Exemption Evaluation under Directive 2000/53 EC

ACEA et al. Answers to Stakeholder Consultation Questionnaire

of Bio Innovation Service
and The United Nations Institute for Training & Research (UNITAR)
and Fraunhofer Institute for Reliability and Microintegration (IZM) dates 08.02.2024

Exemption 8(e). Lead in high melting temperature type solders
(i.e. lead-based alloys containing 85 % by weight or more lead)

Application for an extension of Annex II EU ELV exemption No. 8(e).

(Lead in high melting temperature type solders)

This application is supported by the following associations:

- ACEA, the European Automobile Manufacturers Association, Brussels
  (transparency registration ID number 0649790813-47)
- CLEPA, the European Association of Automotive Suppliers, Brussels
  (transparency registration ID number 91408765797-03)
- JAMA, the Japan Automobile Manufacturers Association, Tokyo / Brussels
  (transparency registration ID number 71898491009-84)
- JAPIA, the Japan Auto Parts Industries Association, Tokyo
- KAMA, the Korea Automobile & Mobility Association (KAMA), Seoul

This document consists of following two elements:

PART A Background and technical information
PART B Answers to the questionnaire

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PART A Background and technical information

Acronyms and definitions

BGA	Ball Grid Array
COM	European Commission
ECB	Electronic circuit board
EEE	Electrical and Electronic Equipment
HMP	High melting point
HMPS	High melting point solder, i.e. solder with a lead content of 85 % by weight or more
Lead-free	Not containing lead in the application in the scope of the exemption under review
Pb	Lead
RoHS	Directive 2011/65/EU on the Restriction of Hazardous Substances in Electrical and Electronic Equipment

1. **Introduction to exemption 8(e)**

With Commission delegated Directive (EU) 2020/363[1] from 17. December 2019, the Commission decided to extent the exemption 8(e), as there are currently no suitable alternatives to the use of Lead for the materials and components covered by this exemption. A date for a new review of this exemption should therefore be set. The review is determined for the year 2024.

The decision was based on a stakeholder consultation launched in May 2018 and an assessment of exemption 8(e) of a consultant consortium led by Oeko-Institut and undertaken by the Oeko-Institut and Fraunhofer Institute IZM. Then consultant consortium published their final draft report[2] in October 2019.

Concerning ELV Annex II exemption 8(e), this report resumes:

´ …*The information made available by the applicants suggests that the use of lead in LHMPS is still unavoidable. In line with Art. 4(2)(b)(II), the consultants can therefore recommend continuing exemption 8(e). The substitution or elimination of lead in LHMPS may become feasible, but it is explained to be unlikely that such solutions are available for automotive uses in the coming years.* …` (page 24)

The report gives recommendations to the European Commission, which the Commission may take into account in view of the amendment of Annex II Annex to Directive 2000/53/EC. For entry 8(e)., the consultants recommended to continue the exemption 8(e), and to set a review date in 2024. With delegated Directive (EU) 2020/363, the Commission followed the recommendation.

[1] Commission delegated Directive (EU) 2020/363 of 17 December 2019 amending Annex II to Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles as regards certain exemptions for lead and lead compounds in components; OJ L 67/119, 5.3.2020

[2] (Oeko-Institut e.V. 2019) Consultant report on Review in the light of scientific and technical progress of exemptions 8(e), 8(f)(b), 8(g) and 14 and re-evaluation of entry 8(j) of Annex II to Directive 2000/53/EC (ELV exemptions Pack 3) – Draft Final 02.10.2019

Exemption 8(e) is part of Annex II since 2010.

The Commission decided with Commission Decision 2010/115/EU of 23 February 2010, to split the previous exemptions 8(a). *Solder in electronic circuit boards and other electrical applications except on glass,* and, 8(b). *Solder in electrical applications on glass,* prior defined in Commission decision 2008/689/EC of 1 August 2008.

The split was extended to 10 new defined entries. For the new introduced subentry 8(e), 2010/115/EU determined a first review in 2014.

The previous old exemption 8(a). was 2010 redefined into a new worded exemption 8(a). ´*Lead in solders to attach electrical and electronic components to electronic circuit boards and lead in finishes on terminations of components other than electrolyte aluminium capacitors, on component pins and on electronic circuit boards* ´ , with an expiry date for vehicles type approved after 1 January 2016.

With the new entry 8(a). from 2010, the new entry 8(e). was required. To realize the new entry 8(a). , the use of Lead-free solders with an around 40 K higher melting temperature was required to produce Lead-free soldered electronic circuit boards (ECB). The new solder temperatures in ECB production now increased to around 240 °C up to 260 °C.

As a consequence of the higher solder temperatures needed to fix electronic components on the ECB, the inner connections in the components had to be changed, as the inner soldered contacts in the components may not melt during the Lead-free soldering of the board. Inside the components now, the use of appropriate high melting temperature type solders became mandatory, also replacing solders, which were Lead-free before.

On ECB level, the combination of Lead-free soldering on the board and switch to the use of high melting temperature Lead solders inside the components effected a Lead reduction of 90 to 95 % on ECB level resp. the average Lead content on full equipped ECB´s decreased to less than 0,1 wt.%.

In 2016 with Commission Directive (EU) 2016/774 of 18 May 2016, the Commission decided to continue exemption 8(e) and a review date in the year 2019. And, as outlined above, the Commission decided with Directive (EU) 2020/363 to continue exemption 8(e) and a review in 2024.

