NANOSTREEM

NANOSTREEM

Nanomaterials: **Str**ategies for saf**e**ty Ass**e**ssment in advanced Integrated Circuits **M**anufacturing

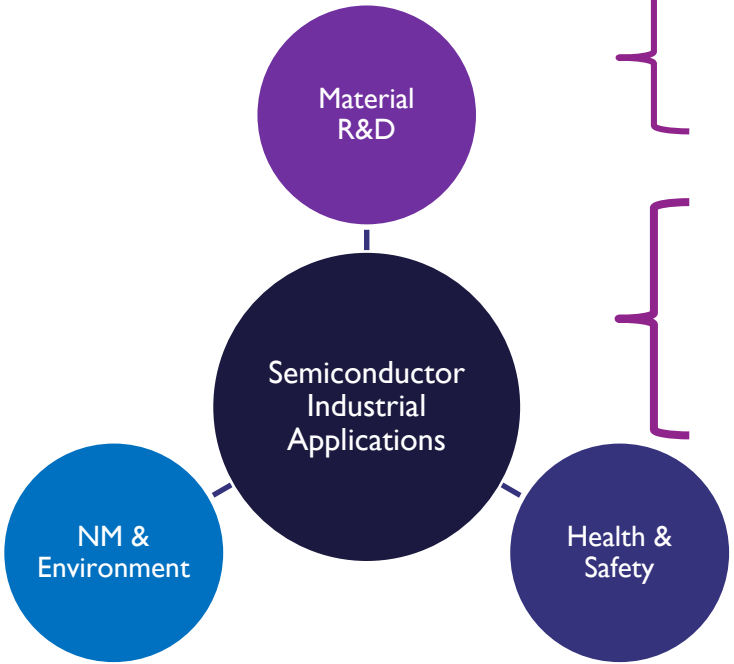
Dimiter Prodanov, Imec

NanoSafe 16, Grenoble

This project receives funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 688194.

WHO ARE WE?

- 14 partners
- 6 European countries



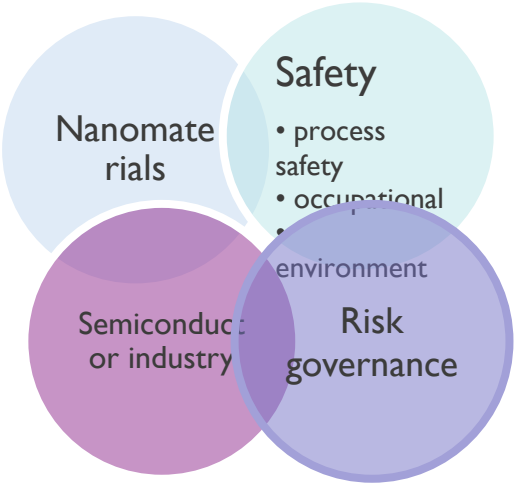
- IMEC (Coordinator)
- Fraunhofer
- Tyndall

- Intel
- Lfoundry
- NXP
- Soitec
- STMicro
- Texas Instrument

- VITO
- CEA
- CBNI/ UCD

- TNO
- Premed

AMBITION



- understand better the occupational hazards related to the use of nanomaterials
- better govern the potential risks caused by handling nano-materials,
  using the semiconductor industry as an example
- investigate occupational hazards related to the use of nanomaterials and promote the public knowledge
- intensify the international cooperation in the areas of standardization and the governance of the risk brought about nanomaterial use

imec

WHY NANOELECTRONICS?

Nanoelectronics is a key enabler for industrial development worldwide and in Europe

- 200K direct jobs in Europe
- ~ 1 million indirect jobs
- 10 % of the global market

Nanoelectronics is a use case for development of EHS policies related to the use of (engineered) nanomaterials

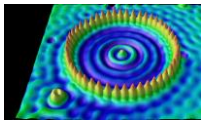
- fast material innovation cycle
- stringent environment, health and safety practices – **100s of compounds and process**
- Industrial processes at the **nanoscale**

