# Exemption Request Form

Date of submission: 17.01.2023

## 1. Name and contact details

### 1) Name and contact details of applicant:


| | | | |
|---|---|---|---|
| Company: | Bruker Optics GmbH&Co.KG | Tel.: | +49 7243 504-2686 |
| Name: | Dr. Michael Jütte | E-Mail: | michael.juette@bruker.com |
| Function: | Product Development | Address: | Rudolf-Plank-Str. 27, 76275 Ettlingen, Germany |


### 2) Name and contact details of responsible person for this application (if different from above):


| | | | |
|---|---|---|---|
| Company: | Bruker Optics GmbH&Co.KG | Tel.: | +49 7243 504-2893 |
| Name: | Dr. Roland Harig | E-Mail: | roland.harig@bruker.com |
| Function: | head of R&D, managing director | Address: | Rudolf-Plank-Str. 27, 76275 Ettlingen, Germany |


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## 2. Reason for application:

Please indicate where relevant:

☐ Request for new exemption in:

☐ Request for amendment of existing exemption in

☒ Request for extension of existing exemption in

☐ Request for deletion of existing exemption in:

☐ Provision of information referring to an existing specific exemption in:

☐ Annex III ☒ Annex IV

No. of exemption in Annex III or IV where applicable: 1c

Proposed or existing wording: The existing wording "Lead, cadmium and mercury in infra-red light detectors" contains the materials which this application focuses on (cadmium, mercury).

Duration where applicable: Application for maximum validity period (7 years) starting from 21 July 2024 for industrial monitoring and control instruments

☐ Other: _____

## 3. Summary of the exemption request / revocation request

This exemption request relates to the substances mercury and cadmium which are integral material components of photon sensitive semiconductor elements in light detectors (HgCdTe or, simplified, MCT detectors) designed for operation in the mid-infrared spectral range. Bruker Optics manufactures FTIR spectrometer systems which use this detector type as an indispensable detecting component for mobile, advanced and research applications in the field of mid-infrared spectroscopy.

In the mid-infrared spectral range ($400cm^{-1}$ … $4000cm^{-1}$), and, particularly, in the so-called fingerprint range (~ $1500cm^{-1}$ - $700cm^{-1}$), there is no suitable substitute available to replace MCT detectors regarding the following combination of unique features:

- The sensitivity has its peak in the spectral range below $1500cm^{-1}$ and is at least of the order $10^{10}$…$10^{11}$ Jones (when cooled at liquid nitrogen temperature). In addition, the sensitivity can be further spectrally fine-tuned by the relative material composition of the detector element to be optimal for the corresponding spectroscopic application
- The detector allows for high interferometer scanning velocities and can provide a time resolution with a rise time down to the nanosecond range

Infrared spectroscopy with FTIR instruments is a widely used technique in many fields, e.g., life and material science, chemistry, pharma, forensics. The extension of the existing exemption, which Bruker Optics applies for in this form, would make possible to retain the high level of quality in this research fields within the EU for the upcoming years.

## 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: Fourier Transform Infrared Spectrometers and Microscopes including their accessories, which are designed for use in the mid-infrared spectral range

a. List of relevant categories: (mark more than one where applicable)

☐ 1 ☐ 7
☐ 2 ☐ 8
☐ 3 ☒ 9
☐ 4 ☐ 10
☐ 5 ☐ 11
☐ 6

b. Please specify if application is in use in other categories to which the exemption request does not refer: Category 8 applications

c. Please specify for 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

2. Which of the six substances is in use in the application/product?
(Indicate more than one where applicable)
☐ Pb ☒ Cd ☒ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

3. Function of the substance: Component of the light detecting, active area of detectors for the measurement of infrared radiation

4. Content of substance in homogeneous material (%weight): Hg: ~1-51%, Cd: ~7-46% (content different for different types of MCT detectors)

5. Amount of substance entering the EU market annually through application for which the exemption is requested: Hg: < 0,1g, Cd: < 1g
Please supply information and calculations to support stated figure.
The calculation is confidential and is provided separately.

