ENVIRONMENTAL HEALTH AND SAFETY: PHOTONICS

Photonics includes the generation, emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing of light. The commercial applications of nanotechnology in the field of photonics include: lasers and parts thereof, nano-engineered photonics materials, communications & all-optical signal processing, and nanoscale functional imaging and spectroscopy. Products for the sector photonics range from communication technology such as Low-Power 100 Gb/s Optical Engine by Mellanox Technologies and Rings of fire by HP to laser devices such as the Comb-Laser by Innolume.

A number of nanoparticles have been identified in the overview of commercially-available products as being used in photonic products (see section on Products in Photonics):

- Gallium nitride nanowires
- Germanium nanoparticles
- Graphene
- Silicon dioxide (silica), crystalline
- Silicon dioxide (silica), synthetic amorphous
- Single-walled carbon nanotube (SWCNT)
- Titanium dioxide (titania, rutile, anatase)

A risk-banding tool called Stoffenmanager Nano[1,2] has been used to prioritise the health risks occurring as a result of respiratory exposure to nanoparticles for the relevant exposure scenarios.

The respiratory route is the main route of exposure for many occupational scenarios, while the oral route of exposure is considered minor and sufficiently covered, from a safety point of view, by good hygiene practices established in production facilities as prescribed through general welfare provisions in national health and safety legislation in EU countries (ECHA 2012)[3]. In view of the nature of the products in this sector, oral exposure of consumers is also considered to be minor.

The dermal route may be the main route of exposure for some substances or exposure situations, and cause local effects on the skin or systemic effects after absorption into the body (ECHA 2012). However, nanoparticles as such are very unlikely to penetrate the skin (Watkinson, et al. 2013), and consequently nanospecific systemic toxicity via the dermal route is improbable. Therefore, when evaluating nanorisks for the respiratory route, the most important aspects of occupational and consumer safety are covered.

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1 Marquart, H., Heussen, H., Le Feber, M., Noy, D., Tielemans, E., Schinkel, J., West, J., Van Der Schaaf, D., 2008. 'Stoffenmanager', a web-based control banding tool using an exposure process model. Ann. Occup. Hyg. 52, 429-441.

2 Van Duuren-Stuurman, B., Vink, S., Verbist, K.J.M., Heussen, H.G.A., Brouwer, D., Kroese, D.E.D., Van Niftrik, M.F.J., Tielemans, E., Fransman, W., 2012. Stoffenmanager Nano version 1.0: a web-based tool for risk prioritization of airborne manufactured nano objects. Ann. Occup. Hyg. 56, 525-541.

3 ECHA, 2012. Chapter R.14: Occupational exposure estimation., in: Anonymous Guidance on Information Requirements and Chemical Safety Assessment., Version: 2.1 ed. European Chemicals Agency, Helsinki, Finland.

Hazard assessment of nanoparticles

In Stoffenmanager Nano, the available hazard information is used to assign specific nanoparticles to one of five hazard bands, labelled A to E (A= low hazard, E= highest hazard). The table below presents an overview of selected nanoparticles of the photonics sector and their hazard bands, either taken from le Feber et al. (2014)[4] or van Duuren et al. (2012), or derived in this project.

Hazard bands for selected nanomaterials

Nanoparticles	Hazard band	Source
Gallium nitride nanowires	E	This report, see Annex
Graphene	E	This report, see Annex
Silicon dioxide (silica), crystalline	E	van Duuren et al. (2012)
Silicon dioxide (silica), synthetic amorphous	C	le Feber et al. (2014)
Single-walled carbon nanotube (SWCNT)	E	This report, see Annex
Titanium dioxide (titania, rutile, anatase)	B	le Feber et al. (2014)

Exposure assessment of nanoparticles

Based on the provided overview of commercially available products, engineered nanomaterials are present in the products as part of a matrix. No free solids or liquids containing engineered nanomaterials, which can become airborne during the use-phase, were listed. During the production of these photonic products, employees can be exposed to free engineered nanomaterials. However, as many of these activities are performed on a R&D scale, exposure to engineered nanomaterials will be relatively low. In conclusion, the use of photonic nanoproducts results in an exposure band 1 (consumers and workers), whereas during the production of photonic products an exposure band 2 (workers) is believed to be realistic.

Risk assessment of nanoparticles

The hazard and exposure bands are combined to yield so called priority bands, according to the scheme depicted in the table below. A high priority implies that it is urgent to apply exposure control measures or to assess the risks more precisely, and a low priority implies that it is not very urgent to apply exposure control measures ort to establish the risk involved with more precision. It should be emphasised that because of the scarcity of available information, the scheme is set in a conservative way (according to the precautionary principle).

4 Le Feber, M., Kroese, E.D., Kuper, C.F., Stockmann-Juvala, H., Hyytinen, E.R., 2014. Pre-assigned hazard bands for commonly used nanoparticles. TNO2014 R11884.

Priority bands in the Stoffenmanager system

Hazard band / Exposure band	A	B	C	D	E
1	3	3	3	2	1
2	3	3	2	2	1
3	3	2	2	1	1
4	2	1	1	1	1

Key:

Hazard: A = lowest hazard and E = highest hazard;

Exposure: 1 = lowest exposure and 4 = highest exposure;

Overall result: 1 = highest priority and 3 = lowest priority (Van Duuren-Stuurman, et al. 2012).

Risks based on the hazard and exposure banding applied to the sector are listed in the table below. There is a high risk to workers and consumers from gallium nitride nanowires, crystalline silica and single-walled carbon nanotubes, with respect to use and production. Furthermore, there is a moderate risk to workers from amorphous silica and a low risk from the use and production of titania and from the use of amorphous silica and titania.

Priority bands for nanotechnology photonics

		Exposure band		
		Workers (production)	**Workers (use)**	**Consumers (use)**
Nanoparticle	**Hazard band**	**2**	**1**	**1**
Gallium nitride nanowires	E	1	1	1
Silicon dioxide (silica), synthetic amorphous	C	2	3	3
Silicon dioxide (silica), crystalline	E	1	1	1
Single-walled carbon nanotube (SWCNT)	E	1	1	1
Titanium dioxide (titania, rutile, anatase)	B	3	3	3

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