SEMICONDUCTOR (CMOS) SCALING

45/40 nm	32/28 nm	22/20 nm	16/14 nm	10 nm	7 nm	<5 nm

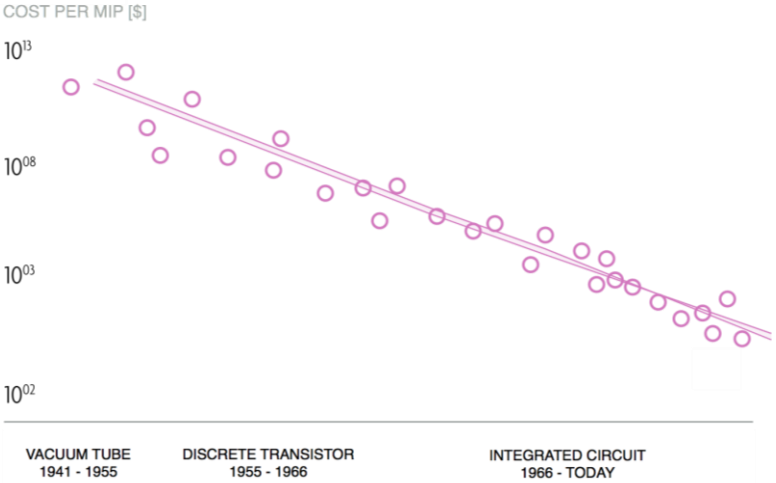
65 nm : 291M transistors
45 nm : 410M transistors

Process complexity
- > 200 chemical products used
- Almost all chemical elements



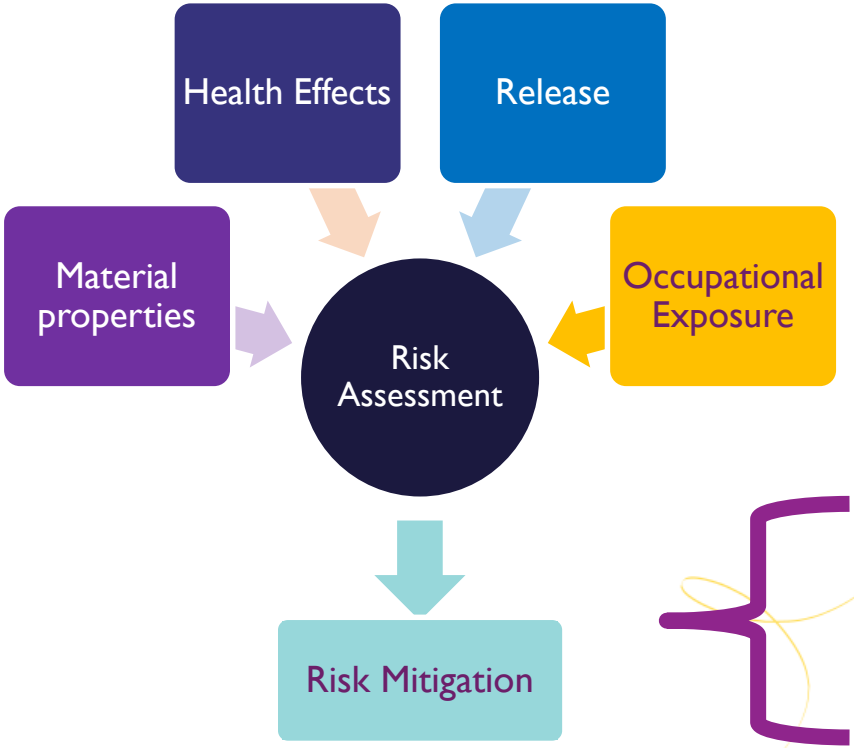
Novel architectures

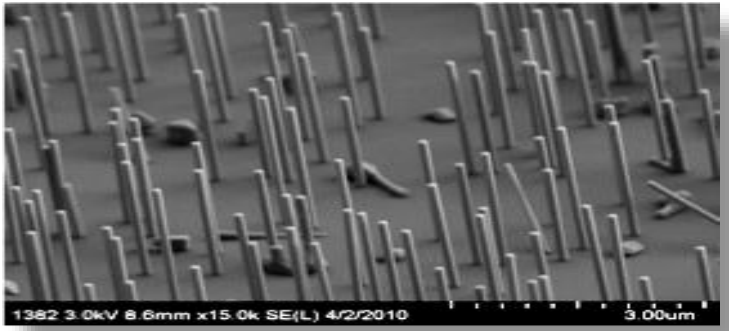
Novel materials



imec

Approach to Safety of Nanomaterials





14nm finFET technology. InAs Nano wire on <111> Si

- Measures of risk
- Engineering controls
- Working practices
- Training of workforce
- Communication with society

