# BANDING APPROACH FOR ENGINEERED NANOMATERIAL RISK ASSESSMENT AND CONTROL

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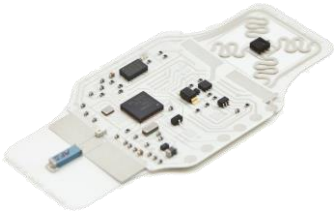
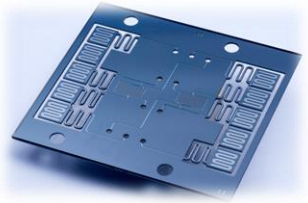
- Core CMOS
  - transistor dimensions smaller than 5nm.
  - new materials and transistor architectures,
  - processing technologies,
  - 3D system integration
- Heterogeneous integration and flexible electronics
  - Imagers, photonics, chemical sensors
- Internet of things
- Health applications
  - In vitro diagnostics, bioreactors
- Power applications
  - photovoltaics





**INTERNET OF THINGS**

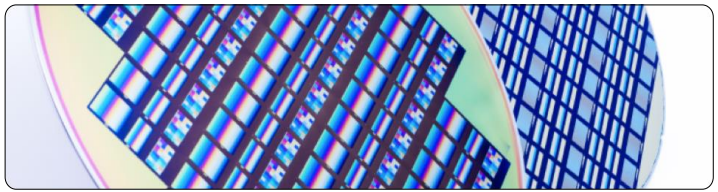
Sensing & connectivity solutions

**HEALTH**

BAN
Life sciences

**INTERNET OF POWER**

Photovoltaics
Power devices



**CORE CMOS**

Lithography Devices Interconnects

**FLEXIBLE ELECTRONICS AND HETEROGENEOUS INTEGRATION**

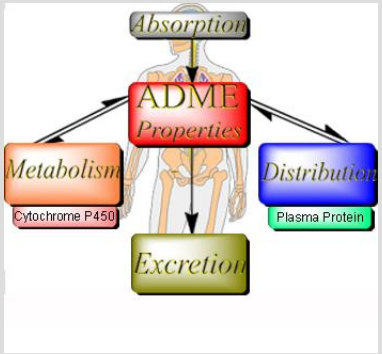
Goal: *creating the solutions and building blocks for a better, healthier life in a sustainable environment – through innovations in nanoelectronics.*