On 08. February 2024, a stakeholder consultation for the review of exemption 8(e) was launched in order to assess developments concerning replacement options for Lead high melting point solders. The stakeholder consultation ends on 18.April 2024. The consultant consortium consisting of BioIS, Unitar and Fraunhofer IZM has provided a comprehensive questionnaire.

The answers of ACEA et al to the exemption 8(e) questionnaire of the consultants are given in Part B of this submission.

2. Exemption for HMPS under RoHS

Under Directive 2011/65/EU (RoHS2) there is a corresponding exemption for electrical and electronic products. This RoHS exemption is the exemption 7(a) with following definition:

7(a) Pb in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more Pb)

According the specific rules of the RoHS legislation, the stakeholders applied to continue this exemption with submission of 06.01.2020. As long as there is no COM decision to the submission, the exemption remains valid.

The submissions of the RoHS stakeholders have been scrutinized by a consultant consortium, mandated by the COM. The consortium members are the Fraunhofer-Institute for Reliability and Microintegration (IZM), the United Nations Institute for Training and Research (UNITAR), and BIO Innovation Services (Bio IS).

The same consortium is engaged for the review of ELV Annex II (with amended contract to ENV.B.3/FRA/2019/0017, Assistance to the Commission on technical, socio-economic and cost-benefit assessments related to the implementation and further development of EU waste legislation).

In their final report [3], dated of 15. 02. 2022, the consultants give the recommendation to split this yet quite specific exemption into even new subentries. At our understanding, in following reviews, it shall be evaluated if for a specific subentry a setting of a final expiry date will be possible.

This recommendation is not supported by the industry, which states that this splitting of the exemption 7(a) will not eliminate existing functional requirements for LHMPS, nor will it improve the availability for Pb-free alternatives.

The Commission has not yet met any decision up to now, if they will follow the recommendation. A final decision is planned for third quarter 2024. [4].

3. Challenges of substitutes

If there will be a new applicable substitute found, the economic implications of changing designs and validation will be very high and time consuming.

Any substitute and the processing chemicals, needed for their application, should have clear evidence for reducing environmental loads. In this sense the Lead-free criterion should align with further targets of the European chemical policy and best available technology approach.

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[3] Study to assess requests for a renewal of nine (-9-) exemptions 6(a), 6(a)-I, 6(b), 6(b)-I, 6(b)-II, 6(c), 7(a), 7(c)-I and 7 (c)-II of Annex III of Directive 2011/65/EU (RoHS Exemption Evaluation Pack 22) – Final Report (Amended Version)

[4] see https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14170-Hazardous-substances-exemption-for-lead-in-high-melting-temperature-type-solders_en; last accessed 08.04.2024

PART B Answers to Questionnaire

Information from Consultant Consortium

Table 1: Current wording of exemption 8(e

No.	Exemption	Scope and dates of applicability
8(e)	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)	This exemption shall be reviewed in 2024

Figure B 1: Table 1 of consultant questionnaire

Consultant questionnaire text:

1. Background

Bio Innovation Service, UNITAR and Fraunhofer IZM have been appointed by the European Commission (COM) for the evaluation of applications for new exemptions and the renewal/continuation of exemptions currently listed in Annex II of the ELV Directive 2000/53/EC .

This questionnaire has been prepared for the stakeholder consultation held as part of the evaluation. The objective of this consultation is to collect information and evidence for subsequent review to assess whether the exemption is still justified according to the criteria listed in Art. (4)(2)(b)(ii) of Directive 2000/53/EC (ELV Directive).

Additional background information can be found on the exemption review page accessible through the following link: www.elv.biois.eu

We welcome your contribution to this stakeholder consultation. We recommend reading the below section before you answer the questions.

2. Main Observations in Previous Reviews

The above exemption was reviewed by Gensch et al. (2015) last time under the ELV Directive, and the consultants concluded that overall the use of lead was not yet avoidable. During the review, however, the applicants illustrated the manifold uses of lead-containing high melting point solders (HMPS) on the one hand but on the other hand strongly based argumentation and the efforts to find lead-free solutions on the activities of the DA5 Consortium since 2010 who focus on research to substitute lead in die attach. The same phenomenon can be observed in the report prepared by Baron et al. (2022) in the review of the request for renewal of the corresponding RoHS-exemption III-7(a). The underlying strategy has been that the DA5 find a lead-free solution for die attach and to use this substitute for all types of leaded HMPS applications, i.e. a 1:1 substitution of leaded HMPS by one single lead-free alternative for all the uses of this solder. So far, to the consultants' best knowledge, this approach has not resulted in successful substitutions of lead in any applications where leaded HMPS have been used. Gensch et al. (2016) already raised doubts whether and how far a solution for lead-free die attach could be used to replace HMPS in all its other applications. Instead, application-specific research could be more promising, i.e. that lead-free solutions should be researched for individual, or for groups of applications with similar requirements.

Baron et al. (2022) aspired turning the purely material-specific exemption III-7(a) in the RoHS Directive towards a more application-specific one by structuring the various applications of the leaded HMPS solder as illustrated in the table on the next page. The COM's official decision as to the recommended renewal of RoHS exemption III-7(a) is still pending.