Overall Project Objectives

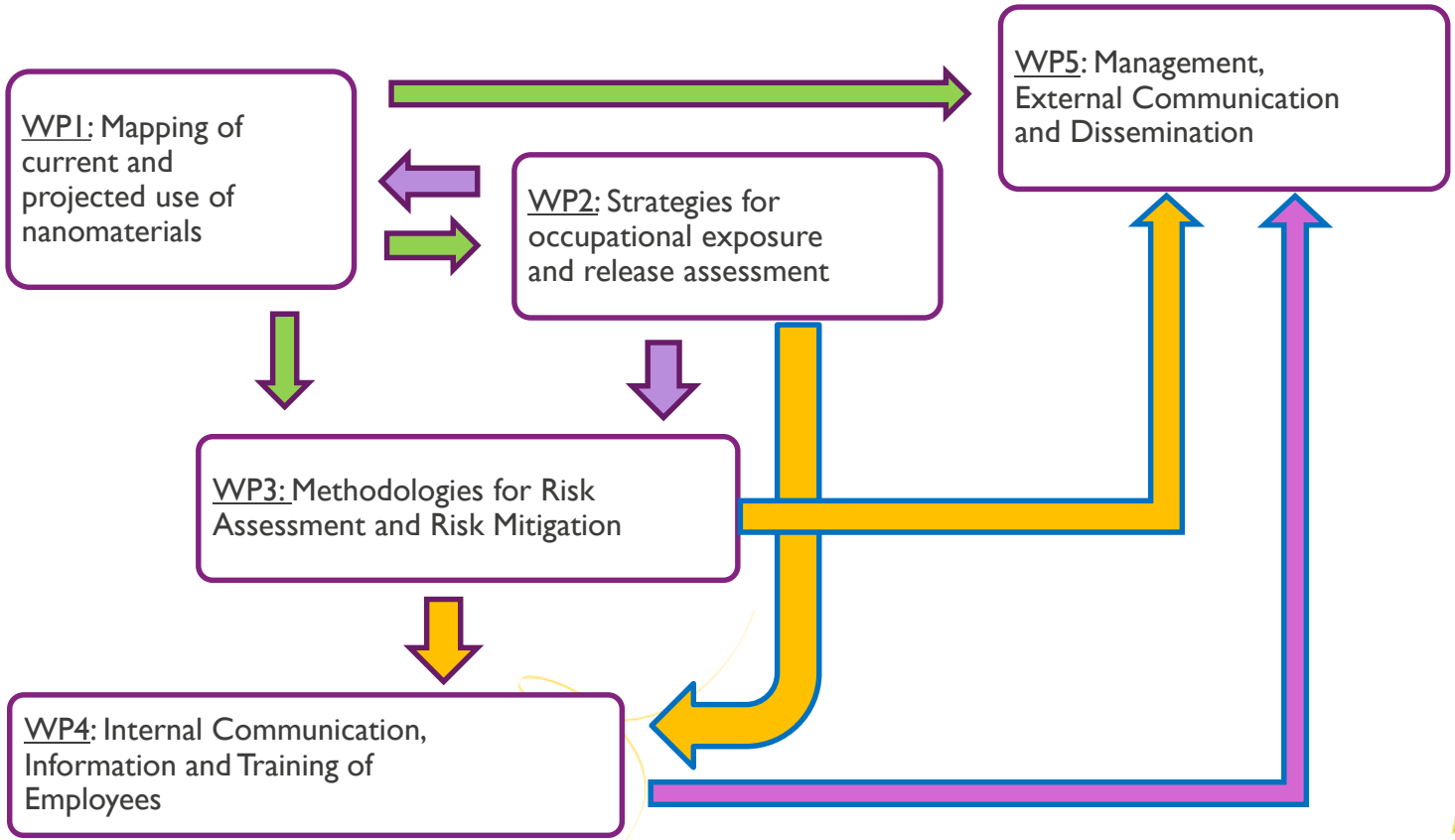
- Build inventories of materials, research topics and directions relevant for nanomaterial use and exposure in nano- electronics manufacturing (WP1).

- Identify gaps in knowledge and methodologies to assess the risk of nanomaterials
  - used in semiconductor manufacturing (ENM) or
  - incidentally released as by-products (WP2 and WP3).