# WHY BANDING APPROACH?

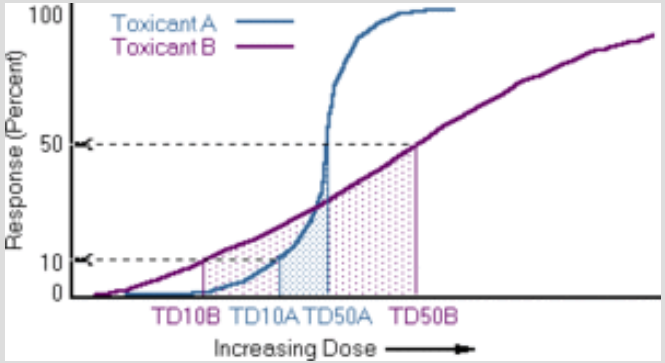
# CONVENTIONAL RISK ASSESSMENT PROCESS FOR BULK MATERIALS

Exposure: Mass and composition

Metabolism and toxico-kinetics




Dose / Effect response

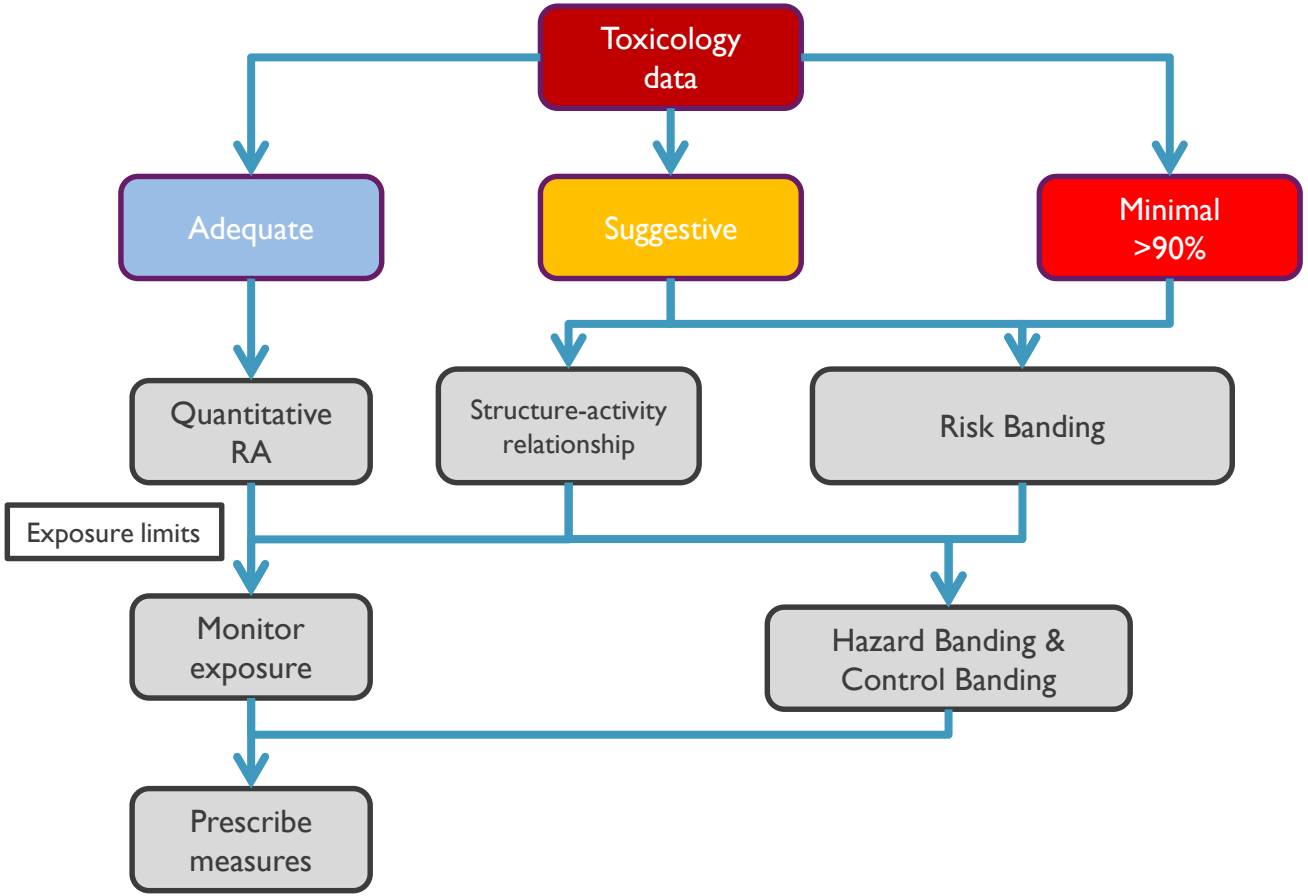


# CONVENTIONAL PROCESS NOT APPLICABLE FOR NANOMATERIALS

- Not enough data available:
  - How does the metabolism deal with nanomaterials?
  - What kind of toxicokinetic mechanisms are playing?
  - What is the dose/effect relationship of nanomaterials?
- Fast evolution of use of nanomaterials in day-to-day life
  - Quantification of data takes too long

