Request to renew Exemption 39(a)

under Annex III of the RoHS Directive 2011/65/EU

Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications (< 0,2 µg Cd per mm2 of display screen area)

Date: April 30, 2018

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

Contents

1 Name and contact details

OSRAM GmbH	OSRAM Opto Semiconductor GmbH
Dr. Georg Niedermeier	Dr. Norwin von Malm
Environment, Health and Safety	Director Material Innovation Backend Technology
Marcel-Breuer-Straße 6 D-80807 Munich, Germany	Leibnizstr. 4 D-93055 Regensburg, Germany
Tel. +49 89 6213-3715	Tel: +49 941 850 2651
E-Mail: g.niedermeier@osram.com	E-Mail: norwin.vonmalm@osram-os.com

2 Reason for application

OSRAM GmbH and OSRAM Opto Semiconductor GmbH (hereafter OSRAM) submit this application **to request for extension of existing exemption no. 39(a) in Annex III.**

Current wording of exemption 39(a)

Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display and projection lighting applications (< 0,2 µg Cd per mm^2 of display screen area)

For reasons outlined in the application below, mainly the change from surface and edge illumination to on-chip technology, OSRAM proposes **to change the existing wording** of the exemption.

Proposal for new wording of the exemption:

Cadmium in downshifting semiconductor nanocrystal quantum dots directly deposited on LED chips for use in display and projection applications (< 5 µg Cd per mm² of light emitting LED chip surface).

The highly innovative technology needs further research and development for the LED itself but also for existing and new applications where the components are intended to be used. These innovation steps need legal certainty and time. Therefore OSRAM requests a duration of 5 years.

3 : Summary of the exemption request

The validity period of DIRECTIVE 2011/65/EU Article 5(2) Annex III Exemption 39(a) will end automatically per 31/10/2019, unless an application for renewal has been made to the Commission in accordance with Annex V.

With reference to the above, this request concerns the extension of the current Annex III exemption 39(a) regarding Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications. The currently allowed amount of cadmium shall not meet or exceed 0,2 µg Cd per mm^2 of display screen area.

This is a request to renew the exemption for the use of very small amounts of Cadmium in RGB applications, as with today there is no alternative to Cadmium containing Quantum Dots to convert blue LED light efficiently into narrow red or green colour and that can withstand the reliability requirements on LEDs. Especially, there is no technical alternative at all for very small converters in nanometer size.

For displays or projection applications regularly broad spectra are filtered to pure colours. The narrower the spectrum the less amount of photons is wasted, i.e. the system is more energy efficient, and the gamut colour quality is higher. Cd- free quantum dots do not offer the same narrow spectra and they do not withstand the LED reliability requirements.

In our trend for miniaturizing less and less material is needed. LED chips get tiny and the development of pixelated chips allows to reduce the amount of chips needed. Future innovations require µ-displays. Applications like augmented or virtual reality cannot be realized with OLEDs due to their lack of reliability and their low brightness. For µ-displays very small converter grains are needed in the size of nanoparticles that in addition allow dense packing to realize very thin converter layers (~1µm). Today, this can be realized with an intelligent core-shell concept that can be done by Cd-containing Quantum Dots, solely.

However, as these is a µ-display the amount of converter needed is extremely low, i.e. the amount of Cadmium is very low - much lower as the use of conventional converter material. Thus, also less energy is needed to produce the converter material.

Quantum Dot Semiconductor technology is currently in development and use for different lighting applications. It is very promising regarding reduction of energy use, increasing energy efficiency. Therefore the renewal of exemption 39 for the use of Cd for in display applications was granted by EU legislation (Commission Delegated Directive (EU) 2017/1975 of August 2017, to be read in conjunction with the Corrigendum)[1] and a new exemption request was applied for general lighting applications by LightingEurope[2].

From OSRAM point of view currently and in the foreseeable near future there is no technical alternative to Cd containing Quantum Dot materials with comparable high energy saving potential. In addition the material has technical advantages making innovative new applications possible. The potential to save energy is so high that from a life cycle perspective, considering the EU energy mix, LightingEurope believes the amount of Cadmium emissions from power plants that can be avoided is higher than the Cd amount needed for the products. In addition the Cd in products can be collected by the EU WEEE take back and recycling schemes, while Cd from power plants currently is emitted to air.

