Consultation Questionnaire Exemption 1(c) of RoHS Annex IV

Current wording of the exemption:

Lead, cadmium and mercury in infrared detectors

Expires on 21 July 2021 for equipment of cat. 8 and 9 other than in-vitro diagnostics and industrial monitoring and control instruments

1. Acronyms and Definitions

FTIR	Fourier transform infra-red
HgCdTe	Mercury cadmium tellurium (MCT)
JBCE	Japan Business Council in Europe
LWIR	Long wavelength infrared
MCT	Mercury cadmium tellurium
MWIR	Medium wavelength infrared
PbSe	Lead selenide
PbS	Lead sulphide
PPTF	Polish Technological Platform on Photonics
PZT	Lead zirconate titanate
IR	Infrared
S/N	Signal over noise

2. Background

Bio Innovation Service, UNITAR and Fraunhofer IZM have been appointed[1] by the European Commission through for the evaluation of applications for the review of requests for new exemptions and the renewal of exemptions currently listed in Annexes III and IV of the RoHS Directive 2011/65/EU.

COCIR, JBCE, LASER COMPONENTS, PerkinElmer and PPTF have submitted requests[2] for the continuation of the above-mentioned exemption. The requests have been subject to a first completeness and plausibility check. The applicants have been re-quested to answer additional questions and to provide additional information, available on the request webpage of the stakeholder consultation.[3]

[1] It is implemented through the specific contract 070201/2020/832829/ENV.B.3 under the Framework contract ENV.B.3/FRA/2019/0017

[2] Exemption requests available at https://rohs.biois.eu/Ex_1c-IV_COCIR_Renewal-Request.pdf, https://rohs.biois.eu/Ex_1c-IV_JBCE_Renewal-Request.pdf, https://rohs.biois.eu/Ex_1c-IV_LC_Renewal-Request.pdf, https://rohs.biois.eu/Ex_1c-IV_PE_Renewal-Request.pdf, https://rohs.biois.eu/Ex-1c-IV_PPTF_Renewal-Request.pdf

[3] Clarification questionnaire available at https://rohs.biois.eu/Ex_1c-IV_COCIR_Questionnaire-1_Clarification.pdf, https://rohs.biois.eu/Ex_1c-IV_JBCE_Questionnaire-1_Clarification.pdf, https://rohs.biois.eu/Ex_1c-IV_LC_Questionnaire-1_Clarification.pdf, https://rohs.biois.eu/Ex_1c-IV_PerkinElmer_Questionnaire-1_Clarification.pdf, https://rohs.biois.eu/Ex_1c-IV_PPTF_Questionnaire-1_Clarification.pdf

trinamiX would like to provide a stakeholder contribution.

SUMMARY OF THE EXEMPTION REQUEST OF **JBCE**

JBCE requests the renewal of the exemption in its current scope and wording:

Lead, cadmium and mercury in infrared detectors

According to JBCE, "Infrared (IR) analysis and measuring instruments provide a rapid, accurate analysis of materials to provide information on the chemical composition, surface properties and spatial distribution of substances. The technology is utilised by a wide variety of industry sectors, researchers and for educational purposes, examples of which are given in this exemption request.

The choice of semiconductors intrinsically affects the infrared range detectable and usefulness of the signal produced. The current infrared detectors have features such as higher sensitivity and wider measurement wavelength ranges than their substitutes; as such substitutions are not capable to fulfil the requirements of analysis and measuring instruments."

The applicant requests a renewal of this exemption for 7 years for all equipment of cat. 8 and 9.

SUMMARY OF THE EXEMPTION REQUEST OF **COCIR** AND **LASER COMPONENTS**

COCIR and Laser Components request the renewal of the exemption with the following scope and wording:

*"**Lead in infra-red light detectors**".*

Both applicants request a renewal period of 7 years.

According to COCIR, "PbSe infrared detectors are used in medical devices called capnometers, which are used to monitor the breathing of patients in EU hospitals and clinics. PbSe is the only detector material that meets all of the essential criteria and is able to detect small changes in breathing using a capnometer that can be indicative of health conditions as well as difficulties with breathing. All potential substitutes either do not adequately respond to changes in CO_2 concentrations in patients' exhaled breath, they respond too slowly, or the detectors require cooling. Cooling requires extra bulky equipment and would cause condensation of water from exhaled air onto the detector's surface. This will freeze and the ice crystals will block infrared light and so make the detector insensitive."