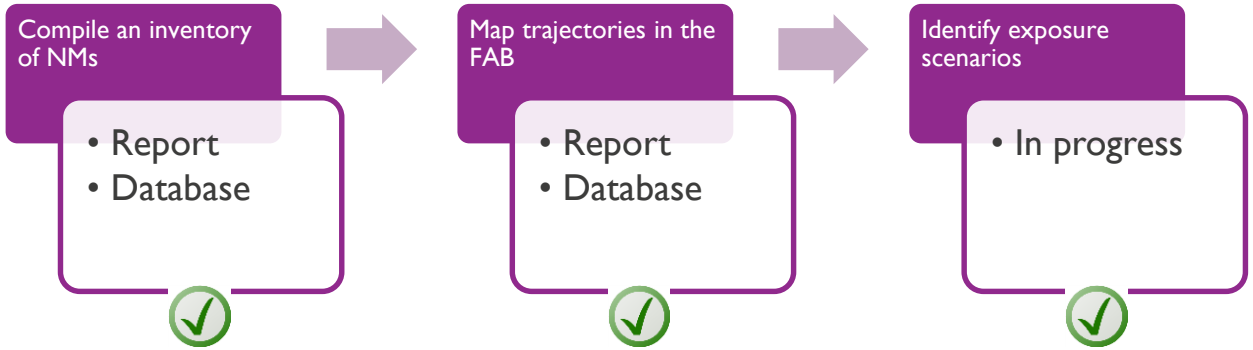
- Apply results for better governance, dissemination and outreach (WP4 and WP5).

imec

WORPACKAGES AND INFORMATION FLOW



MAPPING OF CURRENT AND PROJECTED USE OF NANOMATERIALS



WP2, WP3

Databases

- ENM used in the semiconductor industry
- Risk-prioritized operations
- Typical exposure scenarios
- Future materials to be considered further

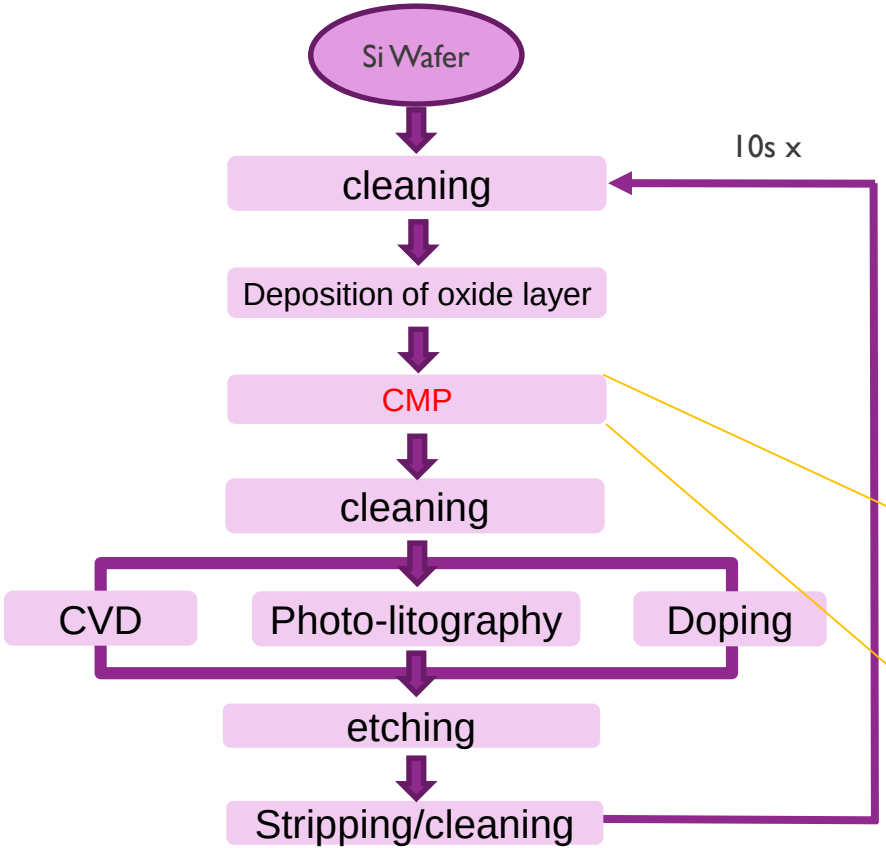
Also public versions will be make available

