CITIC-UGR
CENTRO DE INVESTIGACIÓN EN TECNOLOGÍAS DE LA INFORMACIÓN Y LAS COMUNICACIONES

+QChip: Heterogeneous integration of 2D materials and Si-CMOS at wafer level for neuromorphic computing

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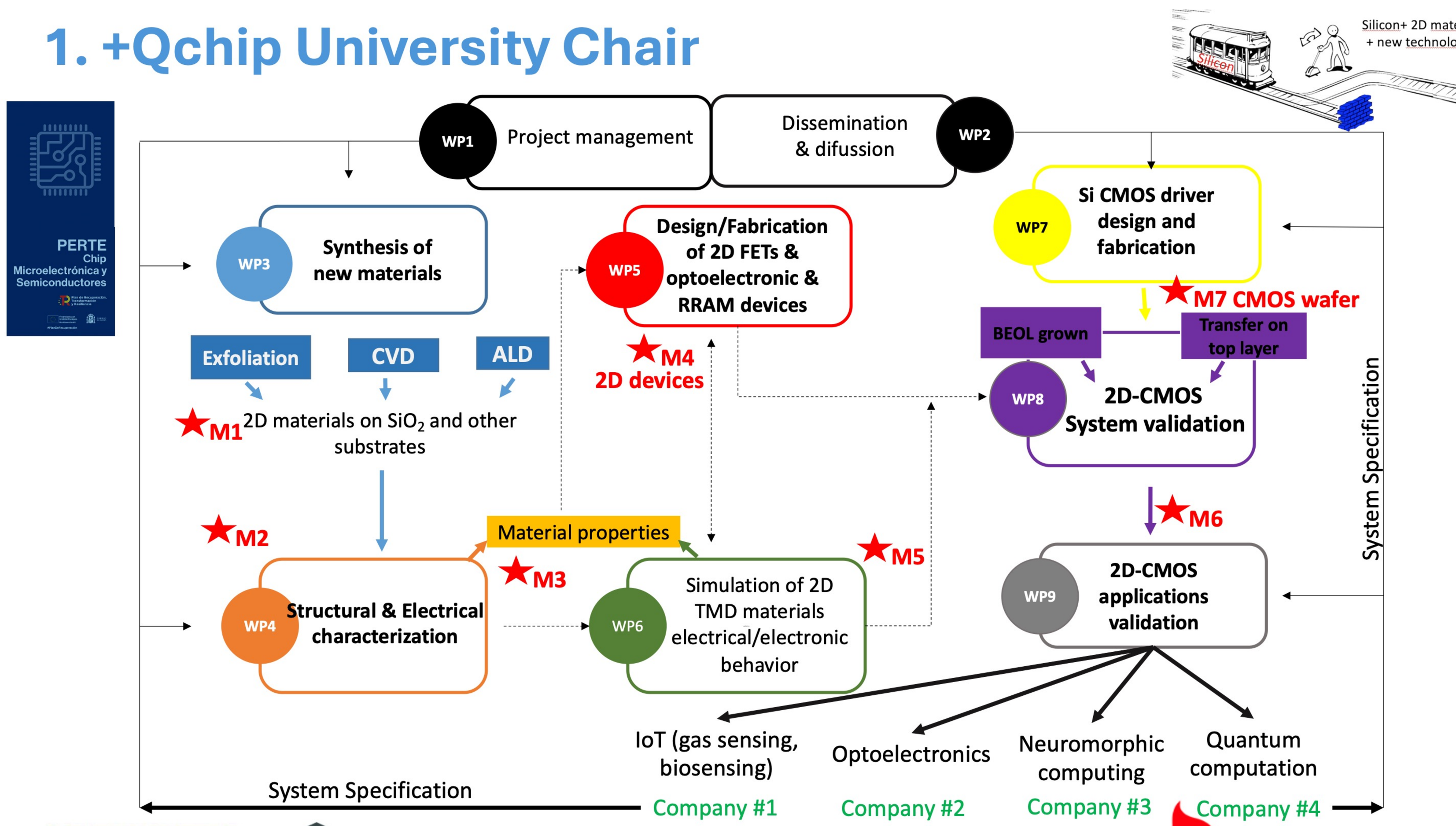