According to Laser Components, "PbSe and PbS infrared detectors have unique characteristics that enable them to be used in a wide variety of applications. They are used in near infrared analysers used by very many diverse industries, medical devices for analysis of carbon dioxide in patients' breath and in spark detection systems. These detectors are used because of their high sensitivity in the near infrared range and can be used without cooling. Another advantage over thermal heat detectors is the very fast response times of the lead based detectors, which is essential in many applications."

SUMMARY OF THE EXEMPTION REQUEST OF **PPTF**

PPTF requests the renewal of the exemption with the following scope and wording:

*"**Cadmium and mercury in infra-red detectors**"*

According to PPTF, "The variable band gap $Hg_{1-x}Cd_xTe$ (also called in short HgCdTe or MCT) has been undeniably the champion among the large variety of material systems, offering 2x up to 100x better detectivity levels in the MWIR (3 to 8µm) and especially LWIR (8 to 14µm) spectrum. The are possible substitutes used in less demanding measurement applications – III-V compound semiconductor detectors. However, despite many years of development there have not been yet any commercially available detectors matching MCT detectors in terms of detectivity."

The applicant requests a renewal of this exemption for 7 years.

SUMMARY OF THE EXEMPTION REQUEST OF **PERKINELMER**

PerkinElmer requests the renewal of the exemption with the following scope and wording in the clarification questionnaire:

*"**Cadmium and mercury in infra-red detectors of Fourier transform infra-red (FTIR) spectrometers and microscopes**"*

PerkinElmer claims "[…] that MCT [mercury cadmium telluride] is the only detector material currently available which is able to provide all of the following characteristics required for FTIR spectrometers and microscopes:

- *Photoconductor with an electrical resistance that decreases as the level of incident infra-red light increases;*
- *High sensitivity to small infra-red light level changes producing a strong signal;*
- *Low dielectric constant, ensuring that the signal to noise ratio is maximised;*
- *Relatively low electrical resistance when not exposed to infra-red light;*
- *Low noise, otherwise averaging methods have to be used which increases measurement time by a factor of 4 for an improvement of the signal to noise ratio of two due to a square law relationship;*
- *Ability to detect over a wide range of IR regions therefore requiring both low and high carrier concentrations; and*
- *FTIR spectrometers for kinetics studies must have very fast response to changes in concentration of substances with typical requirements being the ability to measure spectra in times that are 1000 times shorter than the overall changes in concentration."*

The applicant requests the renewal of this exemption for 7 years.

The stakeholder consultation is part of the review process for the request at hand. 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.[4]

To contribute to this stakeholder consultation, please answer the questions below by December 2nd, 2020.

3. Questions

1. The applicants have requested the renewal of exemption 1(c) of RoHS Annex IV with partially different scopes and wording.

   a. Please let us know whether you support or disagree with any of the above wordings, scopes and requested durations of the exemption. To support your views, please provide detailed technical argumentation / evidence in line with the criteria4 in Art. 5(1)(a).

      By 2045, the global population is expected to reach nine billion[5]. To ensure to enough food for these people the food production has to be further improved. Today still a certain share goes to waste. With more solutions to measure the ripeness, freshness and quality of food this share can be reduced significantly. Here, near-infrared spectroscopy can be a relevant role.

[4] Directive 2011/65/EU (RoHS) available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT

[5] https://www.un.org/development/desa/en/key-issues/population.html [access Nov 23, 2020]

Near-infrared spectroscopy (NIRS) for analytics

Near-infrared spectroscopy (NIRS) has been a working horse in high-end analytics for decades. It covers the wavelength range from 0.9 to 2.5 µm (or 11000 to 4000 cm-1). This spectral range allows to measure overtone (0.9 to 2 µm) and combination bands (2 to 2.5 µm) of molecular vibrations in organic materials. The overtone bands are 1st, 2nd, and 3rd order overtones:

	Range	*Rel. intensities*
1st overtones:	*1700 - 2000 nm*	*1*
2nd overtones:	*1100 - 1700 nm*	*0.1*
3rd overtones:	*850 - 1100 nm*	*0.01*

The combination bands carry very detailed information on the samples under test, e.g. the fatty acid composition in oilseeds or the amino acid profile in protein. Hence, laboratory spectrometers capable of measuring up to 2.5 µm are widely used in agriculture for quality control and pricing.