Research, development and improvement of components and products with new innovative materials is very time consuming. After development of components for serial production also products and applications using these improved and innovative LED need time for development, testing and production. That is why OSRAM is requesting an extension of current exemption with a maximum validity period and no expiry date.

4 Technical description of the exemption request

4.1 Description of the technology

4.1.1 Light Emitting Diodes covered by this exemption are state of the art

Conventional solid-state lighting technology is based on blue LEDs exciting a green, yellow and/or a red phosphor (phosphorescent light downconverter) to generate green, yellow and some red light. For white LEDs this is mixed together to form white light for illumination purposes.

White LEDs are used as well for backlighting purposes. Here, the light is then filtered and combined with LCD technology to end up in pure colours. In projectors single-coloured

[1] See: *http://ec.europa.eu/environment/waste/rohs_eee/legis_en.htm*
[2] LightingEurope, 2017: *LightingEurope request for a new exemption for the use of cadmium in luminescent material for on-chip application on LED semiconductor chips (lighting), Annex III of RoHS Directive 2011/65/EU*

LEDs are used in red, green, and blue. Direct emitters are in use for this purpose but as it is more energy efficient, full-conversion is used to make green LEDs from blue-emitting LEDs. However, as the green spectrum has a large bandwidth still a high amount of light (=energy) is wasted as it needs to be filtered for a proper colour.

The materials used as down-converters typically are garnets and nitrides for illumination purposes. For displays more narrow phosphors are advantageous. There also Oxynitrides are in use. Partly, sulfides are in discussion as well, however they suffer from reliability issues. In recent years, two new types of down-converters came to market. One is PSF (potassium fluorosilicate) as a new material class between the established inorganic phosphors. This is a manganese doped material that emits from an f-f transition leading to several very narrow peaks between orange and infrared that has replaced other nitride phosphors in backlighting diodes to enhance the colour gamut. The others are Quantum Dots.

Quantum Dots (QDs) down-convert light – like phosphors from higher energy wave-lengths (like blue) to lower energy wavelengths (like red or green). Several material classes are known here, however the ones with the by far best performance contain cadmium as main element. Their beneficial properties are a high efficiency coming with a narrow full width half maximum making it attractive for any display or projection applications, i.e. where very pure colours are required, but for illumination as well as one can avoid typical losses in infrared making high quality light. Further they offer a tunability in wavelengths that is not given in any other phosphor material system – especially not in PSF.

The benefit of Quantum Dots for lighting and display is described in Yole report 2017[3]. Display technology uses colour filters to receive red, green, and blue colour. The filtered photons reduce the efficiency. The more narrow a spectrum the more efficient the emitter can be (for same initial quantum efficiency). Yole also states that the use of quantum dots can increase the overall display efficiency by a factor of 2.3 to 2.6 depending on the colour gamut target by simulation. The author assumes a factor of 1.5 to 2.0 in reality.

[3] Source: Yole report 2017, YOLE Development: Phosphors and Quantum Dots: LED Downconverters for Lighting and Display Applications; http://www.yole.fr/Phosphors_QD_BusinessOverview.aspx#.WucPipVPq71

