GOOD PRACTICE MANUFACTURING AND MANIPULATION OF MANUFACTURED NANO OBJECTS.

1. Case metadata

- ***Country/ies of origin:***

Netherlands

- ***Year of publication by agency:***

2012

- ***Sector:***

C20.1 Manufacture of chemicals and chemical products (NACE II)

- ***Keywords:***

24401C Case studies

13841E Elimination of hazards

24361C Good practice

40256C Nanoparticles

40271B Nanotechnology

29241B Chemical hazards

18161E Chemical safety

19641D Risk Assessment

2. Organisations involved

TNO, Quality and Safety, PO Box 360, 3700 AJ, Zeist, The Netherlands

IMEC Belgium, Kapeldreef 75, B-3001 Leuven, Belgium.

3. Description of the case

3.1. Introduction

Manufactured nano objects

Manufactured nano objects (MNO) are purposefully manufactured, and consists of certain engineered chemical and physical properties. Nanoparticles and nano shaped structures have an extremely large surface compared to their mass (1000 m^2/gram). Therefore, they have more atoms, molecules and/or radicals on their surface, which gives them unique properties. Size and surface treatment give nanoparticles exceptional chemical, mechanical, electrical, physical and magnetic properties.

In order to exploit these properties, it is essential for industry to ensure sustainable development of these materials, particularly with respect to managing potential health and safety risks to workers.

Potential Health Risk

As with any material being developed, scientific data on the health effects in exposed workers are largely unavailable. In the case of nanomaterials, the uncertainties are even greater because the

characteristics of nanoparticles may be different from those of larger particles with the same chemical composition.

IMEC is a research institute performing research in nano-electronics and nano-technology. Its staff of more than 1,900 people includes over 500 industrial residents and guest researchers. IMEC's research is applied in better healthcare, smart electronics, sustainable energy, and safer transport. Usually about 80 to 90 persons work within IMEC with MNO at gram scale. Within IMEC, a myriad of MNO are being used. From many of these, the hazards are yet unclear, though for some there are clear indications that inhalation might lead to adverse health effects (e.g. carbon nanotubes - Poland et al., 2008). Until the results from research studies can fully elucidate the hazards to human health, precautionary measures are warranted. Therefore current good practice for the handling of MNO is to minimise potential exposition of workers particularly via inhalation.

Case study

This document describes the various risk management measures (RMM) and procedures introduced by IMEC, a world-leading research institute in nano-electronics scale, to minimise exposure to MNO in a reasonable way for their employees. The RMM and procedures applied by this company could serve as a good practice advice for handling all kinds of MNO at gram scale.

3.2. Aims

The main aim was to minimise MNO exposure to workers by application of various RMM during manufacturing and manipulation of these MNO. The intention is not to take unnecessarily severe or too many measures. The aim is to find appropriate RMM for the given activity and material.

3.3. What was done, and how?

IMEC currently applies the precautionary principle as one of the general principles of risk management. This resulted in various RMM. The company developed a qualitative control-banding tool to adapt the RMM to the potential exposure of the nanomaterial and activity performed with the nanomaterial.

The qualitative control-banding works as follows:

The nano objects within IMEC are subdivided into three hazard bands based on their chemical and physical properties. Exposure is assigned within IMEC into three exposure bands based on the exposure potential of the activities and operating conditions.

The combination of the hazard band and exposure band will define the risk category. When either or both hazard and/or exposure are classified in a high potential band the risk category will be defined as 'likely'. When both hazard and exposure are classified in a moderate potential band the risk category will also be defined as 'likely'. When either hazard or exposure is classified in a moderate potential band and the other in low, the risk category will be defined as 'potential'. Only when both hazard and exposure are classified in a low potential band, the risk category will be defined as 'unlikely'. This is depicted in Figure 1 below.

Figure 1: Risk banding category

Risk assignment	High Exposure Potential	Moderate Exposure Potential	Low Exposure Potential
High Hazard Potential	Likely	Likely	Likely
Moderate Hazard Potential	Likely	Likely	Potential
Low Hazard Potential	Likely	Potential	Unlikely

This resulted in the following procedure and RMM.

