Exemption Request Form

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1. Name and contact details

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2. Reason for application:

Request for extension of existing exemption in Annex III 39(a)

Proposed wording: Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications (<0.1 µg per mm^2 of display screen area)

Duration: Extension for 2 years.

3. Summary of the exemption request:

Cadmium selenide QDs have excellent luminescent property, and energy effectiveness, while Cadmium free QDs still can not satisfy customers with its normal performance even in October 2019. QDs industry may be severely effected due to the weakness showed by Cadmium free QDs, as display industry is very competitive, market may choose less energy effective technology to fullfill customer's need. QD industry' growth is slow, we are perfecting cadmium QDs for 20 years, and have a deep knowledge towards QDs, we apply for 2 years extension for QD companies to perfect cadmium free QDs, based on the information we got, till now there is no equivalent accomplished in the world.

4. Technical description of the exemption request/revocation request

(A) Description of the concerned application:

1. To which EEE is the exemption request/information relevant?
Name of applications or products: Quantum dot light converting film used in display device.

a. List of relevant categories:
1. Large household appliances.
2. Small household appliances.
4. Consumer equipment.
5. Lighting equipment.

2. Which of the six substances is in use in the application/product? Cd

3. Function of the substance

The substance is Cadmium-based quantum dots (QDs). QDs are semiconductor nanocrystals, with sizes ranging from 1~100 nm, and have quantum confinement effect. By tuning sizes through synthesis process, QDs are able to emit different wavelengths, such wavelengths cover can the whole visible light spectrum from blue wavelength range to red wavelength range. QDs are amazing photoluminescent material that human can manipulate them to grow and achieve desired light emitting property, differentiating itself from other photoluminescent materials, such as phosphor, or organic dye.

QDs emit narrow full width at half maximum (FWHM) light, which means the color is pure to human eyes. Having such property, QDs are used in display panels and become the best wide color gamut solution. Besides the color gamut increase, QDs shows energy efficiency comparing with other traditional components in liquid crystal display, such as phosphor LED or cold cathode fluorescent lamp.

Cadmium-based QDs are first studied type QDs, from laboratory to factory, it takes nearly 30 years to mature. Till now, cadmium-based QDs has 20~30 nm of FWHM and are stable in display applications, with expected lifetime for 10 years.

4. Content of substance in homogeneous material (%weight):

Please see the following Table 1, as the area getting bigger, the film thickness getting thinner, the weight percentage of cadmium increases.

Display device categorized by screen area	ppm
TV	240~500
Monitor	300~400
Pad	600~800
Cellphones	800~1000

5. Amount of substance entering the EU market annually through application for which the exemption is requested:

It is estimated that typically 101 kg of cadmium will be placed on the EU market annually by this application. Table 2 outlines the calculations used to develop this estimation. Please note that the applications are all LCD type display.

Application	EU Annual shipment	LCD %[3]	EU Annual LCD Area (m^2)	% Using QD Film in EU (m^2)	LCD Area Using QD Film in EU (m^2)	Typical Cd content per LCD Screen Area (μg/mm^2)	Total EU Cadmium (kg)
4K/8K TV	24,000,000	85%	17,013,600	5%	850,680	0.05	42.534
Monitor	24,000,000	85%	2,019,600	10%	201,960	0.05	10.098
Notebook	25,000,000	80%	920,000	35%	322,000	0.08	25.76
Pad	32,000,000	80%	345,600	25%	86,400	0.08	6.912
Small displays (phones, etc)	180,000,000	50%	630,000	25%	157,500	0.1	15.75
Total							101.054

In 2014 the worldwide shipment: LCD TV was 253 million units, Monitor was 156 million units, Notebook was 199 million units, Pad was 93 million units [1]. We predict the shipment based on the trend that LCD TV, Monitor, Notebook may be deceased in 201911~202110 due to mobile terminals are more popular and most of them has long lifetime and low replacement rate, Pad may increase slowly since 2014. Smart phone shipment was 1.44 billion units in 2017 according to IHS[2]. Suppose that EU market has a market ratio of 25%, 55 inches TV's area = 0.834 m^2, 19 inches Monitor's area= 0.099 m^2, 13 inches Notebook's area= 0.046 m^2, 7 inches Pad's area = 0.0135 m^2, 5 inches cellphone's area= 0.007 m^2. The percentages using QD film actually are optimistic prediction by us. The percentages using QD film in TV in China last year was about 2%.

Note: The quantum dot tube is an existing product but it is decreasing and may disappear in 2019, so cadmium of such product is not calculated.

