OSRAM Contribution to 2nd Stakeholder Consultation:

ROHS Annex II Dossier for Indium phosphide.

Restriction proposal for substances in electrical and electronic equipment under RoHS
Report No. 3, Version 2
Substance Name: Indium phosphide (InP)
EC Number: 244-959-5
CAS Number: 22398-80-7
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Postal address:
80807 Munich
Germany

Office address:
Marcel-Breuer-Str. 6
80807 Munich
Germany

OSRAM GmbH
Chairman of the Supervisory Board:
Peter Bauer

Managing Directors:
Dr. Olaf Berlien (Chairman)
Ingo Bank
Dr. Stefan Kampmann

Commercial registry:
Munich HRB 201526

WEEE-Reg.-Nr. DE 71568000

We want to thank the Oeko-Institute for consideration of the contributions of IMAT e.V. (representing the German semiconductor industry) to the 1st stakeholder consultation (June, 2018)[1]. OSRAM as a member of IMAT was and is involved in the contributions and fully supports them. We also fully agree that InP is essential for many existing and potentially future applications. Therefore we support the recommendation of the Oeko-Institute not to add InP to Annex II of the RoHS Directive although we are aware of the classification of InP according Regulation (EC) No 1272/2008 (Carc. 1B, Repr. 2, STOT RE 1).

Although InP is currently not used in products produced and marketed by OSRAM GmbH and OSRAM Opto Semiconductor GmbH we would like to additionally comment and answer to uses of InP in display technologies as well as to perspectives of InP in solid state lighting.

In the RoHS Annex II dossier for InP the consultant Oeko-Institute rises several questions and assumptions and is asking for contributions. We try to answer the questions to the best of our knowledge and are available for any further questions.

Comments and Contributions to the report

Ad Chapter 2.1.: *Function of the substance*

According our knowledge InP is used in quantum dot applications for display lighting (indirect configurations “on edge” and “on layer”; no direct configuration “on chip”). Quantum Dot LED based on InP in “on-chip” configuration are to the best of our knowledge not available. Therefore InP based quantum dot technology for solid state lighting is not a suitable technology accepted by the markets due to disadvantages regarding energy and material efficiency, costs and design obstacles.

On-chip quantum dot configurations currently are only possible with Cadmium based QD materials leading to

- substantial reduction of hazardous material “on chip” compared to the other configurations in display technology (ca. 0.2 mg CdSe compared to 30 mg InP per m² display area)
- substantial increase of energy efficiency for high CRI LED (+ 20%) compared to best available non QD technology

Ad Chapter 2.2.: *Types of application / types of materials*

As outlined above InP is currently according our knowledge not in use as a material in solid state lighting applications. OSRAM Opto Semiconductor GmbH has started a cooperation with the US DoE on the development of semiconductors using InP QD technology in the configuration “on chip”[2]. Products ready for the market are not expected before 2024-25. Only “on-chip” QD-LED are suitable and acceptable for the market from our current point of view. This is due to disadvantages regarding energy and material efficiency, costs and design obstacles of “on layer” and “on edge” configurations. Only remote configurations are possible due to stability to light flux which have a highly colored yellow/orange off state that has been found not to be acceptable to the market.

Regarding safety in QD materials in displays we would like to mention that Cadmium based LED in “on chip” configuration are in development which can be used without layers and

[1] https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_IMAT_InP_RoHS_Consultation_20180615.pdf

[2] https://www.energy.gov/eere/ssl/downloads/environmentally-robust-quantum-dot-downconverters-highly-efficient-solid-state

tubes. Products will be available in a foreseeable timeframe. The amount of the hazardous substance can be reduced dramatically. While according to the data provided by the company Nanoco[3] 30 mg InP are required per m² display area an amount of ca. 0.2 mg of Cd is expected to be required for the same size. This corresponds to a reduction of a substance classified hazardous of 99,3 %. This could only be achieved, if the exemption renewal for the corresponding RoHS Annex III exemption 39 would be granted.

While for Cadmium according the new eco-design requirements for displays Cd based solutions will require special labelling for recyclers this is not required for InP based QD solutions.

Ad 2.3.: *Quantities of the substance used*

OSRAM is not familiar with the display market. According to information from IMAT the forecast of the use of InP for displays in section 2.3 of the dossier of up to 600 kg per year in 2028 in Europe is not realistic. In addition the use of CdSe based QD LED with "on chip" configuration could lead to lower amounts if the respective RoHS Annex III renewal request would be granted. Theoretically, in case the growth of the QD LED market would grow as predicted, the 600 kg InP could be replaced by 4 kg CdSe in 20 Million m² display area. This would correspond to a concentration of ca. 0.007 mg/kg (ppm) TV, assuming 25 kg for a 55 inch TV being much lower than the limit values for cadmium in certain food as regulated in Regulation (EC) No 1881/2006 in the current version.

According our knowledge the current use of InP in solid state lighting is **0 kg** in Europe und this is not expected to change in the next 5 years. OSRAM has started a cooperation with the US DoE on the development of semiconductors using InP QD technology suitable also for solid state lighting in the configuration "on chip"[4]. Products ready for the market are not expected before 2024-25. Only "on-chip" QD-LED are suitable and acceptable for the market from our current point of view. This is due to disadvantages regarding energy and material efficiency, costs and design obstacles of "on layer" and "on edge" configurations. Therefore the assumption that "*the specific amount of InP is double the amount of CdSe"* is from our point of view not correct. We believe the assumption comes from the use of InP/CdSe in QD technologies in "on layer" and "on edge" configurations. The amount of CdSe or InP in "on-chip" applications would be substantially lower.

