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Silicon nitride platform for visible, near and mid-infrared integrated photonics

Prof. Dr. Ing. Pascual Muñoz

Photonic IC Group – Photonic Research Labs

Universitat Politècnica de València – www.prl.upv.es - Valencia (Spain)

Co-founder, Board of Directors

VLC Photonics S.L. – www.vlcphotonics.com – Valencia (Spain)

Facility Manager

UPVfab, the micro-fabrication R&D and pilot line facility – www.fab.upv.es



EPIC Online Technology Meeting on Mid-IR Photonics
13th of May, 2020 – 15:00-17:30 h CEST

Photonic integration ecosystem in Spain

Actors that have outstanding international reputation on PICs

Research and Technology Organisations

Universitat Politècnica de València – PRL – Photonic IC

University of Málaga (UMA)

University Carlos III Madrid (UC3M)

Instituto de Microelectrónica de Barcelona (IMB-CNM-CSIC)

- Brought generic photonic integration to Spain
- Advanced PIC modeling and design
- Terahertz photonic chips
- The reference cleanroom in Spain

Start-ups (some from the RTOs) working on PICs

Medlumics

VLC Photonics (from PRL)

QuSIDE (from ICFO)

Alcyon Photonics (from UMA)

Ommatidia

iPRONICS (from PRL)

- Optical coherence tomography
- A photonic integration company
- Quantum on chip
- Design and IP development
- LIDAR
- Programmable photonic chips



collaborate to innovate



Next 22nd May 2020 – 12 h CET
(in English)

<http://www.secpho.org/actoagenda/who-is-who-en-fotonica-integrada/>

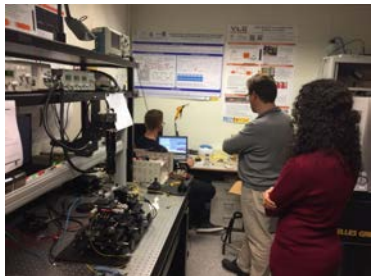
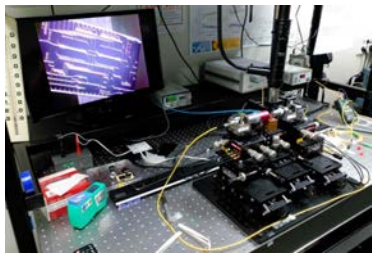
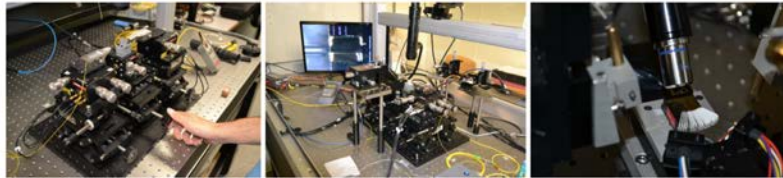
About the Photonic IC group - facilities



<http://www.prl.upv.es/>



<https://www.fab.upv.es>



Photonic testing labs - 500 m² (~6M€)
digital 40Gbps
RF analog signals 50 GHz

Class 10.000 - 500 m² (~10M€)
6 inch wafers - automation
Process gases (SiH₄, SiCl₂H₂, NH₃, Ar, O₂, N₂, H₂, CHF₃, CF₄)

Deposition: PECVD, LPCVD, sputtering (RF/DC)

Lithography: contact mask aligner double side alignment.

Etching: wet and dry (ICP-RIE)

Metrology: SEM, FESEM, FIB, FTIR, profiler, ellipsometer

Assembly: μ Transfer-Printing, Flip-chip



Photonic integration: applications, materials & platforms

Rationale for a **Silicon nitride Broadband** Photonic Integration Platform

Photonics ...