Exemption formulation 7(a)	Duration
Lead in high melting temperature type solders (i.e., lead-based alloys containing 85 % by weight or more lead) (*excludes those in the scope of exemption 24)*	For all categories except applications covered by point 24 of this Annex, expires on 21 July 2024.
Lead in high melting temperature type solders (i.e., lead-based alloys containing 85 % by weight or more lead) when used for the following applications (excludes those in the scope of exemption 24): *I) for internal interconnections for attaching die, or other components along with a die in semiconductor assembly with steady state or transient/impulse currents of 0.1 A or greater or blocking voltages beyond 10 V, or die edge sizes larger than 0.3 mm x 0.3 mm* *II) for integral (meaning internal and external) connections of die attach in electrical and electronic components, if the thermal conductivity of the cured/sintered die-attach material is >35W/(m*K) AND the electrical conductivity of the cured/sintered die-attach material shall be >4.7MS/m AND solidus melting temperature has to be above 260°C* *III) In first level solder joints (internal or integral connections - meaning internal and external) for manufacturing components so that subsequent mounting of electronic components onto subassemblies (i.e., modules or sub-circuit boards or substrates or point to point soldering) with a secondary solder does not reflow the first level solder. This item excludes die attach applications and hermetic sealings* *IV) In second level solder joints for the attachment of components to printed circuit board or lead frames:*	Applies to all categories except applications covered by point 24 of this Annex, expires on 21 July 2026.
1. in solder balls for the attachment of ceramic ball-grid-array (BGA) *2. in high temperature plastic overmouldings (> 220 °C)* *V) as a hermetic sealing material between:* *1. a ceramic package or plug and a metal case,* *2. component terminations and an internal sub-part* *VI)* for establishing electrical connections between lamp components in incandescent reflector lamps for infrared heating or high intensity discharge lamps or oven lamps VII) *for audio transducers where the peak operating temperature exceeds 200°C*	

Figure B 2: Table 2 of consultant questionnaire: Renewal of current RoHS exemption 7(a) recommended by Baron et al (2022)

Consultant Questions

Answers in blue colour

Question 1:

What is the amount of lead that would be contained in vehicles

a. placed on the EU market

b. worldwide

in case the exemption is continued beyond 2024?
Please provide at least a rough calculation to substantiate your figures.

With more electronic systems and sensors in a modern vehicle, we estimate that the ongoing miniaturization of electronics cannot completely compensate the increased demand for electronic components and use of HMPS therein.

Last review 2018:

At the stakeholder consultation for the last review of exemption 8(e), we estimated the amount of Lead used under exemption 8(e) per vehicle the two approaches below.

1) Calculation based on investigation result on amount of ECB per vehicle and amount of Lead used under exemption 8(e) per ECB

2) Anonymized investigation to OEMs in associations

As a conclusion, we assumed 1g/vehicle for average volume calculation of Lead used by exemption 8(e). Further details can be found on page 7 of the response we submitted in the previous review. The response document can be downloaded from the following link:

https://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2018-1/Contribution_ACEA_et_alt_8_e__questionnaire_20180718.pdf

We will explain the details later, but an alternative technology for HMP Leaded-solder is not yet available. Therefore, we assume that the amount of lead under exemption 8(e) remains almost unchanged.

Current review 2024:

Based on a volume of 12.910.891 new registered vehicles in 2022 of category M1/N1 the total amount of Lead would be below 12.91 million x 1,6 g = around 21 t tons of Lead in LHMTS solder per year. The figures are based on samples currently provided (anonymized investigation) and mean value calculation.

As reason for the increase in the volume per vehicle from 2018 to 2024 we see the intensified use of electronic systems and we see this linked with an increase of entry 8(e) applications.

We would like to mention, that the solder in most cases is encapsulated in the components and that during component use in vehicle a release of Lead can be excluded. In ELV utilization procedures, we expect that most of the Lead will enter metal recovery routes.

Question 2:

Can you report any progress as to lead-free solutions for automotive applications that have been using leaded HMPS since the last review of exemption 8(e) by Gensch et al. (2015)?

Since the last review of exemption 8(e) in 2018, the automotive industry has been engaged in research on alternative materials that take into account a wide range of possibilities, including additive elements in solder, conductive adhesives, and silver sintering. However, for three intended uses (Table 2), an alternative technology with similar ductility, strength and further physical properties as Lead is not yet available. The details of these efforts will be explained in the answer for Question 4.

Question 3:

Can you think of any automotive application of leaded HMPS that would not be covered by the scope of the exemption proposed by Baron et al. (2022) in Table 2?

Since we do not have the necessary technical information or knowledge to determine whether all the solder applications are listed by subdivision of the exemption wording in Table 2, we leave the technical decision to the EEE industry.

We are aware that the Umbrella Project (UP) has taken a stand against any subdivision of the exemption wording as it is described in section 10.6.2 of the consultation report of Pack 22 for evaluation of exemption requests under Directive 2011/65/EU.

They are highlighting that several applications might exist that are not covered by the subdivided wording of the exemption which the consultants recommended as The LHMPS materials are used in a huge variety of applications. They assume that any split will enact legislation, which will not be implementable and will cause increased administrative burden, only. They also raise some other concerns.

We in the automotive industry have a same position with the Umbrella Project.

A deep scrutiny along the supply chain will take much more time than granted for answers. Each entry 8(e) use would be needed to assessed, if and to what subgroup it could be allocated or not. To avoid misallocations, for the whole supply chain trainings will be needed at first. So currently we are not able to answer this question in detail.

In general, we see the intention to limit the scope, but consider the split of this exemption into seven sub categories as inappropriate. Especially as we see missing substitutes. Splitting entry 8(e) into seven sub-entries will cause enormous efforts in changing data reporting and assessment tools along the supply chain. Their implementation would take several years. With missing technical alternatives, this could end in a red-tape action.