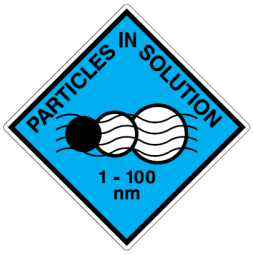
For all risk bands ('likely', 'potential' and 'unlikely');

- If possible for the scientific work, MNO are used in a matrix or in liquids.
- MNO are handled and manufactured in closed environments depending on the exposure potential of the material and activity. This is determined by the qualitative control-banding tool. In general, handling of powders or spraying is done in fully closed glove boxes, while cleaving wafers debris or handling nanoparticles in a matrix or in liquids is done in a clean room environment, under a flow hood or under wet benches. When it is not possible to perform the activity in a sufficient closed environment FPP3-masks are worn.
- Adequate air filter systems are present in the workplace to prevent dispersion of MNO into the workplace or into the environment.
- All workers receive specific information, instructions and safety awareness courses on working with MNO.
- When handling MNO fully disposable durables are used.
- The disposed of material, durables and gloves are handled as chemical waste.
- Receptacles containing MNO are tagged with a specific label. These labels are IMEC – specific labels.

  The following labels apply:

  - The label 'PARTICLES IN SOLUTION' applies to all liquids that contain MNO.

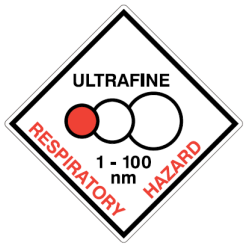
  Figure 2: Label used for solutions that contain nano particles.



  - The label 'ULTRAFINE' applies to all receptacles or carriers of MNO that contain MNO that may get airborne such as powders and carbon nanotubes present on

wafers. When the nano particles get embedded the sticker is removed from the receptacle.

Figure 3: Label used for powders that contain nano particles.



- When handling MNO, disposable gloves are worn.

Additionally for the risk bands 'potential' and 'likely':

- The work place is subject to an air sampling and/or exposure monitoring survey.

Additionally for the risk band 'likely';

- If technically possible, all manipulations must be done in full containment – closed environment (glove box or vented filtered enclosure such as the biological cabinets)
- If working in a closed environment is technically not feasible, partial enclosure must be used (fume hood, elephant trunk, wet bench). Air velocity must be kept as high as possibly within the partial enclosure. A high air velocity prevails over under pressure conditions.
- If working in a closed environment or working in a partially closed environment is not possible, personal protective respirators must be used.
- If the work conditions allow doing so and if the person doing the manipulations is qualified to do so, self-contained breathing apparatus must be used.
- If the work conditions do not allow wearing self containing breathing apparatus, a FP3 dust mask must be used.

3.4. What was achieved?

By introducing various situation specific RMM in a research institute, MNO exposure has been reduced to a minimum. The measurement in the clean room indicated the nanoparticles concentration was below the detection limit of the measurement equipment both during the activities as during the background measurements. This confirmed that no significant exposure to nanoparticles is expected when applying the described RMM.

3.5. Success factors

The main success factors have been the direct communication with the workers (specific information, instruction, safety awareness courses) in this company and the discrimination of different situations by exposure potential using a risk banding tool.

Distinguishing specific situations for more stringent RMM by the control-banding tool resulted in a more workable situation compared to applying the stringent RMM throughout the institute.

As all employees are scientists, the scientific insecurities related to the exposure and hazardous properties of MNO were shared with all of them. Moreover, a list of frequently asked questions related to these topics was distributed among the employees. This created awareness and a feeling of shared responsibility among the employees. This ensured proper use of the developed procedures and personal protective equipment on top of the engineered RMM thereby ensuring a high standard of safety.

3.6. Further information

IMEC Belgium

Kapeldreef 75
B-3001 Leuven
Belgium

www2.IMEC.be

3.7. Transferability

Other companies working with nano products could adopt successfully the RMM. However, manufacturing and handling of MNO in IMEC is at gram scale, so scaling might be required when working on a larger scale. When working on a larger scale it might be required to intensify the measures.

Also, other organisations could adopt the use of control-banding . The tool used by IMEC is (not yet) available for others. However, in order to prioritise work situations for more stringent measures, various risk banding tools have been developed. An example is the freely available and web-based Stoffenmanager Nano, which is comparable to the tool used within IMEC.

4. References, resources:

- Poland C.A., Duffin R, Kinloch I, Maynard A, Wallace W.A.H., Seaton A., Stone V., Brown S., Macnee W. and Donaldson K. (2008) Carbon nanotubes introduced into the abdominal cavity of mice show asbestos like pathogenicity in a pilot study, Nature Nanotechnology 3, p. 423 – 428. doi: 10.1038/nnano.2008.111
- http://nano.stoffenmanager.nl