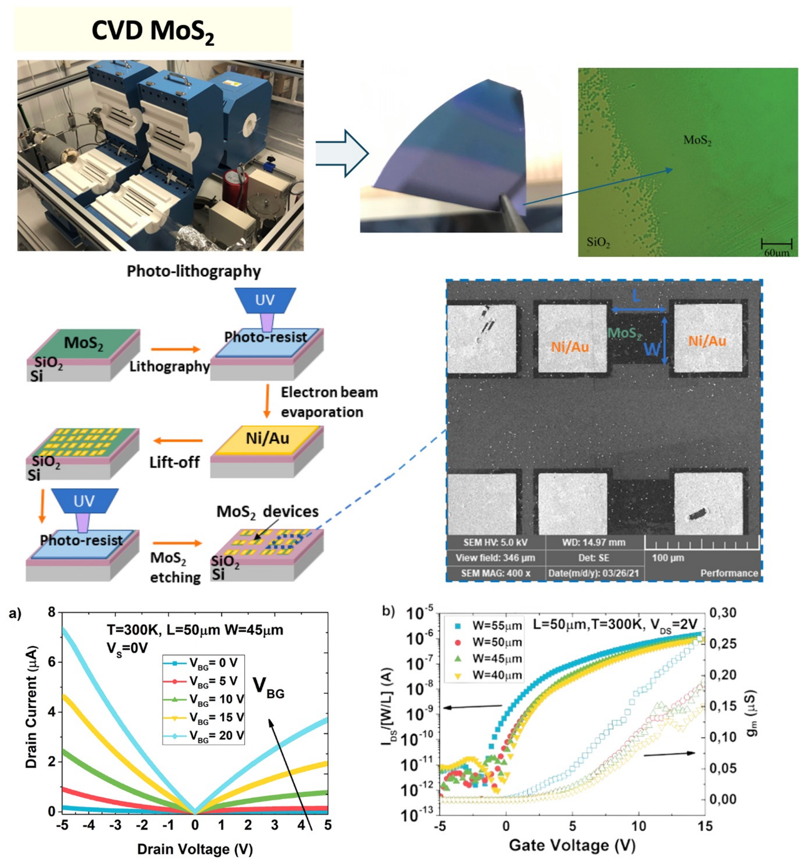
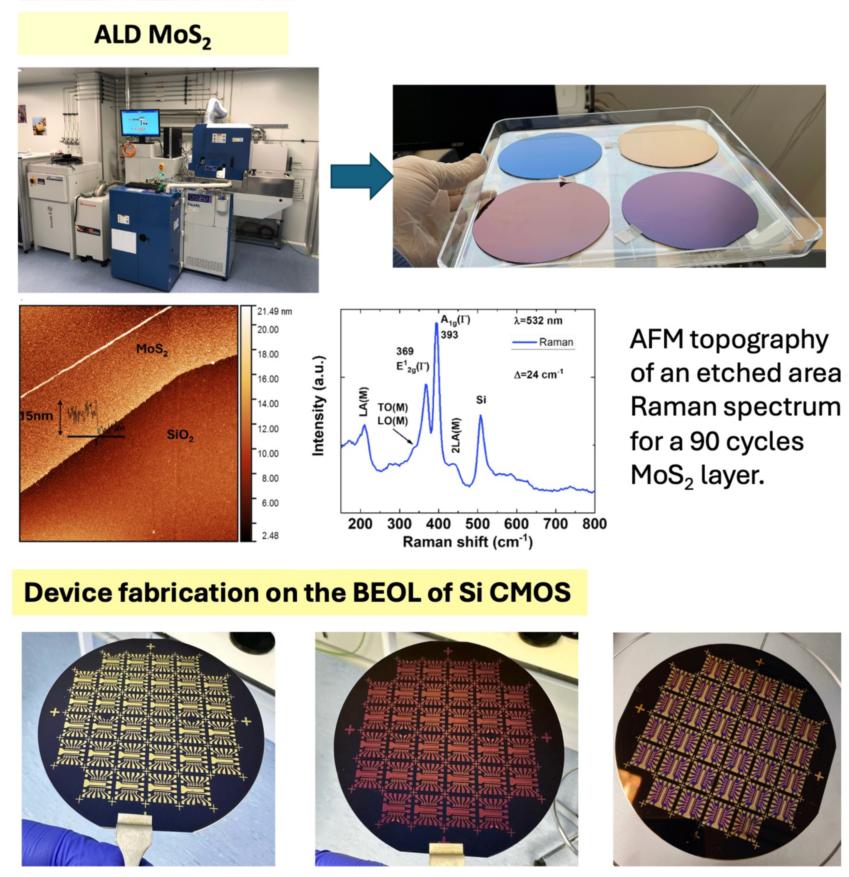
1. +Qchip University Chair



2. TMDs at wafer level



(a) Output characteristic for different back-gate biases. (b) Transfer characteristic and the correspondent transconductance.

