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Workshop report

Novel materials and nano-risk in semiconductor industry

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Contents

The NanoStreeM project held a workshop for the industrial stakeholder community as a satellite event at SEMICON Europa, Munich on 14 Nov 2018. In the present year SEMICON Europa was co-located with ELECTRONICA 2018, the strongest single event for electronics manufacturing in Europe. SEMICON Europa features highly technical content specific to the manufacture of microelectronics (IoT, MEMS, imaging, power electronics, flexible hybrid electronics, automotive, med-tech, smart manufacturing, and much more). The NanoStreeM workshop attracted attention from the industrial delegates. The panel statement will be disseminated in an upcoming publication.

Workshop Agenda

12:15 – 12:30 **Strategies for Safety Assessment in Advanced Integrated Circuits Manufacturing – Current Status and Perspectives**

Dimiter Prodanov, Imec

12:30 – 13:00 **Current engineered nanomaterial use and hotspots of risk in semiconductor fabs. Findings of NanoStreeM**

Dimiter Prodanov, Imec

13:00 – 13:30 **Nano REACH and advanced materials**

David Carlander, NIA

13:30 – 14:00 **Future materials and emerging hazards**

Michael Jank, Fraunhofer IISB

14:00 – 14:30 **2D materials: The long journey from a lab to the fab environment**

Salim El Kazzi, Imec

14:30 – 15:30 **Panel discussion**:

Panellists: David Carlander, (NIA), Michael Jank (Fraunhofer IISB), Salim El Kazzi

Moderator: Dimiter Prodanov, Imec

- How do future materials fit into the risk assessment framework?

- What competences do we need to evaluate emerging risks?

- How can the risk be communicated along the supply chain?

15:30 **Summary statement of the panel and conclusions**

Abstracts

2D materials: The long journey from a lab to the fab environment

Salim El Kazzi, Imec

The use of graphene-based materials opens a new era of innovation in different fields. The imagination of researchers has allowed them to use 2D materials for water treatment, clean energy, (bio)sensing, optics and Internet of Things (IoT). In this talk, we will share on our journey to bring 2D materials from a lab to the fab and the obstacles to be undercome. The discussion will be focused on the growth and transfer of 2D materials and how we are trying to understand and solve the main challenges of these Van der Walls materials. An emphasis will be given to the role of surface tension and interface engineering in the making of the 2D-based devices. In a final part, the talk will cover our strategy to integrate 2D materials in a fab production environment while using the learnings from the lab. This work is expected to offer insights on both the main challenges and solutions of MX2 integration for future CMOS technology.

Strategies for Safety Assessment in Advanced Integrated Circuits Manufacturing – Current Status and Perspectives

Dimiter Prodanov, Imec

The fast innovation cycle of nanoelectronics brings about a variety of new materials functionalized at the nanoscale into everyday life. New materials, including synthetic nanoparticles are used in the development of advanced technology nodes. Understanding their occupational hazards is a continuous challenge for the nanoelectronics industry. As a step in the direction of addressing this challenge 14 industrial and academic institutions from 6 EU member states initiated a collaborative project named NanoStreeM, funded under Horizon 2020 EU Framework Program for Research and Innovation. The project focuses on establishing trajectories of nanomaterials in semiconductor production facilities, identifying operations of concern and hot spots of risk. The presentation will give a broad overview of the present status and results collected in the project. In particular I will focus on the tiered nanosafety risk assessment approach and the identified gaps related to the available safety information.

Current engineered nanomaterial use and hotspots of risk in semiconductor fabs. Findings of NanoStreeM

Dimiter Prodanov, Imec

In the second talk, I will present the findings of NanoStreeM concerning the use of nanomaterials in semiconductor processing. Nanoparticle preparations in the form of slurries are ubiquitously used in chemical mechanical planarization process. Identification of operations of concern and exposure scenarios is used in the risk assessment approach developed at present in the context workpackage 1 in NanoStreeM. Collected information is used for comparing different risk assessment approaches developed in the context of other EU nanosafety projects with the ones currently tested by the industry, in particular, different control banding approaches. Based on the industry feedback the NanoStreeM project has proposed a guidance for nano-hazard process risk assessment in the semiconductor industry.

Future materials and emerging hazards

Michael Jank, Fraunhofer IISB

Nanomaterials like nanowires or 2-dimensional semiconductors offer unprecedented properties with respect to carrier mobilities or channel control in MOSFETs making them highly attractive for integration into ULSI technologies. Within NanoStreeM project funded by the European Union via its Horizon 2020 program, a study on emerging and future nanomaterials is conducted to identify potential risks and hazards from the adoption of engineered nanomaterials in the semiconductor industry. The presentation reviews the emergence of 0-, 1- and 2-dimensional nanomaterials from concept via initial realization in laboratory until large-scale integration with current FEOL and BEOL schemes. Bottom-up and top-down approaches for materials synthesi and device application are discussed in the light of technological viability and nanomaterials safety.