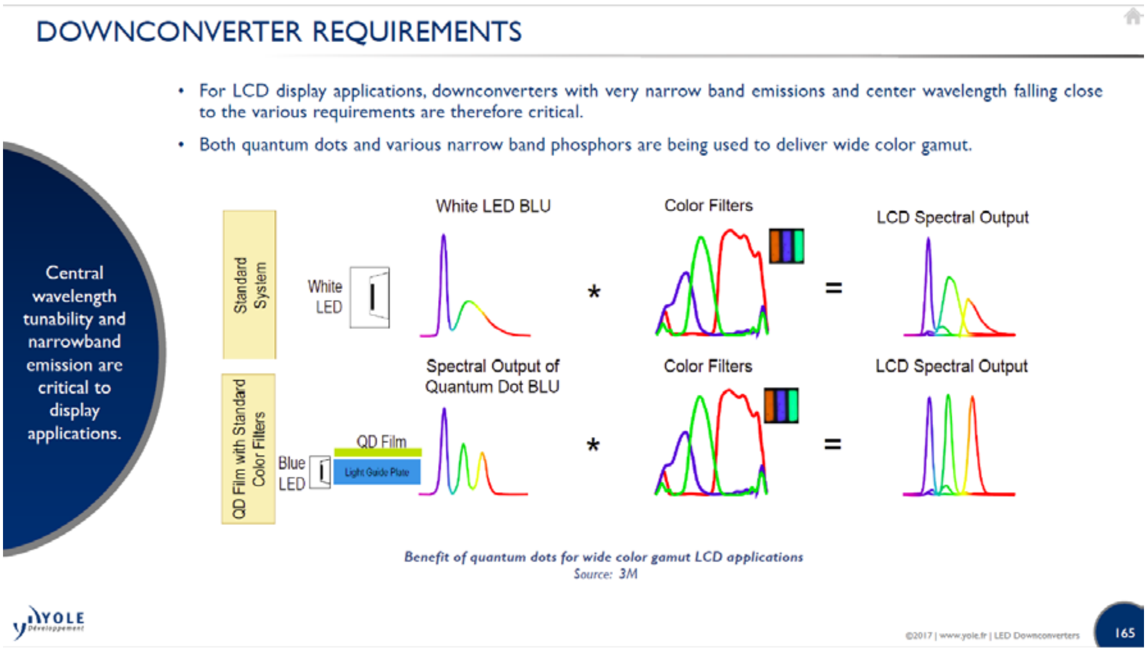


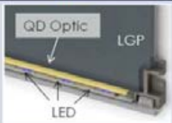
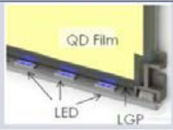
Figure 1: Spectra for backlighting LEDs with standard phosphors compared to the use of a film containing quantum dots[4].

In principle, there are three different ideas for the use of quantum dots in a display: a sheet in display size, a tube that has the lengths of an LED row, and the quantum dots that are directly in the LED package. The closer the converter material is placed towards the blue emitter the less material is needed.

Yole estimates ~ 40mg cadmium per 55" TV screen when a QD film is in use. The author further estimates for the same display size **less than 1 mg Cd** would be needed for one 55" TV when directly converted LEDs are used. The concentration of the near-chip solutions are higher in the applicable homogenous material than in the QD film but the absolute amount is much lower. Depending how the converter is applied within the LED and the desired degree of conversion the amount of converter differs significantly. For conversion to cold-white much less converter is needed than for warm-white or full colour conversion. However, if a very concentrated layer is placed directly on the chip less converter is needed than compared to the usual amount in volume cast which is a common conversion type.

[4] Source: Yole report 2017, YOLE Development: Phosphors and Quantum Dots: LED Downconverters for Lighting and Display Applications; http://www.yole.fr/Phosphors_QD_BusinessOverview.aspx#.WucPipVPq71

SUMMARY

	On-Chip	Edge	Surface
			
Photon recycling	Essentially single pass: high concentration required.	Little recycling: fairly high concentration required.	Multiple light reflection (up to 7x), further improved by adding scattering particles.
QD quantity estimates	At least 5x to 10x less than edge. Will depend on quantum efficiency.	1~2 mg for a 55" TV	3-6ug/cm → ~40 mg for a 55" TV
QD relative quantity	Lowest	Scales linearly with display diagonal.	Scales as the square of display diagonal.
Blue photon flux	Very high (20-50 W/cm²) → Requires very stable QDs	High (typical: 2W/cm²)	Low (< 1 W/cm2) → Increased stability, lifetime
Temperature	Very high 100°C+ → Requires very stable QDs	High (typical: 100°C)	Medium (50°C) → Increased stability, lifetime
Compatibility with standard LCD BLU design	No change in BLU design (replace standard phosphor with QD in the LED package). Edge or direct backlight.	BLU modification to affix the tubes, additional space required. Edge lighting only (no 2D local dimming).	Simple substitution of the diffuser sheet. Edge or direct backlight, compatible with 2D local dimming.
Additional BLU cost	Will depend on high stability QD cost.	~ $30-$35 for 55" TV	~ $50-60 for a 55" TV as of Q1-2017
Comments	Requires very stable QDs.	Cost-efficient for largest displays but incompatible with direct backlight and local dimming.	Easy to implement but cost scales up with display surface.
2017 status	First demonstration. 2018-2019 at best for commercial products.	Abandoned in 2017 models.	100% market share in 2017.