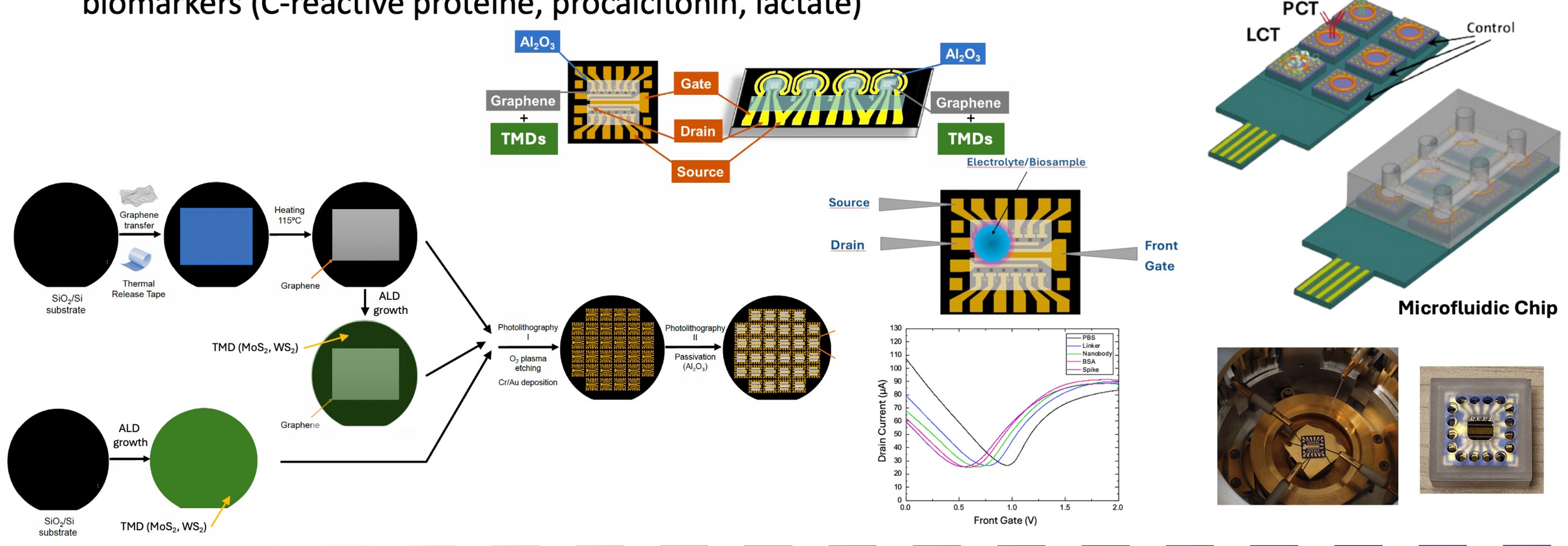


Before deposition of TMDs (metallization 10/50 nm Cr/Au)
After deposition of MoS_2 layer (12 cycles @ 380 ºC)
After lithography, RIE etching and Al_2O_3 passivation

3. TMDs-CMOS Integration: Biosensors for Healthcare

Project "GREPSIS: Development and clinical validation of an interconnected graphene-based biosensor platform for the early diagnosis of SEPSIS at the point of care and the optimization of its clinical management"
Partners: UGR, Hospital UVG, Lybelium, UCMadrid, ATIS