6. Name of material/component: Mercury Cadmium Telluride (HgCdTe or, simplified, MCT)

7. Environmental Assessment: _____
LCA: ☐ Yes
☒ No

**(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 RoHS regulated substances mercury and cadmium are used in infrared light detectors with a material composition $Hg_{1-x}Cd_xTe$ of the light sensitive detector element. These detectors are usually called MCT (**m**ercury **c**admium **t**elluride) detectors. The exact composition determines the spectral range where these detectors are sensitive. MCT detectors are used in the mid infrared spectral range with photon energies so low, that usually cooling is required to reduce the influence of the thermal background. When operated at liquid nitrogen temperature (-196°C), for FTIR typical MCT detectors are available for wide range (420cm$^{-1}$ … 12000cm$^{-1}$), mid-range (600cm$^{-1}$ … 12000cm$^{-1}$), and narrow range (850cm$^{-1}$ … 12000cm$^{-1}$) detection. Thermo-electrically cooled MCT detectors are another option if the ease of operation outweighs the need for ultimate sensitivity (e.g., in mobile applications).

Infrared light detectors are essential components for FTIR spectrometer which are the most popular analysing tools for the infrared spectral range for many reasons. FT-IR spectroscopy is very easy to learn and can be applied by almost everybody. For this reason, the FT-IR technology can be implemented in any quality control line at a very short time scale. FT-IR spectroscopy is applicable on solid materials, powders, coatings, liquids and even on gases. If the FT-IR device is initially established to control the quality of one product, its application range may be extended later for the quality control of other products. The original costs for an FT-IR spectrometer are moderate in comparison to other analytical equipment in the range of spectroscopy and chromatography. Due to the long lifetime of all the included components the maintenance costs are extremely low. As only electrical power is required for FT-IR and the power consumption is further very low, the operational costs are also negligible. FT-IR is a method which evaluates the interaction of light with the measured material. The results are very reliable and reproducible since the absorption of light follows fundamental physical laws and the FT-IR instrumentation is internally calibrated. During the FT-IR analysis the sample is just illuminated by infrared light. There is no chemistry with potentially toxic substances involved or harmful radiation applied. FT-IR is therefore very safe and does not endanger the operator.

MCT DETECTORS ARE UNIQUE FOR THEIR HIGHEST SENSITIVITY IN THE MID INFRARED SPECTRAL RANGE (D* approx. $10^{10}$ … $10^{11}$ Jones at liquid nitrogen temperature) and as such indispensable in applications with low light levels. Examples are given in the following sections.

**High spectral resolution measurements**:

Spectral resolution is one of the most important attributes of spectrometers, since it defines the ability of the instrument to resolve the bands of close proximity, as required e.g., in atmospheric and climate research.

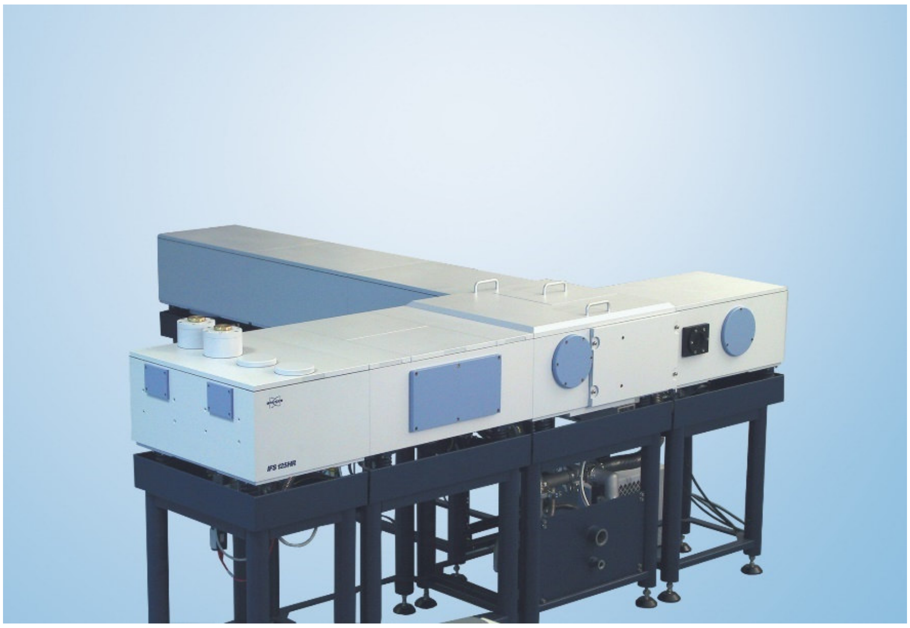


Figure 1: Bruker IFS125HR spectrometer for high resolution measurements (standard 0.007cm$^{-1}$, optional 0.0009cm$^{-1}$)

High resolution measurements require a high sensitivity for the following reasons.