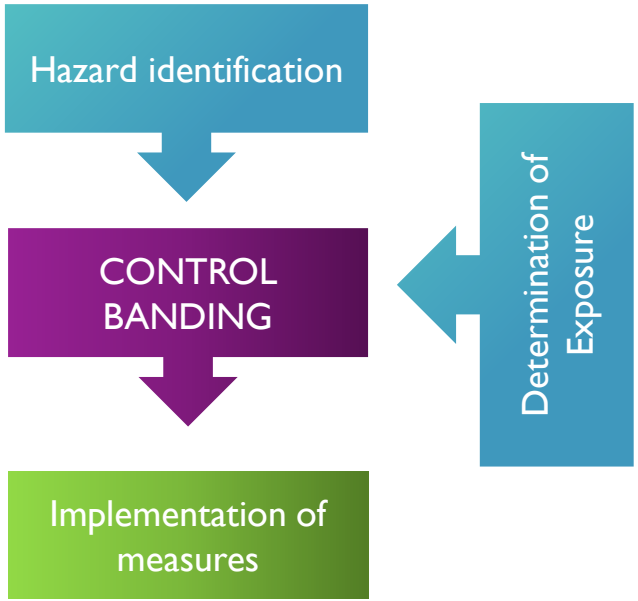
    → can we refer to bulk material?
- Extrapolation of data from bulk materials is challenging
  - Properties of the nanomaterial are substantially different from the bulk material

# METHODS THAT CAN BE USED



# CONTROL BANDING

Control banding is a qualitative risk management process developed originally by the pharmaceuticals industry, and used by the British Health an Safety Executive (HSE) in the *COSHH Essentials* model (HSE, 1999; Oldershaw, 2001). It can be defined as: A strategy or process in which a single control technology (such as general ventilation or containment) is applied to a defined range or band of exposure to a chemical (such as 1-10 mg/m3)(Schulte et al, 2008), that falls within a given hazard group (such as harmful by inhalation or irritating to respiratory system