- is used in numerous applications
- applications are linked to wavelength
- Visible (VIS): bio-photonics
- Near-infrared (NIR): tele/datacom
- Mid-infrared (MIR): sensing

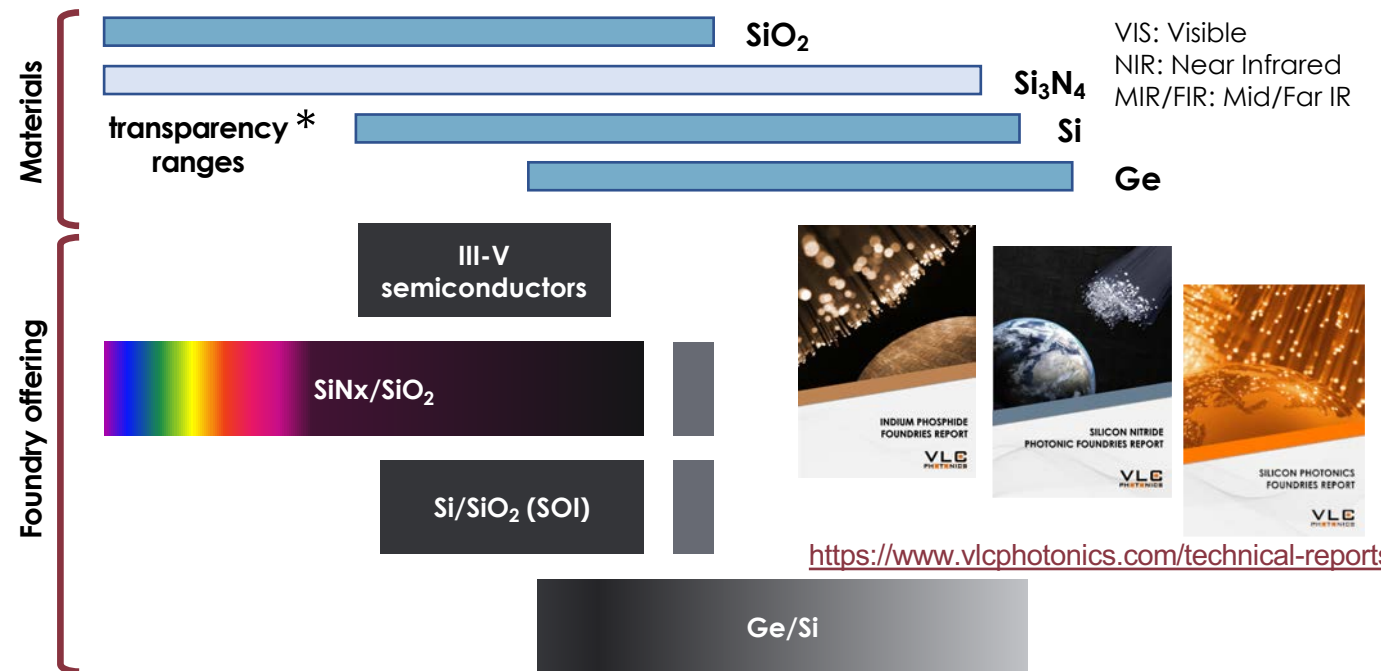
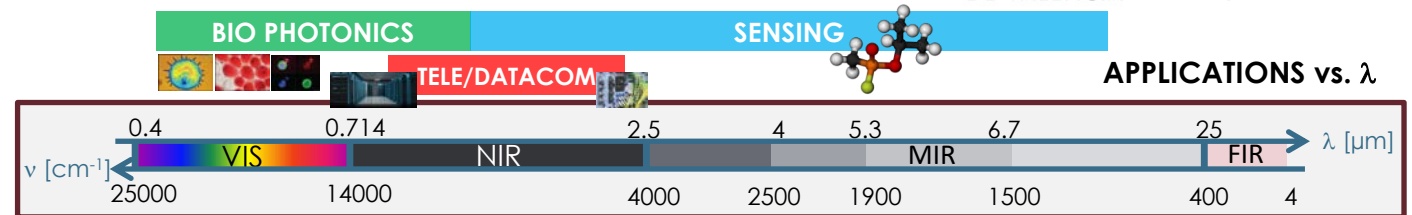
Materials used in integration ...

- Transparency in the band of interest
- Absorption/emission in the band

Wanted requirements ...