Regarding the assumption: "*The market share of cadmium-based QDs in lighting applications, which was estimated with 5% in 2015 and causes a CdSe consumption of 8 kg, will be taken as a starting point"* we would like to state that the exemption for the use of Cd compounds in QD LED for lighting has expired. CdSe based QD LED exceeding 0.01% Cd in homogenous materials currently are not allowed. A new exemption was requested by LightingEurope in 2017[5]. The decision on the request is still pending.

Highly energy efficient CdSe based QD LED not exceeding 0.01% Cd in homogenous materials have been introduced in the market by OSRAM earlier this year[6][7][8]. CdSe based QD

[3] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_Nanoco_InP_Consultation_20180615.pdf

[4] https://www.energy.gov/eere/ssl/downloads/environmentally-robust-quantum-dot-downconverters-highly-efficient-solid-state

[5] https://rohs.exemptions.oeko.info/index.php?id=316

[6] https://www.osram.com/os/press/press-releases/quantum-dots-from-osram-make-leds-even-more-efficient-osconiq-s-3030-qd.jsp

[7] https://edisonreport.com/wp-content/uploads/2019/05/Top-10-Release-2019.pdf

[8] https://www.ledsmagazine.com/company-newsfeed/article/14068957/opulent-americas-announces-linear-led-module-product-release-built-with-osram-osconiq-s-3030-quantum-dot-ideal-for-indoor-lighting-

LED for high colour rendering index (CRI) applications slightly exceeding the RoHS limit are ready for the market. They reveal even15-20% higher energy efficiency compared to the RoHS conform variant. They can only be used in products for the EU market if the LightingEurope exemption request is granted.

Overall we would like to summarize: It is currently not possible to predict the amount of InP in lighting products in 2028. We expect an amount much smaller compared to *256 kg* as currently assumed by Oeko-Institute, starting earliest 2024-25.

Ad 5.1.: *Description of waste streams*

As outlined above we are not aware of Category 3 products – lamps using InP in the past. We do not expect such products in the coming 5 years. If such lamps would become available they would remain in the market for 5+ years. So we do not expect InP in lamps in the waste stream for the next 10+ years. We recommend to change table 5.1 accordingly.

Ad 5.3.: *Waste treatment processes relevant for assessment under RoHS*
and 5.4.: *Releases from (relevant) WEEE treatment processes*

As explained above we are not aware that InP containing lamps have been put on the market or that this will happen the next 5 years. We do not expect InP in lamps in the waste stream in the next 10+ years.

Recently it was decided in the Ecodesign Implementing Measure for displays, that a marking has to be applied in case Cd based QD technologies are used. This is not the case for InP materials (foils, tubes).

Ad 6.2.: *Human exposure estimation*
and 6.3.: *Environmental exposure estimation*

As outlined above we are not expecting InP in lamps in the waste stream in the next 10+ years.

Ad 8.1.: *Availability of substitutes / alternative technologies*
and 8.2.: *Hazardous properties of substitutes*

Regarding lighting applications OSRAM again wants to stress that InP is not in use according our market knowledge. Therefore the question of substitution of InP in solid state lighting is currently not relevant.

Quantum Dot LED based on InP in “on layer” or “on edge” configuration is not a suitable technology for solid state lighting accepted by the markets due to disadvantages regarding energy and material efficiency, costs and design obstacles.

Regarding displays we are working on “on-chip” quantum dot configurations which currently are only possible with Cadmium based QD materials. This configuration would allow a substantial reduction of hazardous material compared to the other configurations currently

applications?utm_source=LED+Weekly&utm_medium=email&utm_campaign=CPS191030009&o_eid=1762I7153845C5V&rdx.ident%5Bpull%5D=omeda%7C1762I7153845C5V&oly_enc_id=1762I7153845C5V

realized in display technology. Instead of 30 mg InP per m² display[9] area only ca. 0.2 mg CdSe would be required according our current status (or 0.16 mg per 55 inch TV screen). This technology will also allow new material- and energy-efficient applications in case the exemption renewal request of April 2018 is granted[10].

OSRAM is not familiar with the future display market. According to information from IMAT the forecast of the Oeko Institute in section 2.3 of the dossier of up to 600 kg InP per year (EU) put on the market in 20 Million m² display screen area in 2028 is not realistic. Even in such a case the use of CdSe based "on chip" QD LED could lead to a total use of 4 kg CdSe in 20 Million m² display area or a concentration of ca. 0.007 mg per kg (ppm) TV (assuming 25 kg for a 55 inch TV) which is much lower than the limit values for cadmium in certain food as regulated in Regulation (EC) No 1881/2006 in the current version.

We believe that such a reduction outweighs the disadvantages of the use of Cd in this case.

Ad 9: 9. *Description of the socio-economic impacts*

OSRAM has recently started a cooperation/funding with US DOE on the development of "on chip" InP based QD materials[11]. A prohibition of InP would severely endanger such work for the future use of InP in lighting applications.

Ad 10.: *Rationale for the inclusion of the substance in annex II of RoHS*

OSRAM is convinced that the prohibition of InP would not serve the goals and targets of the RoHS Directive but put huge damage on European industry and society.

Nevertheless we recommend to change some of the conclusions in this chapter:

- The amount of InP put on the market in the EU is lower than predicted in the dossier. With our knowledge today we strongly doubt that a total quantity of 1000 kg will be realistic for 2028.
- Cd based QD for lighting have a considerable advantage to higher energy efficiency compared to all other available LED for high CRI applications. They have a much better environmental performance compared to InP for solid state lighting as InP solutions would today only be technically possible in "on layer and on edge" configurations.

[9] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_Nanoco_InP_Consultation_20180615.pdf

[10] https://rohs.exemptions.oeko.info/index.php?id=316

[11] https://www.energy.gov/eere/ssl/downloads/environmentally-robust-quantum-dot-downconverters-highly-efficient-solid-state