# THE PRECAUTIONARY PRINCIPLE IN PRACTICE:

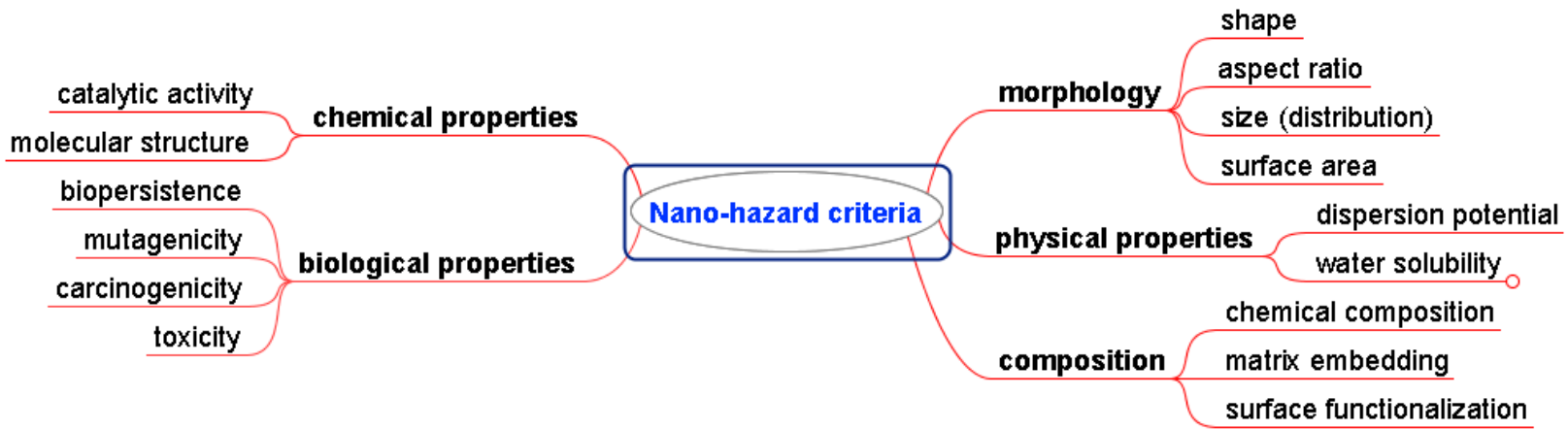
# BANDING APPROACH AT IMEC

# IMECS APPROACH

## OECD Nanohazard Parameter Set

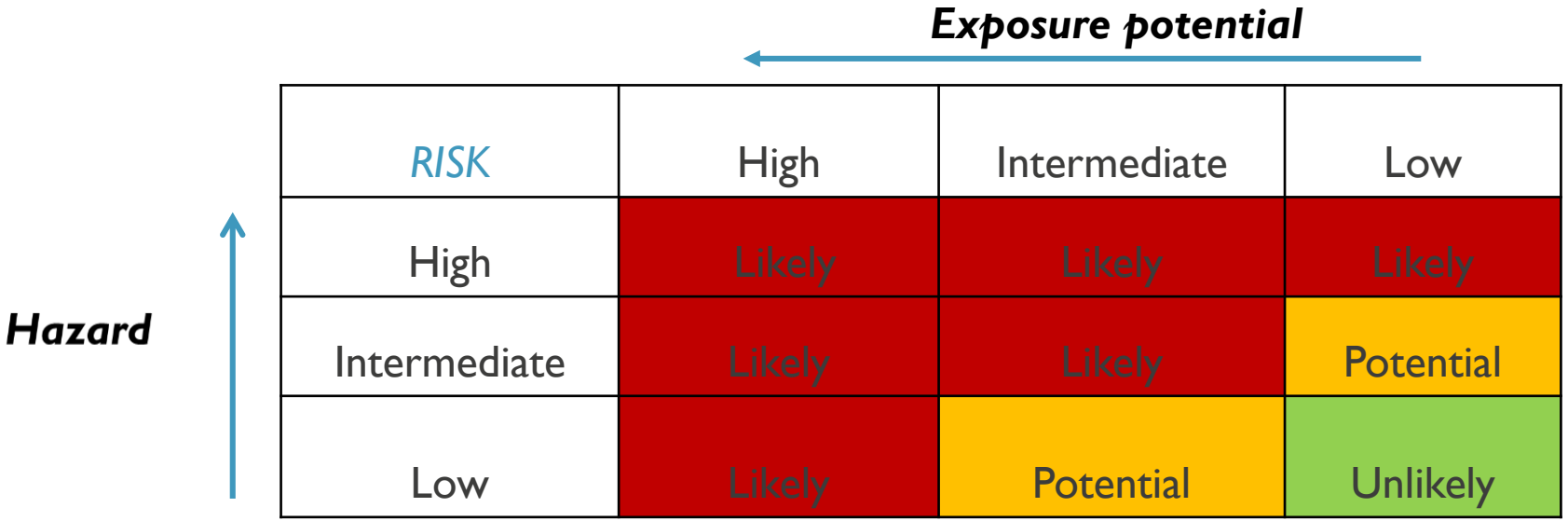
| Properties of parent material | Solubility and dispersion potential | Size and shape | Miscellaneous |
|---|---|---|---|

- Simplified to parameters that are available in practice:



# CONTROL BANDING – RISK BANDS

## ARBITRARY – AS SET BY IMEC




| *RISK* | High | Intermediate | Low |
|---|---|---|---|
| High | Likely | Likely | Likely |
| Intermediate | Likely | Likely | Potential |
| Low | Likely | Potential | Unlikely |

# EVALUATE HAZARDS → KNOWN PROPERTIES

## CLASSIFICATION AS HIGH HAZARD

### Solubility and dispersion capacity

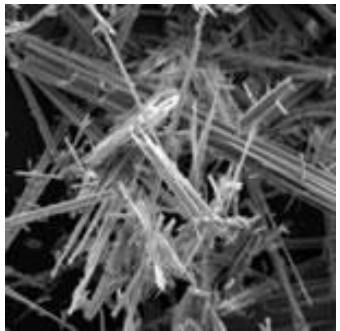
- ☐ water insoluble material
- ☐ Bio persistent material
- ☐ Material with high dispersion capacity