If the resolution is increased by a factor of 2, the noise will be twice as high. The noise decreases as the square root of acquisition time. For example, it will take 16 times longer to collect a spectrum of equivalent signal-to-noise, when the spectral resolution is increased by four. Moreover, resolution better than 4cm-1 requires the use of smaller apertures in the spectrometer that reduces the beam intensity and leads to additional noise. The purpose of the aperture is to achieve the necessary degree of beam collimation in the interferometer.

Hence, the use of MCT detectors is obligatory for high spectral resolution measurements in the mid infrared range.

**Infrared microscopic measurements**:

Conventional microscopy is clearly one of the most widespread analytical techniques in research, forensics, failure analysis, life-science and electronics. Adding FTIR, gives a precise and even more powerful tool for a comprehensive microanalysis, e.g., to characterize tiny particles, product defects or tissue anomalies. Infrared spectroscopy gives an abundance of molecular information for inorganic and organic materials alike.

Figure 2: Bruker microscopes, left: Lumos II, right: Hyperion attached to an Invenio spectrometer

In infrared microscopy, sample areas are investigated with a spatial resolution down to a few micrometers. This typically reduces the available light level by several orders of magnitude compared to measurements without spatial resolution. MCT detectors are used by standard for microscopic analysis in the mid-infrared, either as a single element detector or as an infrared imaging camera (focal plane array detector) with thousands of pixels.

MCT DETECTORS ARE ALSO UNIQUE FOR THEIR FAST RESPONSE in time resolved measurements in the mid-infrared range. To investigate a rapidly changing chemical or physical system, mainly two techniques are available.

**Rapid-Scan TRS**

One technique that provides several advantages is time-resolved spectroscopy (TRS) using a Fourier Transform Infrared (FTIR) spectrometer. FTIR offers high sensitivity and specificity for monitoring almost any given species, and because it is a broadband experiment, several species can be monitored simultaneously, for example, the decay of one chemical species and the simultaneous production of another. Also, for any physical or chemical phenomenon that cannot be electronically triggered and is not many-times reproducible, rapid-scan with a fast-scanning interferometer is the right solution. The precondition for a successful temporal resolved Rapid-Scan application is that the FTIR spectrometer is equipped with a liquid nitrogen cooled MCT detector. Besides its higher sensitivity compared to a room temperature DTGS detector, it provides the advantage of a much higher detection speed without reduced responsivity. More than 110 spectra per second can be achieved at 16cm$^{-1}$ spectral resolution.

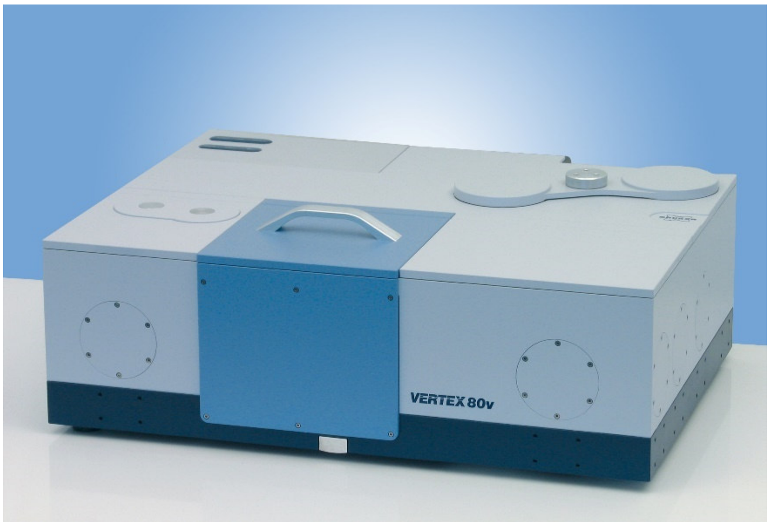


Figure 3: Bruker Vertex 80v research spectrometer for advanced time-resolved measurements

