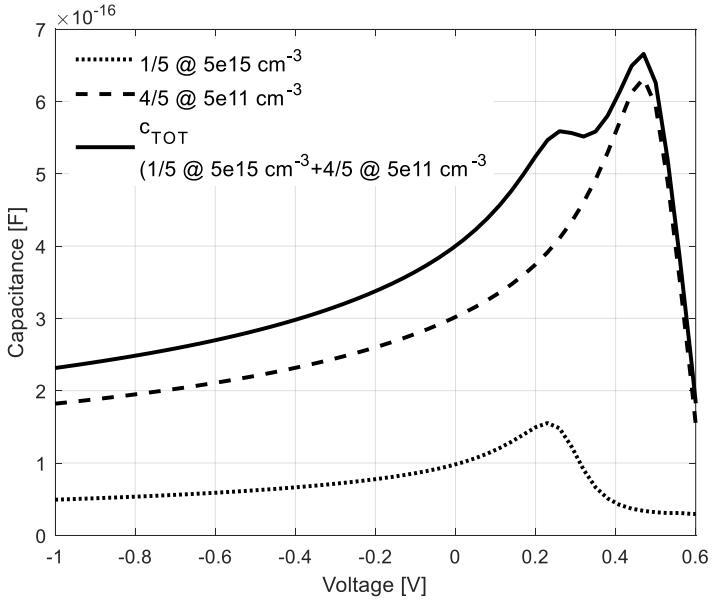

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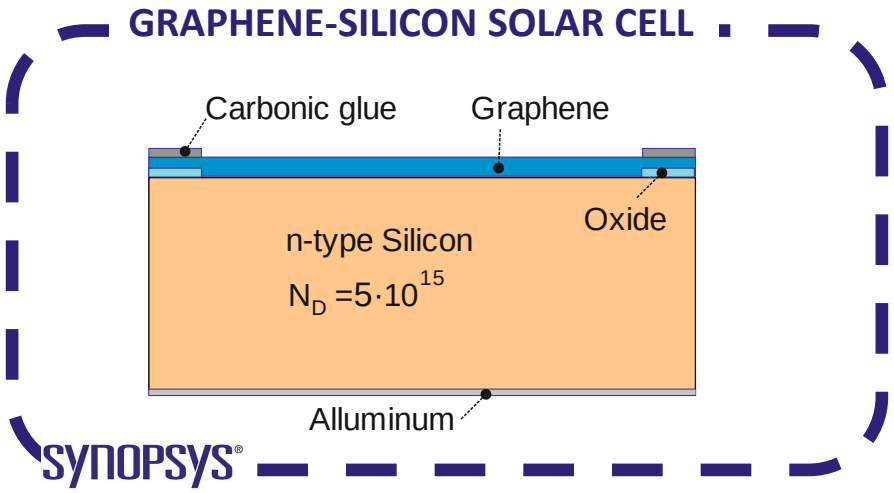
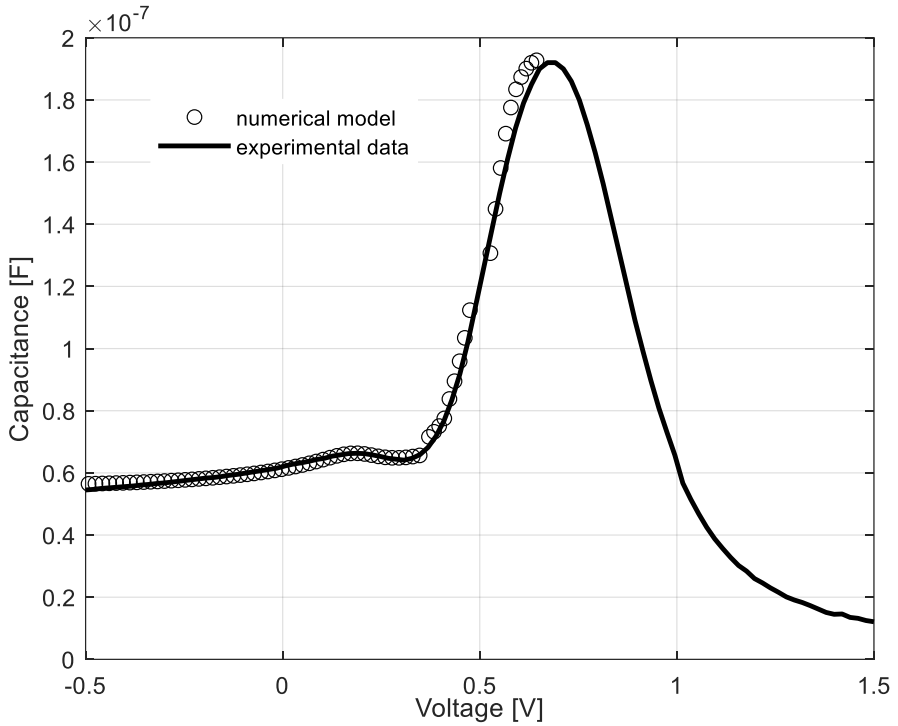
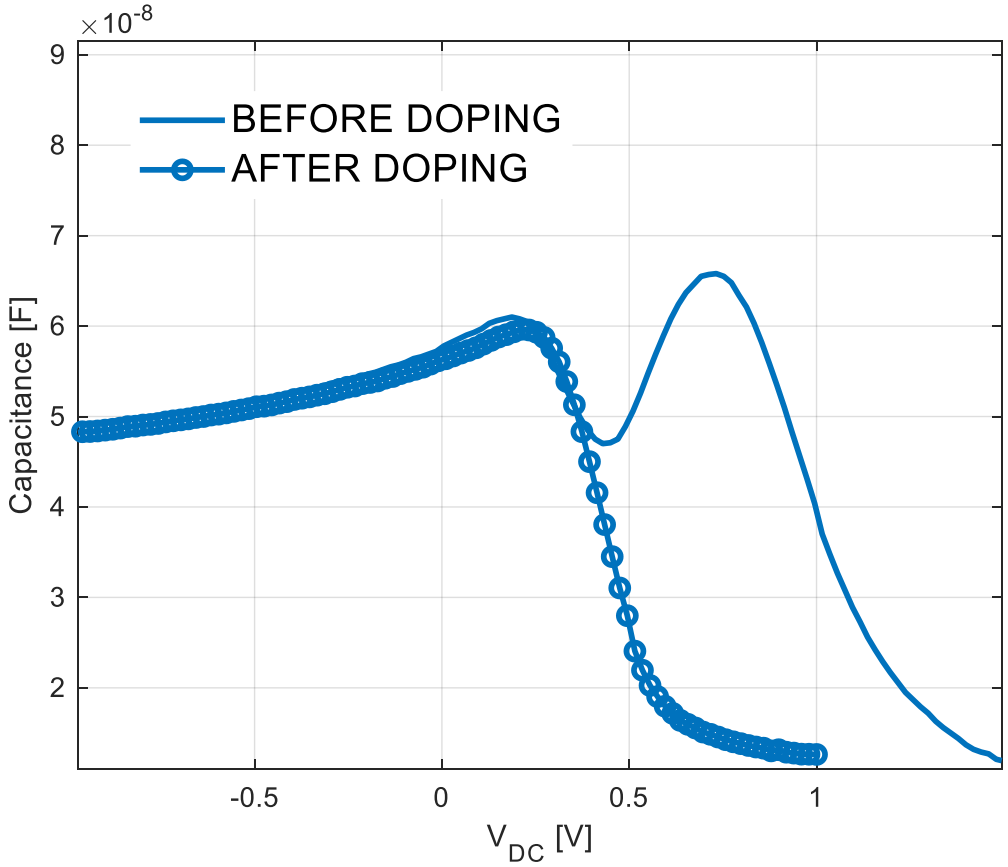
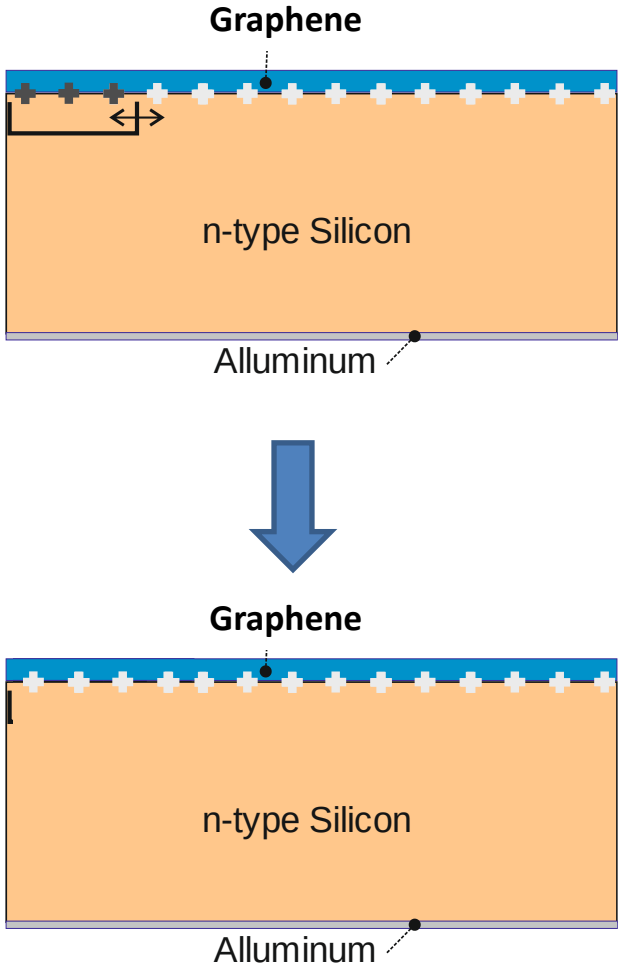