- To support a wide range of wavelengths
- Base in abundant materials

Silicon and compounds are excellent candidates



<https://www.vlcphotonics.com/technical-reports/>

*R. Kitamura, L. Pilon, and M. Jonasz, "Optical constants of silica glass from extreme ultraviolet to far infrared at near room temperature," *Applied Optics*, vol. 46, no. 33, pp. 8118+, Nov. 2007. <http://dx.doi.org/10.1364/ao.46.008118>

Si₃N₄ is transparent from 400 to 6700 nm
Must avoid using SiO₂

Institute of Microelectronics Barcelona

Centro Nacional de Microelectrónica - CSIC



Adscription & location



Clean Room Characteristics

1,500 m² (2,900 m² services)

“House in House” structure

Class 100-10,000 (ISO 5-7)

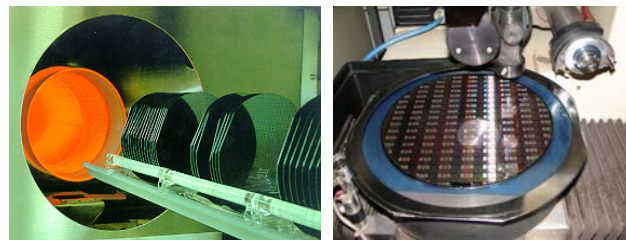
Wafer size 100-150 mm

Stepper + EBL.

CMOS ICs

MEMS/NEMS

Nanofabrication



<http://www.imb-cnm.csic.es/index.php/en/clean-room>



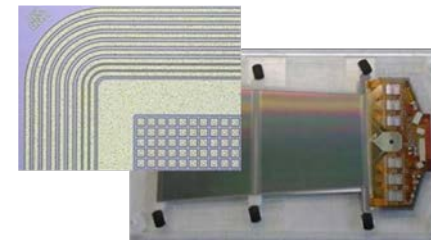
Operations

From TRL 2 to TRL 9 (**concept** → **market**)

