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Application of RoHS exemptions No. 13b “Cadmium and lead in filter glasses and glasses used for reflectance standards” and No 39 on Colour Conversion Diodes for Nanosys quantum dot technology

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1. Background

Nanosys has developed novel technology based on optical devices that contain cadmium which are intended to be used in a variety of electrical products. As these contain cadmium, Nanosys needs to establish whether they are within the scope of RoHS exemptions 13b or 39. Nanosys has asked ERA for its opinion as ERA originally carried out an investigation into exemption 13 for the European Commission in 2004 and is also very familiar with exemption 39.

2. Scope of exemptions

The similarities and differences between the Nanosys products and the technology used for exemptions 13b and 39 are as follows:

	Nanosys optical filter	Exemption 13b: Optical filter glass	Exemption 39: Colour converting II-VI LEDs
Applications (examples)	Light projectors, displays, LED filters	Projectors, runway lighting	Solid state illumination (lighting) or displays
Light filtering element	Cadmium compounds such as cadmium selenide	Cadmium compounds	Compounds of cadmium and group VI elements such as selenium and tellurium

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Matrix	Glass polymers	All types of glasses, would include both inorganic and organic	Layers of II-VI compound
Unique properties	Sharp cut-off characteristics produced by cadmium compounds	Cadmium filters have a very sharp cut off which is essential for some applications and not achievable by alternative materials	Converts blue LED light into any combination of visible light wavelengths
Function	Converts light of one colour (from LED) into light of different wavelengths	Most optical filters adsorb part of the visible spectrum to allow a specific portion to pass through. In practice, the adsorbed light energy is converted into energy of other wavelengths (e.g. as heat)	Converts blue LED light into light of a different wavelength

Nanosys have developed materials that behave as conversion filters based on nanosize particles of cadmium compounds embedded in a glass – polymer matrix. This technology clearly has similarities with both exemptions 13b and 39. Nanosys conversion filters, 3M’s II-VI light converter technology (exemption 39) and traditional glass optical filters (exemption 13b) are used for similar applications and the optical effect is achieved in both by the characteristics of the cadmium compounds used. It was established in the ERA 2004 review and in 2008 by the Oko Institut review that no suitable alternatives to cadmium are currently available for these applications. There are differences relating to the exemptions between the Nanosys material, traditional glass filters and the II-VI materials of exemption 39 which are discussed below.

Exemption 13b: In 2004, no filters based on polymer glasses existed and so were not considered in the ERA review. Nanosys refer to the filter material as an organic glass or a glass polymer. Glass is traditionally understood to be an inorganic material but developments over recent years have changed the perception of what glass is. RoHS exemptions are themselves definitions of scope. In the case of exemption 13b, the scope is broad and covers all optical and filter glass. This was accepted because lead and cadmium based optical filter glass is in general more expensive than lead and cadmium free types and so manufacturers use glass containing these elements only in applications where there are no substitutes available. In applications where lead-free and cadmium-free glass can be used, these are automatically chosen because of the price advantage and so the exemption definition does not result in unnecessary use of these elements. Neither the definition nor ERA’s report defined the term “glass”, as in 2004 this was not deemed necessary.

It is apparent from published literature that the term glass is understood by the general public to be an inorganic material but those involved in research and development of novel materials have a much broader understanding of the term and there are several references to organic or polymer glasses. As an example,

Eastman markets a copolyester resin under the trade name “Glass Polymer”². Traditionally glass has been made by melting materials together and the glass forms on cooling. However glass is now also made by other techniques such as sol-gel which is a chemical process. Contact lenses can be made by sol-gel and soft contact lenses are transparent organic “glassy” materials such as 2-hydroxyethyl methacrylate hydrogels. Transparency does not appear to be an essential requirement as metals can exist in a glassy (non-crystalline) state and volcanic rocks such as obsidian have long been regarded as glasses. Some older definitions of glass regard it as a super-cooled liquid but this is now regarded as wrong. True super-cooled liquids are still liquids not solids and glass is now widely understood to be a non-crystalline, amorphous or vitreous materials that have disordered structures. Therefore if an organic material has these properties it would follow that it could be regarded as a glass.