Nano REACH and advanced materials

David Carlander, NIA

REACH has adapted to the growing use of nanomaterials through an update to Annexes that introduce nano-specific regulatory criteria for the first time. Nanoforms are specifically referenced, with the aim to allow applicants to reduce data submission requirements through creating 'sets' of nanoforms determined as similar for hazard. The advanced materials industry now must integrate these nano-specific requests into its materials development, with clearly defined material set and justification of their selection. The coming years will mark an evolution in the way that nanomaterials are presented within regulatory dossiers and in particular, the arguments for grouping of nanoforms and linking of physico-chemical characteristics with material hazard.

Panel report

The workshop ended with a panel discussion between Dr Michael Jank, Fraunhofer IISB; Dr Dimiter Prodanov, Imec; and Mr. David Carlander, Nanotechnology Industry Association. The panellists discussed three interrelated questions:

- How do future materials fit into the current risk assessment framework?

- What competences do we need to evaluate emerging risks?

- How can the risk be communicated along the supply chain?

How do future materials fit into the current risk assessment framework?

D Carlander expressed the view that the existing regulatory risk assessment approach employed by REACH allows for integration of novel materials deployed by the semiconductor R&D. It is also very likely that novel advanced nanomaterials or articles patterned at the nanoscale can fit into the present framework. D. Prodanov pointed out that R&D grade materials will most likely fall under the tonnage requirements set out in REACH, which can present a problem for occupational risk assessment as demonstrated in NanoStreeM.

M. Jank summarized his presentation by the observation that employing nano-features does not necessarily mean the direct use of "free" engineered nanomaterials. The literature survey employed in NanoStreeM further indicates that most likely novel materials will morph into existing planar Si/Ge processing technology, which avoids handling of "free" nanomaterials. Therefore, top-down production of nano-functionalized materials and device approaches will not add additional hazards only because it is "nano".

D Prodanov pointed out that metrics for hazard at the nano-level most likely will remain number or area based for inhalation hazards. The case of dissolution however, as pointed out by M Jank, for example of Ag, exposes the ion toxicity, which is related to the mass. Therefore, the route of exposure will eventually determine the most appropriate metrics. In the occupational setting of the semiconductor processing this is clearly the inhalation hazard during maintenance. This compounds with other hazards, for example the outgassing of wafers as demonstrated by Salim El Kazzi.

What competences do we need to evaluate emerging risks?

The panellists agreed that competence development regarding nanosafety is very important for the safety professionals. A challenge in the filed is even the identification of the fact that certain products contain nano-forms. This bring about development of dedicated training packages, for example the ones developed in NanoStreeM.

D Carlander pointed out that the findings of several projects, including NanoStreeM, demonstrate necessity for specific service provision facilitating occupational risk assessment by means of monitoring of nanomaterial emissions. Challenges there are the lack of harmonized measurement protocols and lack of service suppliers with sector-specific experience.

How can the risk be communicated along the supply chain?

The panellists agreed that communication along the supply chain is difficult and will remain an issue in the future. The regulatory options for example of specific labels or modification of CAS numbers for nanoforms can be considered. On the other hand, labelling can present a risk for miscommunication with the general public if the social dialogue about nanotechnology is not effective.

Panel statement

The research and development (R&D) approach in semiconductor industry represents an example of Safe-by-Design approach that may have some generic properties transferable to other industries. Furthermore, the existing European regulatory risk assessment approach, represented by the REACH Regulation 1907/2006, the CLP Regulation 1272/2008 and the Chemical Agents Directive 98/24EC in combination with the ISO Standard ISO/TS 12901-2:2014, can be also used suitably also for the novel materials deployed by the semiconductor R&D. However, more attention is needed in assessing possible environmental hazards at the end-of-life of different products.

Metrics for establishing for hazard at the nano-level most likely will remain number or area based for inhalation hazards. However, the route of exposure will eventually determine the most appropriate metrics.

Competence development regarding nanosafety is very important for the safety professionals. A challenge in the field is even the identification of the fact that certain products contain nano-forms. This bring about development of dedicated training packages, for example the ones developed in NanoStreeM.

Communication along the supply chain is difficult and will remain an issue in the future. The regulatory options, for example, of specific labels or modification of CAS numbers for nanoforms can be considered. On the other hand, labelling can present a risk for miscommunication with the general public if the social dialogue about nanotechnology is not effective.