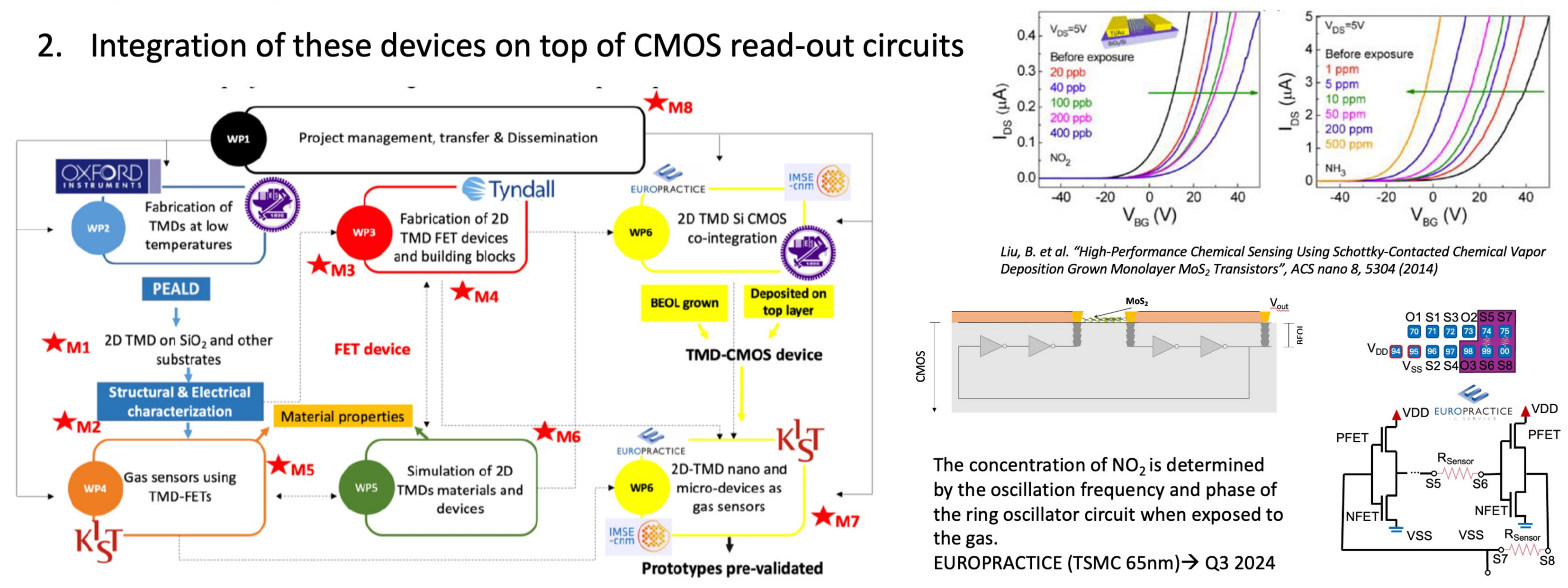
i) Differential diagnosis of viral and bacterial infections in a rapid and accurate manner for evaluating properly the judicious use of antibiotics.
ii) Multiplexing of 6 graphene biosensor chips individually functionalized to be active versus specific biomarkers (C-reactive proteine, procalcitonin, lactate)



3. TMDs-CMOS Integration: Gas sensors

Project "GRANADA: Co-inteGRAtion of two-dimeNsional mAterials with silicon CMOS for embeDded gAs sensors"
Partners: UGR, KIST &Hanyang U.(Korea), NYCU (Taiwan), IMSE-CNM, Tyndall (Ireland)

1. Development of gas sensors (NH_3, NO_2, H_2O_2, acetone) at wafer level using 2Dmaterial heterostructures
2. Integration of these devices on top of CMOS read-out circuits

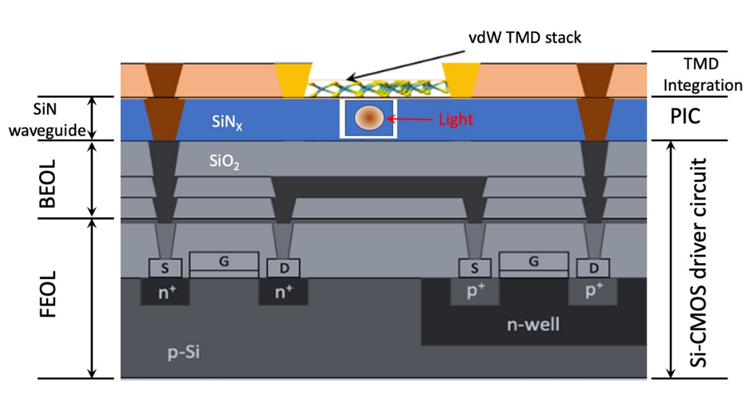


The concentration of NO_2 is determined by the oscillation frequency and phase of the ring oscillator circuit when exposed to the gas.
EUROPRACTICE (TSMC 65nm)→ Q3 2024