There are 3 competing detector technologies of practical use (operating at room temperature) for the above-mentioned wavelength range: pyroelectric detectors, extended InGaAs, and PbS. Pyroelectric detectors are robust and readily available; however, they lack in sensitivity and response time when compared to semiconductor-based detectors. InGaAs detectors are very fast and sensitive. However, they are grown epitaxially on Indium phosphide (InP) substrates. The largest commercially available InP wafers are 100 mm in diameter6 (compare to 450 mm for Si, 20x larger area), limiting the InGaAs supply. Standard InGaAs detectors have a composition of In0.53Ga0.47As to match the InP lattice, and a band gap that is too large to cover the full NIR range (limited to 1.7 µm at the high wavelength end). Extended InGaAs with a band gap small enough to cover the full NIR range up to 2.5 µm has a composition that is not lattice matched to the InP substrate, thereby inducing strain and limiting yield and growth speed in production. PbS is fabricated by chemical bath deposition, a process that is fast, scalable, and does not depend on lattice matched substrates. In addition, response time and sensitivity of PbS detectors match InGaAs detectors, as both are semiconductor-based. For these reasons, NIR spectrometers are widely equipped with PbS detectors, especially for applications in agriculture or food processing.

Fairly recently, NIR spectrometers have managed to break out of their well-controlled laboratory environment by becoming smaller, lighter, and scalable. In general, there are two approaches for handheld NIR spectrometers: (i) devices based on line array detectors, where the dispersive element splits the wavelength range in space and each pixel detects a certain wavelength; (ii) devices based on single pixel detectors using an interferometer with mechanically moving parts as dispersive element, such as MEMS Fourier-Transform (FT) or Fabry-Perot interferometers (FPI). Whereas the PbS detector technology is compatible with

[6] Indium phosphide (InP) for optical interconnects (2017), https://doi.org/10.1016/B978-0-08-100512-5.00004-8

both approaches, InGaAs detectors are only used with option (ii), as extended InGaAs line array detectors are too scarce for widespread utilization in handheld devices.

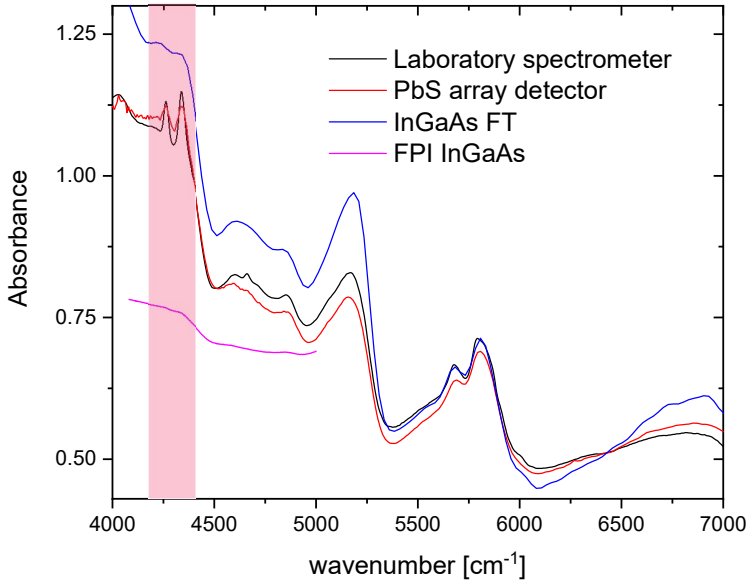

Figure 1: NIR spectra of canola. A spectrum of a canola sample measured with a benchtop laboratory spectrometer is compared to spectra measured with 3 handheld devices, using a PbS line array detector, a single pixel InGaAs FT device, and a single pixel InGaAs FPI device, respectively. Notably, the double peak indicative for saturated/unsaturated fatty acids at 4300 cm-1 is clearly visible for the PbS based handheld but smeared out for the single pixel InGaAs devices.

Handheld NIR spectrometers with single pixel detectors suffer from an inherent disadvantage compared to array-based spectrometers. The moving mirror makes them mechanically frail, causing problems in rough environments such as agricultural or industrial applications. Moreover, FT and FPI handheld spectrometers have a limited spectral resolution at large wavelength (low wavenumbers). This is exemplified in Figure 1, where the spectrum of a canola sample measured with a benchtop laboratory spectrometer is compared to spectra measured with 3 handheld devices, using a PbS line array detector and a single pixel InGaAs FT and FPI devices, respectively. Notably, the double peak indicative for saturated/un-saturated fatty acids at 4300 cm-1 is clearly visible for the PbS based handheld but smeared out for the InGaAs devices.

b. If applicable, please suggest an alternative wording and duration and explain your proposal.