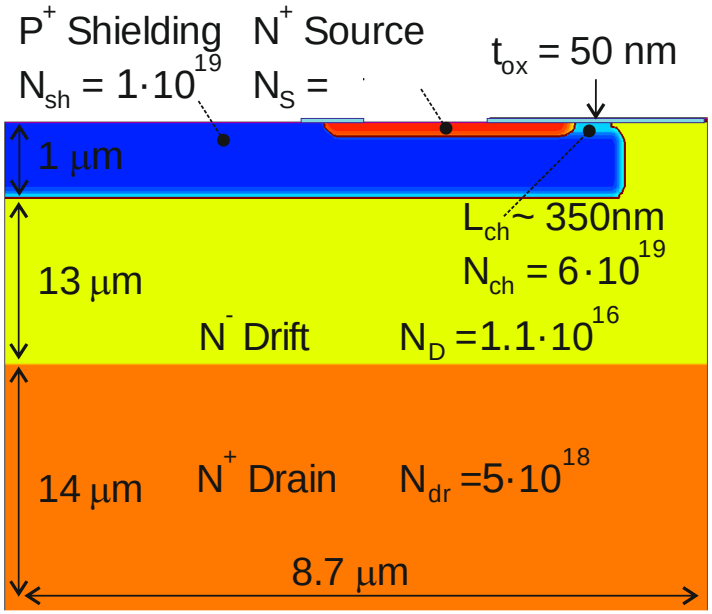
FIXED CHARGE CONCENTRATION AREA [cm^{-3}]	AREA [cm^2]
5e15	0.7
-2.3e15	0.3