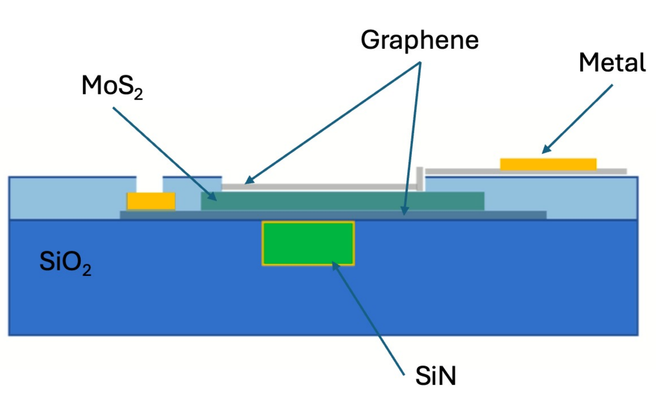
3. TMDs-CMOS Integration: Photonics

Project "WOW-2D: Wafer-scale integration of Optoelectronic 2D van-der-Waals heterostructures on standard photonics integrated circuit (PIC) platforms
Partners: UGR, Graphenea, CNM-CSIC, IMM-CSIC, UPM (Spanish Research Agency)

i) Developing optoelectronic devices (both photodetectors, light sources and modulators) at wafer level using 2Dmaterial heterostructures
ii) Integration of these devices on top of a photonic integrated structure fabricated using a PIC platform based on silicon nitride (SiN), by directly growing the 2D devices on the SiN waveguide structure.

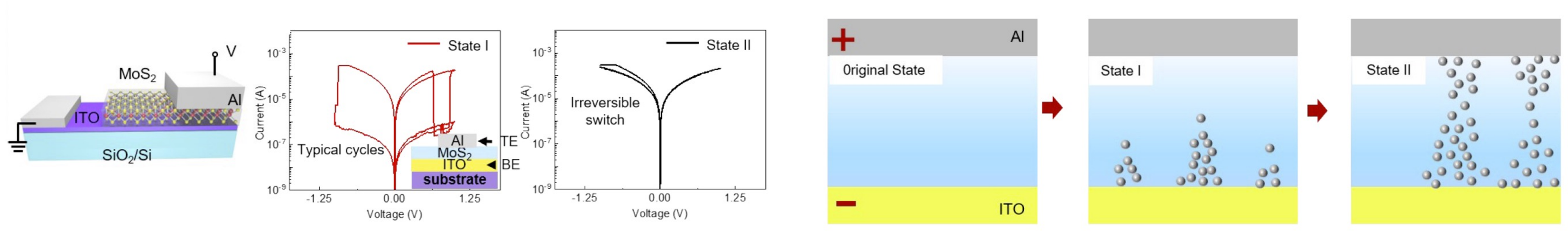


Sketch of the monolithic integration of TMDs photonic devices, PICs and CMOS.

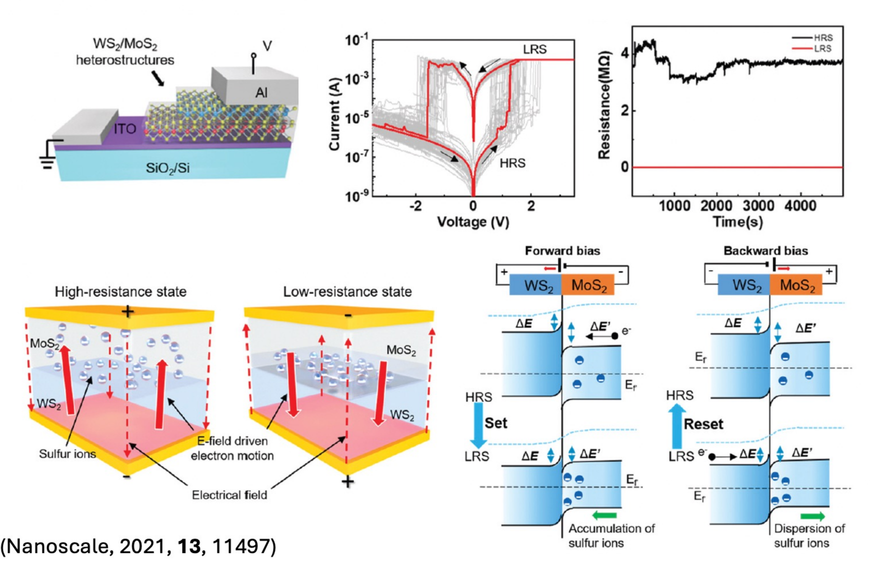


4. Memristors based on TMDs

1. Metal-Insulator-Metal structure (MIM)



2. Metal-VdW Heterostructure-Metal (MHM)



a) MIM structures, based on the formation and fusing of conductive filaments, suffer from serious structural damage of the 2D material → low reliability, rapid failure

b) MHM structures take advantage of the band modulation of the heterointerface, which occurs as a result of the sulfur ions in the MoS2 being drifted to or from the interface by the electric field during the set/reset processes

→ high reliability,
→ large switching ratio
→ stable memory windows
→ many times of set/reset cycling processes.