Question 4:

Please describe your efforts to find lead-free solutions for the applications of leaded HMPS described in Table 2 as long as they are relevant for automotive uses, and for other applications (see question 3).

As answered for the Question 3, we do not agree subdivision of the exemption wording shown in Table 2, therefore we cannot answer for the applications described in that. However, we answer as our efforts for the current exemption 8(e) as following.

We have been engaged in research on alternative materials that take into account a wide range of possibilities, including additive elements in solder, conductive adhesives, and silver sintering.

Table 1 lists typical types and melting temperatures of solders currently (as of April 2024) used in applications falling under this exemption. For your reference, it also lists types and melting temperatures of solders containing 85% or less Lead, use of which is prohibited under ELV Directive.

Category	Solder Type	Alloy Composition (wt. %)	Melting Temperatures (Solidus Line-Liquidus Line) [C]
Lead-containing Solder	High temperature type Lead-containing solder (Falling under exemption under ELV Directive)	Sn-85Pb	226~290 C
		Sn-90Pb	268~302 C
		Sn-95Pb	300~314 C
	<Reference> Lead-containing solder Use thereof prohibited under ELV Directive	Sn-37Pb (Conventionally used)	183 C
		Sn-60Pb	183~238 C
		Sn-70Pb	183~255 C
		Sn-80Pb	183~280 C

Table 1: *Composition and Melting Temperature of Lead-Containing Solders*

Table 2 lists intended uses and related products, in which HMP Leaded-solders under exemption 8(e) are utilized. The table also includes reasons why they are needed.

<table>
<tr><th>Intended use</th><th>Examples of related products</th><th>Reasons for necessity</th></tr>
<tr><td>Solders used for internally combining:
– a functional element with a functional element
– and a functional element with wire/terminal/heat sink/substrate, etc.
within an electronic component.</td><td>Resistors, capacitors, chip coil, resistor networks, capacitor networks, power semiconductors, discrete semiconductors, microcomputers, ICs, LSIs, chip EMI, chip beads, chip inductors, chip transformers, etc.
(<u>Annex:</u> Fig.1 to 3)</td><td rowspan="3">– Stress relaxation characteristic with materials and metal materials at the time of assembly is needed.
– Stress absorption (ductility) is needed to prevent damage to jointed materials and components during lifetime.
– When it is incorporated in products, it needs heatproof characteristics to temperatures higher than 250 to 260°C.
– It is needed to achieve electrical characteristic and thermal characteristic during operation, due to electric conductivity, heat conductivity, etc.
– It is needed to gain high reliability for temperature cycles, power cycles, etc.*</td></tr>
<tr><td>Solders for mounting electronic components onto sub-assembled module or sub-circuit boards.</td><td>Hybrid IC, modules, optical modules, etc.
(<u>Annex:</u> Fig. 4)</td></tr>
<tr><td>Solders used as a sealing material between a ceramic package or plug and a metal case</td><td>SAW (Surface Acoustic Wave) filter, crystal resonators, crystal oscillators, crystal filters, etc. (<u>Annex:</u> Fig.5)</td></tr>
</table>

Table 2: Intended Use and Examples for Related Products in which HMP Lead-solders are utilized

**) long term reliability under the harsh environmental conditions of use in vehicles according to automotive specifications (e.g.AEC-Q100) need to be assessed and qualified according to automotive specifications*

Lead-free solders of metallic systems that have a required solidus line temperature of 250°C or higher and electrically conductive adhesive systems have important disadvantages (as shown below in table 4) and thus cannot substitute for HMP Lead (Pb) solders. In addition, as a trend of vehicle components, further miniaturization of structures proceeds, and brings increase of thermal and mechanical load on components. Especially components requiring long-term reliability (e.g. powertrain system components, high power applications such as generator diode etc.) and safety relevant components (Brake ECU, Steering ECU etc.) will be largely affected.

In recent years, advances in automatic operation and electrification have led to the development of electronic control systems and electrification of power trains. Electronic components are required to be more reliable and high-performance than ever before because the safety of drivers and their surroundings is greatly affected by the functions of automobiles such as autonomous driving and collision safety. In addition, with the adoption of electric powertrains, electric components with higher current and voltage specifications, such as power modules and inverters, tend to be newly installed, but the required level of reliability has become increasingly severe. The long-term reliability of automotive electronic is essential for vehicle functions. Many applications are specified for more than 20 000 operating hours.

In addition, after production technology has been changed, very careful scrutiny is needed to maintain required high quality of components in the process to avoid failure in actual field.

Table 3 (below) lists types and melting temperatures of Lead-free solders that are currently (as of April 2024) in use and of which commercial viability is currently under study.

