

Consultation Questionnaire Regarding CdQD Exemptions:

Ex. Re. No. 2013-2 for „Cadmium in colour converting II-VI LEDs (< 10 µg Cd per mm² of light-emitting area) for use in solid state illumination or display systems" (Request for renewal of Exemption 39 of Annex III of Directive 2011/65/EU)

Ex. Re. No. 2013-2 for „ Cadmium in light control materials used for display devices”

Abbreviations and Definitions

Cd	Cadmium
QD	Quantum dots
LCD	Liquid crystal display
SSL	Solid state lighting

Background

The Oeko-Institut has been appointed within a framework contract¹ for the evaluation of applications for the renewal of exemptions currently listed in Annexes III of the new RoHS Directive 2011/65/EU (RoHS 2) by the European Commission.¹

In December 2012 the Commission received a request for the renewal of Annex III exemption 39 from QD Vision, Inc., and in May 2013 a request for a new Annex III exemption was submitted by 3M Company, Optical Systems Division. The exemptions, both dealing with cadmium quantum dot applications, were both evaluated in the course of an evaluation performed in 2013-2014. The final report was published in April 2014.

On the 20 May 2015, the European Parliament objected to the Commission Delegated act adopted on the basis of the mentioned report, claiming that the report need be updated; thus the reevaluation of these requests is to be performed in the course of the current project.

The following summary is based on information available from the first evaluation and on the answers of the applicants and a manufacturer of a candidate for substitute to a first set of clarification questions prepared in the course of the current project:

QD Vision has explained that the requested exemption (renewal) is required to enable manufacturers to bring to the market a quantum dot down-conversion material for use in two kinds of applications: solid state lighting and display lighting applications. The II-VI down-conversion materials (e.g. quantum dots), due to their narrowband, tuneable, stable and efficient properties, will provide consumer products with the superior performance, efficiency, and net benefit to the environment for which there currently is no substitute available. In lighting, narrowband emission translates to warmer light sources

¹ Contract is implemented through Framework Contract No. ENV.C.2/FRA/2011/0020 led by Eunomia

with 20 - 40% greater efficacy. Such products have already been placed on the market in the US. In the display market, narrowband emission translates to televisions, monitors, tablets and cell-phones that can achieve 100% of colour gamut (as defined by NTSC). This property has the added benefit of increasing light throughput through the display, which can in turn reduce energy consumption for identical perceived brightness by as much as 20%.²

3M³ explain that quantum dots (QDs) are a new class of non-naturally occurring materials that can be tuned to efficiently emit narrow spectral distribution light at the optimum wavelength for LCDs.⁴ QDs are semiconductor nano-crystals, on the order of 3-7nm in size, in which excitons (an electron and hole excited pair) are confined on all three spatial dimensions. The wavelength of the light output from a semiconducting material is dependent on the band gap between normal and excited electron energy states. The spatial confinement of the electrons and holes of the quantum dot materials leads to higher band gaps compared to the band gap of same material in bulk. As a result, the band gaps of the quantum dots can be changed continuously by changing their physical size. Quantum dots are typically synthesized via solution chemistry (carefully controlled precipitation processes). By controlling different synthesis conditions, e.g., precursor; ligand concentrations; temperature; and time of the reaction, QDs of different sizes can be obtained. Quantum dot emission can be tuned across most of the visual spectrum by controlling the size of the quantum dot as it is fabricated. According to the applicant, thin quantum dot light control films contain cadmium for which substitution is currently not technically practical. Alternative LCD technologies give broader ranges of colours which cannot be tailored to optimum wavelengths.⁵

Quantum dots can be pumped with a blue source, such as the GaN LED, to emit at any wavelength beyond the pump source wavelength. The emission spectra of QDs have narrow line-widths and are free of satellite peaks, thus making them ideal candidates for display backlights to achieve high colour purity and increased system energy efficiency. QDs convert light with very high efficiency (>88% quantum efficiency) and with very narrow output spectral distribution of only 30 – 40nm full width at half maximum (FWHM). Due to their tuneability, narrow spectral output distributions, and high quantum efficiencies, quantum dots are ideal for creating BLU light sources to increase colour gamut size and maximize LCD colour performance.⁶

QD Vision⁷ state that the net benefit to the environment, of allowing the use of cadmium in the mentioned applications, is a result of the system level increase in efficiency that is achieved using the II-VI down-conversion materials, due to their narrowband, tuneable, and efficient nature.