25% yearly income is from industry

Industrialized technologies

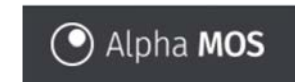
Radiation detectors



SiC rectifiers for space



Chemical sensors ISFETs



Si3N4 Photonic Integration Technologies at CNM

Visible (340 nm), Near (300 nm) and Mid-infrared (650 nm) –

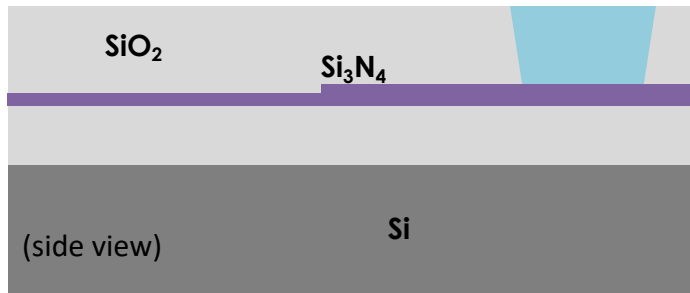
High quality LPCVD Si3N4 films



Dedicated run



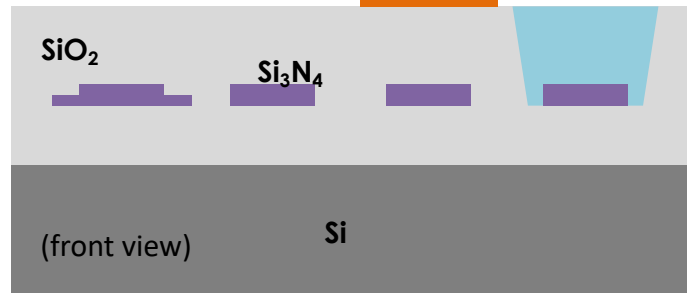
Main application: bio-sens



MPW & dedicated runs



Applications: generic

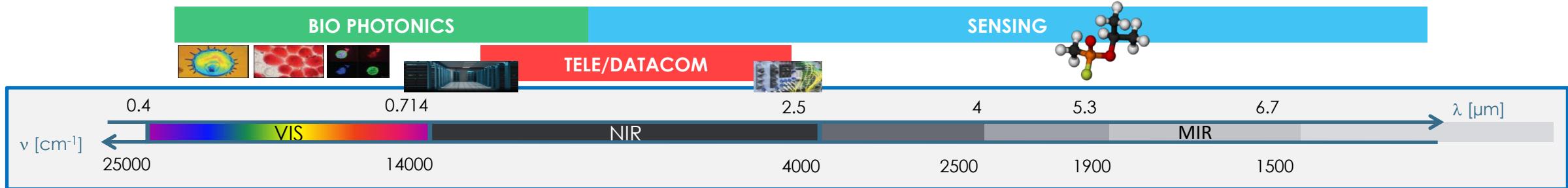
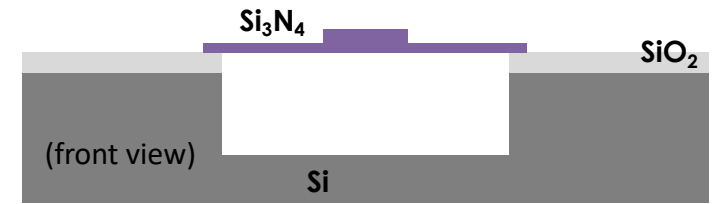


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MPW & dedicated runs

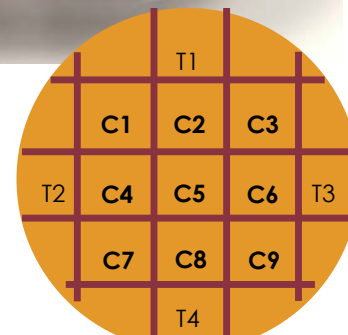
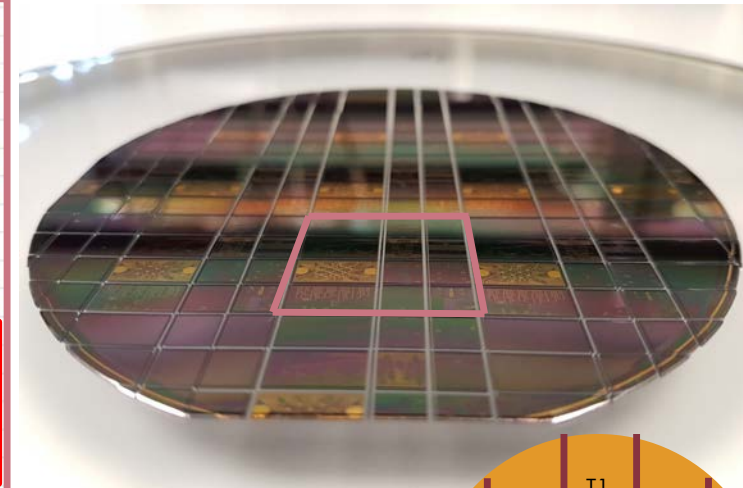
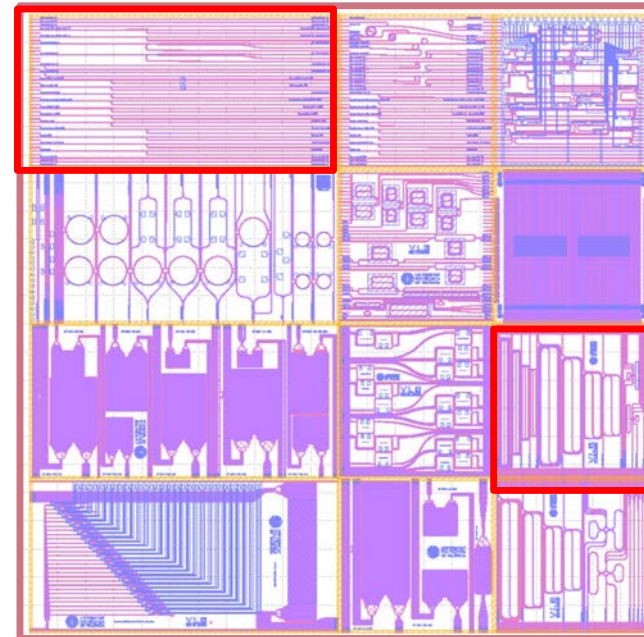
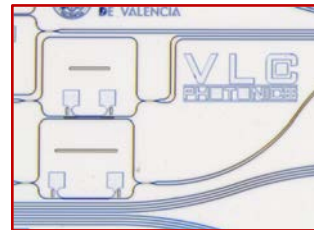