Category	Solder Type	Alloy Composition [wt. %]	Melting Temperatures (Solidus Line / Liquidus Line)
Lead-free solders (Solidus Line 250°C or lower)	Sn-Zn (-Bi)	Sn-8.0Zn-3.0Bi	190~197 °C
	Sn-Bi	Sn-58Bi	139 °C
	Sn-Ag-Bi-In	Sn-3.5Ag-0.5Bi-8.0In	196~206 °C
	Sn-Ag-Cu-Bi	Sn96Ag2.5Bi1Cu0.5	213~218 °C
	Sn-Ag-Cu	Sn-3.0Ag-0.5Cu	217~220 °C
		Sn-3.5Ag-0.7Cu	217~218 °C
		Sn-4Ag-0.5Cu	217~229 °C
	Sn-Cu	Sn-0.7Cu	227 °C
	Sn-low Sb	Sn-5.0Sb	235~240 °C
Lead-free solders (Solidus Line more than 250°C)	Bi system	Bi-2.5Ag	263 °C
	Au-Sn system	Au-20Sn	280 °C
	Sn-high Sb	Sn->43Sb	325~>420 °C
	Zn-Al system	Zn-(4-6)Al(Ga,Ge,Mg)	About 350~380 °C
	Sn system & high melting temperature type metal	Sn ＋ (Cu,Ni,etc.)	≧about 230~ >400 °C

Table 3: *Composition and Melting Temperatures of Main Lead-free Solders*

Figure 3 (below) shows the relationship of types and melting temperatures of Lead-containing solder and Lead-free solders, based on the data shown in table 1 and table 3 (above).

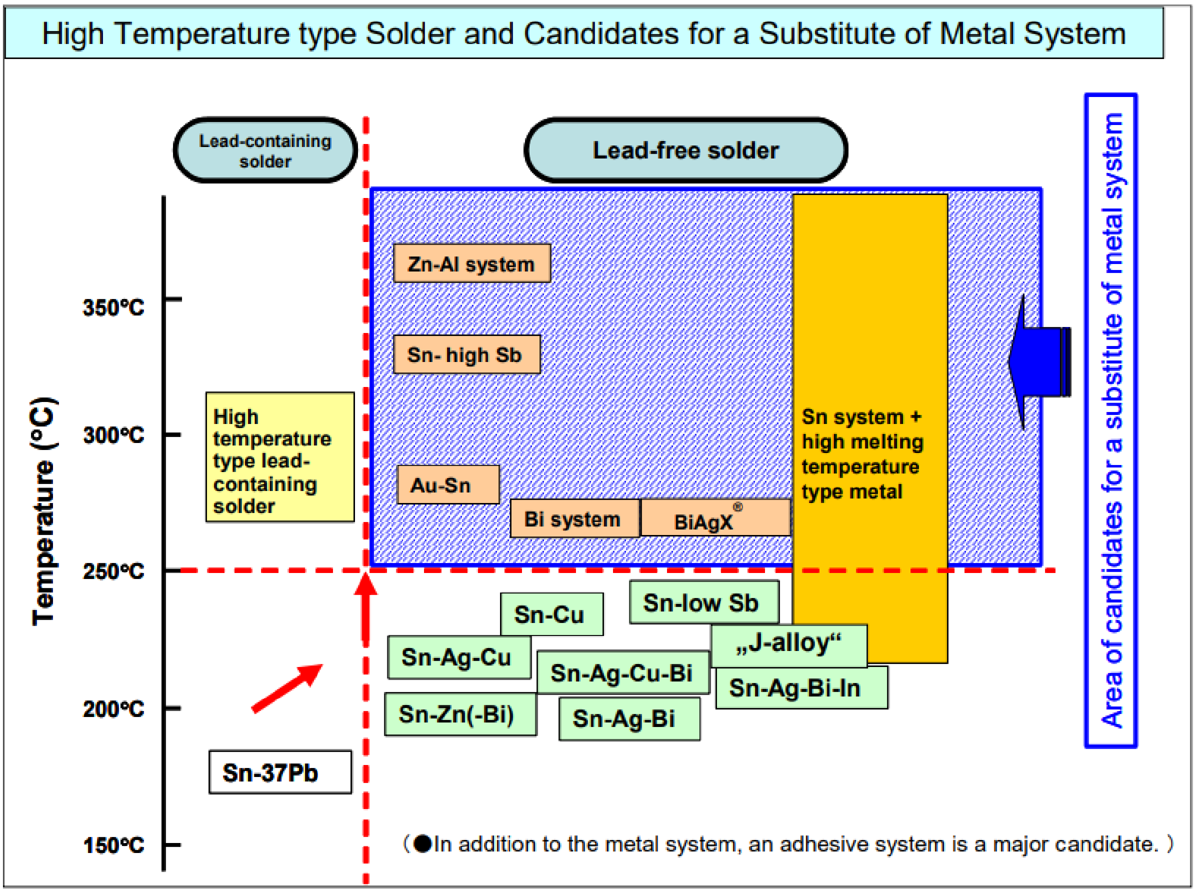


*Fig. 3: Relationship Diagram of Solders and Melting Temperature**

* This diagram is quoted from RoHS Exemption 7a Dossier for Renewal submitted by the Umbrella Project in January 2020

Soldering temperatures in production processes have risen to 250 to 260°C for Lead-free solders, mainly composed of Sn-Ag-Cu, while soldering temperatures in production processes for solder joints were 230 to 250°C in conventional Lead-containing solders. Thus, availability of high melting temperature of more than 85% of that falls under the expectation of ELV Directive has gained in importance.