3M have stated in the past that the primary justification for this exemption is that only QD LCDs are able to achieve 100% colour gamut for all screen sizes and a secondary justification is that the potential substitutes have a greater negative environmental impact.⁸

² QD Vision (2013a), QD Vision original exemption request document concerning exemption request 2; available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_IX/Request_2013-2/20132301_NON-CONFIDENTIAL_Request_for_renewal_of_exemption_39.pdf, retrieved on 12.12.2013

³ 3M (2013a), 3M Optical Systems Division original exemption request document concerning exemption request 2; available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_IX/Request_2013-5/3M_QDEF_Exemption_Dossier.pdf, retrieved on 05 June 2013

⁴ Quoted by 3M (2013a) as: Hartlove, J. 2011. Quantum dots unleash high-colour-gamut performance in LED-backlit displays. LEDs Magazine

⁵ Op. cit. 3M (2013a)

⁶ Op. cit. 3M (2013a)

⁷ Op. cit. QD Vision (2013a)

⁸ Op. cit. 3M (2013a)

At the time of the first review, a contribution was made by Nanoco-Dow⁹ to the stakeholder consultation providing information regarding a potential substitute – Cd-free quantum dots. This substitute was explained to be a quantum-dot material and in that sense similar in how it could be applied in display and lighting applications as a possible substitute. Lack of detailed quantifiable information at the time did not allow an actual comparison on the system level of the two technologies.

The understanding that articles using Cd-free QD technologies had not been placed on the market at the time of the first review led to a recommendation to grant a short termed exemption for Cd-QDs used in display applications. As it was understood that solid state lighting applications did not exist on the market at that time for either technologies, the consultants recommended not granting an exemption for the use of Cd-QDs in lighting applications.

However, in the time that has passed since the initial review of these requests, changes have taken place in the availability of products using both the Cd-based and the Cd-free QD technologies mentioned. Information provided by 3M, QD vision and Nanoco suggests that various articles are available on the market using these technologies. For further detail please see the various documents available on the consultation specific page: <http://rohs.exemptions.oeko.info/index.php?id=265>

Further information from the first evaluation is also available under the following request specific pages:

Ex. Re. 2013-2: <http://rohs.exemptions.oeko.info/index.php?id=262>

Ex. Re. 2013-5: <http://rohs.exemptions.oeko.info/index.php?id=267>

The objective of this consultation and the review process is to collect and to evaluate information and evidence according to the criteria listed in Art. 5 (1) (a) of Directive 2011/65/EU (RoHS II), which can be found under: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT>

If you would like to contribute to the stakeholder consultation, please answer the following questions:

Questions

1. The two applicants originally requested exemptions with different wording formulations, however in the course of the first evaluation it was understood that both exemptions are to allow placing Cd QD technologies on the EU market in various products. During the first evaluation the applicants were asked to confirm if the following formulation would cover the applications for which the exemptions had been requested:

Cadmium in components for lighting applications and display lighting applications, containing downshifting cadmium based semiconductor nanocrystal quantum dots, where the cadmium per display screen area is limited to less than 0.2 ug/mm²

This formulation was later used as a basis to separate between display lighting and solid-state lighting applications in the context of a possible exemption. If the exemption is to be recommended, a split shall most likely be proposed between the use of such cadmium components in solid state lighting applications and in display lighting applications.