Applications: generic



Silicon Nitride Multi-Project Wafer runs

<http://www.imb-cnm.csic.es/index.php/en/clean-room/silicon-nitride-technology>



Three waveguide cross-sections (nitride film 300 nm height, shallow 150/300, deep 300 and mini-deep 150 nm)

Thermo-optic tuners

Selective area trenching

Blocks developed: waveguides, inverted taper, MMI couplers, Mach-Zehnder Interferometers, Sagnac interferometers, Arrayed Waveguide Gratings, ring resonators, ...

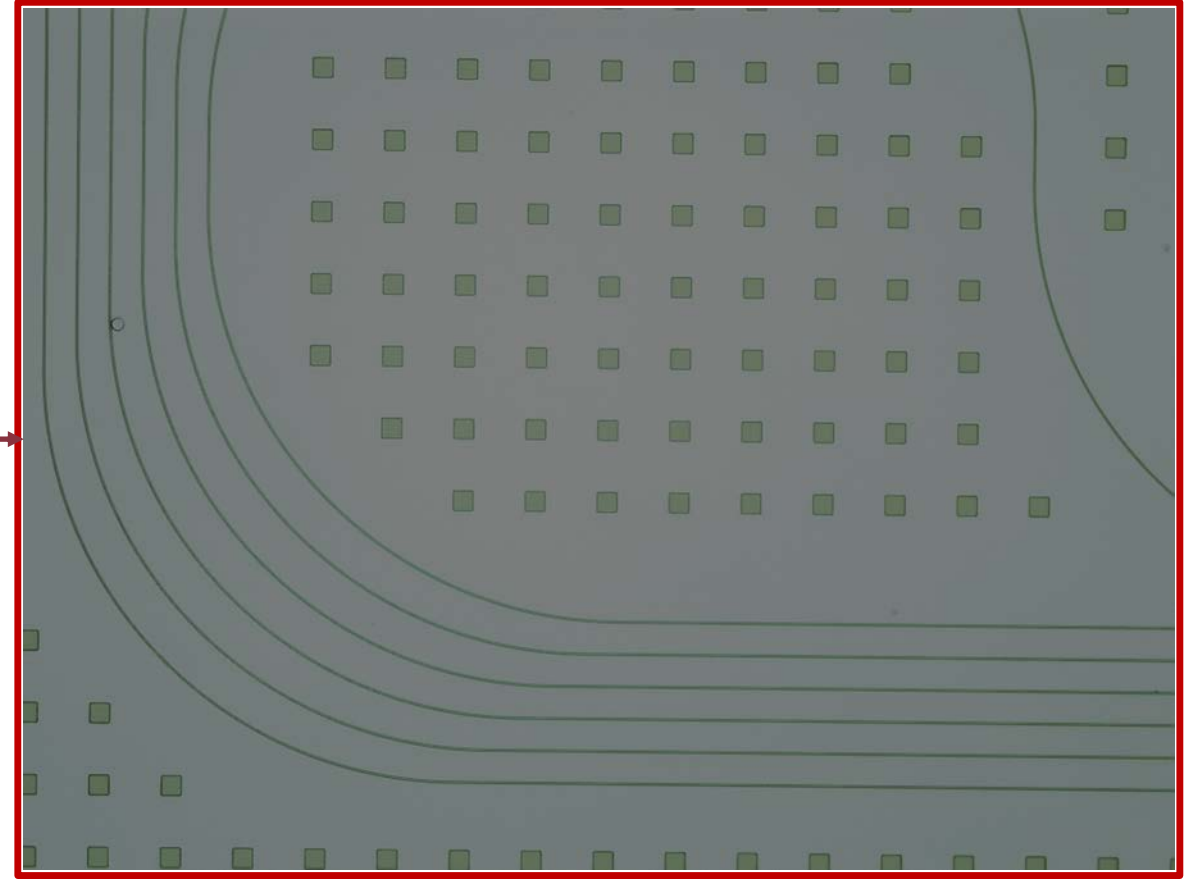
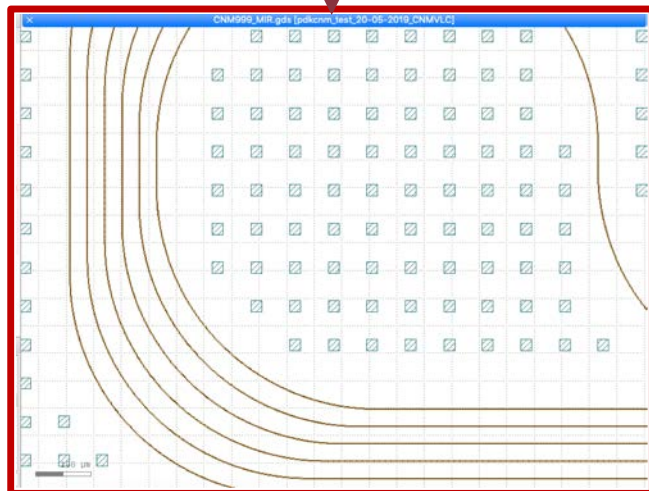