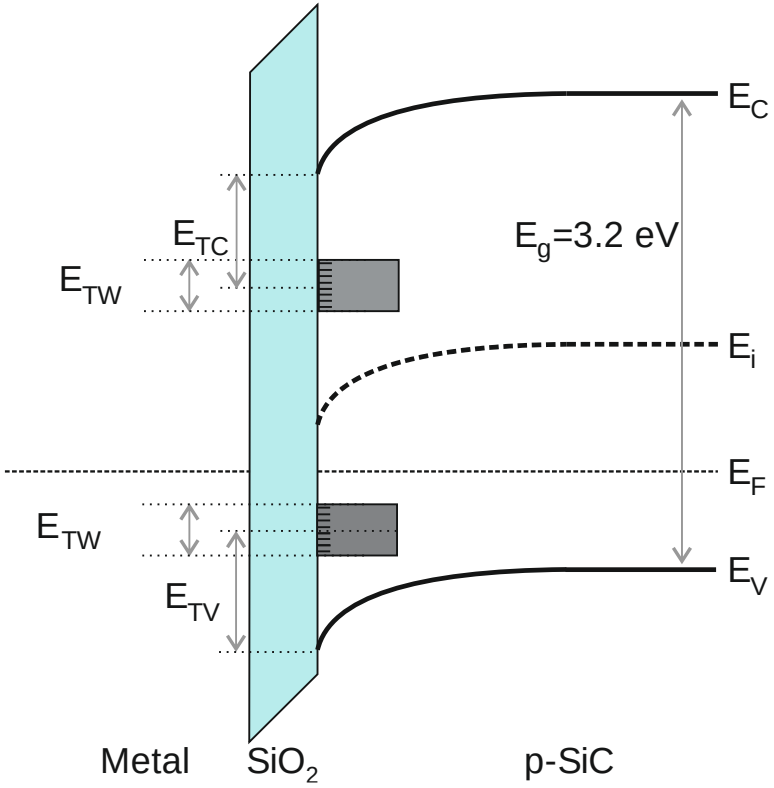
Capacitance versus voltage curves





C-V curves of SiC Power MOSFETs

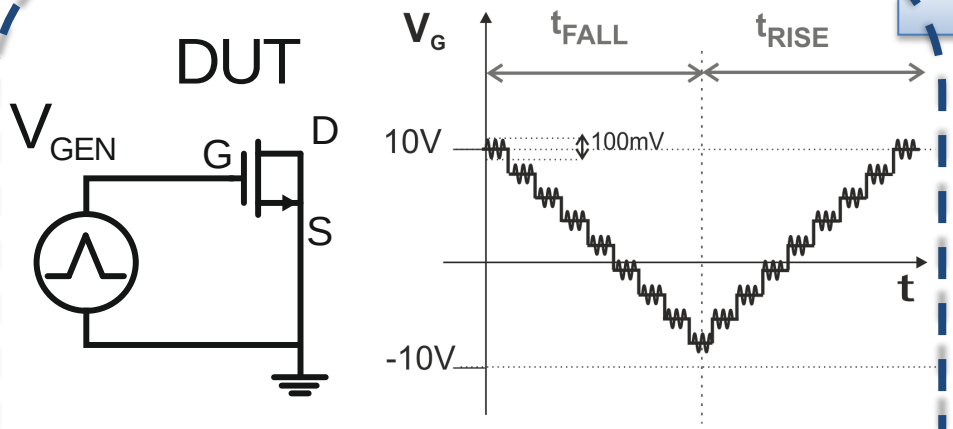




SYNOPSYS®

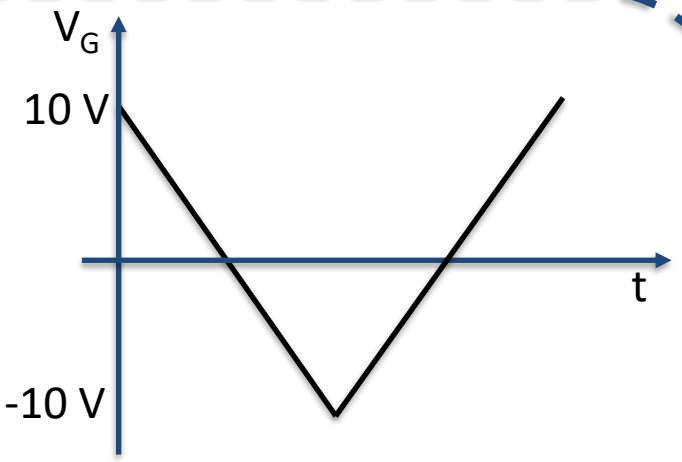
C-V curves of SiC Power MOSFETs

Experimental setup



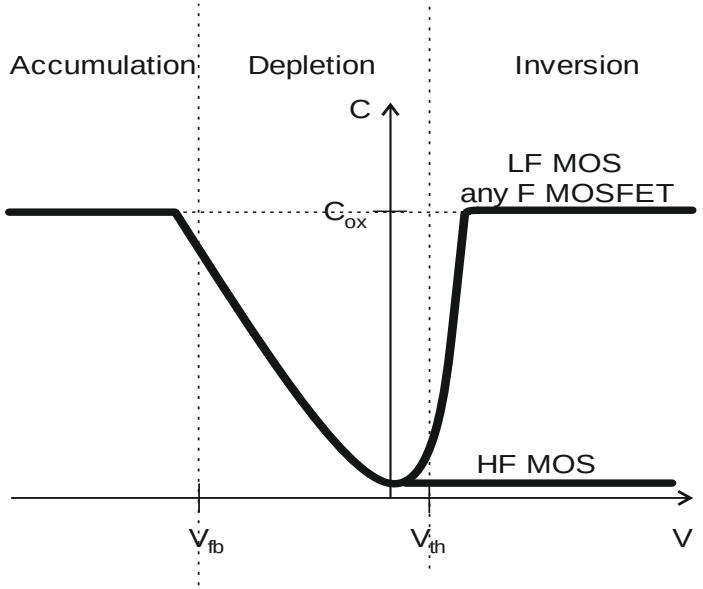
- Drain and Source are connected to ground and the Gate terminal to the C-V curve tracer.
- A linear ramp is applied to the DUT and each point of the C-V curve is measured by applying a sinusoidal small signal for a short time.