©2017 | www.yole.fr | LED Downconverters |182

Figure 2: Comparison of different technological approaches for display illumination[5].

Recently technology has been developed which allows QDs to be deployed inside the LED package. This allows LED manufacturers to use the least amount of QD material per lumen of light, and is also the lowest cost and most flexible way to utilize quantum dots in either lighting or displays. The added benefit of being able to use QDs directly in the LED package is utterly important for making this technology more economic and energy-efficient. However, solely cadmium-containing, high-performance QDs are applicable for on-chip LED application to-date. By design, QDs developed for use inside LED packages contain significantly less total cadmium than the remote QD implementation systems that are currently available and still preserve the performance benefits of increasing energy efficiency, higher quality of light and better color gamut that have been documented in previous RoHS exemption applications for cadmium in lighting and display applications[6].

[5] Source: Yole report 2017, YOLE Development: Phosphors and Quantum Dots: LED Downconverters for Lighting and Display Applications; http://www.yole.fr/Phosphors_QD_BusinessOverview.aspx#.WucPipVPq71

[6] LightingEurope, 2017: *LightingEurope request for a new exemptionfor the use of cadmium in luminescent material for on-chip application on LED semiconductor chips (lighting), Annex III of RoHS Directive 2011/65/EU*

What's next? – Future innovations

For future technologies µ-LEDs are needed for the use in displays and projectors. µ-LEDs are either LEDs that are much smaller in size than classical LEDs, e.g. 10µm x 10µm compared to 1mm², or a regular sized LED is segmented in a higher amount of small or tiny pixels that are individually addressable. Figure 3 shows cross-sections for a conventional converted LED and a pixelated LED. In this case the pixel pitch is 125µm. In this case no individual pixel conversion is shown. All pixels are converted to cold white for the use in automotive headlamp.

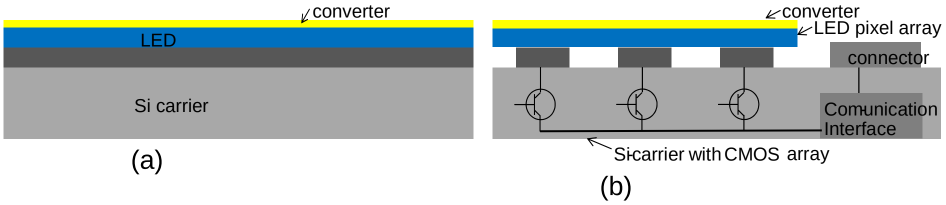


Figure 3: Schematic cross-section of a) a conventional LED and b) a pixelated LED array with the LED pixel array, the CMOS array and the assembly technology to connect both arrays[7].

For a µ-display or a µ-projector the pixels need to be much smaller and need to be converted individually to red or green. µ-displays and µ-projectors will enable the field of augmented and virtual reality as well as make for instance head-up displays more efficient. To cover a cross-sectional view of a µ-display is shown in Figure 4.

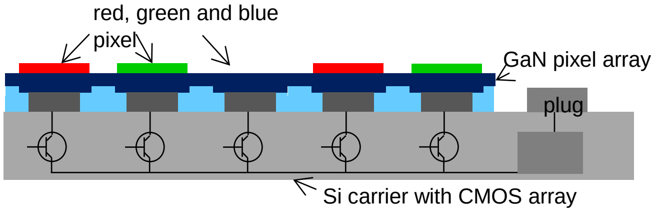


Figure 4: Micro-display with red and green converted pixels.

Augmented reality displays and Smart Glasses require micro-displays for image generation. Current technologies are based on reflective micro-displays like DLP (Digital Light Processing) and LCoS (Liquid Crystal on Silicon) or Micro-OLED displays. The

[7] 11th International Symposium on Automotive Lighting – ISAL 2015 – Proceedings of the Conference; http://www.beck-hop.de/fachbuch/inhaltsverzeichnis/9783831644827_TOC_001.pdf

reflective micro-displays are passive i.e. require an illumination optics which adds complexity and size to the system. The illumination is independent of image content i.e. all pixels are illuminated even if they are in off status. This means that power consumption is high. Micro-OLED are emissive i.e. active micro-displays. There is no need for illumination optics. There is no power consumption for pixel in off mode. Disadvantage of Micro-OLED is the relative low luminance and lifetime issues especially for blue. Therefore a Micro-LED micro-display would be a perfect solution. Luminance would be about 10x higher compared to Micro-OLED. RGB Pixel pitch needs to be in a range of 5µm and pixel count from 500k up to 2kk.