[1]: IHS technology, Large area display market tracker 2015, by Peter Su, Senior Analyst

[2]: IHS Markit: Global smartphone unit shipments grew 3% in 2017, by Jusy Hong, Gerrit Schneemann.

[3]: optimistic prediction by us, OLED has a strong momentum in small displays, but low penetration rate in big screens, because the cost of OLED is too high to enlarge the market.

6. Name of material/component:

Material with Cadmium-based QDs dispersed in an optically transparent media, the media may be plastics, glass or ceramic. The material can be in film-shaped, and used as a component in LCD backlight.

7. Environment Assessment: We incorporate 3M LCA as reference.

B) In which material and/or component is the RoHS-regulated substance used, for which you request the exemption or its revocation? What is the function of this material or component?

The quantum dot converting film is used to convert the blue light emitting from LED chips to green and red light, thus mixing RGB to produce white light, then the white light passes liquid crystal and color filter to form RGB pixels.

C) What are the particular characteristics and functions of the RoHS-regulated substance that require its use in this material or component?

The cadmium-based quantum dots have very narrow photoluminescent peak, it is easy to provide wide color gamut, moreover, the energy can be saved by this property. The detailed function and characteristics are described by 3M and QD vision.

5. Information on Possible preparation for reuse or recycling of waste from EEE and on provisions for appropriate treatment of waste.

1)Please indicate if a closed loop system exist for EEE waste of application exists and provide information of its characteristics (method of collection to ensure closed loop, method of treatment, etc.)

Currently, the application of QDs is mainly various sized liquid crystal display devices. As LCD falls into the scope of WEEE directive, percentage targets of LCD waste stream be 80% wt Recovery and 70% wt reuse and recycling in August 2018, EU countries has its own system to achieve those targets. The LCD waste process usually comprises consumption—collection--transport—sorting--depollution/dismantling/shredding--secondary processing--secondary raw materials /land fill/reuse. The main product format of QDs is QD converting film, in the post-consumer phase, plastic collection can be managed by the LCD recycling system, honestly, plastic reuse may be challenging. The plastic film is made by curing a mixture of resins and QDs embedded in those resins. The cadmium originated from QDs can be collected after combustion of plastics, however this challenge happens in various plastics too, such as mixture of plastics cannot be separated back to single plastic, or plastic with dyes cannot change back to clear plastic.

2) Please indicate where relevant:

Article is collected and dismantled:

There is a wealthy resource in LCD, such as precious metals, specific type of plastics, steels, glass, liquid crystal. Table 3 is cited to show the resource of LCD waste.

Material	Component	Part
Aluminized mylar	Backlight assembly	Corner tape
Aluminum	LCD assembly; power supply assembly	Glass panel assembly (thin-film transistor); heat sink
Beryllium copper	LCD assembly; rear cover assembly	Metal clip, beryllium-copper fingers
Borosilicate	LCD assembly	Glass panel assembly
Brass	Backlight assembly	Brass threaded stand off
Chromium	LCD assembly	Glass panel assembly (black matrix for color filter)
Discotic liquid crystal	LCD assembly	Glass panel assembly (compensation films)
Epoxy resin	LCD assembly	Glass panel assembly (sealant)
Foam rubber	Backlight assembly	Gasket
Gold	LCD assembly	Glass panel assembly (electrical conducting dots)
Hi-mu ferric	Backlight assembly	Flat cable toroid
Indium-tin oxide (ITO)	LCD assembly	Glass panel assembly (electrode)
Iodine	LCD assembly	Glass panel assembly (polarizers)
Lead	LCD assembly	Solder
Liquid Crystals	LCD assembly	Glass panel assembly
Molybdenum	LCD assembly	Glass panel assembly (thin-film transistor)
Nylon	Backlight assembly; base/stand assembly	Nylon clamp; strain relief bushing
Plastics and plasticisers (phthalates)	Power supply assembly; rear cover assembly; base stand assembly	Power cord receptacle; rear covers
Polycarbonate	Backlight assembly	Light guide; rear plate assembly