We support the current wording of the exemption and a duration of 7 years

2. Please provide information concerning possible substitutes or elimination possibilities at present or in the future so that the requested exemption could be restricted or revoked. Please specify which of the requested exemption scopes and wordings you address in your answers.

a. Please explain substitution and elimination possibilities and for which part of the applications in the scope of the requested exemption they are relevant.

Please refer to 1a

b. Please provide information as to research to find alternatives that do not rely on the exemption under review (substitution or elimination), and which may cover part or all of the applications in the scope of the exemption request.

trinamiX is conducting research activities together with external partners for more than 4 years to find RoHS compliant IR sensitive materials. An IR active material that is comparable to PbS e.g., requires a bandgap smaller than 0.4 eV. In this range it is very difficult to identify materials that do not rely on toxic elements such as cadmium, mercury, lead, arsenic or tellurium. So far, no materials with comparable or improved IR characteristics compared to PbS or PbSe have been identified which are suitable for our spectroscopic purposes, which are focused on robust results also in rough environments.

c. Please provide a roadmap of such on-going substitution/elimination and research (phases that are to be carried out), detailing the current status as well as the estimated time needed for further stages.

We can share further information if requested as confidential information

3. Do you know of other manufacturers producing devices of comparable features and performance like the ones in the scope of this exemption request that do not depend on RoHS-restricted substances, or use smaller amounts of these substances compared to the applications in the scope of this exemption?

Please refer to 1a

4. As part of the evaluation, socio-economic impacts shall also be compiled and evaluated. For this purpose, if you have information on socioeconomic aspects, please provide details in respect of the following:

a. What are the volumes of EEE in the scope of the requested exemptions which are placed on the market per year?

trinamiX GmbH is a new player in the EEE industry. Therefore, a solid comment on the volumes and the market is not possible. However, near-infrared spectroscopy can create a significant value in different applications like Agriculture, Food & Beverage and Pharma & Care; in some of these industries benchtop near-infrared spectroscopy devices are already in use for years. The technology will gain even more relevance with a miniaturized and mobile solution at hand.

b. What are the volumes of additional waste to be generated should the requested exemption not be renewed or not be renewed for the requested duration?

trinamiX is focusing to bring IR spectroscopy to the sample and not the sample to the benchtop IR spectrometer.

In the case of agriculture and food production, the advantage of this approach is that the fruit sample can be measured directly on the field. This is reducing waste caused by transportation and packaging on one side but is also improving the data quality (reliability of results) as the fruit composition (ripeness, freshness, nutrient content etc) does not change because of transportation and the measuring results are not corrupted. Food loss from farm to fork is estimated to account for 20% of the total food production in the EU.[7] By reducing transportation time and standby time while waiting for lab results, an affordable handheld spectroscopy solution can help reducing food loss significantly.

c. What are estimated impacts on employment in total, in the EU and outside the EU, should the requested exemption not be renewed or be renewed for less than the requested time period? Please detail the main sectors in which possible impacts are expected – manufacturers of equipment in the scope of the exemption, suppliers, retail, users of MRI devices, etc.

No data available. TrinamiX is in advanced discussions with various industries e.g. agriculture, food, health and nutrition to implement the handheld spectrometer throughout the value-chain.

d. Please estimate additional costs associated should the requested exemption not be renewed, and how this is divided between various sectors (e.g. private, public, industry: manufacturers, suppliers, retailers). Please specify which of the requested exemption scopes and wordings you address in your answers.

No data available

5. Any other information you would like to share?

The trinamiX spectroscopy solution is based on a PbS line array comprising very thin lines of PbS on a tiny chip. We have optimized the usage of PbS to a maximum, so that less than 0.01mg of Pb are needed per device. This means by selling one million spectrometers trinamiX is putting less than 10 grams of lead into circulation.

Please note that answers to these questions can be published in the stakeholder consultation, which is 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.

Please do not forget to provide your contact details (Name, Organisation, e-mail and phone number) so that the project team can contact you in case there are questions concerning your contribution.

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[7] http://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf

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