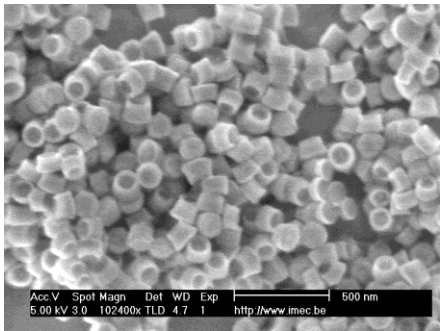
### Size and shape

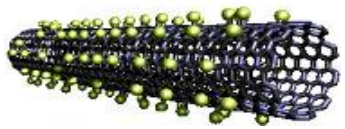
- ☐ Powders with diameter<10nm
- ☐ High aspect ratio
- ☐ Fiber or needle structure

### Toxicity of the bulk material

- ☐ Toxic bulk material
- ☐ Material contains transition metals
- ☐ Material is functionalized by adding toxic products
- ☐ Material has a highly reactive surface





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# EVALUATE HAZARDS → KNOWN PROPERTIES

## CLASSIFICATION AS INTERMEDIATE OR LOW HAZARD

### Intermediate hazard

- Particles with diameter>10nm but <100nm
- ENM aggregates or agglomerates
- ENM with irregular shape

### Low hazard

- Water soluble materials
- Materials that are embedded in fixed matrices
- Materials that are dissolved in liquids
- Materials with low dispersion capacities

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# EVALUATE EXPOSURE POTENTIAL

## CLASSIFICATION AS HIGH EXPOSURE POTENTIAL

### Proximity and duration of exposure

- Operations in the breathing space <0.5m

### Kind of activity

- Mechanical manipulations (sanding, polishing,...)
- Spraying of aerosols with ENM
- Mechanical cleaning of process chambers
- Cleaning of particle traps

# EVALUATE EXPOSURE

## CLASSIFICATION AS INTERMEDIATE OR LOW EXPOSURE POTENTIAL

### Intermediate exposure

- Manipulations in ‘near field’: >0.5m <1m
- Duration <4uur/dag, 3 days/week
- Cleaning of reactors with wet tissues
- Quantity of ENM >1g

### Low exposure

- Manipulations in ‘far field’: >1m
- Quantity of ENM <1g

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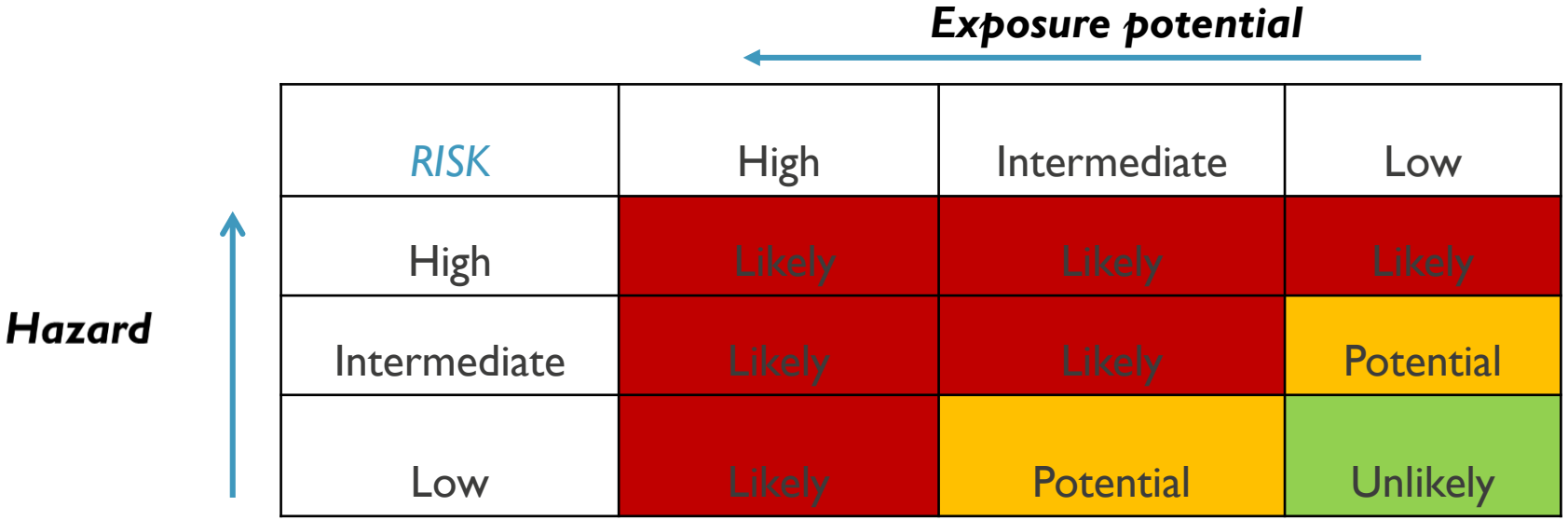
# RISK BANDS CAN NOW BE SET TO DEFINE MEASURES