<u>Size Considerations</u>

Conventional inorganic phosphors come in grains of ~20µm in diameter. Obviously, it is not possible to convert pixels of 5µm or 10µm edge length with such grains. Therefore, converter material is needed that is much smaller in dimensions. Quantum Dots are only few nm in size. Organic molecules are even smaller but are, unfortunately, very instable against blue light. With having an extremely tiny emission area, e.g. 100µm², conventional volume cast techniques or similar is not an option. What is needed is a very thin concentrated conversion layer. Further, no high conversion thicknesses are wanted as illustrated in Figure 5. If the conversion thickness is too high, there will be cross-talk between the pixels ending in unwanted colour mixing. Therefore, a highly concentrated thin conversion film is necessary.

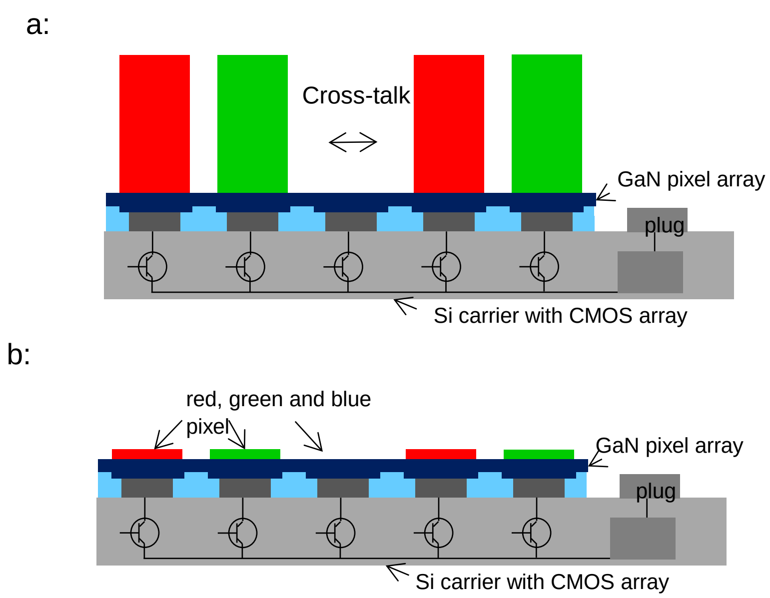


Figure 5: Scheme of pixel conversion with high and low converter thickness. a: strong cross-talk, b: thin layers lead to pure colours.

Most phosphor show re-absorption and concentration quenching effects that lower the efficiency of the device. It helps therefore to separate absorption and emission of the emitter. In Quantum Dots this is possible due to the core shell system in case the shell is grown adequately. Figure 6 shows the absorption and emission characteristics of conventional quantum dots (left side) and quantum dots where absorption and emission are more separated by a different core-shell concept (right side). With this separation the self-absorption effect are smaller allowing more dense packing.

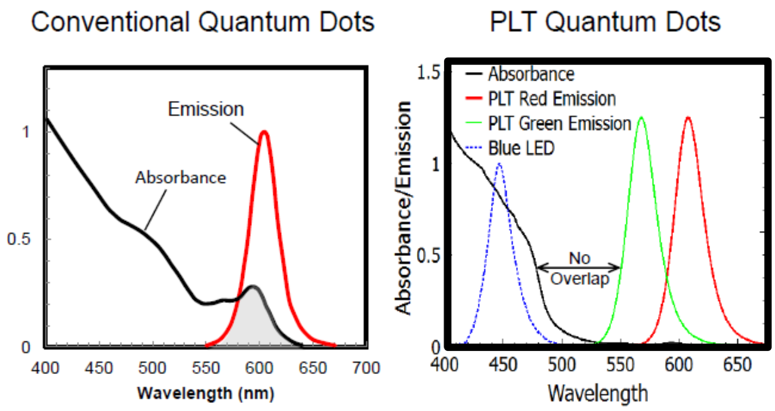


Figure 6: Example of absorption and emission spectra of conventional quantum dots and quantum dots with a different core-shell concept that separates absorption and emission[8].