## Step Scan TRS

For higher temporal resolution the Step-Scan technique is the right solution for repetitive and reproducible kinetics experiments. During the last few years, it attracted interest for research and developmental application and led to many scientific publications. In the mean-time step scan TRS has already been applied to kinetic studies of e.g., organo-metallic complexes, ferroelectric liquid crystals, crystalline laser material, semiconductor material and to photo-biological systems.

For these applications the spectrometer is equipped with the Step-Scan option and a fast liquid nitrogen cooled MCT detector to achieve a temporal resolution in the low micro-second range. For faster kinetics experiments the spectrometer must be equipped with an ultra-fast photo voltaic MCT detector and a PC-based external transient recorder board (TRB). In this configuration an extreme temporal resolution in the low nano-sec range can be achieved for repetitive kinetic experiments.

## Rapid scan imaging

Modern FTIR imaging spectroscopy makes use of the latest generation of MCT imaging FPA (focal plane array) detectors with applications, for example, in imaging microscopy and remote sensing. Such FPA detectors consist of an array of thousands of detector elements, e.g., ~16k elements for a 128x128 array FPA used in microscopy. For optimum performance and lowest measurement times, it is important to read out the FPA frames in a continuous and fast way which needs to be adapted to the standard scanning velocities of the interferometer. Therefore, fast FPA detectors with high frame rates in the kHz range are required, e.g., ~1.6kHz for a 128x128 array FPA.

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

HgCdTe is the most widely used material for high-performance mid-infrared photodetectors due to its favorable optical and material properties

- The operating wavenumber range can be optimized for FTIR application which means for operation in the fingerprint range ($<1500 cm^{-1}$). This is possible as HgCdTe is a combination of mercury telluride (HgTe) and cadmium telluride (CdTe). The relative concentrations of both parts are adjusted in the growth process to obtain the desired mixture. If we let x indicate the relative concentration of CdTe, the concentration of HgTe would be 1-x. The variable concentration allows one to adjust the cutoff wavelength and operating temperature of the detectors.
- Direct bandgap semiconductors, such as HgCdTe, have a sharp onset of optical absorption as the photon energy increases above the bandgap. Strong optical absorption allows MCT detector structures to absorb a very high percentage of the signal while being relatively thin. Minimizing the detector thickness helps to minimize the volume of material which can generate noise.
- High D* and high signal-to-noise ratio in the mid infrared range: typically, $D^*=10^{10} \ldots 10^{11}$ Jones at -196°C operating temperature, depending on the spectral bandwidth of the detector
- MCT devices achieve a high quantum efficiency, which exceeds 90% when an antireflection coating is applied, which is essential for a good responsivity and the detection of low signals
- Photovoltaic MCT detectors can have a rise time as short as 10 nsec making them suitable for time resolved measurements of fast kinetics

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## 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.)**

No closed loop system.

**2) Please indicate where relevant:**

☐ 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

MCT detectors have a very long lifetime of many years or even decades. Such detectors are often reused in new instruments, either directly or after refurbishing by Bruker that offers customer-specific engineering services as part of its business.

**3) Please provide information concerning the amount (weight) of RoHS substance present in EEE waste accumulates per annum:**

☐ In articles which are refurbished ______

☐ In articles which are recycled ______

☐ In articles which are sent for energy return ______

☐ In articles which are landfilled ______

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## 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**

Bruker is a manufacturer of FTIR spectrometers and as such it does not manufacture infrared detectors but depends on what is offered on the commercial market. The developments of this market are regularly observed for any possible replacement detectors.

So far, a suitable alternative for MCT detectors for the use in FTIR spectroscopy is not available.