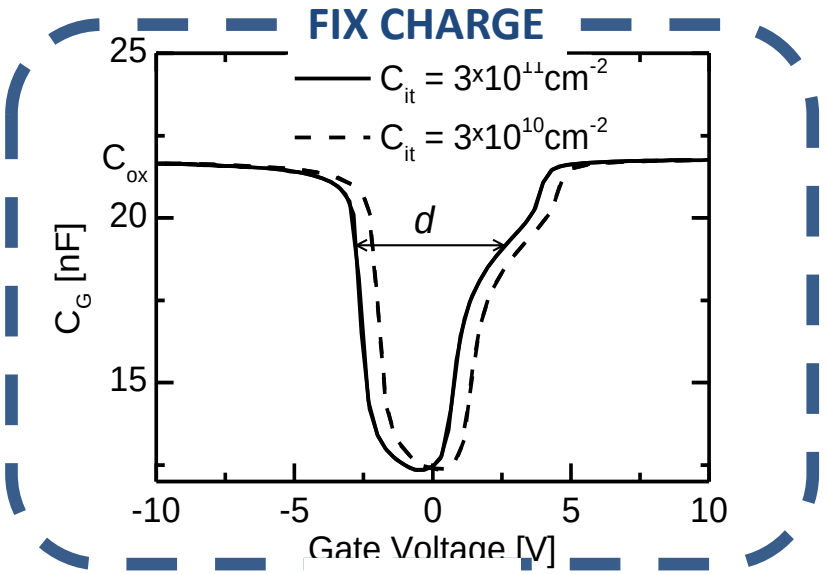
Mixed-mode TCAD simulation framework

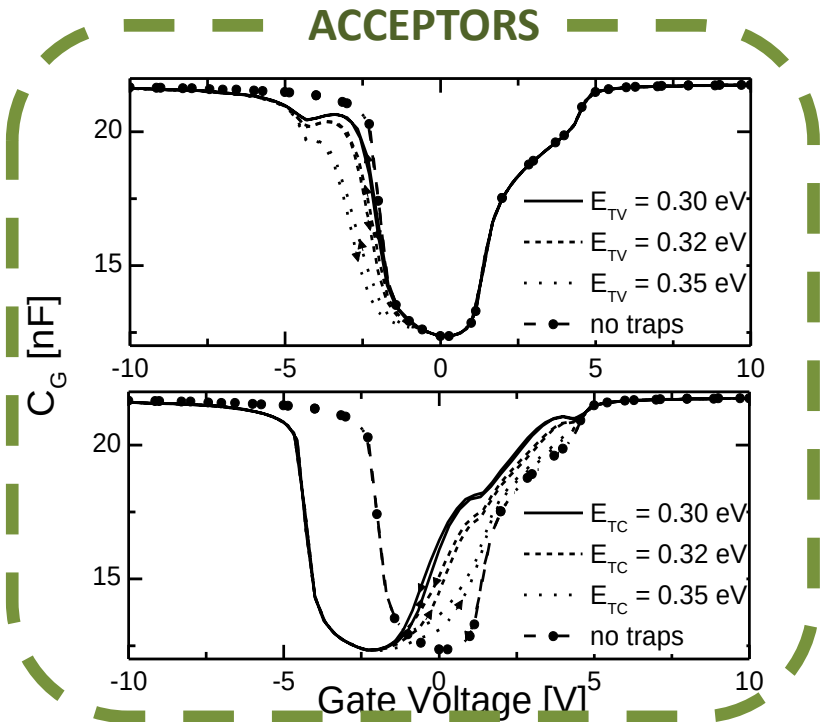


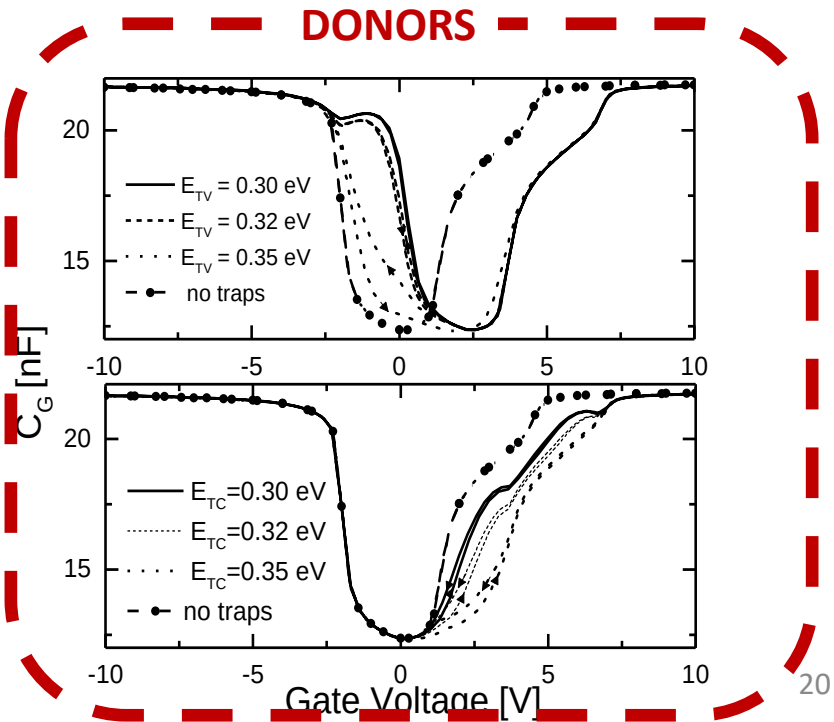
- The C-V curve is carried out by TCAD simulations. A sawtooth signal is applied to the Gate of the TCAD model and for each time step an AC simulation is carried out.
- This is fundamental to keep into account for the effects of long-time-constants traps.