Material	Component	Part
Polycarbonate, glass-filled	LCD assembly	Plastic frame
Polyester	LCD assembly; power supply assembly; backlight assembly; rear cover assembly	Brightness enhancement films; opaque diffuser; white reflector; insulator; power switch
Polyester, glass-filled	Base/stand assembly	Upright
Polyimide	LCD assembly	Glass panel assembly (alignment layer)
Polymethyl methacrylate	Backlight assembly	Clear protector
Polyvinyl alcohol (PVA)	LCD assembly	Glass panel assembly (polarizers)
Resins	LCD assembly	Glass panel assembly (color filter)
Silicon nitride (SiNx)	LCD assembly	Glass panel assembly (thin-film transistor)
Silicone rubber	LCD assembly; backlight assembly; base/stand assembly	Gaskets; light assembly (shock cushion); rubber feet
Silver	LCD assembly	Glass panel assembly (electrical conducting dots)
Soda lime	LCD assembly	Glass panel assembly (glass)
Stainless steel	Base/stand assembly	Swivel bearing
Steel (iron)	Power supply assembly; backlight assembly; LCD assembly; rear cover assembly; base/stand assembly	Housing; screws; metal plate; rear plate; hold-down plate; metal plate brackets; waskers; axle and spring; base weight; C-clip
Triacetyl cellulose (TAC)	LCD assembly	Glass panel assembly (polarizers)

Source: Handbook of Visual Display Technology, Sustainability in LCD Manufacturing, Recycling and Reuse, pp 2621-2639, Author: Avtar Singh Matharu

3) Please provide information concerning the amount (weight) of RoHS

substance present in EEE waste accumulates per annum:

Quantum dots have its lifetime, after consumption, the quality of quantum dots degrade, making the QD film unable to be refurbished, so the accumulates per annum is zero. Land-filled is not suitable for plastic film, very likely difficult to be decomposed in nature, thus we suggest the accumulates per annum is zero. Energy return is of high possibility, the cadmium will be 101 kg/year as estimated before.

6. Analysis of possible alternative substances

(A) Please provide information if possible alternative applications or alternatives for use of RoHS substances in application exist. Please elaborate analysis on a life-cycle basis, including where available information about independent research, peer-review studies development activities undertaken

The possible alternative substance is cadmium free quantum dots, at present, cadmium free QDs still suffer from wide emission spectra and higher energy compared with Cadmium-based QDs, though a lot of efforts have been put into.

The life cycle of Cd QDs will be described as the following.

The worker's contamination of cadmium is very low in large scale manufacturing, machine operation is more frequent than hand operation, by enhancing proper practice training and protection, contamination can be controlled at zero, in the past years our workers were tested for blood cadmium level, all the results were normal. In addition, our factory is in China, so it will not affect European workers.

After manufacturing, QDs are incorporated into a polymer matrix as a homogenous material (and then either placed between low-permeability barrier films), then QD films are incorporated into displays covering the full size of the display and placed behind the LCD screen. Unlike CFL light sources, there is no mechanism for the release of the QD material from the display itself. The QD materials are non-volatile and are encapsulated in the film.

The potential risk for cadmium exposure is when after the service life the devices are disposed of. Especially airborne emissions due to incineration can have a significant effect on human health. Therefore, multiple end-of-life scenarios are included to take into account the uncertainty related to future actions. The first two scenarios are in accordance with current practice, namely sanitary landfill and municipal waste incineration. As a highly conservative assumption, uncontrolled open air incineration has been included as well. This is not common practice in the European Union due to current waste treatment regulations, but since the related emissions have a significant effect on human health, it is included as a 'worst case' scenario.

The life cycle of cadmium free QDs is similar to cadmium based QDs, except that cadmium free metal is less toxic to environment. The most promising cadmium free QDs are Indium phosphide.

Cd is not considered a "critical raw material" and supply is expected to remain plentiful. In contrast, indium has been identified as a "critical raw material" by the EC because of its growing use in electronics, photovoltaic and other applications. Unfortunately, there is little, if any indium recycling, with recycling limited to recovery of industrial production waste. Increasing demand, coupled with heavy dependence on imports from China, which is the largest supplier of indium, can lead to a significant supply risk. An estimate of the indium demand from In-based QDs suggests an increase of “just 15%” compared to standard LCD displays. Fifteen percent is not a negligible increase in demand and could easily lead to substantially more expensive QDs and other products relying on indium as supplies are stressed.

(B) Please provide information and data to establish reliability of possible substitutes of application and of RoHS materials in application

Cadmium free QDs are manufactured and placed into market by Samsung, so reliability of Cadmium free QDs is not the big concern, our concern is their performance.

7. Proposed actions to develop possible substitutes

(A) Please provide information if actions have been taken to develop further possible alternatives for the application or alternatives for RoHS substances in the application.