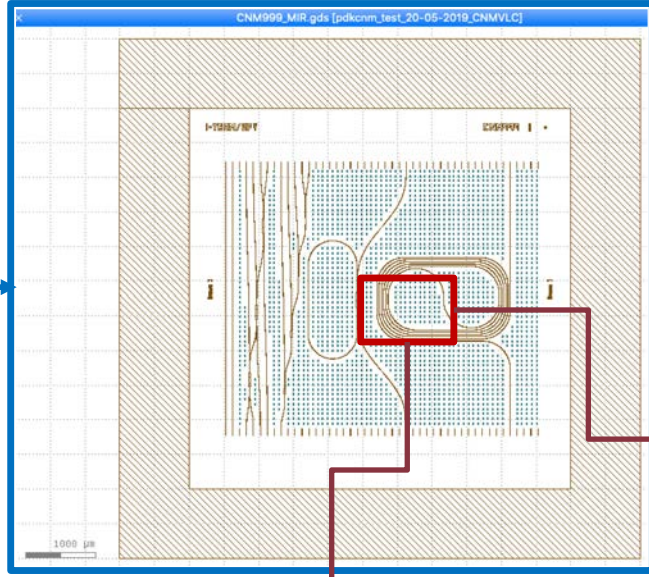
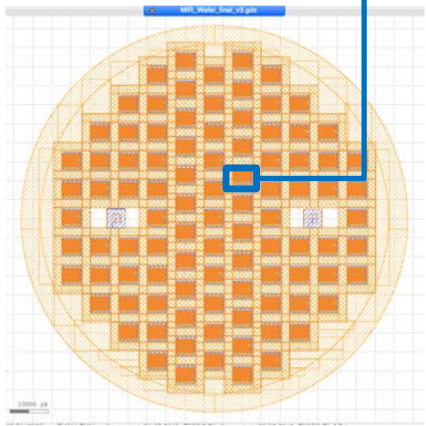
MWP#0, MPW#1, MPW#2, MPW#3 & MPW#4 finalized
MPW#5 Course and Mask deadline along 2020
Cells size L 5.0x10 mm² & Cells size M 5.0x5.0 mm²

SiNx Broadband Photonic Integration Platform

Silicon nitride membrane based – 2nd PoC run finished



DoE chips λ
1-2 μm
2-3 μm
3-4 μm



Mask CNM-999
Run 13137-MIR

Next actions (paused during COVID-19 lock-down)
Process refinements to improve the under-etch @ CNM
OFDR based PIC characterization @ UPV