In the following, Table 4 shows advantages and disadvantages of Lead-free solders with a solidus line temperature of 250°C or higher and electrically conductive adhesives that are candidates for the replacement of high temperature type Lead-containing solders as listed in fig.3

Candidate for Substitution		Advantages	Disadvantages
Metal System	Bi system	- Solidus line is high. - Joint operating temperature is comparable with conventional high temperature type solders. - Relatively low-cost	-Low ductility (very brittle) -Low strength -High electrical resistivity
	BiAgX®	- Easy drop in replacement for Pb-containing solder paste - Relatively low cost	-Brittle solder joints (solder cracks) -Poor wetting, solder voids (can cause bond failure and other reliability issues) -Thermal impedance increases (so unsuitable where heat conduction is required) -Melting temperature is 263°C
	Au-Sn	- Solidus line is high. - Joint operating temperature is comparable with conventional high temperature type solders. - Strength is high.	-Low ductility (too hard, so when used between parts with different CTE, this causes high strain leading to bond failure) -Lower melting point compared to HMP Lead (Pb) solder
	Sn-high Sb	- Solidus line is high	-Low ductility -Concern of Sb toxicity (on REACH CoRAP list) -Temperature required to solder is ~50°C higher than Pb-based HMP solder and is too hot for some processes (as this will damage most polymers and possibly the silicon chip)
	Zn-Al system	- Solidus line is high	-Brittle and low ductility -Susceptible to corrosion and early failure -Temperature required to solder is significantly higher than Pb-based HMP solder and is too hot for some processes.
	Sn system + High melting temperature type metal	- It is still retentive even if it is remelted. The joint operating temperature is comparable with that of conventional high temperature type solder, depending on a combination of remelting. - Solidus line is high if all can be made inter-metal compounds.	-For a resin mold, there is fear that a molten part may exude to outside of a component. -Joint operating temperature is high, extending solder duration which might lead to high intermetallic growth which is often brittle and leads to a reliability issue. -Fragile or low ductility because joint is mainly made of brittle inter-metallic compounds
Electrically conductive adhesive system		- No concern of remelting due to thermal hardening.	-Poor heat conductivity -Poor electrical conductivity which can deteriorate with age. -Susceptible to humidity -Difficult to repair -Insufficient reliability when qualifying for higher junction temperature T_j ($T_{j\,max}$ = 175°C or above) -Concern of some components' toxicity (classified as CMR)
Ag sintering systems		- No concern of remelting due to thermal hardening and/or pressure assisted sintering. - High electrical and thermal performance	-Additional stress during processing (pressure assisted sintering) on the chip -Susceptible to humidity (porosity of Ag sponge) -High stress on chip due to stiff die-attach material -Concern of some components' toxicity (classified as CMR)

*__Table 4__: Advantages and Disadvantages of High Temperature Lead-free Solutions **

** This table is quoted from RoHS Exemption 7a Dossier for Renewal submitted by the Umbrella Project in January 2020*

As shown in table 4, both Lead-free solders of metallic systems that have solidus line temperature of 250°C or higher and electrically conductive adhesive systems have problems and thus cannot substitute high-temperature type Lead-containing solders.

The above data explains that alternative Pb-free HMP materials currently in the market do not meet or exceed the required functionality and reliability for the intended uses (Table 2). Yet the materials industry continues to develop potential future alternatives in conjunction with component manufacturers.

The Die Attach 5 (or DA5, a consortia to develop a Pb-free die-attach solution, consisting of STMicroelectronics, NXP Semiconductors, Infineon Technologies, Bosch (Division Automotive Electronics), and Nexperia) consortia has been working with suppliers for several years to identify and evaluate alternatives to HMP Lead (Pb) solders. An introduction to the DA5 and summed up results can be downloaded from the following link:

https://www.infineon.com/dgdl/DA5+Customer+Presentation+23112023.pdf?fileId=5546d4616102d26701610905cfde0005

They have evaluated a variety of new materials from leading global suppliers of solders, adhesives, Ag sintering and transient liquid phase sintering (TLPS) materials. The DA5 evaluations recognize continuous improvement in the evaluated materials over the past 13 years.

According to the DA5 report published in December 2023, more than 175 materials from more than 17 suppliers were evaluated. About 50 of those materials were selected for extensive testing by DA5 member companies. But even the best of these materials do not meet the DA5 requirements for quality, reliability and manufacturability. This research has shown that the substitute bonding technologies are not at least as good as the traditional high melting Pb solders. More information can be referred from their report via web link above. Many solutions are still under development, constantly being revised and strictly guarded by suppliers under non-disclosure agreements. They are not available yet for mass production.

Therefore, the use of Lead in the application addressed under exemption 8(e) is still unavoidable.

Question 5:

Do you know of any promising materials or alternative technological approaches that could substitute lead in HMPS or eliminate the use of leaded HMPS?

As far as we know, there is no such a promising materials or alternative technological approach.

Please see also information given in table 4.

Question 6:

Please provide a roadmap specifying the past and necessary next steps/achievements in research and development including a time scale for the substitution or elimination of lead in this exemption.

Technology development and production technologies for semiconductors and electronic components are not a core competence of the automotive industry. As an end user, the automotive industry and OEM´s specify the demands that electronics components and systems have to fulfil in a vehicle over service life. The requirement of availability of electronic components validated for automotive uses over such a long time, limits the offer by their producers.
Due to our knowledge suitable materials or technologies which could be used as generic alternative are missing (see table 4).

The automotive industry is continuously researching alternatives, however currently no lead-free alternative technology can be predicted accurately for the short term.

If they will be available in future, we estimate that validation and industrialization into volume production of vehicles takes at least around 6 years.

Conversions cannot begin until Lead-free alternatives are developed and perfected by material producers, processes and equipment are installed and implemented within component manufacturing lines, components are qualified, and those components are made available to automotive Tier1s and OEMs for:
- development of
- assessment of, and
- replacement with alternative products.