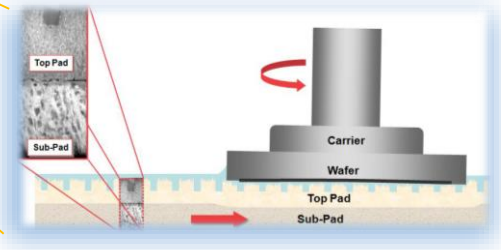
Materials in future technology nodes

- Review

imec

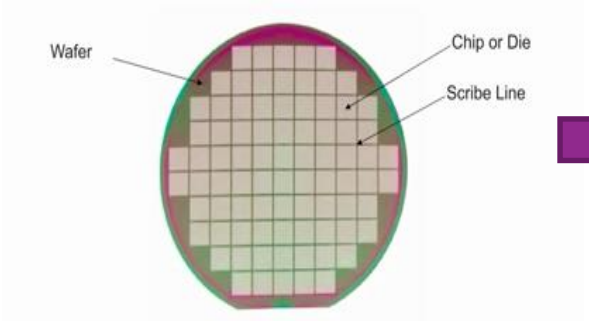
INTEGRATED IC MANUFACTURING OVERVIEW

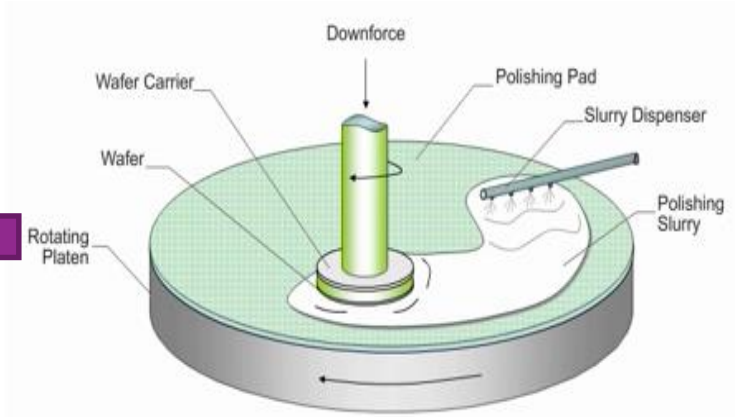


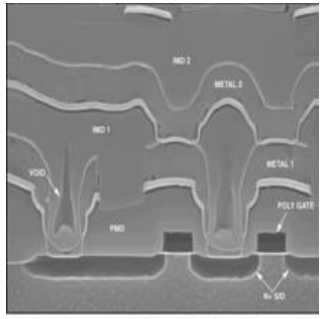


Chemical Mechanical Planarisation step

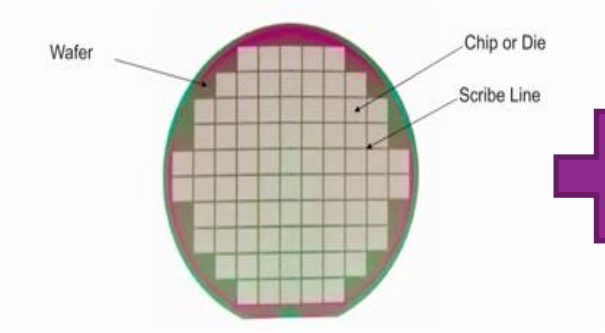
imec

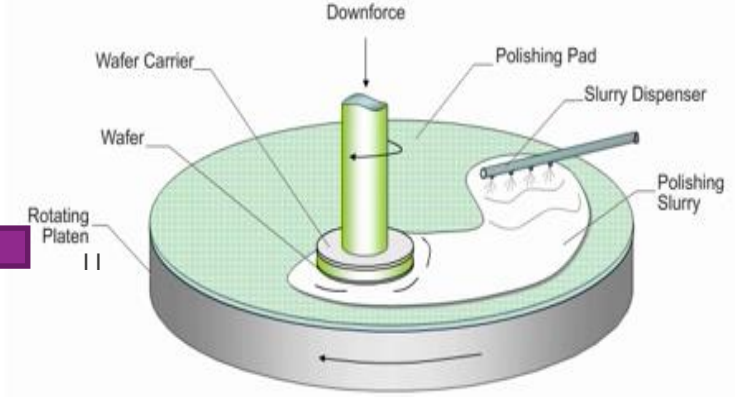


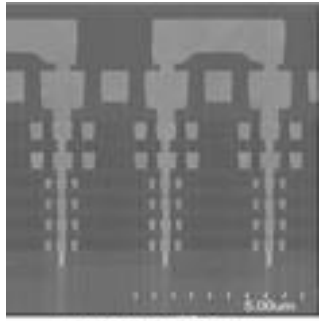




Non-planarized IC Product



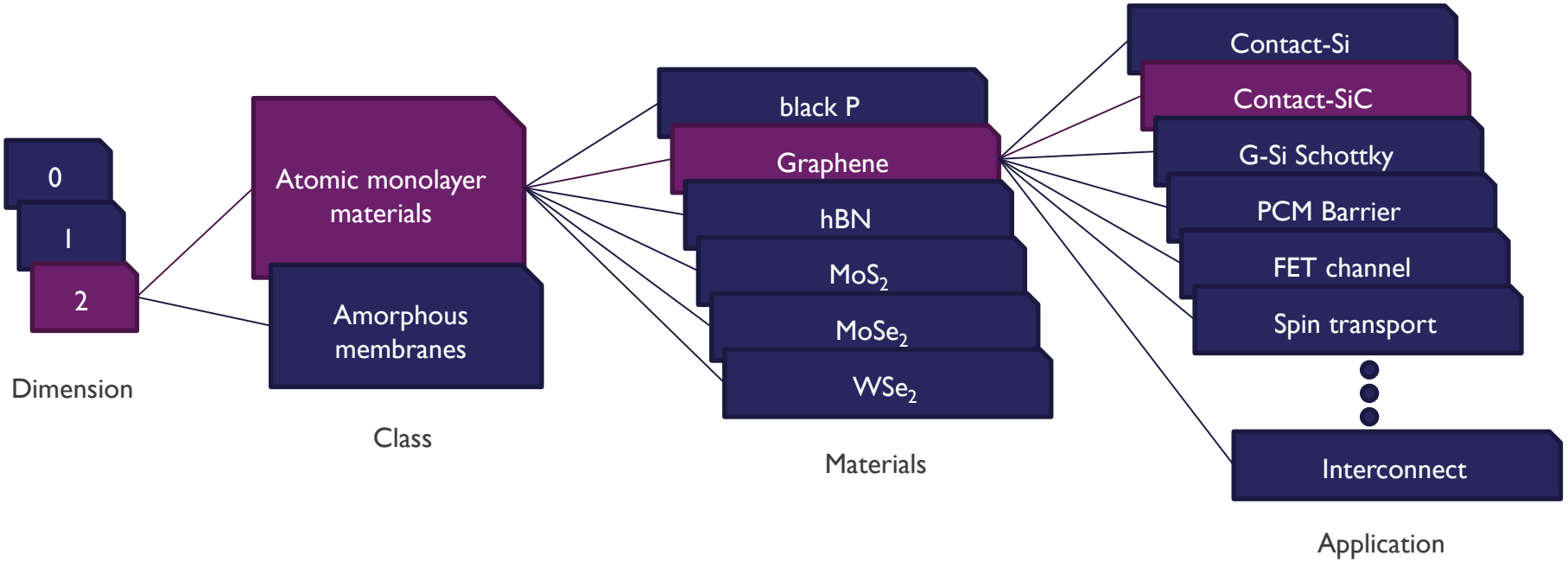




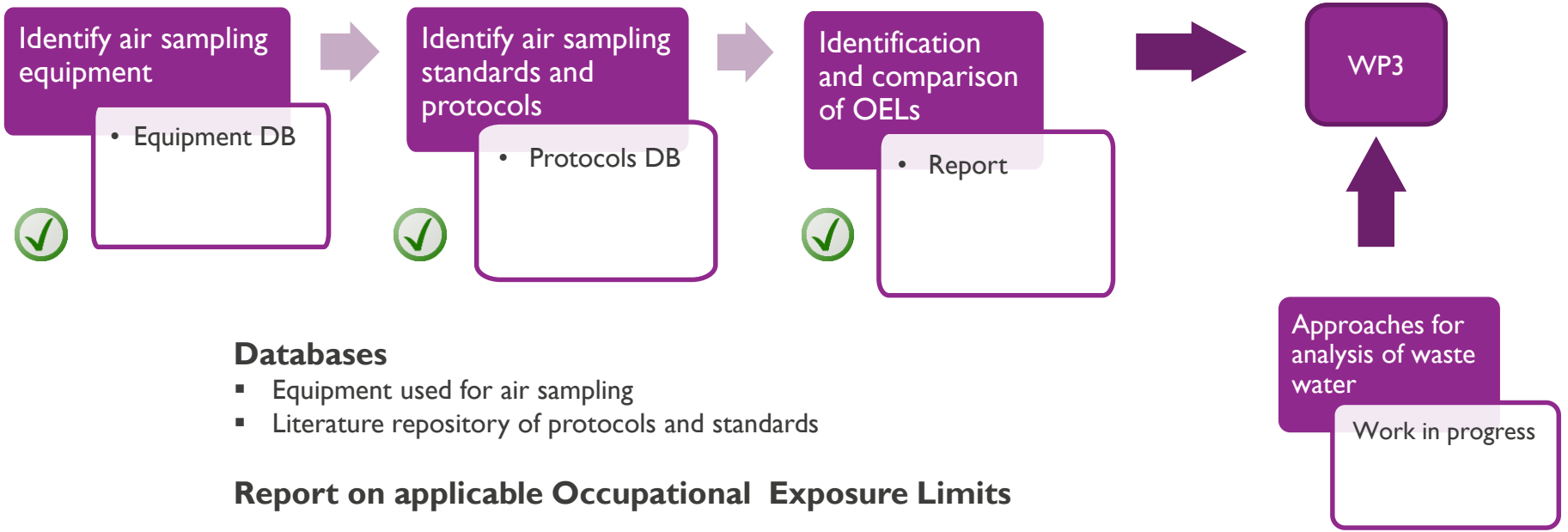
Planarized IC Product

imec

FUTURE NANOMATERIALS CLASSIFICATION



STRATEGIES FOR OCCUPATIONAL EXPOSURE AND RELEASE ASSESSMENT



Databases

- Equipment used for air sampling
- Literature repository of protocols and standards

Report on applicable Occupational Exposure Limits

SUMMARY: PARTICLE COUNTS

38 investigated devices

- counters with internal background must be excluded

- only condensation particle counters
- a portable device based on CPC method, was identified for individual monitoring.
  - Their usefulness have to be discussed considering their constrains for the worker vs. concentration level expected in normal conditions of work