Quantum dots serve as a replacement for conventional phosphors. They enable higher color quality and higher energy efficiency. At this time there are no alternatives to cadmium in quantum dots that can withstand the operation condition inside an LED package while providing the necessary performance and stability. The only quantum dot compositional system to date that has been proven to directly replace phosphors in LED packages is the Cd-based core/shell system.

In a neat film of Cadmium Sulfide (CdS) that is a good absorbing material a thickness of 530nm be sufficient to absorb ~99% of blue light. This corresponds ~2 – 5 µg per mm^2 on the chip surface. For most displays and projection areas the screen will be around a factor 100 larger. For augmented and virtual reality micro-display sizes of 0.2” to 1” would

[8] Source: Yole report 2017, YOLE Development: Phosphors and Quantum Dots: LED Downconverters for Lighting and Display Applications; http://www.yole.fr/Phosphors_QD_BusinessOverview.aspx#.WucPipVPq71

be used, i.e. the diagonal of arrangement of chips. The virtual image size results then in 5” to 50”, i.e. an enlarging factor of 25 to 50.

Coming from 2-5 µg Cd/mm² on the chip surface one ends up at 0.08 – 0.2 µg Cd/mm² screen area or less. In reality, the 530nm neat film from theory will be replaced by a highly concentrated film of QDs in a matrix of only few nm and the resulting Cd content might be higher, but even the double content will be far below 0.2µg/mm² screen area.

The requirement of an efficient emitter that is tiny in size and can be applied in very thin layers – today – can be fulfilled only by certain types of Cadmium containing Quantum Dots. However, the needed amount are very low. Additionally, the chips as well undergo a trend of miniaturizing further reducing the total amount of Cadmium.

Rationale for the exemption

This request for a RoHS exemption is justified on the basis that the safe use of minimal amounts of cadmium leads to a significant increase in the luminous efficacy of LEDs The same energy savings cannot currently be reached with similar technologies while maintaining product reliability and lifetime. As a result, utilization of cadmium-containing quantum dots has an overall positive environmental impact due to their lower energy consumption compared with currently available technologies. With reference to Article 5(1)(a) third criterion, a specific exemption for the use of cadmium for lighting applications is therefore justified. In addition to the reduction in energy and CO_2 emissions, other emissions derived from power plants will be reduced, including cadmium emissions. In fact, the low amount of safely incorporated cadmium per QD LED is much smaller than the amount of cadmium emitted over the lifetime of the LED by the generation of the additional electricity required if less efficient LED packages or competitive technologies would be operated. Additionally, on-chip QD technology enables the use of significantly less cadmium than use in remote applications. This application for an exemption is dedicated to on-chip QD downconverters for energy efficient display and projection applications. There is no technical substitute developed yet for the cadmium-based on-chip quantum dot technology. This application is intended to demonstrate that potential Cd-free alternatives fall far behind the performance and stability requirements to reliably. Due to their wider emission peak width and poor performance at elevated temperatures, as well as poor reliability, Cd-free QD materials are inadequate for the use in on-chip applications.

The technical description above shows that the intensive research and development on LED using Cadmium Quantum Dot technology led to innovations which:

- are suitable to reduce energy consumption of today used displays
- reduce materials and resources in these technologies
- need > factor 10 less Cadmium per appliance
- allows new and innovative applications which are not possible today with existing or announced technologies

Therefore we propose to use a change in the wording and propose:

Cadmium in downshifting semiconductor nanocrystal quantum dots directly deposited on LED chips for use in display and projection applications (< 5 µg Cd per mm^2 of light emitting LED chip surface).

4.1.2 Annex I category covered by this exemption.

List of relevant Annex I categories for this exemption

☒ 1 ☒ 2 ☒ 3 ☒ 4 ☒5

☒ 6 ☒ 7 ☒ 8 ☒ 9 ☒ 10 ☒ 11

Application in other categories, which the exemption request does not refer to: N/A

Equipment of category 8 and 9:

The requested exemption will be applied in

☒ monitoring and control instruments in industry

☒ in-vitro diagnostics

☒ other medical devices or other monitoring and control instruments than those in industry

Displays are in use in electrical and electronic equipment belonging to all 11 defined categories.