A main question therefore is whether the organic polymer matrix used by Nanosys can be regarded as a “filter glass” and so be within the scope of exemption 13b. From ERA’s recent investigations, it appears that there is strong evidence that “glass” can be both inorganic and organic materials; the only important characteristic is that it is a completely non-crystalline solid.

The intended applications of Nanosys technology are similar to those that use traditional inorganic optical glass filters, i.e. lighting and displays. However, most optical filters function by adsorbing unwanted wavelengths and allow the other wavelengths to pass unaffected. There are also optical filters that change the wavelength range by interference and so achieve a filtering effect in a different way. The technical mode of function of the cadmium in the Nanosys technology is slightly different to band-pass and interference filters in that it adsorbs the incident wavelength and then re-emits the light at a different wavelength, i.e. it behaves as a conversion filter. Other suppliers of light conversion filters include Schott³. Nanosys filters achieve a sharp wavelength cut-off that is characteristics of inorganic band-pass filter glasses but they use a light conversion mechanism to achieve this.

Exemption 39: This exemption was requested by 3M to cover their novel II-VI technology⁴ which uses II-VI compounds that may contain cadmium. The II-VI compounds may be adjacent to the diodes or used as separate layers within the device as described by the patent. RoHS exemption 39 allows the use of “colour converting II-VI LEDs” for use in two applications, i.e. lighting and displays. Therefore, this exemption is limited to devices based on LEDs with some form of colour converting material that is based on II-VI compounds, that changes the colour of the light emitted from the LED into light of different colours. Exemption 39 does not specify the construction or design of the diode device or the form of the II-VI compounds that are used. Exemption 39 would include cadmium compounds dispersed into a transparent glass or polymer matrix, as long as this is used with a diode, where the cadmium compound is a II-VI compound that “colour converts”. Nanosys uses cadmium selenide which is an example of a II-VI compound and this is used for colour conversion. The Nanosys technology may be packaged in a variety of ways. This can be as a laminated film or a sealed package (e.g., a glass capillary or disk with the quantum dot

² Website <http://www.innovationlab.eastman.com/InnovationLab/Materials/GlassPolymer/index.htm>

³ <http://www.optical-filters.com/conversion.html>

⁴ US Patent US 7863634 “LED device with re-emitting semiconductor construction and reflector” M. A. Haase.

material sealed inside) and is sold either as an integral part of the LED device (e.g., adjacent to the light emitting diode) or as a separate layer/part to be integrated with the light emitting diode, similar to 3M's patented technology. The Nanosys technology, which emits light upon excitation, can be either a "II-VI LED device" within the definition of this exemption, or can be an integral part of an LED device and so would also be covered by this exemption.

3. Discussion and Conclusions

Two exemptions have been considered for applicability to Nanosys technology that uses a dispersion of cadmium compounds in a polymer glass matrix to convert light of one colour into another. In many respects, the transparent matrix could be described as a "filter glass", being transparent and amorphous it is a type of glass and as it is coloured and changes the wavelength of light that passes, it could be described as a type of optical "filter" although it is not the same as most types of optical filters that function by blocking certain wavelengths and allowing others to pass unchanged, i.e. no wavelength conversion occurs within the filter material. Nanosys technology does appear to be within the scope of exemption 13b as the quantum dot technology is a type of "optical filter". Exemption 39 has a narrower scope than 13b and is specific to electrical devices based on diodes that are associated with a II-VI compound within the device that "colour converts". These devices are exempt only for illumination and display applications. This exemption is therefore also applicable to Nanosys technology that uses the wavelength converting cadmium based organic glass matrix with a LED device for lighting and display applications.

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