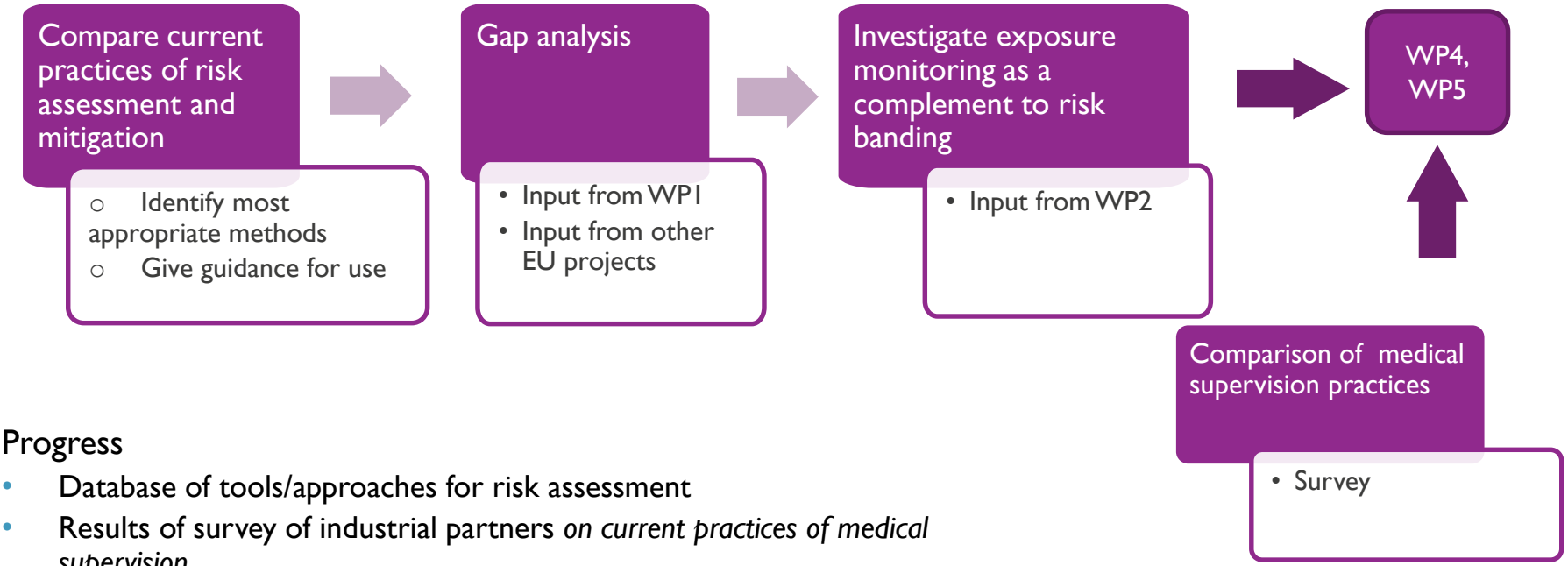
SUMMARY: SIZE DISTRIBUTION

- no obvious solution for very low concentrations of nano-objects

- For submicronic particles, OPC counters appear as not the best solution, but the only technique adapted.

- No solution have been found for size distribution for individual monitoring.

METHODOLOGIES FOR RISK ASSESSMENT AND RISK MITIGATION



Progress

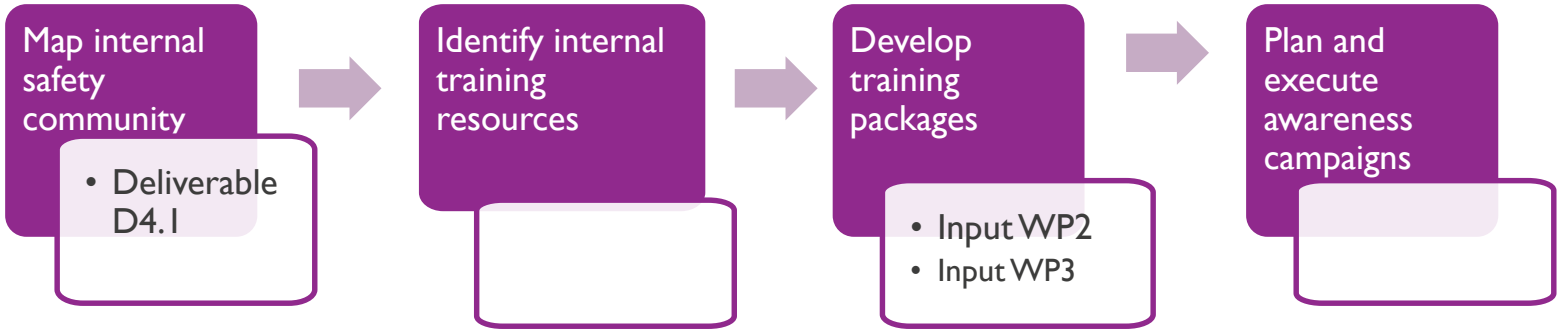
- Database of tools/approaches for risk assessment
- Results of survey of industrial partners *on current practices of medical supervision*

MAPPING OF CURRENT RA APPROACHES

Models/approaches	Number of identified tools/approaches (occupational)	Examples of tools/approaches
(semi) quantitative approaches	12	DNEL, ISO approach for OELs, dossiers (ECHA, OECD), CEN tiered approach for exposure measurements
(semi) quantitative models	13	ART, Riskofderm, DREAM, Nanosafer, Consexpo, ENPRA model, ECEL, ECETOC-TRA, Guidenano tool Environment: EUSES Wastewater: EcoInvent, EUSES
qualitative approaches and models	7	Mainly Control Banding tools: ESIA approach for CMP, EMKG-Expo, Stoffenmanager-nano, ISO-CB, CB Nanotool, Precautionary Matrix

imec

INTERNAL COMMUNICATION, INFORMATION AND TRAINING



MAPPING OF EXTERNAL TRAINING RESOURCES

- Exposure standards have not been established for nanomaterials internationally .
- Lab safety guidelines generally used to minimize potential exposures to themselves and others.
  - engineering controls (fumehoods, containment or exhausted enclosures)
  - work practices (selection of NMs, hygiene, labeling, etc.)
  - personal protective equipment.
- External resources sometimes used (videos, tutorials etc)

Engineering Controls

PPE

Work Practices

imec

SATELLITE WORKSHOP

10TH NOV

ENGINEERED NANOMATERIALS IN THE SEMICONDUCTOR FAB

RISK ASSESSMENT AND MITIGATION APPROACHES

INTERNAL COMMUNICATION AND TRAINING OF STAFF

THANK YOU FOR THE ATTENTION!

IMEC campus

Leuven, Brussels area