4.2 Description of the substance

4.2.1 Substance covered by this exemption

LightingEurope is asking for exempting

☐ Pb ☒ Cd ☐ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

Cadmium compounds (e.g. Cadmium selenide, Cadmium sulphide)

4.2.2 Function of cadmium in the light emitting diode

See description under chapter 3.

Quantum Dots (QDs) down-convert light – like phosphors from higher energy wavelengths (like blue) to lower energy wavelengths (like red or green). Several material classes are known here, however the ones with the by far best performance contain cadmium as main element. Their beneficial properties are a high efficiency coming with a narrow full width half maximum making it attractive for any display or projection applications, i.e. where very pure colours are required, but for illumination as well as one can avoid typical losses in infrared making high quality light. Further they offer a tunability in wavelengths that is not given in any other phosphor material system.

4.2.3 Location of Cadmium in light emitting diodes

See description under chapter 3.

Recently technology has been developed which allows QDs to be deployed inside the LED package. This allows LED manufacturers to use the least amount of QD material per lumen of light, and is also the lowest cost and most flexible way to utilize quantum dots in either lighting or displays. The added benefit of being able to use QDs directly in the LED package is utterly important for making this technology more economic and energy-efficient. However, solely cadmium-containing, high-performance QDs are applicable for on-chip LED application to-date. By design, QDs developed for use inside LED packages contain significantly less total cadmium than the remote QD implementation systems that are currently available and still preserve the performance benefits of increasing energy efficiency, higher quality of light and better color gamut that have been documented in previous RoHS exemption applications for cadmium in lighting and display applications[9].

[9] LightingEurope, 2017: *LightingEurope request for a new exemption for the use of cadmium in luminescent material for on-chip application on LED semiconductor chips (lighting), Annex III of RoHS Directive 2011/65/EU*

4.2.4 Amount of Cadmium per LED and total estimated Cadmium per year

See description under chapter 3.

The amount of Cadmium compounds in the homogenous material (from production point of view) can be up to 100% in a surface of ca 1-2 µm thickness. The overall amount per mm² light emitting chip surface is below 5 µg. According calculations in the YOLE report less than 1 mg Cadmium would be needed for a 55 inch TV screen, while with todays technology 40 mg would be needed.

According a very rough estimation 100 Mio TV screens (55 inch diameter) would need less than 100 kg Cadmium (compounds). The realistically estimated amount of Cadmium to be put on the market would be a few kg per year.

4.2.5 Environmental assessments, LCAs

See description in chapter 3.

Due to the similarity in technology OSRAM would like to reference to the LCA as provided by LightingEurope in their application for a new exemption for a very similar technology for lighting applications[10].

The technical description above shows that the intensive research and development on LED using Cadmium Quantum Dot technology led to innovations which:

- are suitable to reduce energy consumption of today used displays
- reduce materials and resources in these technologies
- need > factor 10 less Cadmium per appliance
- allows new and innovative applications which are not possible today with existing or announced technologies

[10] LightingEurope, 2017: *LightingEurope request for a new exemption for the use of cadmium in luminescent material for on-chip application on LED semiconductor chips (lighting), Annex III of RoHS Directive 2011/65/EU*

5 Waste management

5.1 Waste streams

☒ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

- ☐ The following parts are refurbished for use as spare parts: _____
- ☐ The following parts are subsequently recycled: _____

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

LED are part of nearly every electronic product (EEE). In the requested exemption the LED are used for display illumination. LED contain different materials for recycling (e.g. gold, plastics) as well as for non-recyclable materials. Most of these EEE are in the scope of EU Directive 2012/19/EU – WEEE. Take back systems are installed in all EU Member States: end users and most commercial customers can bring back display containing products (e.g. TV screens) free of charge. These end-of-life products are collected separately from general household waste and recycled in suitable facilities.

5.2 Amount of Cadmium in WEEE

Currently no data are available as the technology is in development. An estimated calculation for a 55 inch TV screen reveals less than 1 mg Cadmium compounds in total.