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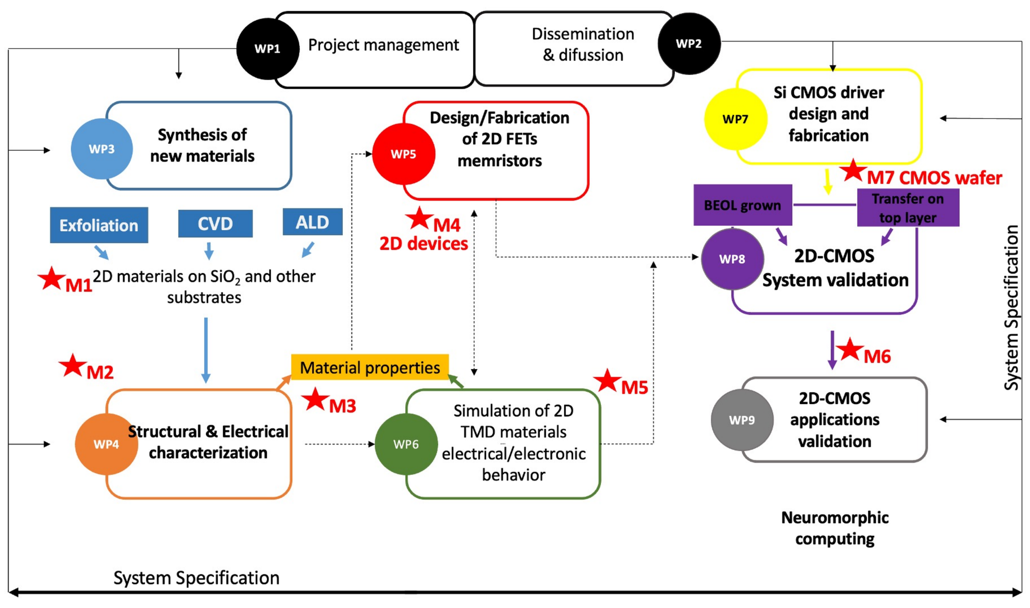
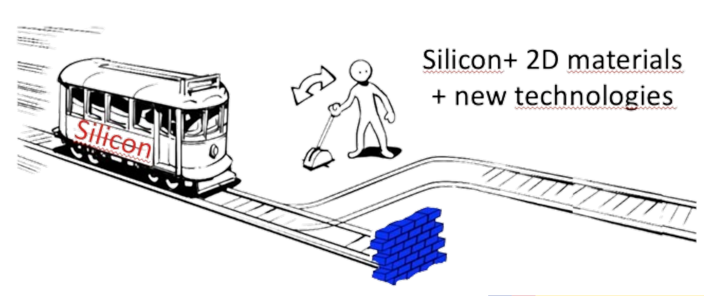
5. 2D Materials, Heterogeneous Integration, and Neuromorphic Computing

1. Demonstration of memristor and memtransistors using TMDs at wafer level and compatible with BEOL of Si-CMOS technology.
2. Array configuration and integration
3. Functionality
4. Performance evaluation.



6. Conclusions

- Two-dimensional materials (2DMs) remain an active field of research in science and engineering, more than 15 years after the first reports of 2DMs.
- The potential of 2D materials for applications in electronics, photonics, and sensing has been theoretically and experimentally demonstrated at the lab scale.
- However, 2D-material-based applications have not yet been widely adopted in industry due to the dominance of silicon technology and the relative immaturity of 2D technology.
- The co-integration of 2D materials and silicon CMOS can expand the range of applications of silicon, while technology maturity issues are addressed and resolved.
- These "More than more applications" range from optoelectronic applications to sensors and flexible electronic devices.
- We have presented some ongoing projects and results of the University of Granada in these fields.
- We are looking for collaborations to go on further on these "More-than-Moore" applications of 2D materials, and particularly in neuromorphic computing



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