C-V curves of SiC Power MOSFETs

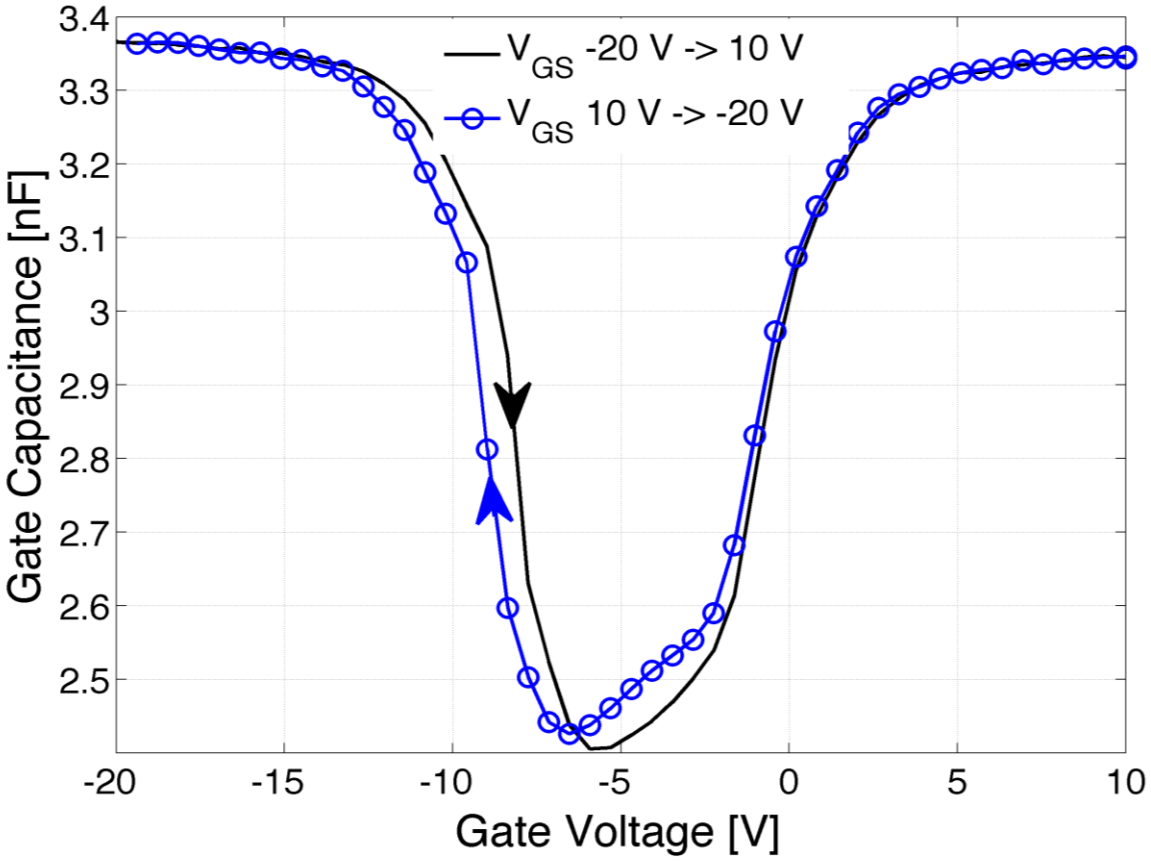








C-V curves of SiC Power MOSFETs



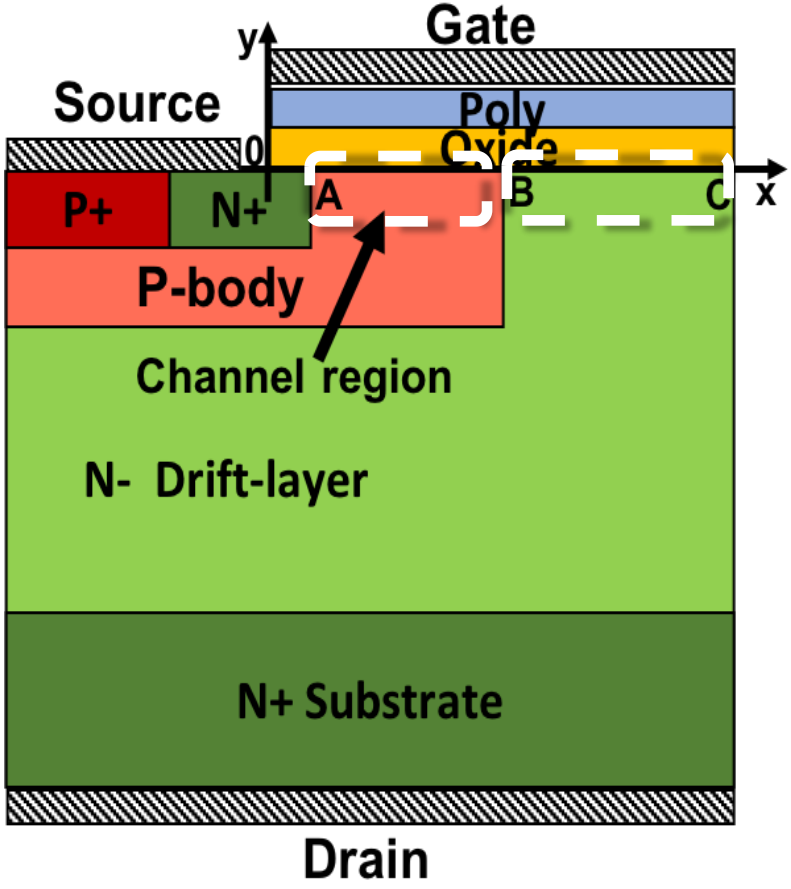
$t_{RISE} = t_{FALL}$ = 90 s, T = 300 K, *f*=100kHz

- The hysteresis effect is visible, especially for $V_G < 0V$.
- The voltage hysteresis is not constant along the C-V curve.
- Even if t_{RISE} = 90 s, the hysteresis effect is visible. This can be due to :
  - the injection of carriers into the oxide
  - the effect of traps with a very long time constant.