Looking at potential alternatives to HMP Lead (Pb) solder for attaching die within semiconductor packages, we are informed that the DA5 consortium is working on solutions since years. The automotive industry welcomes this initiative and appreciates the high engagement of the DA5 consortium to find solutions. The DA 5 consortium is working with selected material suppliers on the development of an appropriate replacement for lead solder (DA5 scope). The properties of the needed die-attach material are specified by the DA5 (material requirement specification) and provided to the material suppliers. Selected material suppliers offer their materials, which are evaluated by one of the DA5 companies together with the supplier. The detailed results are discussed with the material suppliers and all DA5 companies on a regular basis in face-to-face meetings. The results lead to further optimizations of the materials (development loop). The combined results are published by DA5 (Customer Presentation).

Based on current status, DA5 cannot predict a date for customer sampling as no suitable materials have yet been identified.

This why we take reference to the generic DA5 automotive release process scheme (see fig.4).

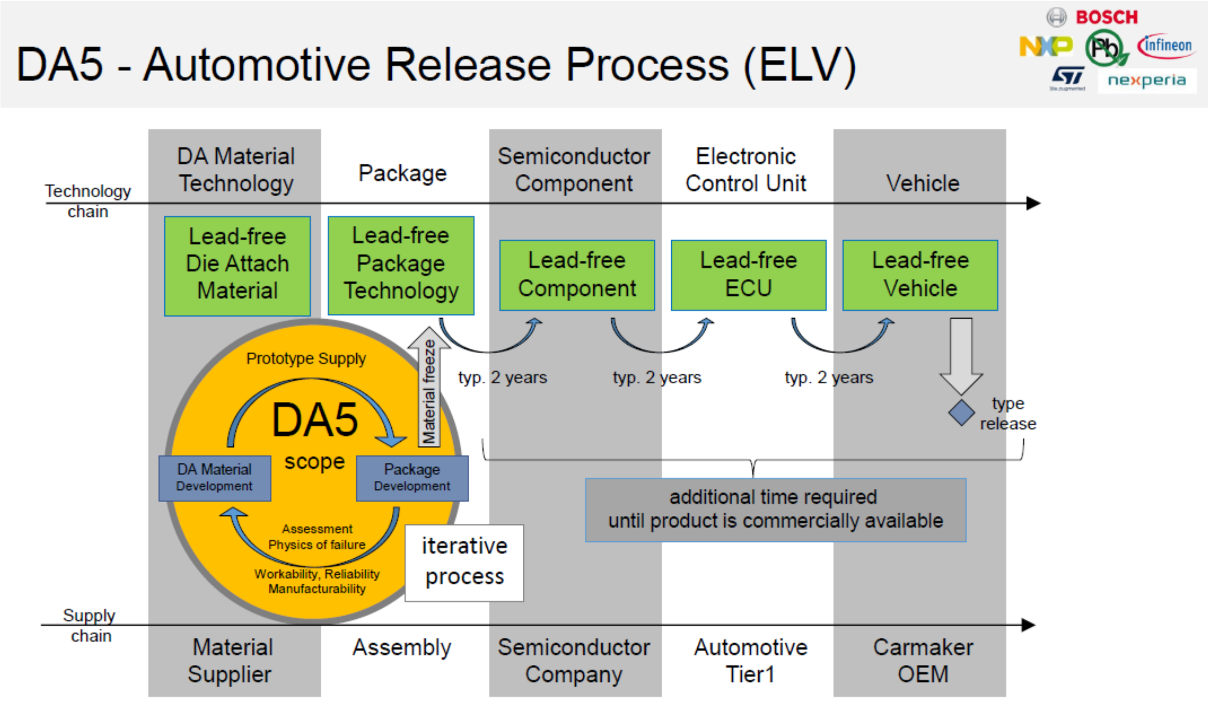


Fig. 4: *DA5Automotive Release Process (ELV)*

** This figure is quoted from Technical report from DA5 Project in November 2023*

Question 7:

Overall, please let us know whether you agree with the necessity to continue the exemption and your arguments for or against the continuation.

In general, we agree with the necessity to continue the exemption 8(e).

As stated above, currently no alternative Lead-free technology can be predicted for the future. The investigated potential alternative materials currently available have some drawbacks on reflow temperature and component design etc. that make them not suitable for all automotive application. Therefore, automobile industry request continuation of the current exemption.

Question 8:

Is there any other information you would like to provide?

There is no further information to be provided.

Your contact details

Please see general association document giving information on the contact partners

. /. Annex: 3 pages

Annex (page 1/3)