SiNx Broadband Photonic Integration Platform

Process Design Kit (PDK), building blocks & technology roadmap



		PDK 2020					PDK 2021					PDK 2022				
Wavelength band		1-2 μm	2-3 μm	3-4 μm	5-6 μm	6-7 μm	1-2 μm	2-3 μm	3-4 μm	5-6 μm	6-7 μm	1-2 μm	2-3 μm	3-4 μm	5-6 μm	6-7 μm
Waveguide	SHWVG	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	DEWVG	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	WVGX	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Couplers	Y-B	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	DC	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	MMI	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Optical I/O	SPGC	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	PSGC	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	SSC	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Tuning	EA-MOD	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	TO-MOD	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Filter	RR	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	AWG	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	DBR / DFB	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Hybrid actives	SOA	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	Laser	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	PD	Green	Green	Green	Grey	Grey	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

Color code: Green=Available, Grey=Not Available. Abbreviations: SHWVG Shallow waveguide, DEWVG Deeply etched waveguide, WVGX Waveguide crossing, Y-B Y-branch, DC Directional coupler, MMI Multi-Mode Interference coupler, SPGC Single Polarization Grating Coupler, PSGC Polarization Splitting GC, SSC Spot-Size Converter, EA-MOD Electro-Absorption Modulator, TO-MOD Thermo-Optic Modulator, RR Ring Resonator, AWG Arrayed Waveguide Grating, DBR Distributed Bragg Reflector, SOA Semiconductor Optical Amplifier, PD Photo-Detector



process development
wafer fabrication
technology validation



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PDK design, photonic
experimental validation



μ TP process dev

Need cooperation with III-V epitaxy / device supplier for hybrid photonic integration

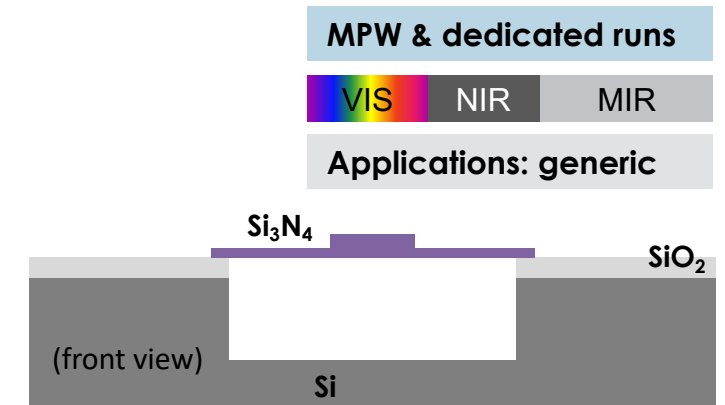
Conclusion: Silicon nitride platform for visible, near and mid-infrared integrated photonics



What are we offering? What are we looking for?

- Multi-Project Wafer run schedule

	2019			2020												2021												
	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
PoC #1																												
PoC #2		■	■	■	■	...			■	■																		
MPW#0														■	■	■	■											
MPW#1																									■	■	■	■
MPW#2																												



- What are we offering?
 - Short term: early access to MPW#0 (Nov'20) for proof of concept of mid-infrared photonic chips
 - Mid/long term: a broad-band (VIS-NIR-MIR) active + passive photonic integration platform
- What are we looking for?
 - Technology side: cooperation with III-V epitaxy and device suppliers for hybrid photonic integration
 - Application side: early adopters and seed demonstrators

Silicon nitride platform for visible, near and mid-infrared integrated photonics



Thank you! ... and acknowledgements



Excellent Science R+D+I Projects
Silicon Nitride Spectrometers 2017-2019
Broadband hybrid SiN platform 2020-2022



Marie Curie Innovative Training Netw.
MICROCOMB – Si3N4 freq. combs 2019-2022



R+D+I Industrial Contracts
PIC BBs for Generic Foundries 2016-2018
Application Specific SiN PICs 2019-2021

Research facilities valorization
PIC characterization services 2017-2019



Infrastructure Acquisition Program
PIC characterization equipment 2018-2019
µ-fabrication cluster automation 2019-2020

Infrastructure Acquisition Program
UPVfab Micro-fab pilot line 2018-2020
UPVfab Technology Pole 2020-2021



Personal acknowledgements:
Prof. Carlos Domínguez (CNM) & clean room team (CNM)
Photonics Research Labs team (UPV)
R&D department (VLC Photonics)
Prof. Fernando Rey (ITQ)
Prof. Antonio Arnau (CI2B)



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