⁹ Nanoco-Dow (2013a), Contribution made concerning Ex. Re. 2013-2 – answers to RoHS Consultation Questionnaire, submitted by Nanoco Technologies Limited & Dow Electronic Materials on 06.11.2013, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_IX/Request_2013-2/20131106_Nonoco_Dow_Contribution_Ex_2013-2_Response_to_RoHS_Questionnaire.pdf

- a. Do you agree that the formulation above covers the cadmium quantum dot technologies addressed in the two exemption requests? If not, please explain why.
 - b. If the exemption is to be split according to application field (SSL and display lighting) please specify what wording formulation would best cover each of the application areas.
 - c. Please suggest an alternative wording and explain your proposal, if you do not agree with the proposed exemption wording or with the proposed split.
 - d. Please explain why you either support the applicant's request or object to it. To support your views, please provide detailed technical argumentation / evidence in line with the criteria in Art. 5(1)(a) to support your statement.
2. At the time of the first review, difficulties regarding the comparison of Cd QDs in display applications and Cd-free QDs in display applications, did not allow making a well-balanced comparison of these technologies. In the meantime, it has become apparent that the market situation of these products has changed, possibly allowing a better comparison and evaluation as to the environmental performance of these technologies and other related aspects. The two applicants and a manufacturer of a substitute candidate have provided information regarding applications that are already on the market using the Cd based and Cd free technologies. Please review this information and comment:
- a. Regarding the availability of Cd-based and Cd-free products for display applications using these technologies, please specify if you are aware of **additional** products that have become available since 2014 (display type, dimensions and other characteristic aspects for clarifying the performance class) other than those specified by the applicants and the substitute candidate manufacturer.
 - b. Please state if you agree with the detailed parameters mentioned by the three actors as relevant for enabling a comprehensive comparison of performance of the technologies (general performance and environmental performance); Please explain your views and if relevant specify other parameters that should be considered.
 - c. The various actors mention the following standards among others as relevant for comparing the technologies used in display applications: NTSC and Adobe RGB as well as the REC 2020 standard that is understood to be in adoption stages. Please comment as to the suitability of these standards for comparing QD technologies in display applications.
3. Please specify on the basis of what regulations/standards a comparison of these technologies in relation to the performance of the relevant product (TV, display, tablet, mobile-phone, solid state illumination applications) can be made, in particular in relation to the consumption of energy during various use modes (standby and other operation modes, operation with different brightness/contrast settings; display of images with higher or lower contrast or differing hues; etc.)
4. At the time of the first review, it was understood from various stakeholders that the Cd-based and Cd-free quantum dot technologies were also being developed for possible future use in solid-state illumination applications. The two applicants and a manufacturer of a substitute candidate have provided information regarding applications that are already on the market using the Cd based and Cd free technologies. Please review this information and comment:

- a. If **additional** lighting products (*solid state illumination*) have become available on the EU market since 2014.
 - b. Please clarify for Cd-based and Cd-free products as described in a), what parameters are relevant for enabling a comprehensive comparison of performance to clarify how the technologies compare in relation to performance in general and in particular to environmental performance;
 - c. Please state if you agree with the detailed parameters mentioned by the three actors as relevant for enabling a comprehensive comparison of performance of the technologies (general performance and environmental performance); Please explain your views and if relevant specify other parameters that should be considered.
5. The applicants and a manufacturer of a substitute candidate have provided information as to the compounds used in Cd-free and Cd-based technologies relevant to the exemption requests, and as to their potential hazardousness and toxicity. Please state with which of the views presented you agree or disagree and explain why;
6. Please provide information as to research initiatives which are currently looking into the development of possible alternatives for some or all of the application range of Cd in the scope of the requested exemptions (and among others in the scope of Ex. 39);
- a. Please explain what part of the application range is of relevance for such initiatives (in what applications substitution may be possible in the future).
 - b. Please provide a roadmap of such on-going research (phases that are to be carried out), detailing the current status as well as the estimated time needed for further stages.

Please note that answers to these questions are to be published as part of the available information relevant for the stakeholder consultation to be carried out as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be made public along with a confidential version, in which proprietary information is clearly marked.