Pyroelectric detectors, mainly **DLaTGS** detectors, cover and partly extend the spectral range of a MCT detector. Further advantages are the operation at room temperature and the excellent linearity even at higher intensity levels. On the other hand, the specific detectivity ($D^*\approx 3\times 10^8$ Jones) is typically a factor of 10 to 100 lower than the specific detectivity of MCT detectors cooled by liquid nitrogen which are commonly used in FTIR spectroscopy, resulting in a correspondingly lower performance of the spectrometer (signal-to-noise ratio in spectra, detection limits of compounds), and prohibiting many applications of the spectrometer. In addition, the long response time prevents the use in applications which need time resolution. Moreover, the responsivity of DLaTGS detectors depends on the frequency and results in different responsivities of the spectrometer at different wavelengths in an FT-IR spectrometer (as the modulation frequency depends on the wavelength). Over a wide range, the responsivity depends inversely on the modulation frequency, resulting in the requirement to operate the interferometer at low velocities of the optical path difference, which results in higher vibration sensitivity of the spectrometer system (slow movement of the moving mirror results in vibration sensitivity). Thus, operation in harsh environments (industry, mobile operation) is hampered. Therefore, this type of detector is appropriate and used by default only in standard (routine) laboratory applications in the mid infrared spectral range. More advanced (research) applications, many industrial applications and mobile applications require the use of MCT detectors.

**Bolometers** (Si bolometer) also cover the MCT spectral range at least in principle. In practice, the operation is limited to <900cm-1 because of the heat load. They typically require an expensive cooling with liquid Helium and have a long response time in the millisecond range.

Hamamatsu offers a **type II superlattice detector** of InAs and GaSb layers, (P15409-901, liquid nitrogen cooled) which is advertised as replacement for MCT detectors. However, this detector has several drawbacks for the use in FTIR spectroscopy and it is therefore not an appropriate substitute for MCT detectors:

- The peak wavenumber is at about 1850cm$^{-1}$ which is significant higher compared to MCT detectors (e.g., about 800cm$^{-1}$ for a mid-band MCT). Therefore, this spectral range is not well adapted to the important fingerprint range below 1500cm$^{-1}$ which is essential in mid infrared spectroscopy.
- The peak specific detectivity is $1.6\times10^{10}$ Jones at 1850cm$^{-1}$ and approximately a factor of 7 lower (~$2.3\times10^{9}$ Jones) at 800cm$^{-1}$ where the mid-band MCT has its maximum. This means that a MCT with a maximum D* = $4.5\times10^{10}$ Jones exceeds the superlattice detector in sensitivity at this spectral position by a factor of ~20. If this should be compensated for in the measurement, one had to increase the measurement time by a factor of ~400. Moreover, the MCT in comparison here has an element area which is larger by approximately a factor of 130. Reducing the element size of the MCT detector to the same level of the superlattice detector would further reduce its noise and increase the already existing performance gap to the superlattice detector as the specific detectivity typically increases with decreasing detector size.
- The element size is Ø=0.1mm compared to 1×1mm$^2$ for MCT detectors used in FTIR spectrometers. Therefore, it is poorly adapted to the typical optical chain of FTIR spectrometers which is throughput-(Étendue)-

optimized for the extended field size of thermal light sources which typically require an element size of about $1mm^2$ using the maximum spectrometer field aperture. The power received by the superlattice detector is approx. a factor of 130 lower compared to a standard MCT detector, resulting in a correspondingly lower signal-to-noise ratio in the spectra.

Although superlattice detectors with an improved performance have been demonstrated in research projects and for use in focal plane array detectors, there are no detectors on the market that are competitive to MCT detectors for use in FT-IR spectrometers (in terms of element size, specific detectivity, and spectral range). Therefore, an extension of the exemption request is needed while the development and availability of these detectors can be further observed for any progress.

There are a few **other detector types** available in the market, which operate within or close to the mid-infrared spectral range but fail to cover the (complete) fingerprint region:

- InSbAs (P12691, Hamamatsu): $1200cm^{-1}$ … $3000cm^{-1}$ (only low D*, max. $6\times10^9$ Jones at ~$1500cm^{-1}$)
- InSb: $1850cm^{-1}$ … $10000cm^{-1}$
- PbSe: $1920cm^{-1}$ … $10000cm^{-1}$ (also no alternative in terms of RoHS)
- PbS: $3000cm^{-1}$ … $10000cm^{-1}$ (also no alternative in terms of RoHS)
- InAs: $3300cm^{-1}$…$12800cm^{-1}$
- TE-InGaAs: $4000cm^{-1}$ … $12800cm^{-1}$

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

So far, no suitable alternative to MCT detectors has been developed.