Assuming a weight of 20 kg for a 55" TV screen the total amount of CD per TV is less than 0.05 ppm (parts per million).

6 Substitution

Can the substance of this exemption be substituted?

☐ Yes, by
☐ Design changes:
☐ Other materials:
☐ Other substance:

☒ No
Justification: see chapter 3

6.1 Substituting cadmium in QD LED

The technical description above shows that the intensive research and development on LED using Cadmium Quantum Dot technology led to innovations which:

- are suitable to reduce energy consumption of today used display applications
- reduce materials and resources in these technologies
- need > factor 10 less Cadmium per appliance
- allows new and innovative applications which are not possible today with existing or announced technologies

At the same time the total amount of Cadmium is very low.

Quantum dots serve as a replacement for conventional phosphors. They enable higher color quality and higher energy efficiency. At this time there are no alternatives to cadmium in quantum dots that can withstand the operation condition inside an LED package while providing the necessary performance and stability. The only quantum dot compositional system to date that has been proven to directly replace phosphors in LED packages is the Cd-based core/shell system.

6.2 Socio-economic impact of substitution

Economic effects related to substitution: The described advantages are not feasible without using minimal amounts of Cadmium. Besides increased energy and resource efficiency also decreased prices for products and energy costs during use would not be possible.

☒ Increase in direct production costs
☐ Increase in fixed costs
☐ Increase in overhead

☒ Possible social impacts within the EU
☒ Possible social impacts external to the EU
☒ Other: higher costs for products and energy consumption.

6.3 Impact of substitution on innovation

Cadmium Quantum Dot LED for displays are very innovative components which while using very low amounts of the RoHS regulated substance offer high potential for energy efficiency and resource efficiency. They will allow new and innovating applications in the area of display and projection applications. Not granting the exemption will severely hamper innovation. According to the calculations in the LightingEurope exemption request for Cd-QD in lighting applications due to the similar technology OSRAM estimates that the reduction of Cadmium emissions from power plants outweigh the introduction of small amounts Cadmium in products.

6.4 Links to REACH, according to RoHS Directive Article 5(1)(a)

Do any of the following provisions apply to the application described?

no

☒ Authorisation	☐ Restriction	☐ Registration
☒ SVHC	☐ Annex XIV	
☐ Candidate list	☐ Annex XVII	
☐ Proposal inclusion Annex XIV	☐ Registry of intentions	

Provide REACH-relevant information received through the supply chain.
Not applicable due to the low amount

Not Applicable

7 Removal of cadmium

Can cadmium be eliminated?

☐ Yes.
☒ No, as explained in chapter 3

Cadmium free QD technology offering equal energy and resource efficient technologies are not available in the market and will not be as far as foreseeable in the coming 5 years.

8 Reduction of cadmium content in LED

See description in chapter 3.

According calculations in the YOLE report[11] less than 1 mg Cadmium would be needed for a 55 inch TV screen, while with today's technology 40 mg would be needed.

So the research and development on Cd-QD technology brought significant progress regarding the amount of Cadmium compounds in the final application

9 Other relevant information

OSRAM would like to reference once more the Exemption Request of Lighting Europe including the accompanying LCA and Impact Assessment and including the references and arguments therein. The contact persons under chapter 1 are available for any kind of question or information request[12].

10 Information that should be regarded as proprietary

Not applicable

[11] Source: Yole report 2017, YOLE Development: Phosphors and Quantum Dots: LED Downconverters for Lighting and Display Applications; http://www.yole.fr/Phosphors_QD_BusinessOverview.aspx#.WucPipVPq71

[12] LightingEurope, 2017: *LightingEurope request for a new exemptionfor the use of cadmium in luminescent material for on-chip application on LED semiconductor chips (lighting), Annex III of RoHS Directive 2011/65/EU*

List of abbreviations

Cd QD	Cadmium Quantum Dot
LCA	Life cycle assessment
LED	Light Emitting Diode
lm	Lumen
PSF	Potassium fluorosilicate
R&D	Research and Development department(s)
REACH	Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals, 1907/2006/EC
RoHS	EU Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
SSL	Solid State Lighting
SVHC	Substances of Very High Concern
WEEE	Waste Electrical and Electronic Equipment