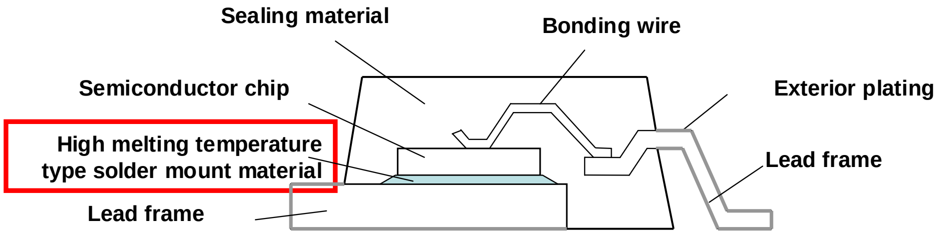


Fig. 1 Schematic Cross Sectional View of Power Semiconductor

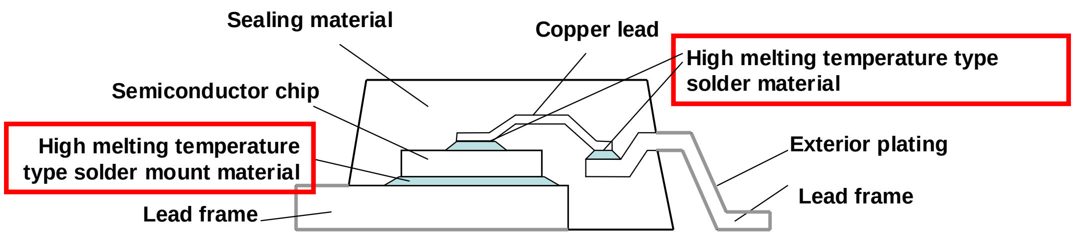
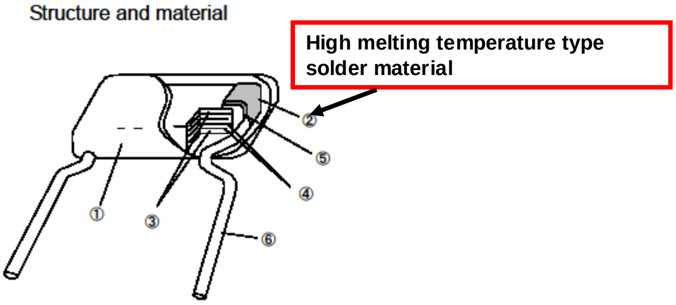


Fig. 2 Schematic Cross Sectional View of Internal Connection of Semiconductor

Annex (page 2/3)

Structure and material

1. Structure



2. Material and Description

No.	Material	Description
①	Enclosure	Epoxy resin
②	Inner solder	Sn-Pb type solder *1
③	Dielectric	Ceramic
④	Inner electrode	Ni or Pd or Ag/Pd
⑤	Outer electrode	1)Ag/Pd or 2) Ag or Ag/Pd or Cu + Ni plating + Sn plating
⑥	Lead wire	Solder(Sn-2.5Cu) coated copper wire or Solder(Sn-2.5Cu) coated CP wire

*1 Lead in high melting temperature type solders （Pb：85% or more）are exempted from the requirements of RoHS.

Fig. 3 Schematic View of Capacitor with Lead

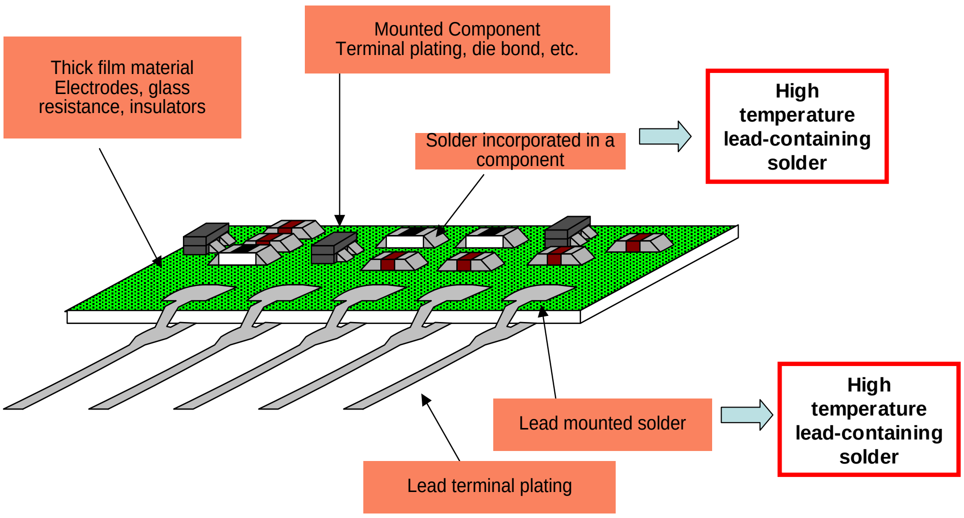


Fig. 4 Schematic View of Circuit Module Component

Annex (page 3/3)

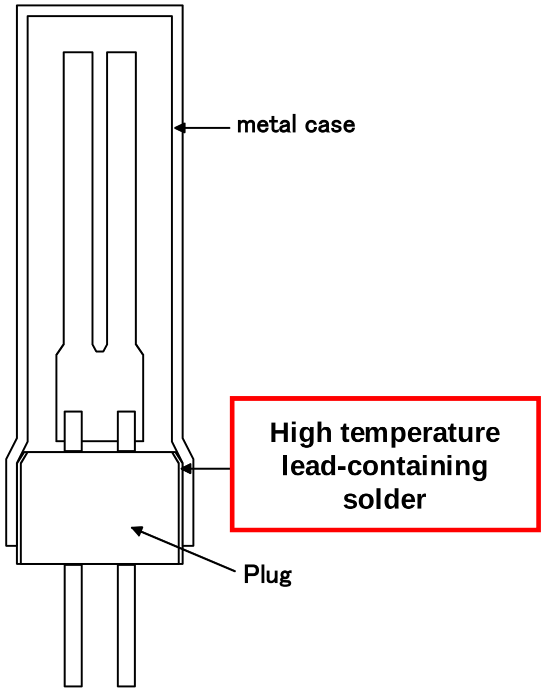


Fig. 5 Schematic View of Crystal Unit