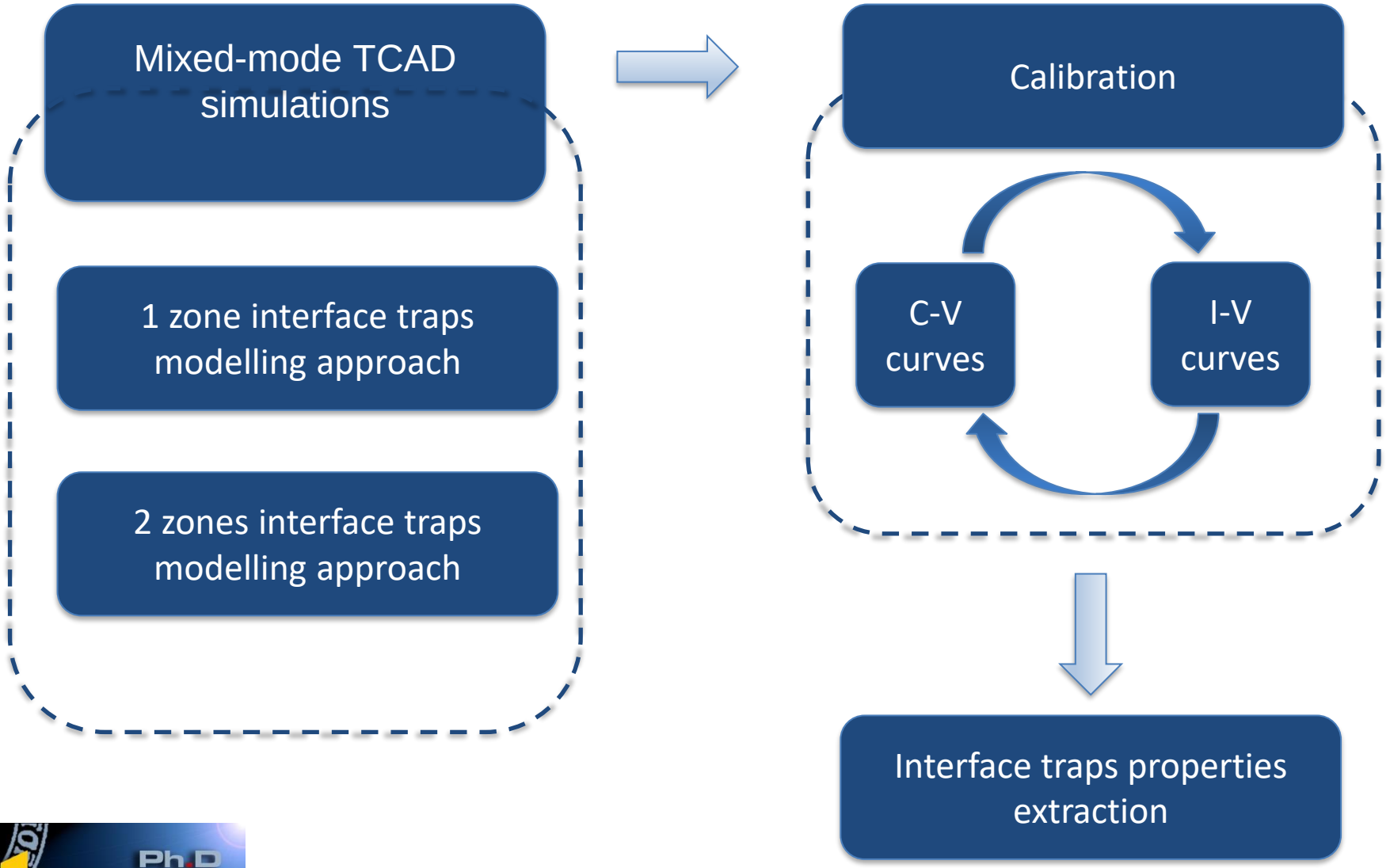
C-V curves of SiC Power MOSFETs

Two TCAD models have been considered for the calibration:

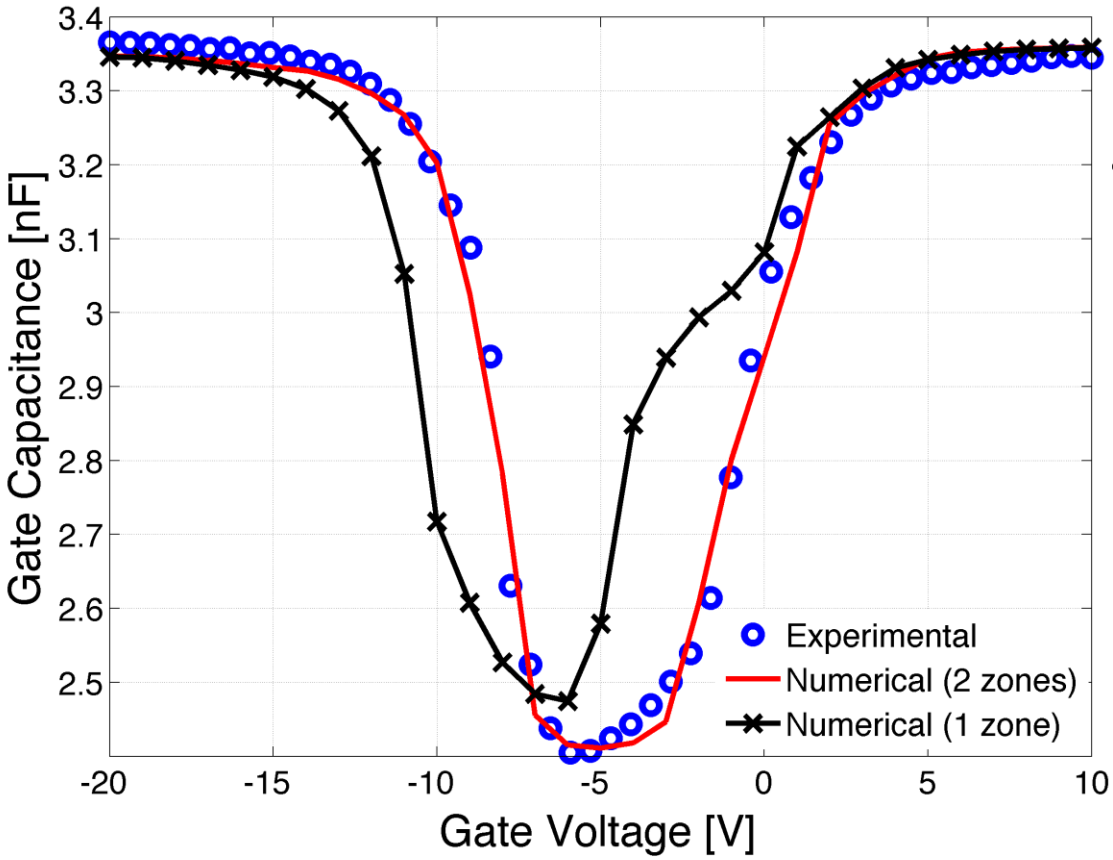
- A model with a uniform trap distribution at the SiC/SiO_2 interface along A-C.
- A model with different trap distribution along A-B and B-C.