Indium phosphide (InP) QDs are the most attractive alternative for RoHS substances in the application owing to their lower toxicity and emission tenability ranging from visible to near-infrared region. However, two major challenges need to be addressed to release the full potential of InP QDs in display applications. First, the color purity of InP QDs needs to be improved. The commercialized cadmium-free QDs film of Samsung have 40nm full width at half maximum (FWHM), which are wider than Cd QDs (<30nm FWHM). Second, the quantum efficiency need to be increased. The high quantum efficiency of the Cd QDs is typically higher than 88%, which is necessary for QD film based backlights to deliver higher power efficiency (12% - 45% more energy efficient than traditional LED LCDs for color gamut sizes from 70% NTSC to 100% NTSC). However, the quantum efficiency of the Cd-free QDs is lower than 70%.

(B) Please elaborate what stages are necessary for establishment of possible substitute and respective timeframe needed for completion of such stages.

The performance of Cd-free quantum dots (based in InP) is expected to reach the current color quality and energy consumption performance of cadmium quantum dots by 2020. Full commercialization will be achieved by 2022.

8. Justification according to Article 5(1)(a)

(A) Links to REACH: (substance + substitute)

1) Do any of the following provisions apply to the application described under (A) and (C)?

Only Restriction Annex XVII, others are NO.

2) Provide REACH-relevant information received through the supply chain.

Cadmium and its compounds are listed in No. 23 of Annex XVII .Mixtures and articles produced from plastic material as listed shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0.01 % by weight of the plastic material.

The requirement that cadmium content less than 0.01% is as same as limitation of RoHS. Regarding the plastic material that quantum dots embedded in, there are other options for quantum dots besides the plastic types described in REACH, such as polyacrylate, silicone, meaning Annex XVII 23 can be satisfied in practice.

The raw materials for colloidal chemical synthesis of quantum dots include cadmium precursor, such as cadmium oxide, cadmium carboxylate, and organic solvent, such as octadecylene, and ligands for protecting quantum dots, such as fatty acids. Only cadmium oxide among all cadmium precursors has been entered into the SVHC list.

(B) Elimination/substitution:

1. Can the substance named under 0(A)1 be eliminated?
No. Justification:

Test was conducted to detect the performance difference between Cadmium based QD film and Cadmium free QD film. From energy saving perspective, Cadmium based QD film has saved 16% energy compared with Cadmium free QD film. Energy saving is the most attractive strength for mobile society and severe energy shortage human confronts.

TV	QD Film	Luminance(nit)	Power (W)	Luminance Efficiency (nits/W)	Energy saving	NTSC Area (1931)
TCL X3	CdSe-based	484.5	170	2.85	116%	110.32%
Samsung Q7C	InP-based	686	280	2.45	100%	99%

2. Can the substance named under 0(A)1 be substituted?

Yes. Indium-based quantum dots are under developed with gradualproperty improvement.

3. Give details on the reliability of substitutes (technical data + information):

The Indium-based QDs have been commercialized by Nanoco and Samsung, even though the properties has a gap between Cadmium-based quantum dots.

4. Describe environmental assessment of substance from 0(A)1 and possible substitutes with regard to Environmental impacts, Health impacts, Consumer safety impacts.

We incorporate 3M LCA and QD vision LCA in 2015 as references.

(C) Availability of substitutes:

a) Describe supply sources for substitutes:

Cd-free dots (InP QDs) were synthesized by In precursor and P precursor. In precursor is typically Indium salt, such as, Indium acetate，Indium chloride. Indium is a very scarce material obtained as a byproduct from mining other metals. P precursor is typically Tris(trimethylsilyl)phosphine ($(TMS)_3P$). At present, there are only a few companies, such as Samsung, Dow and Nanoco, which can produce Cd-free InP-based quantum dots.

b) Have you encountered problems with the availability? Describe:

Yes. Many problems with the availability should be resolved. First, the performance of the InP dots from different company are different. Second, the performance of the InP dots are lower than the Cd dots. And these hinder the applications of the InP dots.

c) Do you consider the price of the substitute to be a problem for the availability?

Yes. The price of InP dots is higher than Cd dots, because their synthetic materials are expensive and their synthetic process is more complex.

d) What conditions need to be fulfilled to ensure the availability?

(1) High color quality (high color gamuts), which is an extremely important factor in determining a display’s perceptual quality. Minimize the FWHM of the InP dots.

(2) Low energy consumption, improvement of Quantum yields of the InP dots.

(D) Socio-economic impact of substitution:

What kind of economic effects do you consider related to substitution? Increase in direct production costs. The cost of manufacturing InP QDs is much higher than Cadmium-based quantum dot.

Provide sufficient evidence (third-party verified) to support your statement: We incorporate 3M Socio-economic in 2016 as reference.

9. Other relevant information

No

10. Information that should be regarded as proprietary

No