Semiconductor technology & processing

Assessing nanorisks in the semiconductor industry

NanoStreeM unites 14 partners from R&D, industry and academia to improve the way how nanomaterials are handled in the semiconductor industry.

To keep up with the rapid pace Moore's law dictates, the semiconductor industry has introduced a variety of novel materials, often on nanoscale. Nanomaterials can have desirable properties such as increased strength or modified chemical or electrical characteristics. These features have opened possibilities for many sectors: energy production with solar cells using nanocrystals, life sciences tools with electrodes using carbon nanotubes, electronics with nanowires and gold particles.

However, some of these materials might have hazardous properties that are still poorly understood, and that has become a concern in the semiconductor industry. The European project NanoStreeM aims to address this concern by shedding light on the risks involved with handling nanomaterials on the workfloor. NanoStreeM is a consortium funded under the H2020 program from the European Commission and brings together 14 partners from three different worlds (R&D, industry and academia).

"We start by tracing the trajectories of the different nanomaterials and investigate in which circumstances they are used. Then, we identify suitable methodologies for conducting risk assessments. Finally, we distill this into different types of information packages for trainings for safety professionals. Our goal is to communicate our findings to the stakeholders in the EU and, in general, to contribute to a better understanding of the occupational hazards of nanomaterials," explains Dimiter Prodanov, project coordinator.

So, what's a nanoparticle anyway?

In fact, there are still only a few distinct sector-specific definitions for food, cosmetics, biocides and chemicals. Europe is in the process of approving an official definition of a nanoparticle for legislational purposes. The current recommendation serves as a guideline for NanoStreeM. For a material to be called nanomaterial, its size must be smaller than 100 nm in at least one of the dimensions, or a nanomaterial should consist for 50 % or more of particles having a size between 1 nm-100 nm. "There are still a lot of question marks to be placed in this recommendation, nor is it easy to use on the workfloor in the semiconductor industry, the focus of NanoStreeM. What is important for us is the size threshold, so that similar materials can be treated the same way," comments Dimiter.

The next question is then, where can we find these nanomaterials in the semiconductor industry? Based on a survey in the beginning of the project, NanoStreeM came up with three possible scenarios under which nanomaterials are produced. “The main source of nanomaterials constitutes parts of polishing slurries. In a process called chemical-mechanical polishing (CMP) the slurry is used to planarize a wafer. In a second scenario, nanomaterials are formed during different deposition processes. The deposition itself takes place in a closed chamber under high temperature and vacuum, but when the chamber is opened the material vapors in the gas phase can nucleate and condense into nanoparticles. Finally, nanoparticles are produced during abatement processes in the waste processing phase. In the pipes connecting the abatement system to the burner, you can find residual material.”

Macro versus nano

> *What makes these nanoparticles special, is that their properties cannot simply be derived from their bulk counterparts due to quantum physics effects. There is a direct effect of size on several physical and chemical properties.*

The light emission of cadmium sulfide quantum dots is, for example, different compared to that of larger particles. Gold particles are another example. They scatter differently with size: if you vary their size, you change their color. “Why the hazardous properties can be different is because the charge density on the surface is different. Since nanoparticles are smaller than bigger particles, the surface is more curved and the charge density is larger. Additionally, their free energy is larger, which can change their catalytic activity. Finally, the number of atoms touching the skin - the first layer of contact - as a percentage is larger than with larger particles,” explains Dimiter. “Some of the nanomaterial properties change in a predictable way, others in a threshold way.”

Does that mean nanomaterials are dangerous? Not necessarily, but some can pose a risk depending on the circumstances that they are used. “If we talk about the scenarios that we evaluated, the inhalation hazard is the most likely. For example, when a chamber is opened after deposition processes the particles can be mobilized in air and can be inhaled by the operator of the chamber.”

Small exposures

“However, keep in mind that we’re talking about very small emissions; most of the installations are closed. The situation is not comparable to the paint or automotive industries, for example. Those are extreme cases. The main exposure scenario in the semiconductor industry is related to accidents. The slurries, for example, are distributed in big barrels. At the moment you connect or disconnect the barrels, there might be leaks. There might also be accidents in the tool itself when a wafer breaks and needs to be taken out for cleaning. Another scenario for exposure occurs during waste treatment and maintenance of the waste treatment system. The personnel can get exposed to nanoparticles, for example, when vacuum cleaning the surface of the reactor after operation. In all of these cases an operator can get into contact with the nanomaterial. These are all well understood scenarios where we can pinpoint the operations that are hazardous and inform the operator about the risks.”

Big impact

With the project ending this year, the NanoStreeM partners are bundling the results into training packages, not only for imec, but for all partners in the consortium. “All partners intend to identify suitable information to incorporate into dedicated trainings related to the use of nanomaterials. We have keen interest from the industrial partners to incorporate the findings of the project and the approach towards the risk assessment into their dedicated training programs.”

“At the moment, we are assembling a training package, collecting information from all parties involved. Afterwards, we will propose a curriculum to be integrated into the standard trainings of the partner. For the training package, we aim at a two-tier training. The first level would be a general type of training to make general users aware that there are specific risks related to nanomaterials. The risk that can arise from different industrial processes are however well understood. The second tier is aimed at professionals. For this training level, we want to communicate the relevant findings of this and other projects and point out specific tools that can further help identify specific risks and hazards in specific circumstances,” concludes Dimiter.

Want to know more?

- To address challenges in nanomaterial risk assessments the H2020 projects NanoStreeM and caLIBRAte organize a joint workshop entitled “Governance of emerging nano-risk in the semiconductor industry”. The event takes place in Brussels on 26 April 2018. For more information and to subscribe to the workshop, go to the event page
- For more information on the training packages or the project, use the project’s contact page

Biography Dimiter Prodanov

Dimiter Prodanov obtained an MD degree from the Medical University – Sofia in 1999. In 2006 he obtained a PhD degree in Neuroprosthetics from the Twente University, Enschede, the Netherlands. He was awarded a fellowship from the International Brain Research Organization to continue his research in the Catholic University of Louvain, Belgium (2006), and later at the University of Liege, Belgium. In 2008 Dimiter Prodanov joined imec, Belgium as a Senior Scientist in the neurotechnology program. Since 2009 he holds the position a biosafety coordinator where he supports actively imec's research programs in life sciences and health care. From 2013 onwards, Dimiter Prodanov became an affiliated researcher in NERF. In 2014 he became responsible for nanosafety at imec and since 2016 he coordinates the H2020 project NanoStreeM.