C-V curves of SiC Power MOSFETs



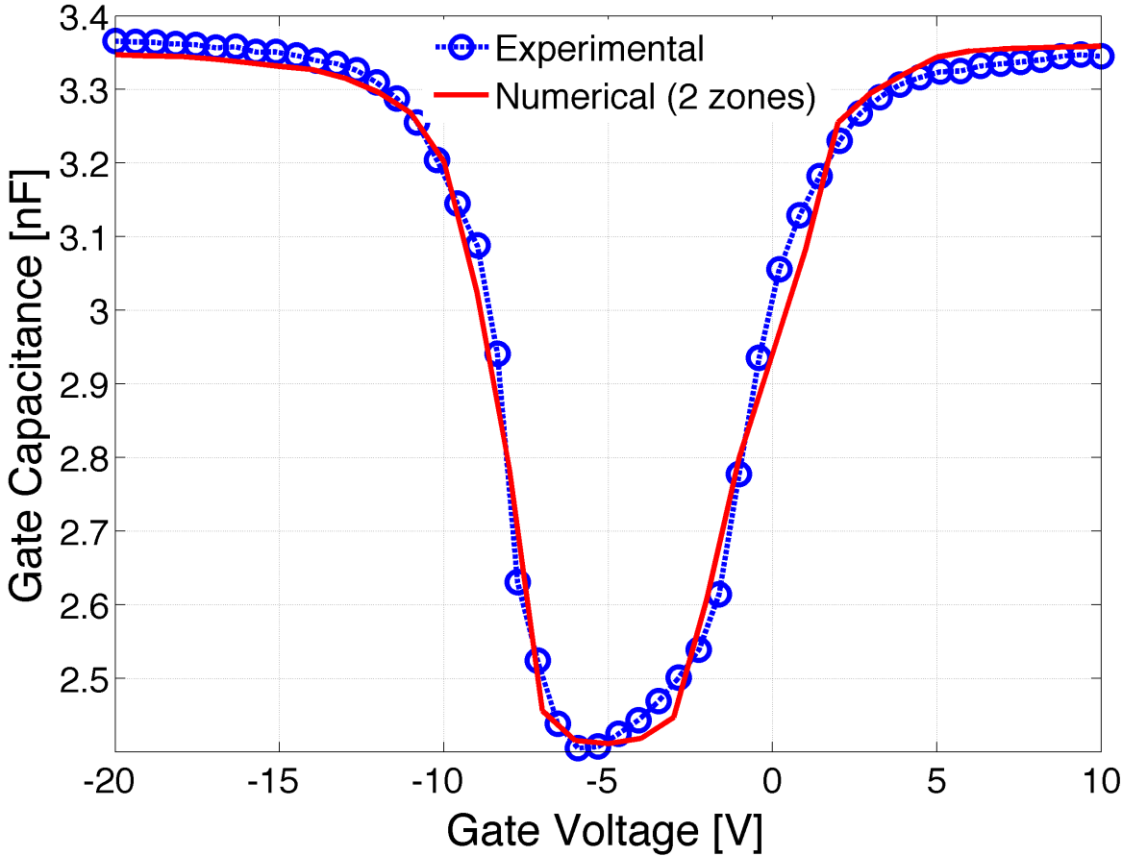
C-V curves of SiC Power MOSFETs



- **$V>V_{TH}$ → Body depletion** the C-V curve with 1 zone matches the experimental curve

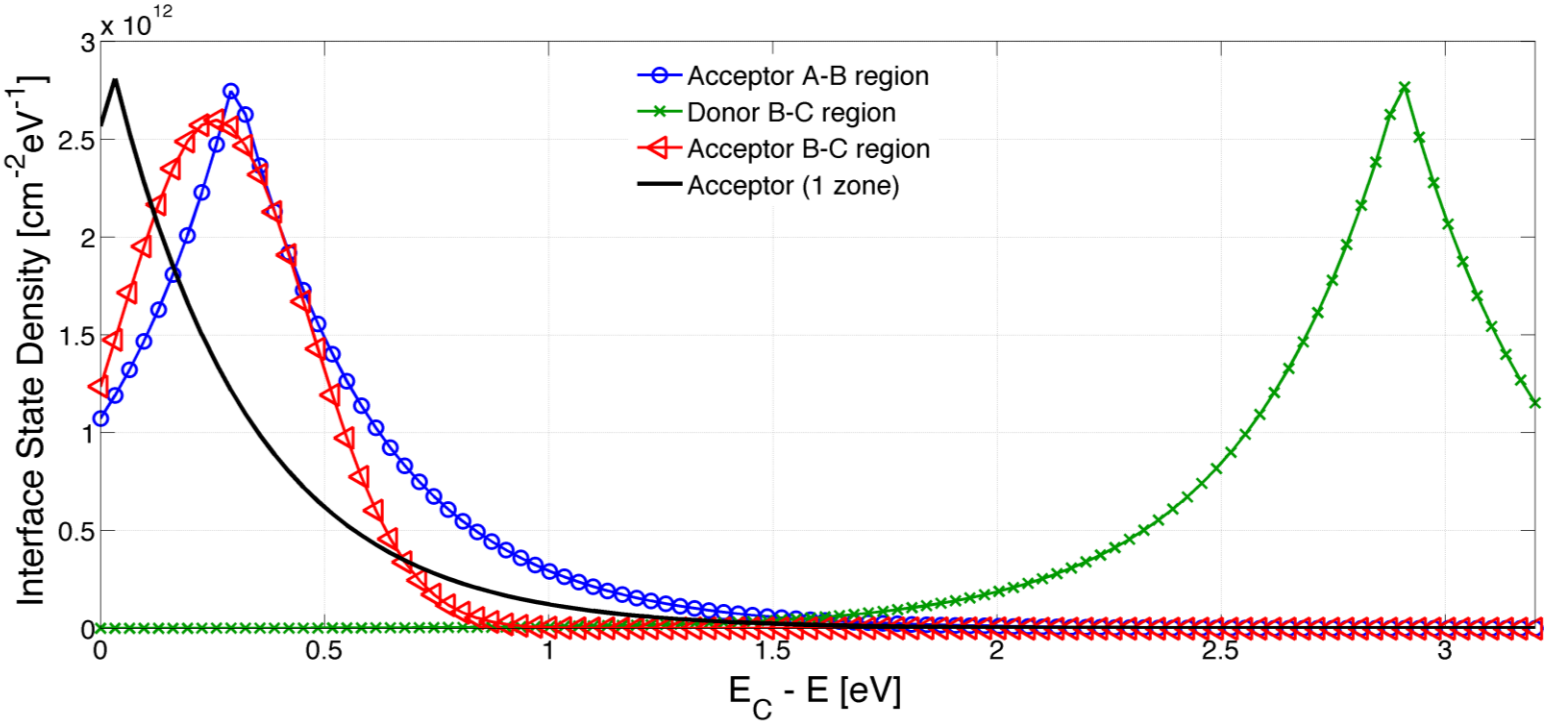
- **$V<V_{TH}$ → JFET+Body depletion** the C-V curve with 1 zone doesn't follow the experimental curve behavior