| *RISK* | High | Intermediate | Low |
|---|---|---|---|
| High | Likely | Likely | Likely |
| Intermediate | Likely | Likely | Potential |
| Low | Likely | Potential | Unlikely |

# RISK CONTROL STRATEGY BASED ON RISK BANDS

# RISK CONTROL STRATEGY

**Unlikely**

- Take general safety measures
  - Housekeeping, labeling, PPE

**Potential**

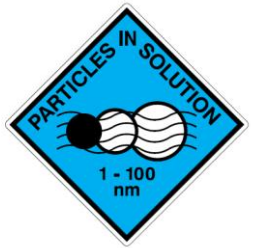
- Take additional safety measures
  - Work place assessment and air sampling

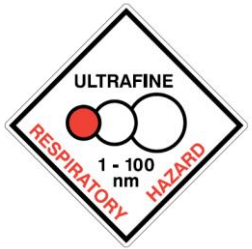
**Likely**

- Take additional safety measures
  - Containment, breathing apparatus

# SAFETY MEASURES

## RISK UNLIKELY




- Signposting, Labeling
  - On receptacles
  - On entrance doors of labs
- Containment
  - Storage of materials in closed receptacles
- PPE
  - Lab coats
  - Chemical resistant gloves
  - Safety goggles
- Training
  - Basic training nano safety
  - Optional (depending on activities: advanced nano safety
- Housekeeping practices
  - working on clean benches

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# ADDITIONAL SAFETY MEASURES
## RISK POTENTIAL

- Workplace assessments
  - = further identifying the potential routes of exposure
- Air sampling
  - If potential routes of exposure are identified

# ADDITIONAL SAFETY MEASURES

## RISK LIKELY

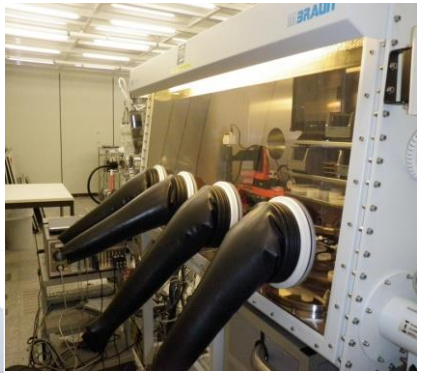
- High/Intermediate Hazard or High/Intermediate Exposure Potential = Protect yourself !

### Containment of manipulations

- Closed environments: e.g. glove boxes
- Ventilated and closed environments: e.g. bio safety cabinets
- Partially closed environments with ventilation: e.g. fume hoods, wet benches,...

### Breathing air apparatus

- Self-contained breathing apparatus
- FFP3 masks

# CONCLUSION

- In order to determine the hazard and exposure potential of the nanomaterial use is made of questionnaires
- A risk band can be derived from the hazard and exposure potential
- Risk banding gives us the opportunity to easily define the measures that need to be taken when an experiment will be started
- Measurements are part of the risk assessment and provide us with means to lower the risk level

# Thanks for the attention