## 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.**

Bruker does not develop detectors but integrates these essential components in its own spectrometer systems. Therefore, Bruker depends on what is available on the market which is regularly observed. The standard mid-infrared detector is the RoHS compatible DLaTGS. MCT detectors are only used for dedicated applications where the performance of a MCT detector is needed.

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

Substitute detectors must match the current MCT detectors regarding the following properties:

- They should offer an at least comparable performance within the same spectral range which a MCT detector can cover. In particular, the low wavenumber range including the so-called fingerprint below 1500$cm^{-1}$ is of essential importance in infrared spectroscopy.
- They should offer an at least comparable fast response for applications in time resolved spectroscopy.
- They should not be significantly more expensive.

From our point of view, which is the point of view of a customer of detector manufacturers, it is difficult to assess the time frame needed for having such a substitute detector in sufficient quantities commercially available. As the example of the Hamamatsu superlattice detector shows, the industry is working on replacement types. Our expectation is that it will take at least 5 more years to realize a commercial substitute.

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## 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)? No

☐ Authorisation

☒ SVHC (Cadmium, not on authorisation list)

☒ Candidate list (Cadmium, since 20.06.2013)

☐ Proposal inclusion Annex XIV

☐ Annex XIV

☐ Restriction

☐ Annex XVII (there are some restrictions for mercury and cadmium but not for the described application of infrared detectors)

☐ Registry of intentions

☐ Registration

2) Provide REACH-relevant information received through the supply chain.
Name of document: _____

**(B) Elimination/substitution:**

1. Can the substance named under 4.(A)1 be eliminated?

   ☐ Yes. Consequences? _____

   ☒ No. Justification: No substitute available

2. Can the substance named under 4.(A)1 be substituted?

   ☐ Yes.

   ☐ Design changes:

   ☐ Other materials:

   ☐ Other substance:

   ☒ No.

   Justification: No substitute available

3. Give details on the reliability of substitutes (technical data + information): N/A
4. Describe environmental assessment of substance from 4.(A)1 and possible substitutes with regard to
   1) Environmental impacts: _____
   2) Health impacts: _____
   3) Consumer safety impacts: _____

⇨ Do impacts of substitution outweigh benefits thereof? No substitute available
Please provide third-party verified assessment on this: N/A

**(C) Availability of substitutes:**

a) Describe supply sources for substitutes: No substitute available

b) Have you encountered problems with the availability? Describe: No substitute available

c) Do you consider the price of the substitute to be a problem for the availability? No substitute available

   ☐ Yes ☐ No

d) What conditions need to be fulfilled to ensure the availability? No substitute available

**(D) Socio-economic impact of substitution:**

⇨ What kind of economic effects do you consider related to substitution?

☐ 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: As no adequate substitute exists, many FTIR spectroscopy applications would be facing severe limitations if the current exemption were not to be renewed. Research and monitoring with infrared spectroscopy in Europe, both academic and industry, would be put at a disadvantage compared to research and monitoring in non-EU countries because the instruments for the European market would suffer from a significantly reduced sensitivity and spectral range within the fundamental fingerprint range. Therefore, negative impact could be expected in any field with needs for monitoring and research by mid-infrared spectroscopy, e.g., pharma, forensic, chemistry, biology, material science, environmental and climate to name a few.

⇨ Provide sufficient evidence (third-party verified) to support your statement: _____

## 9. Other relevant information

**Please provide additional relevant information to further establish the necessity of your request:**

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## 10. Information that should be regarded as proprietary

**Please state clearly whether any of the above information should be regarded to as proprietary information. If so, please provide verifiable justification:**

The calculation of the annual quantity of Cd and Hg, put on the EU market, is confidential and provided separately.

The data sheets of purchased MCT detectors (demonstrating achievable specific detectivity, spectral range and time resolution) are confidential and provided separately.

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