C-V curves of SiC Power MOSFETs



- A **good match** among the curves is visible in **all the gate voltage range**, in the case of 2 zones approach.

C-V curves of SiC Power MOSFETs



- The interface traps above the channel region (A-B region) are acceptors, with a peak close to the conduction band, the interface traps above the JFET region are composed by both acceptor type and **donor** type.

Conclusions

- **Graphene-silicon solar cells** have been characterized using **impedance spectroscopy**. It has been possible to state that new analyzed contact technology, made of colloidal graphitic glue, behaves in different way with respect to conventional one since no parasitic junction is formed between contact material and graphene and therefore this **new contact technology ameliorates solar cells performance**.

- Emergent **perovskite solar cells** have been studied using **impedance spectroscopy**. Two different types of perovskite solar cells have been considered, one with doped ETL and the other with ETL not doped. It has been possible to have information on **perovskite active layer and recombination process** taking place in such material, and it has been possible to understand that some **problems occurred during ETL doping** process causing some issues in the perovskite layer.

- **Capacitance versus voltage curves** have been analyzed in the forward bias region. Experimental C-V curve of a **graphene-silicon solar cell** has been considered. Numerical structure has been realized to align experimental and numerical C-V curves, extracting **defects distributions at MS interface.**

- **Capacitance versus voltage curves** of **power SiC MOSFETs** have also been studied. A numerical structure has been realized and two approaches have been considered for traps modelling. Experimental and numerical C-V curves have been aligned, extracting **traps distribution at SiO2/SiC interface**

Scientific production

Journal papers	Matacena, I., Lancellotti, L., Lisi, N., Delli Veneri, P., Guerriero, P., & Daliento, S. (2020). Impedance Spectroscopy for the Characterization of the All-Carbon Graphene-Based Solar Cell. Energies, 13(8), 1908. Maresca, L., Matacena, I., Riccio, M., Irace, A., Breglio, G., & Daliento, S. (2019). Influence of the SiC/SiO2 SiC MOSFET interface traps distribution on CV measurements evaluated by TCAD simulations. IEEE Journal of Emerging and Selected Topics in Power Electronics. Matacena, I., Maresca, L., Riccio, M., Irace, A., Breglio, G., & Daliento, S. (2020). Evaluation of Interface Traps Type, Energy Level and Density of SiC MOSFETs by Means of CV Curves TCAD Simulations. In Materials Science Forum (Vol. 1004, pp. 608-613). Trans Tech Publications Ltd.
Conference papers	"SiC MOSFET C-V Curves Analysis with Floating Drain Configuration" Ilaria Matacena, Luca Maresca, Michele Riccio, Andrea Irace, Giovanni Breglio and Santolo Daliento, Virtual Issue ECSCRM 2021. "Experimental Analysis Of C-V and I-V Curves Hysteresis in SiC MOSFETs" Ilaria Matacena, Luca Maresca, Michele Riccio, Andrea Irace, Giovanni Breglio and Santolo Daliento. Virtual Issue ECSCRM 2021. "TCAD model calibration for the SiC/SiO2 interface trap distribution of a planar SiC MOSFET" Luca Maresca, Ilaria Matacena, Michele Riccio, Andrea Irace, Giovanni Breglio and Santolo Daliento, WIPDA 2020 P. Guerriero, S.Orcioni, I. Matacena, S. Daliento " A GaN based bidirectional switch for matrix converter applications", SPEEDAM 2020

Scientific production

Conference papers	I. Matacena, et al. “Impedance spectroscopy characterization of a graphene based solar cell with improved contacts”, ELECTRIMACS, 2019. L. Lancellotti, N. Lisi, P. Delli Veneri, E. Bobeico, I. Matacena, P. Guerriero, S. Daliento “Graphene-on-Silicon solar cells with graphite contacts”, ICCEP, 2019. I. Matacena “Equivalent circuit extraction procedure from Nyquist plots for graphene-silicon solar cells”, PRIME, 2019. I. Matacena “Studying the Hot Spot Occurrence in PV Modules". In SIE2018, 50th Annual Meeting of Associazione Societa' Italiana di Elettronica P. Guerriero, I. Matacena, and S. Daliento. "Reconfiguration of solar fields by means of forced activation of bypass diodes." In 2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), pp. 817-822. IEEE, 2018. P. Guerriero, P. A. Cennamo, I. Matacena, and S. Daliento. "Avoiding the Hot Spot Occurrence in PV Modules." In 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), pp. 1-5. IEEE, 2018. L. Lancellotti, E. Bobeico, M. Della Noce, P. D. Veneri, & I. Matacena “Work Function Determination of Transparent Contact for a: Si/c-Si Heterojunction Solar Cells”. In 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), pp. 1-5, IEEE, 2018.

THANK YOU !